Ashley National Forest Assessment

Air, Soil, and Watershed Resources Report

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for:
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Introduction

This document provides a rapid assessment of air quality, soils, water and watershed resources for use in developing a revised Land and Resource Management Plan for the 1,400,282-acre Ashley National Forest, which includes the Flaming Gorge National Recreation Area. The Ashley National Forest is entirely within the State of Utah. The Flaming Gorge National Recreation Area is in the States of Utah and Wyoming. The Ashley National Forest is comprised of four ranger districts (table 1 and figure 1). The 2012 Planning Rule requires the Ashley National Forest to consider air quality, soils, and water and watershed resources when developing revised Forest Plan components. The purpose of this assessment is to evaluate available information about these resources[1].

This assessment describes current conditions and trends regarding these resources. This information is used to anticipate future conditions, and to determine if trends pose risks to system integrity at the forest level. Additionally, this assessment identifies information gaps and any uncertainty with the data. The information contained in this assessment will assist agency officials in identifying any needs for management change to sustain soil, water and air resources, and the ecosystem services they provide.

Table 1. Ashley National Forest ranger districts and associated acreage Note Flaming Gorge Ranger District is in two states.

District	Acres
Duchesne – South Unit	204357
Duchesne – North Unit	161181
Flaming Gorge – Utah	249327
Flaming Gorge – Wyoming	104601
Roosevelt	339598
Vernal	341218
Total	1400282

[1] This document contains non-italicized excerpts, in full or paraphrased, from in-house Forest Service sources. These sources include working documents, planning documents, National Environmental Policy Act documents, resource-area-specific reports, manuals, handbooks, etc. This information may or may not be cited directly in the text, but the source is listed in the information sources sections of the assessment. Information from published literature, such as scientific papers and investigations, is referenced directly in the text, with formal citation in the information sources sections of the assessment.

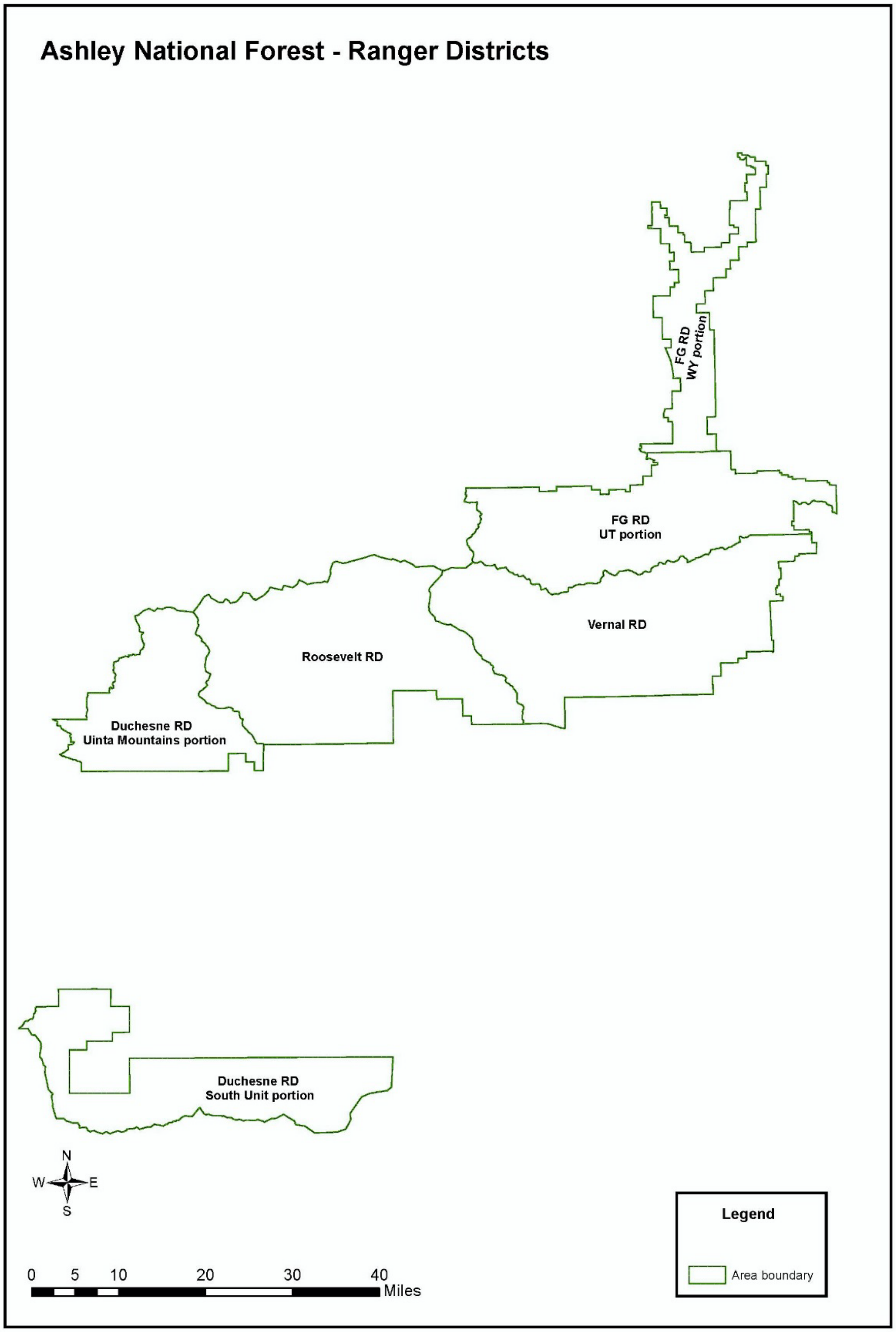

Figure 1. Ranger districts on the Ashley National Forest

The following air resource items are addressed in this assessment, as outlined in Forest Service Handbook 1909.12, chapter 10.

- Airsheds (geographic boundary set for air quality standards) relevant to the plan area
- Location and extent of known sensitive air quality areas, such as class I areas, nonattainment areas, and air quality maintenance areas
- Emission inventories, conditions, and trends relevant to the plan area
- Critical load exceedances, including extent and severity
- Federal, State, and Tribal governmental agency implementation plans for regional haze, nonattainment, or maintenance areas
- Known large, broad-scale, and major geologic hazards that may affect air quality
- Air quality issues important to consider in providing multiple uses and ecosystem services
- Conditions and trends assuming existing plan direction remains in place

The following soil resource items are addressed in this assessment, as outlined in Forest Service Handbook 1909.12, chapter 10.

- Existing inventories of soil conditions and improvement needs
- Important attributes, characteristics, or processes of soils, including soil erosion and sedimentation, that make them susceptible to loss of integrity resulting from specific uses, disturbances, or environmental change
- Existing conditions and trends of soil resources and soil quality, assuming existing plan direction remains in place
- Soil quality/productivity considerations important to consider in providing multiple uses and ecosystem services
- Places on the Ashley National Forest where soil quality/productivity is at risk, or not adequately protected, and management concerns or ecosystem stressors that limit or reduce soil function

The following water and watershed resources items are addressed in this assessment, as specified by Forest Service Handbook 1909.12, chapter 10.

- Condition and trend of watersheds, water quality/quantity in the plan area, as well as those that extend outside the plan area that influence the plan area or vice versa, assuming existing plan direction remains in place
- Surface and groundwater resources, including identification of impaired/contaminated surface and groundwater, and sources of impairment
- Quantity, quality, timing, and distribution of water across the plan area and the area of analysis, including groundwater resources and groundwater-dependent ecosystems
- Flow regimes needed to sustain ecosystems
- Historical context for ecological conditions under which the hydrologic systems developed
- The nature, extent, and role of existing and reasonably foreseeable future consumptive uses and non-consumptive uses
- The nature and distribution of Federal and non-Federal water rights across the plan area

- The reasonably anticipated future patterns of perturbation (such as altered precipitation, changing climate, drought, evapotranspiration patterns, flood, and temperature changes), and how these disturbances may affect watersheds, water quality and/or quantity
- The municipal watersheds, sole source aquifers, and source water protection areas within the plan area and area of analysis, and any management concerns related to these resources
- The effects of land use, projects and activities, and reasonably foreseeable future water withdrawals and diversions, and water storage facilities (surface and subsurface) on hydrologic and geomorphic processes and water resources
- Ecological, social, and economic roles that water resources play in the context of the broader landscape
- Places on the Ashley National Forest where water resources are at risk, and associated management concerns or ecosystem stressors/threats

Resource Area Concepts

Air

Air quality is recognized as an important resource to protect on national forests. The public values the clean air and sweeping vistas that national forests provide. Managers become concerned when poor air quality is or may affect forest resources such as forest health, visibility, water quality, aquatic organisms, or heritage resources.

By identifying national forest components that are impacted by air pollution, and by measuring the effect of air pollution on these sensitive elements, the degree to which air pollution is affecting the forest can be measured. This information can be, and has been, used by air regulators, land managers and concerned citizens to promote improvements in air quality that will benefit national forest areas and the people who visit them.

Impacts of Air Pollution

Air pollution affects the natural quality of National Forest System lands, particularly wilderness areas, and is one reason that it is a concern to managers. High ozone concentrations can injure sensitive vegetation. Atmospheric deposition (transport of gases and particles from the atmosphere to the terrestrial and aquatic surfaces) can cause lake body acidification, eutrophication (accelerated productivity of a lake beyond natural background levels, often expressed as increased plant growth and algal blooms) and hypoxia, soil nutrient changes, and vegetation impacts. Deposition of toxic metals such as mercury and lead can be harmful to both aquatic and terrestrial ecosystems. Visibility in most national forests is obscured some portion of the year by a haze of fine pollutant particles. Air pollution affecting national forests comes from a myriad of sources, large and small, located nearby and far away. The pollution includes:

- emissions from industry;
- oil and gas development;
- power plants;
- cars and trucks;
- wood burning stoves and fireplaces;
- agriculture; and
- ground-disturbing activities such as mining and road construction.

Air pollution typically originates outside of national forest boundaries, but is transported through the atmosphere and deposited inside national forest boundaries.

The impact on the ecosystem is related to the amount of pollution emitted, the distance from the ecosystem of concern, and meteorology affecting the transport and dispersion of pollutants. The ecological effects of air pollution may also vary by location, time, and sensitivity of an individual species. As such, certain species that are known to be sensitive to air pollution can be monitored as an indicator of adverse effects on the ecosystem. For example, changes in lichen communities may be the first signs of adverse impacts on vegetation. If changes are not observed in an indicator species, it is unlikely that adverse impacts will be realized in less sensitive species. However, if changes in sensitive species are observed, then additional signs of adverse impact are often investigated in case there may be new developments causing the changes.

The response of an ecosystem to air pollution is not only dependent upon the amount of contaminants to which it is exposed, but also on the ability of the ecosystem to buffer itself against the effects of air pollution. For example, the geo-biochemistry (chemistry of alpine lake water derived from the local geology and the plants and animals living in the lake) of high alpine lakes determines the lake's ability to neutralize acidic precipitation or to process nutrients. Landform, predominate wind direction, and aspect (the direction a hillslope or valley that drainage faces) affect the microclimate of an area. Temperature, precipitation, soil moisture, type of vegetation, etc. also play significant roles in particulate deposition and accumulation. Additionally, some pollutants accumulate in the food chain in which the effects are only evident in certain species. Hence, understanding and monitoring for air quality values in a national forest requires a comprehensive view, combined with local knowledge.

Wilderness Air Quality Values

Wilderness air quality values are the general categories of features or properties of wilderness that are affected in some way by air pollution. Identified values are visibility, odor, flora, fauna, soil, water, geologic features, and cultural resources.

These values include air quality related values in class I areas, as well as similar features and properties in class II areas, called wilderness air quality values. All wilderness areas 5,000 acres or greater, in existence in 1977, are considered class I areas. All areas designated since 1977 are class II areas. The difference is that class I areas are protected through the Clean Air Act and air quality related values that have been established for each region. The Forest Service is responsible to protect air quality values in wilderness the same, regardless of whether they are class I or class II areas. It is the agency's ability to affect change, and the process that is used in class I areas, that is different. For both class I and II areas, Forests report the results of air quality monitoring and the effects from sources outside wilderness to the state regulatory agency. For class I areas, the Forest Service, working with State regulators, can also model the potential effects of new pollution sources on class I areas and provide comment to the planning and permitting processes.

Similar properties that reflect air quality impacts are atmospheric deposition, snow pack chemistry, and meteorology. Air chemistry and atmospheric deposition monitoring are necessary to establish the linkages between air pollution and any changes to the physical, chemical, or biological condition of the sensitive receptors.

Sensitive Receptors and Indicators

Sensitive receptors are specific types of features or properties within a wilderness that can be negatively impacted by air pollutants, e.g., high-altitude lakes, lichens, and scenic vistas. In other words, sensitive receptors are the specific components of an ecosystem through which change in an air quality related value or wilderness air quality value is quantified. Sensitive receptors are selected for 1) known or suspected sensitivity to pollutants, 2) availability for manageable, cost-effective monitoring, sampling, and analysis methods, and 3) relevance for modeling capabilities. Examples of indicators for sensitive receptors might be: a population survey for a particular amphibian, a plankton count and water quality analysis in a sensitive lake, or an assessment of the vista from a particular viewpoint.

The relationship between air pollution and effects on individual components of the wilderness is influenced by three factors. The factors are: a component's ability to resist displacement from its natural condition, ability to recover from an individual human-caused event, and the number of times the wilderness component can return back to the natural condition after repeated human-caused change incidents.

Critical and Target Loads

Fossil fuel burning emits sulfur dioxide (SO_2) and nitrogen oxides (NO_x) into the atmosphere. Certain types of agricultural activities emit ammonia (NH_3) to the atmosphere. Such emissions can lead to atmospheric deposition of sulfuric acids, nitric acids, and ammonium into national forest ecosystems. In sensitive ecosystems, acid compounds can acidify soil and surface waters, affecting nutrient cycling and ecosystem services. In more resilient ecosystems, nitrogen deposition can lead to chemical and biological changes through nitrogen saturation, which can affect ecosystem services. To address whether atmospheric deposition is having negative effects, critical loads are calculated. If monitoring and modeling indicate critical loads are being exceeded, then target loads are established.

Critical loads are quantitative estimates of exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment are not expected to occur according to present knowledge. Values are scientifically determined based on expected ecosystem response to a given deposition level. When values are exceeded, the environmental effects can extend over great distances. Target loads are acceptable pollution loads or levels agreed upon by policy makers and land managers. Acceptable target loads are based on economic costs of emissions reductions, timeframes, and other matters.

Soil

Soil resources and their proper management are important for five key reasons (Brady and Weil 2002):

- Supporting the growth of plants, mainly by providing a medium for plant roots and supplying nutrients
- Controlling the fate of water in the hydrologic system by regulating water loss, utilization, contamination, and purification
- Serving as nature's recycling system by assimilating waste products and dead organic matter of plants and animals for reuse
- Providing habitat for a myriad of living organisms
- As an engineering medium and foundation for human uses

In other words, soil is the foundation of ecosystem function. It acts as a growth medium and provides nutrients for vegetation, stores and filters water, cleans air, contains habitat for numerous organisms, and is a long-term carbon storage reservoir. The objective of soil management is to maintain or restore soil quality, and manage resource uses and soil resources to sustain ecological processes and functions so that desired ecosystem services are provided in perpetuity.

Soil Quality

Soil quality is defined as the capacity of a specific kind of soil to:

- function within natural or managed ecosystem boundaries;
- sustain plant and animal productivity;
- maintain or enhance water and air quality; and
- support human health and habitation and ecosystem health.

Soil quality is a term that describes both the inherent capability of the soil, and the changes in soil properties created by current soil conditions to support the full range of ecosystem functions and human uses. Soil quality ratings can refer to suitability for uses such as constructing roads, facilities, septic tanks, or recreation sites; they also refer to capabilities for producing vegetation and wildlife habitat.

Soil resource management direction at the forest plan level must address activities undertaken for:

- silviculture;
- fuels management;
- transportation management;
- wildlife;
- watershed;
- fisheries;
- rangelands; and
- recreation programs.

Soils can lose much of their function when altered. Alteration can occur through activities such as timber harvest, grazing, recreation activities, oil and gas development, road construction, off-road motorized use, and natural disturbance events such as wildfire, debris flows and landslides, and floods.

The greatest threat to soil quality is soil erosion, because soil is lost from a site and cannot be replaced during human timespans. Erosion removes topsoil, which contains most of the soil's nutrients. Soil can also be compacted, which reduces the soil's porosity and air and water holding capacity. Soils can lose nutrients from vegetation/litter removal, or damage to soil structure. These actions render soil less capable of supporting some types of vegetation and habitats. Further, soil hydrologic function can be affected, through any of the above processes or when the water cycle is altered, such as when upstream diversions or stream incision in meadows actually reduce the amount of water entering the soil.

Management of Ashley National Forest land includes many projects and activities which may, or may not, cause significant changes in soil quality. In addition, Ashley National Forest lands are subject to various types of natural disturbances which may, or may not, cause significant changes in soil quality. Many naturally sensitive lands are especially susceptible to loss of soil quality with management activities. Alpine soils, riparian zones, and wetlands need mitigation measures to assure soil quality is maintained. On a national forest scale, protection of soil quality centers primarily on four areas:

- Improvement of the soil resource where impacted by poor practices or activities not suited for the area
- Rehabilitation of soil resources where those resources are affected by natural disturbances, when those disturbances contribute to off-site protection of resources such as water, and threat to life and property.
- Maintenance of the soil resource by prescribing soil and water conservation practices. These practices are applied during project planning, monitoring the implementation and effectiveness of these practices. Assessing the validity of the standards and guidelines upon which these practices are based.

- Evaluation of the potential for management activities to cause significant impairment of the productivity of the land. Evaluation includes changes in soil properties, which would result in significant changes in the inherent productivity capacity.

Soil Productivity

Soil productivity is one aspect of soil quality. The National Forest Management Act (NFMA) establishes specific requirements for the management of soil productivity. Soil productivity is defined as the inherent capacity of a soil to support the growth of specified plants, plant communities, or a sequence of plant communities. Soil productivity is generally dependent on available soil moisture, nutrients, texture, structure, organic matter, and length of the growing season.

Physical, chemical, and biological components of the soil reflect the productivity and ability of the soil to support, and interact with, the ecosystems they are part of. Soil productivity is essential to the sustained production of many ecosystem goods and services. But not all resource management activities are directly linked to vegetative growth. Inherent soil productivity is determined by climate, geology, parent material, landform, landscape position, and disturbance.

There is a direct link between inherent soil productivity and vegetation. The health, productivity, and resilience of each are dependent on each other. Changes in soils can occur when vegetation is damaged or replaced by invasive species. Plant cover and composition, roots, and organic additions impact soil properties. Plant cover protects soil from erosion, regulates soil temperature, and adds organic material into the surface soil. Plant roots add organic material, increase soil stability, and provide sites for microorganisms and nutrient cycling. Changes or damage to vegetation will impact the soil and its ability to support productive plant communities.

Water and Watersheds

Watersheds and water resources are credibly the most important resources of, and provided by, national forests. Protection of water quantity and quality, timing of flows, and the watersheds from which water resources are derived, remains critical to sustaining ecosystem function of the Ashley National Forest itself and the socio-economics of surrounding areas. Because of this, watersheds and water resources have been, and will continue to be, a significant part of the history of the Ashley National Forest.

Watershed Processes

Watersheds are drained by a stream network of perennial streams: that flow year-round, intermittent streams that flow seasonally, and ephemeral streams (including swales) that flow only during runoff events. The stream network expands during runoff events. Most material that enters any part of the network will eventually reach an aquatic ecosystem.

Most material that enters streams comes from an adjacent source zone whose width depends on land form, stability, and ground cover. Sediment is natural, but roads and other disturbed sites can act as channels that multiply sediment loads to the stream network during runoff events. Such "connected disturbed areas" can be a major source of damage to aquatic ecosystems.

If organic ground cover in a watershed is reduced enough to markedly increase the magnitude or duration of high flows, stream channels may erode their banks to damage their stability and aquatic habitat. Direct bank damage may add large amounts of sediment directly into streams. Soil quality depends on soil structure, organic matter, nutrient pools, and biotic processes. Soil quality is impaired when these qualities are markedly degraded for a period of years. Severe disturbances can impair soil quality by heating, displacing, compacting, or eroding the soil.

Historic ranges of native aquatic biota were determined by physiographic and hydrologic boundaries and biotic behavior. These patterns have been changed by fishing pressures, introduction of exotics, and migration barriers such as dams and diversions, as well as by habitat impacts. Biotic strategies that address these relationships are needed. Also needed are watershed conservation practices in order to sustain vigorous populations of desired aquatic communities.

Dynamic Equilibrium

A healthy watershed operates in dynamic equilibrium. Soil and water quality, flow regimes, and aquatic and riparian habitats vary within a certain range of conditions. Large natural disturbance events shift a watershed out of equilibrium. Recovery then begins. Poor land management practices can shift a watershed out of equilibrium.

Laws and common sense direct maintaining equilibrium conditions between large natural disturbance events, avoiding actions that may shift a watershed out of equilibrium or worsen major events, and assisting watershed recovery. The natural resilience of the system must be conserved in order to sustain ecosystem health.

Some disturbance can occur and still sustain watershed health. If runoff and sediment regimes, soil and channel conditions, water quality, and aquatic and riparian habitats are maintained between large natural disturbance events, watershed health is conserved.

The concept of dynamic equilibrium can be applied to biological processes, as well as physical landform processes. Natural processes are not static or absolutely stable, but there is a tendency for the form to maintain relatively stable characteristics. Natural perturbations influence these natural processes, which then begin the process of moving toward pre-event characteristics. Dynamic equilibrium can be short or long-term. Short-term could be life-history changes of fish associated with the annual hydrograph. An example of long-term could be the stream channel adjustments following natural fire events.

Land and Stream Types

The goal of watershed conservation is to sustain and restore watershed health in each watershed. Land and water conditions must be kept within the dynamic equilibrium ranges for the local landscape. Land and stream types, and their dynamic equilibrium ranges, vary within and among landscapes due to variations in climate and geology. This variation must be taken into account. In each landscape, dynamic equilibrium conditions vary by land types and stream types. These ranges can be defined by sampling reference land types and stream types in that landscape. The efficacy of watershed conservation practices is assessed by comparing each land type and stream type with its own capability.

Land factors reflecting soil and stream health include groundcover, soil bulk density, connected disturbed areas, and slope stability. Water factors include channel widths and depths, large woody debris, substrate, bank stability, flow regime; and water chemistry. Other factors may also be locally important.

Design and Risk

Watersheds experience periodic disturbance events that vary in their size, duration, and frequency. The randomness of such events implies some level of risk with any design. This risk is a product of the probability of an event occurring and its consequences. Best management practices, sometimes called soil and water conservation practices, are designed to control runoff damage.

Legal Framework

The Forest Service has a role in implementing air, soil, and water and watershed programs. This role is a result of numerous legislative acts, regulations, policy, and standards.

Organic Act

The Organic Act defines original National Forest purposes to improve and protect the forest, secure favorable conditions of water flows, and furnish a continuous supply of timber. Years of concern about watershed damage led to creation of the National Forest System. Watersheds must be cared for to sustain their hydrologic function as "sponge-and-filter" systems that absorb and store water and naturally regulate runoff. The goals are: good vegetation and ground cover, streams in dynamic equilibrium with their channels and floodplains, and natural conveyance of water and sediment.

National Forest Management Act

The National Forest Management Act directed each national forest to prepare, and regularly revise, a land and resource management plan. The act recognizes national forests are ecosystems and their management requires an awareness and consideration of the interrelationships among plants, animals, soil, water, air, and other environmental factors within such ecosystems.

National Forest programs must protect and, where appropriate, improve the quality of soil and water. Timber must be harvested only where:

- soil, slope, and watershed conditions are not irreversibly damaged;
- the land can be adequately restocked within five years after harvest; and
- streams, lakes, wetlands, and other water bodies are protected from detrimental impacts.

The overall goal of managing the national forests is to sustain the multiple uses of its renewable resources, in perpetuity while maintaining the long-term productivity of the land. Maintaining or restoring the health of the land enables national forests to provide sustainable uses, benefits, products, services and visitor opportunities. The goal of the ecological element of sustainability is to support native ecological systems by providing conditions to support a diversity of native plant and animal species. Ecological conditions are the components of the biological and physical environment that can affect diversity of plant and animal communities, and the productive capacity of ecological systems.

Multiple-Use Sustained Yield Act

The Multiple-Use Sustained Yield Act established that watershed resources are a National Forest purpose. The act also says that the sustained yield of goods and services from National Forests must be conducted without permanent impairment of the productivity of the land.

Granger-Thye Act

The Granger-Thye Act authorizes issuance of grazing permits, having terms that preserve land and resources from erosion and flood damage.

Public Rangelands Improvement Act

The Public Rangelands Improvement Act directs that range condition and productivity be improved to protect watershed function, soil, water, and fish habitat.

Federal Land Policy and Management Act

The Federal Land Policy and Management Act contains language saying that rights-of-way for water diversion, storage and distribution systems, and other uses must include terms and conditions to protect the environment.

Pipelines Act

The Pipelines Act mandates erosion control and reclamation on oil-gas pipelines.

Comprehensive Environmental Response, Compensation, and Liability Act

Commonly called CERCLA, this act provides for liability, compensation, cleanup, and emergency response for hazardous substances released into the environment. CERCLA also provides for the cleanup of inactive waste disposal sites.

Oil Pollution Act

The Oil Pollution Act establishes a fund, and concomitant liability, for the removal of discharged oil. The act also provides for the assessment and restoration of natural resource injuries caused by discharges of oil into inland waters and the ocean.

Safe Drinking Water Act

The Safe Drinking Water Act establishes standards for public drinking water systems, well-head protection, and source area assessments.

Wilderness Act

The Wilderness Act directs the management of wilderness areas to secure for the American people, and future generations, the benefits of an enduring resource of wilderness unimpaired for future enjoyment. The act further states that Congress intended to manage these wilderness areas so that the earth and its community of life are untrammeled by man. A wilderness must retain its primeval character and influence and be affected primarily by the forces of nature, with the imprint of man’s work substantially unnoticeable. Congress makes clear in this act that natural conditions in wilderness be preserved and be influenced primarily by the forces of nature rather than by human activity.

Clean Air Act

The regulation of air pollution sources has clearly been delegated by the Clean Air Act to the Environmental Protection Agency (EPA), and as applicable, the States. In Utah, air pollution is regulated by the Department of Environmental Quality’s Division of Air Quality. Specific air quality and pollution regulatory information is located at http://www.airquality.utah.gov/. In Wyoming, air pollution is regulated by the Department of Environmental Quality’s Air Quality Division. Specific air quality and pollution regulatory information is located at http://deq.wyoming.gov/aqd/. Regulatory oversight of the Clean Air Act resides with EPA and the States of Utah and Wyoming. However, the Forest Service has the responsibility under the act to protect particular values of National Forest System lands from the adverse impacts of activities inside and outside the boundary of those lands.

The Clean Air Act, as amended, significantly broadened the authority and responsibility of the Forest Service. Originally passed in 1963, major amendments followed in 1967, 1970, 1977, and 1990. The act’s purpose is to protect and enhance the quality of the nation's air resources so as to promote public health and welfare. The Clean Air Act requires cooperation among all Federal departments and agencies having functions regarding the prevention and control of air pollution.

Though the Clean Air Act provides the legal and regulatory framework for protecting National Forest lands, it is the responsibility of federal land managers to determine exactly how the lands are to be managed. The act requires that the Forest Service comply with all applicable Federal, State, or local air control rules, regulations, and directives. The act also requires compliance with applicable substantive and procedural requirements imposed by a Federal, State, interstate, or local administrative authority or court. Furthermore, the Forest Service must consult with each State having delegated authority on all matters concerning the prevention of significant deterioration of air quality, visibility, air quality maintenance plan requirements, and nonattainment requirements.

The Clean Air Act declared as one of its purposes to preserve, protect, and enhance the air quality in national parks, national wilderness areas, national monuments, national seashores, and other areas of special national or regional natural, recreational, or historic value. The Clean Air Act directs federal land managers and officials who have direct responsibility for management of such lands to protect the air quality related values, including visibility, of any such lands in a class I area. The act also requires consultation with EPA for the approval of a prevention of significant deterioration permit application for a major pollutant source.

National Ambient Air Quality Standards (NAAQS)

In 1971, under the authority of Section 109 of the Clean Air Act, the EPA adopted health-based standards that limit the concentration of certain air pollutants, known as criteria pollutants, throughout all locations across the United States. The criteria pollutants are carbon monoxide, lead, nitrogen dioxide, ozone, particle pollution, and sulfur dioxide.

The limits (http://www3.epa.gov/ttn/naaqs/criteria.html) are known as the national ambient air quality standards. These primary standards are designed to protect public health, including sensitive populations such as the elderly, children, or people with asthma. Secondary standards are designed to mitigate harmful effects to animals, vegetation, buildings, and limit decreases in visibility. Individual States have the responsibility for air quality management and for meeting air quality standards.

Forest Service Conformity with National Ambient Air Quality Standards

Under the Clean Air Act, an area that violates national ambient air quality standards for any of the six criteria pollutants listed is designated as a nonattainment area. Maintenance areas are any nonattainment area that has been re-designated to attainment status and has an approved air quality maintenance plan. Such areas may be more sensitive to maintaining the attainment designation. If a state has a nonattainment area, it must develop a State implementation plan, describing how the state will achieve and maintain Federal and State standards. The conformity rule of the Clean Air Act states no part of the Federal government shall support, license/permit, or approve any activity, which does not conform to an implementation plan.

This rule ensures that federally funded or supported actions taken by Federal agencies and departments, including the Forest Service, meet national standards for air quality in Federal nonattainment and maintenance areas. The rule also requires the Forest Service to demonstrate that its actions, or actions of those who occupy and use National Forest System lands under Forest Service authorization, will not impede the State implementation plans to attain or maintain the ambient air quality standard. A few examples of activities on national forests and grasslands that may require a review for conformity include:

- fuel treatments, including prescribed fire and harvest activities;
- road, trail, or building construction;
- land use and special use permit decisions such as ski or winter sports area, mining, oil and gas development and landfills.

Prevention of Significant Deterioration Program

The prevention of significant deterioration sections of the Clean Air Act include a permit program for certain new sources of air pollution. The purpose of the sections includes the protection and enhancement of air quality in national wilderness areas and other locations of scenic, recreational, historic, or natural value. Before the construction of certain new air pollution sources is approved, the applicants must receive a prevention of significant deterioration permit. The Forest Service manager, during the permitting process, must make three decisions:

1. What are the sensitive air pollution receptors within the wilderness that need protection?
2. What are the limits of acceptable change for these receptors?
3. Will the proposed facility cause or contribute to pollutant concentrations or atmospheric deposition in the wilderness that will cause the limits of acceptable change to be exceeded?

The first two decisions are land management issues, based upon the management goals for the wilderness in question. The third is a technical question, analyzed by models combining proposed emissions, background levels of pollutants, and the sensitivity of visibility and forest resources to the pollutants.

Close coordination between the Forest Service and the appropriate air regulatory agency is essential in the prevention of significant deterioration process. The Forest Service makes a determination of whether a proposed project will adversely impact Forest lands. The air regulatory agency then makes a decision to grant or deny the permit.

Best Available Control Technology Review for New or Modified Pollutant Sources

The Forest Service reviews air permit applications for new and modified industrial facilities. The goal is to ensure that air emissions do not adversely impact the air quality related values, such as visibility, of federally-protected wilderness areas. The agency provides these comments to the permitting authority, typically the state.

One key required part of the air permit application is a review of the air pollution control technology proposed on each of the new or modified emission units at the facility. The air quality regulations envision that it would be most cost effective to require pollution control upgrades at the time new sources are built or modified. This allows plant owners to plan for these costs as part of the construction of a new plant or an overall plant upgrade.

In general, the review of air pollution control technology involves an application of engineering to analyze what types of control technologies are possible for each regulated pollutant from each emission unit at the facility. Then, the best performing option is selected unless it is deemed too expensive, or causes other adverse environmental impacts. Ensuring that the best available control technology is applied to industrial sources reduces air emissions to the lowest possible amount and minimizes air pollution impacts to the National Forests.

Regional Haze Program

The Regional Haze Rule of 1999 requires states and interested tribes to address sources of pollution contributing to regional haze in the 156 mandatory class I areas across the country. To do this, states have developed State implementation plans to demonstrate to the public, the Federal land managers and EPA, how they plan to address regional haze to reach the goal of natural background conditions by the year 2064. The Forest Service, as the federal land manager of 88 mandatory class I areas, has been working closely with the states, interested tribes, EPA, and the regional planning organizations in the development of the technical products and policy documents that are being used by each state as they develop their plans. The Forest Service must comply with State of Utah and State of Wyoming laws and regulations to protect air resources.

Clean Water Act

The Clean Water Act was written to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. Congressional intent is to prevent, eliminate, and reduce pollution. The act recognizes the primary responsibilities and rights of States to prevent, reduce, and eliminate pollution. Congress assigned the EPA authority to administer the Clean Water Act. In Utah, water quality is regulated by the Department of Environmental Quality's Division of Water Quality. Specific regulatory information is located at http://www.waterquality.utah.gov/index.htm. In Wyoming, water quality is regulated by the Department of Environmental Quality's Water Quality Division. Specific regulatory information is located at http://deq.wyoming.gov/wqd/.

There are multiple sections to the Clean Water Act, of which only some are pertinent to national forest management. The following sections will be discussed as they apply to national forest management.

- Section 208 requires States to identify areas that have substantial water quality problems, using guidelines developed by EPA. The States were required to designate an organization that can help develop and implement plans to deal with individual problems. This section also required States and organizations identified by the States (in this case the Forest Service) to "develop a process to identify … silviculturally related nonpoint sources of pollution … and set forth procedures and methods (including land use requirements) to control to the extent feasible such sources." This is the process by which the infamous 208 plans came about. While these plans are outdated, they are good sources of historical information. These plans are useful for example, in discussing past activities as part of National Environmental Policy Act cumulative effects analysis. Section 208 was the original attempt to address non-point sources of pollution. During reauthorization of the Act in 1988, Congress determined the attempt was unsatisfactory. In response, Congress wrote Section 319. Please refer to the section 319 discussion for more information on this.
- Section 209 required the President to prepare level B plans for all basins in the United States. Level B plans were regional or river basin in scope and involve a reconnaissance-level evaluation of water and related land resources for the selected area. These plans are no longer required but do contain much useful information for gaining historical insight into past activities within particular watersheds.
- Section 301 prohibits a person from discharging any pollutant unless the person is authorized by another section of the Clean Water Act.
- Section 302 defines point source effluent (water pollution) limitations and gives EPA the authority to set such limitations.
- Section 303 requires states to develop water quality standards and implementation plans, to be approved by EPA. The standards and plans must meet minimum requirements developed by EPA.

Individual State water quality rules and regulations reflect compliance with this section. States, in accordance with EPA and as required by section 303(d), identify water bodies impaired by specific pollutant(s); a 303(d) listing of impaired waterbodies. The States revise their list every 2 years. Once a water body is listed, the State is required to conduct a total maximum daily load assessment to determine a maximum amount of pollutant allowable in a waterbody and serves as a starting point or planning tool for restoring water quality. Total maximum daily load reports are submitted to the EPA for approval. As part of the assessment, an implementation plan may be developed. The Forest Service may assist the state in collecting necessary data. The Forest Service can also help with providing existing plans and project information (particularly with regard to restoration or improvement projects that have occurred on National Forest System lands in the watershed). Finally, the Forest Service can help in producing the assessment report or assist in development of the implementation plan.

- Section 304 requires EPA to set national water quality standards that States have to meet as a minimum. State water quality plans must provide for anti-degradation. Anti-degradation policies and implementation methods must be approved by EPA. Existing beneficial uses (drinking water, swimming, fishing, aquatic wildlife, agriculture, and other uses) that have occurred and are suitable in a water body since November 28, 1975 shall be maintained and fully protected. Designated beneficial uses cannot be assigned that are less than existing uses. Consult State websites to learn how any particular state addresses anti-degradation.
- Section 305 requires each State to write a report every two years that "… describes the water quality of all navigable waters correlated with the quality of water defined by Section 304 … an analysis of the extent to which all navigable waters provide for the protection and propagation of a balanced population of shellfish, fish, and wildlife, and allow recreational activities in and on the water … recommendations as to actions necessary to improve water quality … a description of the nature and extent of nonpoint sources of pollutants, and recommendations as to the programs which must be undertaken to control each category of such sources". State's most recent reports are available on respective websites. Numerous water bodies found within national forests are listed in these reports.
- Section 309 grants EPA and the States the authority to enforce the Clean Water Act and includes language that responsible corporate officers (line) can be held liable for violations.
- Section 313 states that Federal entities are subject to and must comply with all Federal, State, interstate, and local requirements for the control and abatement of water pollution in the same manner and to the same extent as any nongovernmental entity.
- Section 319 requires the states to assess nonpoint sources of pollution and to develop a management program to control nonpoint sources. The management plan must include best management practices, meaning those practices take on a legal definition. The State's most recent nonpoint source management plans are available on respective websites. Some States also have activity specific best management practices documents for silviculture, grazing, agriculture, hydrologic modification, etc.
- Section 401 requires applicants applying for Federal permits issued under the Clean Water Act, (such as 404 permits) to obtain certification from the respective state that the proposed activity will comply with the state's water quality standards. Each state determines which types of activities need State certification. Detailed information is available at respective State websites.
- Section 402 allows the States and EPA to issue permits for the discharge of point sources of pollution, including storm water runoff. These are called national pollutant discharge elimination system permits. Before approval, the permit is available for public review. After such review, the

permit may or may not be granted. Detailed information is available at respective State websites. Typical Forest Service activities that need national pollutant discharge elimination system permits are control of invasive plants, use of piscicides for reintroduction of native fishes, and gravel source developments.

- Section 404 relates to permits for the discharge of dredged or fill material into waters of the US. This section gives permitting authority to the Corps of Engineers under EPA oversight. Section 404(b)(1) mandates that EPA develop guidelines for implementation of this section of the act. These guidelines can be found at 40 CFR 230 and are to be applied by the Corps of Engineers in the review of proposed discharges. Section 404(c) grants EPA authority to overturn a decision made by Corps of Engineers under Section 404(b). The EPA can determine that the discharge will have an unacceptable adverse effect on municipal water supplies, shellfish beds, and fishery areas (including spawning and breeding areas), wildlife or recreational areas. No discharge of dredged or fill material is permitted if there is a practicable alternative to the proposed discharge, which would have less adverse impact on the aquatic ecosystem, so long as the alternative does not have other significant adverse environmental consequences. No discharge of dredge or fill material is permitted if it:
    - causes or contributes to violations of any applicable state water quality standard;
    - violates any applicable toxic effluent standard or prohibition;
    - jeopardizes the continued existence of species listed under the Endangered Species Act or results in likelihood of the destruction of critical habitat as defined by the Endangered Species Act; or
    - causes or contributes to significant degradation of the waters of the U.S.

  Section 404 has evolved into a very complex system of compliance and enforcement. Detailed information is available at Corps of Engineer regional office websites.

Executive Orders

There are many executive orders with which the Forest Service must conform. Relative to water resources, the two most applicable are Executive Order 11988 (floodplain management) and Executive Order 11990 (protection of wetlands). These two orders are intended to preserve the natural and beneficial values of floodplains and wetlands, e.g. flood moderation, water quality protection, and groundwater recharge.

Memorandums of Understanding

The Forest Service and States of Wyoming and Utah cooperate on nonpoint source pollution control through two memorandums of understanding, one with each State's Department of Environmental Quality. The crux of each memorandum of understanding is the Forest Service will implement best management practices to control nonpoint source pollution derived from management activities. Examples of these activities include grazing, timber harvest, roads, recreational uses, and energy development.

A 2011 memorandum of understanding between the Environmental Protection Agency, the Department of Agriculture and the Department of Interior provides a collaborative approach to facilitate completion of environmental analysis for Federal onshore oil and gas decisions and to mitigate adverse impacts to Air Quality Resource Values. The memorandum standardizes air analysis procedures for oil and gas decisions and states that participating agencies will strive to ensure to the maximum extent practicable, that Federal decisions relating to oil and gas will not cause or contribute to exceedences of the National Ambient Air

Quality Standards, nor adversely impact air quality air quality related values in Class I areas, or sensitive Class II areas.

Agency Manuals and Handbooks

There are multiple Forest Service manuals and handbooks that define agency objectives and policy for management of air, soil, and water and watershed resources.

- Forest Service Manual 2500 provides the legal framework for air, soil, and water resources and general objectives and policy direction.
- Forest Service Manual 2510 provides direction on watershed planning. This planning includes coordination with land and resource management planning, soil and water surveys, and data management.
- Forest Service Manual 2520 provides direction on watershed condition assessment, watershed improvement, burned area emergency response, monitoring, riparian area management, floodplain management and wetland protection, emergency watershed protection, and natural disaster and flood damage surveys.
- Forest Service Manual 2530 provides direction on water resource investigations, water quality management, cooperation with other water-related agency activities, and external water resource development.
- Forest Service Manual 2540 provides direction on determining water rights and needs, establishing rights to water, protecting water rights, managing water rights, and municipal supply watersheds.
- Forest Service Manual 2550 provides direction for soil quality management and soil and terrestrial ecological resource inventories. Specific to the Intermountain Region of the Forest Service, Forest Service Manual 2550 Supplement 2500-2011-1 defines criteria for managing and measuring soil quality, definitions for soil quality, and direction for maintaining soil quality.
- Forest Service Manual 2580 provides direction on managing air resources to protect air quality related values within Class I areas, control and minimize air pollutant impact from land management activities, and cooperate with air regulatory authorities to prevent significant adverse effects of air pollutants and atmospheric deposition on forest and rangeland resources.
- At the national level, Forest Service Handbook 2509.13 provides guidance on burned-area emergency response.
- Forest Service Handbook 2509.16 provides guidance on water resource inventory.
- For the Intermountain Region, Forest Service Handbook 2509.22 provides guidance on the use and implementation of soil and water conservation practices. For the Intermountain Region, as previously noted, there is a manual supplement for soil quality, which incorporates direction that used to be in Forest Service Handbook 2509.18, a handbook that has been removed from the directives system.

The above manuals and handbooks, as well as any others mentioned in this report, can be found at http://www.fs.fed.us/im/directives/.

The Forest Service also utilizes the National Best Management Practices Program. This program serves as an over-arching direction on the importance of prescribing, implementing, and monitoring proven soil and water protection measures at the project-scale on National Forest System lands. Agency policy requires the use of best management practices to control nonpoint source pollution to meet applicable water quality standards and other Clean Water Act requirements.

Ashley National Forest Land and Resource Management Plan

The air, soil, water, and watershed resources are recognized components of the Ashley forest plan (USDA Forest Service 1986). The final environmental impact statement for the forest plan recognized, at that time, that air quality across the Ashley National Forest rated among the best in the country. The final environmental impact statement showed the existing air pollution came mostly from dust from unpaved roads and smoke from prescribed and wildfires. The forest plan also acknowledged the potential for off-Forest sources of air pollution to affect Ashley National Forest resources, particularly the possible sensitivity of certain lakes in the Uinta Mountains to acid deposition.

For soils, the final environmental impact statement noted a mixture of soil patterns with productivity that ranges from high to low. The ranges are due to differences in:

- elevation;
- precipitation;
- aspect;
- texture;
- depth;
- internal drainage;
- content of rock fragments;
- parent material;
- slope; and
- vegetative cover.

High-elevation soils are affected by cold temperatures and topographic exposure that limits the growing season and slows soil development. Many factors combined can make high elevation soils sensitive to disturbance. Mid-elevation soils are more productive, but many areas have seasonally high water tables. Low-elevation soils are limited by minimal precipitation and organic additions to the soil. Soils at low elevations often have less carbon, making them less productive, and often contain salts that make them prone to erosion.

Relative to water and watersheds, the final environmental impact statement acknowledges the importance of watersheds across the Ashley National Forest in contributing water to streams, rivers, lakes, and reservoirs. The water is of high quality and is used and enjoyed on and off the Ashley for domestic purposes, recreation, aesthetics, municipal and industrial uses, irrigation, livestock watering, power production, and fish and wildlife habitat. The final environmental impact statement also acknowledges the demands on water and watersheds will likely increase in the future.

Existing Direction for Soil, Water, and Air

The Ashley National Forest Land and Resource Management Plan contains direction for management of air, soil, and water resources, mostly from goals, objectives, and standards and guidelines. These three resources are, for the most part, addressed throughout the Forest Plan as an entity.

There is no detailed discussion of these resources in the “Desired Future Condition” section of the forest plan (pages IV-3 and IV-4), other than:

1. the quality of water yield will be consistent with current standards set by law;
2. the water resource improvement and rehabilitation backlog of 1,031 acres will be completed by the year 2000; and
3. high mountain reservoirs, which are replaced by other storage projects, will be stabilized at optimum levels for fisheries and recreation use.

There are 14 management area prescriptions in the forest plan (pages IV-5 through IV-13). Only one, "k - Maximum water yield recreation" (page IV-9) deals directly with air, soil or water resources. This prescription centers on increasing water yield through vegetation manipulation, i.e., timber harvest, air, soil, and water are not specifically mentioned as an activity under any of the fourteen prescriptions.

Goals, objectives, standards, and guidelines are outlined by management area on pages IV-14 through IV-55. Management areas include:

- recreation;
- wilderness;
- wildlife and fish;
- range;
- timber;
- soil;
- water and air;
- minerals and energy;
- riparian;
- lands;
- facilities; and
- protection.

Soil, water, and air are discussed on pages IV-37 through IV-42. Specific standards and guidelines are only applicable to certain management areas and are appropriately tagged on those pages.

The forest plan also contains discussion on other management principles and guidelines (pages IV-56 and IV-57. Specific to air, soil, and water resources, this section directs cooperation with other Federal agencies, States, local governments, Forest permittees and operators, special interest groups, and other interested individuals. This section also directs coordination on:

- water quality monitoring through state agencies;
- assistance to the soil conservation service and the State of Utah for snow surveys, flood forecasting, and warning of potential disaster;
- assistance to the environmental protection agency for acid rain surveys;
- cooperation with the soil conservation service on the soil survey program;
- providing information for river adjudication to the State of Utah; and
- mitigation activities on Central Utah Project impacts with the Bureau of Reclamation.

Part G of the forest plan provides a schedule of proposed and probable practices. Within this part, pages IV-105 through IV-107 provide specific information on:

- soil, water, air, and watershed improvement projects;
- an action plan for instream flow quantification for securing favorable conditions of flow by watershed;
- identifying air quality related values and base level air information for the Flaming Gorge National Recreation Area and the High Uintas Wilderness;
- soil and water inventory;
- soil resource inventory;
- water yield modeling;
- geological hazard inventory; and
- riparian community inventory management planning.

Goals

There are three goals for air, soil, and water and watershed resources in the forest plan.

- Goal 1: Increase water yields from national forest watersheds

- Goal 2: Improve and conserve the basic soil and water resources
- Goal 3: Manage for the maintenance of air quality related values

Objectives, and Standards and Guidelines[2]

There are four objectives and multiple standards and guidelines for each objective (see below) for air, soil, water, and watershed resources in the forest plan.

Objective: Increase water yields through resource management activities.

- Utilize appropriate modeling techniques to analyze cumulative impacts of sediment and water yielding resource activities. Determine sediment and water yield thresholds to meet aquatic habitat objectives.
- Utilize timber harvest units and other silvicultural activities to increase water yields.
- Protect all surface waters from chemical contamination.
- Maintain or improve current stream channel stability ratings.
- The stream channel stability rating shown in table 1[3] below will determine the percent of watersheds (1,000 acres or larger) allowed in equivalent clearcut area. Equivalent clearcut area includes actual clearcuts, partial cuts, and the supporting road system. The equivalent clearcut area of partial cuts is shown in Table II[3]. Following timber harvest, the equivalent clearcut area is reduced as hydrologic recovery occurs as shown in Table III.[3]
- Water yield improvement activities permitted [by specific management area] if compatible with wildlife, recreation, visual quality objectives, low to moderate erosion hazard, low landslide hazard.

Objective: Maintain or improve soil stability, site productivity and repair or stabilize damaged watersheds.

- Complete watershed improvement projects identified in the watershed restoration backlog, emphasizing high value watershed where accelerated erosion exists
- Encourage the Forest Service, Vernal City, or Uintah County to purchase or exchange for private property within the Vernal municipal watershed.
- Maintain and protect established watershed improvement projects until project objectives have been met.
- Provide soil and water guidance to other resource activities.
- Complete order three soil surveys for the Ashley National Forest.
- Obtain at least 80 percent of original ground cover within five years after project completion.
- Stabilize road corridors and control road use to reduce soil erosion.
- Stabilize areas damaged by fire, mining, or other events.
- Design activities to minimize project-caused sediment rates, not to exceed a 125 percent increase of the pre-project rates the first year and a 105 percent increase at the end of five years.

[2] The tagging of standards and guidelines to management areas is not shown in the table. This tagging is in the forest plan.
[3] The stream channel stability rating tables are not displayed in this assessment report. They are in the forest plan.

- Conduct damage surveys following disasters to determine restoration needs and take corrective action as soon as funds become available.
- Provide mitigation measures to the Central Utah Project activities such as access, recreation developments, and high lake stabilization.
- Allow no activity that will lower water levels of natural water storage areas (lakes, ponds, etc.) that are currently undeveloped.
- Evaluate flood hazard and resource values for construction or reconstruction projects within the 100-year floodplain or riparian zone where facilities will not be allowed unless other alternatives have been reviewed and rejected as being more environmentally damaging.
- Avoid channelization of natural streams. Where necessary for flood control or fisheries enhancement, use stream geometry relationships to re-establish meanders, width/depth ratios, etc. All dredged material shall be removed above the high waterline or stabilized with armor such as riprap.
- Rehabilitate disturbed areas based on these priority considerations: aquatic ecosystems, riparian ecosystems, and riparian areas outside aquatic and riparian ecosystems.

Objective: Obtain, secure, and protect sufficient quantity of water to provide for development, use, and management of National Forest lands.

- Quantify and inform States of all consumptive Federal reserved water rights, which are pursuant to the Reservation Doctrine.
- Acquire non-reserved water rights through applicable State law.
- Purchase needed water rights where sufficient water cannot be obtained under the Reservation or Appropriation Doctrines.
- Identify, quantify, and assert rights to instream flows to secure favorable conditions of flow sufficient to maintain stream channel stability and capacity to transport water and sediment.
- Assert non-consumptive instream flow needs on perennial streams to protect fisheries.
- Review public notices to water user's involving water right claims and applications of others that involve development on National Forest System lands. File protest with the state engineer in cases where existing or proposed uses conflict with Forest needs and multiple-use objectives.

Objective: Control and minimize air pollutant impacts from land management activities.

- Integrate air resource management objectives into all resource planning and management activities.
- Mitigate any adverse impacts from prescribed fire on the air resource of the Ashley National Forest and the air resource outside Forest Service jurisdiction.
- Detect and monitor the effects of air pollution and atmospheric deposition on Ashley National Forest resources. Monitor air pollutants when Forest Service goals and objectives are at risk.
- Preserve and protect air quality related values within the Flaming Gorge National Recreation Area and High Uintas Wilderness.
- Determine the amount of acceptable human-caused change in the ecological and social factors (limits of acceptable change) of the Flaming Gorge National Recreation Area and the High Uintas Wilderness without loss of the present character.

- Determine the air quality or air quality related values condition (base level) from which increments of limits of acceptable change will be measured.
- Review permits for proposed pollutant emitting facilities, their potential effect on the air quality related values, and make recommendations to the State air regulatory agencies.

Monitoring and Evaluation

Procedures for monitoring the effects of forest plan implementation on air, soil, water, and watershed resources are found on pages V-11 through V-13. This monitoring is intended to provide information on the following:

- Achieving the goals and objectives of the forest plan as predicted
- If standards and guidelines are being applied as specified in the forest plan
- If the effects of implementation are as predicted
- If the air, soil and water programs and management are resolving planning issues
- If the cost of implementing the air, soil, and water program is as predicted. Monitoring specifics are provided for the:
  - ♦ activity, practice, or effect to be measured;
  - ♦ monitoring technique and data source;
  - ♦ sample size;
  - ♦ expected precision and reliability;
  - ♦ responsible official;
  - ♦ measurement frequency;
  - ♦ reporting period; and
  - ♦ variation, which would cause further evaluation a change in management direction, or both.
    - ▪ Items a) and h) are the most relevant to current forest plan revision efforts (table 2)

Forest plan monitoring reports, while not prepared every year since the forest plan was signed, document monitoring efforts that have taken place. All of the reports discuss air, soil and water project level monitoring efforts. But in many cases, the reports do not specifically discuss if there is variation which would cause further evaluation/change in management direction. There is some narrative in some reports that does contain useful information concerning monitoring, i.e., the five items previously mentioned and items in table 2.

Notable information from the various reports, relative to the current plan revision effort, are:

- The 1987-1988 report suggested a change to the unit of measure for compliance with State water quality goals and standards (thousand acre-feet to stream miles), and modification of expected increases in water yield from 0.272 to 0.5 thousand acre-feet per year for the remainder of the plan period due to the effects of a mountain pine beetle epidemic,
- The 1986-1991 Five-Year report notes:
  - ♦ Difficulty in determining the degree to which implementation of forest plan standards and guidelines and Forest Service Handbook 2509.22 is allowing the Ashley National Forest to

meet water quality objectives. A cross-referencing system to project reviews may be useful to resolve this concern.

- ♦ Difficulty in determining whether soil stability and site productivity are being maintained and effective watershed improvement is occurring because there is lack of documentation across program areas and associated projects on implementation and effectiveness of soil and water standards and guidelines.
- ♦ Information is lacking on consumptive and non-consumptive water uses to know if water rights and uses are being properly managed and maintained.
- ♦ The effects of various management activities are not impacting long-term air quality goals, but shortfalls exist in data analysis and air quality related values monitoring.

- The 2003 report, while not specifically mentioning air, soil, and water resources, notes the forest plan fails to consider resources as integral parts of an ecological whole because the Plan directs management by functional program area under the assumption if individual programs are properly managed, the Ashley National Forest, as a whole, will be maintained. In fairness to the developers of the forest plan, the report acknowledges the format of the forest plan was perhaps the only way known at that time on how to tackle the daunting task of developing a forest wide management plan.
- The 2004 report reiterated information in the 2003 report. This report also discussed forest plan revision efforts that were undertaken to resolve the shortcomings of the original forest plan. This included making the forest plan more strategic and focusing on three major themes: water, recreation, and vegetation. Under the water theme, the report noted there is a need for a clearly articulated vision related to water.
- Reports for 2013 through 2015 summarized air quality data collection efforts and presented results of some data analysis. But mostly the reports stated additional years of data collection are needed before trend analysis can be conducted.

Table 2. Ashley forest plan soil, water, and air monitoring and evaluation requirements

Activity, Practice, or Effect to be Measured	Variation Which Would Cause Further Evaluation, Change in Management Direction, or Both
Water yield increases	Violation of State water quality standards or a 20 percent increase in predicted sediment yield. A 20 percent change over five years from projected water yield
Changes in channel stability	Rating lowered to next sequential classification as per R-4 standards
Cumulative sediment impacts and water yield augmentation	Violation of State water quality standards or variation in water yield increases as stated in forest standards and guidelines
Water quality changes on the Vernal municipal watershed	Violation of State water quality standards
Effectiveness of soil and water improvement projects	Unacceptable deviation from environmental assessment or project plan objectives
Project effectiveness for soil resource protection	Project reviews question validity of soil protection measures or mitigation effects
Changes in soil productivity due to management activities; compaction, erosion, fertility	15 percent increase in bulk density or 50 percent decrease in pore space.; 20 percent loss of nutrients

Activity, Practice, or Effect to be Measured	Variation Which Would Cause Further Evaluation, Change in Management Direction, or Both
Progress made towards establishing benchmark soils critical for management	Less than 40 percent accomplishment in five year period
Compliance with Utah and Wyoming state air quality standards by Forest activities	Violation of State air quality standards and adverse public reactions
Changes in air quality related values from off-Forest sources	Air quality related values reduced beyond limits of acceptable change; limits will be established before first reporting period.

Previous Plan Revision Efforts

The existing 1986 forest plan was due to be revised in 2001. Budget constraints at that time resulted in a decision to begin revision in 2004. Various revision tasks were initiated at that time, including completion of an existing conditions and trends report (Forest Service 2009). For various reasons, that revision effort was put on hold.

The 2009 report reiterated information in the 1986-1991 Five-year Plan Monitoring Report discussed previously; most notably a variety of problems associated with budgetary and logistical limitations affecting the ability to implement the forest plan. The report also noted some fundamental shortcomings in the Plan as a guiding document for resource management. To identify specific areas in the Plan in need of a change, an interdisciplinary team was convened in 2004, charged to evaluate:

- current resource conditions and issues in their program area, with emphasis on changes that had occurred since the first forest plan was signed;
- adequacy of existing forest plan direction; for example, whether or not desired conditions were clearly defined and management objectives were identified to help achieve desired conditions;
- adequacy of the monitoring plan - its effectiveness, practicality and consistency with current science and technical guidance; and
- the need for new or revised management direction to deal with current resource issues.

Results of their evaluations showed that, while some existing management direction was still appropriate and effective, many parts of the forest plan could be improved in format and substance. Numerous issues were identified, some of which were localized to one or a few parts of the Ashley National Forest. Some issues were related to difficulties with implementation, rather than flawed plan direction.

However, there were several issues and themes that were raised by multiple resource specialists, and which are clearly strategic or broad-scale in nature. These themes are:

- lack of a clearly articulated desired condition and/or strategy for achieving management goals;
- outdated, inappropriate or impractical management direction, especially regarding monitoring;
- unanticipated or unacknowledged trends in vegetative conditions and disturbance regimes;
- resource impacts due to increased human use; and
- potential for resources impacts due to energy development.

From these themes, the Ashley National Forest proposed the following topics as relevant, timely, and appropriate for consideration in Plan revision:

- Develop clear desired condition statements at socially and ecologically meaningful geographic scales, and tier management strategies and monitoring requirements to those conditions.

- Revise management direction for water resources to include all aspects of watershed health, and integrate water-dependent resources.
- Revise recreation management goals and objectives to reflect current uses and trends.
- Incorporate fire ecology and fuels management recommendations from the Forest-wide fire plan into desired conditions and management strategies. This is designed to help address trends in vegetative conditions and disturbance processes.
- Focus revision efforts on areas of the Ashley National Forest where current direction is vague or outdated. Congressionally designated areas such as the High Uintas Wilderness and Flaming Gorge National Recreation Area have relatively clear direction, tied to their respective enabling legislation and establishment records. In addition, an amendment completed in 1997 provides management direction for the High Uintas Wilderness that is generally still adequate and appropriate. Roll over existing desired condition and management direction for each of these areas with few if any modifications. Focus efforts on developing new direction for the remaining areas of the Forest, i.e., eastern Uintas, western Uintas outside of the wilderness, and the south unit of the Duchesne Ranger District.

With completion and implementation of the 2012 Planning Rule, Ashley National Forest plan revision has been re-initiated. This includes the preparation of this air, soil, and water and watersheds assessment report.

Scale of Analysis for this Assessment

Air Resources

The characterization of air resources in this assessment is generally oriented towards air mass conditions above the Ashley National Forest and Flaming Gorge National Recreation Area. But those conditions are affected by activities within the geographic area around the Ashley National Forest (airsheds) and areas beyond the Ashley (regional and global). In other words, air and various air-borne emissions are not constrained by artificial boundaries, i.e., National Forest boundaries.

Soil Resources

The characterization of soil resources in this assessment is the area defined by the Ashley National Forest and Flaming Gorge National Recreation Area boundaries. This is because management activities rarely affect soil condition on adjacent land. Those few cases where soil condition can affect adjacent land, effects are discussed.

Water and Watershed Resources

The Ashley National Forest is in the Green River drainage, a major tributary to the Colorado River. The Green River drainage begins at the Continental Divide in the Wind River Range in west-central Wyoming and joins the Colorado River in Canyonlands National Park in south-central Utah. The drainage is comprised of the upper Green River basin and the lower Green River basin. These two sub-basins are divided by the Uinta Mountain Range, where most of the Ashley National Forest is located. The Flaming Gorge National Recreation Area is on the north side of the Uinta Mountain Range and in the south end of the upper Green River basin. The South Unit of the Ashley National Forest is in the Tavaputs Plateau.

River basins or watersheds are delineated into a nested hierarchy represented by hydrologic unit codes numbered with two to 12 digits, which are then categorized with names into regions, sub-regions, basins, sub-basins, watersheds, and sub-watersheds (USGS et al. 2013). The Ashley National Forest lies within 10 sub-basins (4th-level or 8-digit code); see table 3. The information on hydrologic unit codes is derived from the Forest Service GIS library. Portions of Ashley National Forest boundary along Reservation Ridge on the South Unit and along the crest of the Uinta Mountain, are not coincident with the hydrologic unit boundaries. For this reason, there are small acreages of the Ashley in the Price, Upper Bear, and Provo 8-digit hydrologic unit codes depicted the table.

Within these sub-basins, there are 45 watersheds at the 5th-level, or 10-digit code that contain National Forest System lands. Watersheds generally range from 40,000 to 250,000 acres in size. Within these watersheds, there are 147 sub-watersheds, at the 6th-level or 12-digit code, that contain National Forest System lands. Sub-watersheds generally range from 10,000 to 40,000 acres in size (figure 2).

The characterization of watersheds and water resources in this assessment is bound by the six sub-basins listed above. But the characterization focuses on conditions and trends on the Ashley National Forest and Flaming Gorge National Recreation Area at the sub-watershed scale.

Table 3. Sub-basins (4th-level or 8-digit hydrologic unit codes) that contain Ashley National Forest acreage

Name	Hydrologic Unit Code	Acres of National Forest
Upper Green-Flaming Gorge Reservoir	14040106	379,249
Blacks Fork	14040107	13,469
Lower Green-Diamond	14060001	8,490
Ashley-Brush	14060002	209,184
Duchesne	14060003	665,224
Strawberry	14060004	116,215
Lower Green-Desolation Canyon	14060005	7,843
Price	14060007	341
Upper Bear	16010101	239
Provo	16020303	28

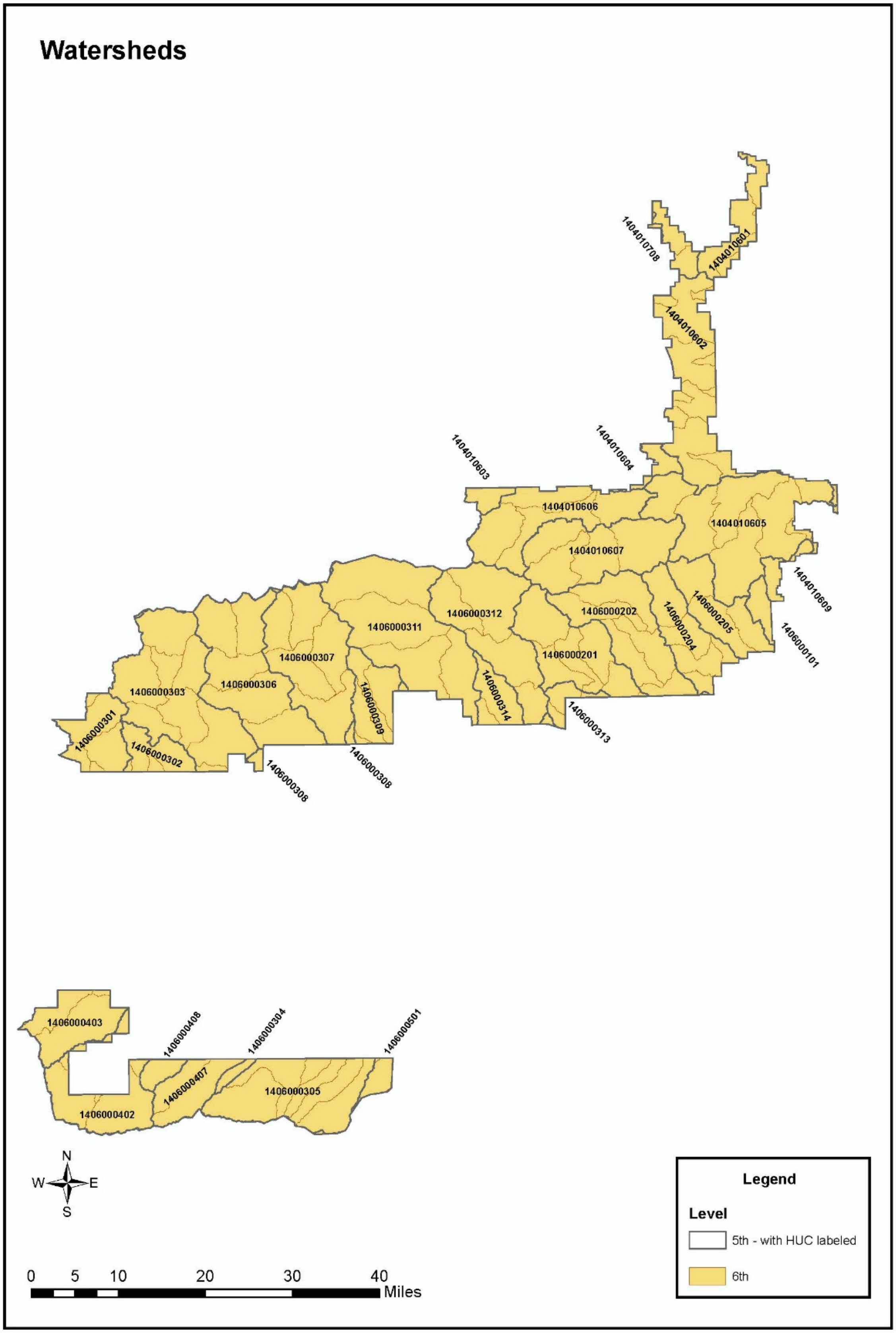

Figure 2. Watershed and sub-watersheds on the Ashley National Forest

Resource Specific Discussion

Air Resources

Airsheds

An airshed is a geographical area where local topography and meteorology limit the dispersion of pollutants away from the area. Airsheds are typically identified as a geographic boundary for air quality assessments. Airsheds can be affected by air pollution emission sources, which are categorized as stationary (point) and area and mobile. Stationary emissions are sources authorized by permit and emit pollution through an identifiable stack. Area and mobile sources are emissions from a number of locations too small, numerous, or difficult to be inventoried individually. They generally extend over a large area and can include vehicle emissions, natural gas wells, and certain commercial operations such as dry cleaners. Fire and windblown dust are often considered area sources as well.

The Ashley National Forest is a large geographical area in northeastern Utah and southwestern Wyoming. The Uinta Mountains, the Tavaputs Plateau, and the southern end of the Upper Green River Basin are the dominant physiographic features. The Utah portion of the Ashley National Forest is in Utah smoke management airsheds 7 and 9. Airshed 7 encompasses the north slope of the Uinta Mountains and Ashley National Forest, down to the Utah-Wyoming state line. Airshed 9 encompasses the south slope of the Uinta Mountains and Ashley National Forest, as well as the South Unit of the Forest in the Tavaputs Plateau. This airshed is roughly equivalent to the Uintah Basin. The basin is a geologic depression bounded by the Wasatch Range on the West, the Uinta Mountains on the north, uplifted areas in northwestern Colorado on the east, and a broad east-west strip of higher plateau that rises sharply to the south, of which the Tavaputs Plateau is a part.

Wyoming does not have predefined airsheds. For the purposes of this assessment, the airshed for the Wyoming portion of the Ashley National Forest is coincident with hydrologic units (watersheds) draining directly into Flaming Gorge Reservoir, minus the Blacks Fork and Green River drainage areas north of Interstate 80. Watershed areas north of Interstate 80, for the purposes of this report, are considered regional airsheds in nature. Relative to the Green River drainage area north of Interstate 80, the airshed only extends to the southern boundary of the ozone nonattainment area (Darla Potter, Wyoming DEQ, personal communication). A map of this area is available at http://deq.wyoming.gov/aqd/winter-ozone/resources/nonattainment-info/.

From a macro-scale airflow perspective, relative to the Ashley National Forest and Flaming Gorge National Recreation Area, the prevailing upper-level winds are from the west and southwest (Mast et al 2005 and Darla Potter, Wyoming DEQ, personal communication). Following the passage of cold fronts, gradient winds shift to a northwest to northerly direction. This condition normally persists for a few days and then changes back to a more westerly and southwesterly flow. Occasionally, gradient wind direction shifts to a more southerly flow. This is particularly common during July and August when summer "monsoon" conditions become established. Most of the precipitation during the summer months is the result of the southerly flow of subtropical moisture. The Uinta Mountains exhibit considerable influence over macro-scale air currents and circulation in the previously defined airsheds.

From a more micro-scale airflow perspective, wind speed and direction exhibit considerable variability due to local topography. While the Uinta Mountains also exhibit considerable influence at the micro-scale level, other geographic features, such as the Uintah Basin, Tavaputs Plateau, Wasatch Range, and Piceance Basin, are influences as well. South of the Uinta Mountains, during calm, cold, and snow-covered conditions in the winter, air tends to stagnate and create inversions in much of the Uintah Basin.

Additionally in this area during the summer, when calm conditions, strong sunlight, and high temperatures occur, stagnant air conditions develop. The inversion ceiling typically levels out at approximately 6,500 feet (Utah DEQ 2016), which is principally below the elevation of the Ashley National Forest acreage in the Uintah Basin. Specifically, the lowermost 16 acres of Right Fork Antelope Canyon and lowermost 165 acres of Left Fork Antelope Canyon are below 6,500 feet.

North of the Uinta Mountains, in the southern end of the Upper Green River Basin, airflow is very robust due to down-sloping winds flowing off the Uinta Mountains. However, during calm, cold and snow covered conditions, inversions can develop. But these inversions generally occur north of the Ashley National Forest and Flaming Gorge National Recreation Area. On rare occasions, the inversions will extend into the far northern end of Flaming Gorge National Recreation Area.

There is one wilderness area, the High Uintas, on the Ashley National Forest. This wilderness area was established under the 1984 Utah Wilderness Act. Consequently, it is a class II wilderness area. The wilderness, which is entirely within the State of Utah, comprises 456,705 acres, of which 276, 175 acres are on the Ashley National Forest. The remaining 180,530 acres are on the Uinta-Wasatch-Cache National Forest. The High Uintas Wilderness is in Utah smoke management airsheds 7 and 9. As noted earlier, none of the wilderness area is in Wyoming. All non-wilderness areas of the Ashley National Forest and Flaming Gorge National Recreation Area are designated class II.

Wilderness air quality values and sensitive receptors have been identified for the High Uintas Wilderness area (table 4) (Nick et al 2012).

Table 4. High Uintas Wilderness air quality values and sensitive receptors (from Nick et al. 2012)

Wilderness air quality values	Sensitive Receptor
Water	Acid-neutralizing capacity values of high-altitude lakes Macroinvertebrate and other organisms
Fauna	None
Flora	Conifers, other ozone sensitive species (for example, *Populus tremuloides*), and lichen
Soils	None
Scenic vistas	None

Areas in and around the Ashley National Forest and Flaming Gorge National Recreation Area are currently in attainment of all national ambient air quality standards. In Utah, there are nonattainment areas along the Wasatch Front and in the Logan/Cache Valley area. The Wasatch Front has areas in nonattainment for particulate matter 10, particulate matter 2.5, and sulphur dioxide. The Logan/Cache Valley area is in nonattainment for particulate matter 2.5. Also in Utah there are ozone and carbon monoxide maintenance areas along the Wasatch Front. These areas are relevant to air quality on the Ashley Forest because they are upwind. State implementation plans for Utah's nonattainment areas are available at http://www.deq.utah.gov/Laws_Rules/daq/sip/index.htm. The EPA and Utah are addressing ozone concerns in the Uintah Basin. This may result in nonattainment designation at some point in the future, with corresponding Implementation Plans for both State of Utah and Indian lands.

In Wyoming, there is only one nonattainment area designated for ozone, located in the northern and central Upper Green River basin. The EPA considers this to be a marginal nonattainment area, thus no State implementation plan needs to be developed. The area is north of the Ashley National Forest and Flaming Gorge National Recreation Area and has no influence on conditions on the Ashley (Darla Potter, Wyoming DEQ, personal communication). Detailed information, including an area map, is available at http://deq.wyoming.gov/aqd/winter-ozone/resources/nonattainment-info/.

Air Quality

There is an abundance of current and historical data related to air quality in or near the Ashley National Forest and Flaming Gorge National Recreation Area. Knowledge of the data and any relevant trends provides an understanding of the air quality parameters that influence air quality on the Ashley that could affect resources impacted by air pollution. Included are general descriptions of baseline emissions inventories, ambient air quality measurements, visibility, and deposition measurements that define current air quality conditions of the plan area.

Existing and Potential Sources and Inventories

Air quality effects on national forests are generally traceable back to the original source of emissions. Therefore, air emission information provides an overview of the magnitude of air pollution and is important in understanding air quality on the Ashley National Forest. Also, trends in precursor emissions would be expected to track with trends on the Ashley (e.g., visibility, acid deposition). For instance, improving visibility conditions in class I areas would generally be associated with corresponding decreases in emissions for visibility precursor pollutants.

Emissions information is generally tracked for pollutants that have health-based air quality standards such as carbon monoxide, nitrogen oxides, sulfur dioxide, volatile organic compounds, and particulate matter.

Volatile organic compound emissions do not have a health-based standard but are involved in the atmospheric chemical reactions that lead to ozone, which does. Ozone pollution is of added concern because it can stress sensitive ecological systems. Particulate matter emissions are generally broken into two categories, based on the size of the emissions. Fine particulate matter is at or below 2.5 microns in diameter. Course particulate matter is at or below 10 microns, but above 2.5 microns, in diameter. Smaller particles have greater health-related impacts because the smaller particles are more easily inhaled into the lungs. Ammonia and mercury are not priority pollutants but can be of concern with National Forest managers due to their deposition effects on water quality and biota.

Stationary, Area, and Mobile Sources

Stationary sources of pollution include facilities such as those used for energy production, mining and milling operations, gravel and cement plants, and ski areas. Areas directly affected by these facilities are typically confined to a radius of tens of kilometers downwind of the facility. The dimensions of the downwind zones of influence are variable, and are primarily controlled by the strength of the effluent at its source, local meteorology, and regional topography. Large stationary sources, typically facilities that produce more than 100 tons per year, can impact national forest areas in excess of 300 kilometers downwind by contributing to pollutant haze layers.

Area and mobile sources of pollution include, among other things, automobiles, agricultural activities, planes, trains, residential wood burning, lawn mowers, and barbeques.

Smoke from wild and prescribed fires, as well as wind-blown dust, are also considered area sources. While stationary sources were the initial focus of the Clean Air Act, pollutants from regional-scale area sources are more likely to affect national forest areas. Global emissions of carbon dioxide and other greenhouse gases are increasing in concentration, and very likely causing changes in climate. The effects from a changing climate may result in the greatest anthropogenic changes to national forest areas. Primary sources for carbon monoxide are wood burning, vehicles, and non-road engines. Primary sources for nitrogen oxides are vehicles, non-road engines, oil and gas, and railroads. Primary sources for sulfur dioxide are wood burning, coal combustion, vehicles, oil and gas, and non-road engines. Primary sources for particulate matter are wood burning, road dust, agriculture tilling, and construction. Primary sources for volatile organic compounds are pesticides, wood burning, non-road engines, oil and gas and vehicles.

The EPA national emissions inventory at http://www3.epa.gov/ttn/chief/net/2011inventory.html was queried for stationary sources of air pollution in and around the Ashley National Forest and Flaming Gorge National Recreation Area. The national emissions inventory is a comprehensive and detailed estimate of air emissions from all sources. It is prepared every three years, based primarily upon emission estimates and emission model inputs provided by State, local, and Tribal air agencies for sources in their jurisdictions. This air, soil, and water report used the 2011 national emissions inventory. Because there was a significant increase in oil and gas activity in Utah and Wyoming after the 2011 inventory was released, the queries used in this report may underestimate emission sources. The Ashley National Forest is encouraged to query the 2014 national emissions inventory (https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei) and use that information in remaining steps of the forest plan revision process.

The database was filtered for counties that contain the Ashley National Forest and Flaming Gorge National Recreation Area or are directly upwind of these areas[4]. Utah counties selected were Daggett, Davis, Duchesne, Morgan, Salt Lake, Summit, Uintah, Utah, Wasatch, and Weber. Wyoming counties selected were Sweetwater and Uinta. Moffat County in Colorado was not chosen because it is downwind of the Ashley National Forest. The following priority pollutants were queried (figure 3 through figure 10):

- Carbon monoxide
- Nitrogen oxides
- Sulfur dioxide
- Particulate matter less than 10 microns and particular matter less than 2.5 microns
- Non-priority pollutants, volatile organic compounds
- Ammonia
- Mercury

The major sources of carbon monoxide, nitrogen oxides, sulfur dioxide, particulate matter $_{10}$, particulate matter $_{2.5}$, and volatile organic compounds are the Wasatch Front, the Wyoming I-80 utility corridor, and the Uintah Basin. The major source of ammonia is the Wasatch Front, with some sources along the I-80 utility corridor and in the Uintah Basin. The major source of mercury is the Wasatch Front, with some sources along the I-80 corridor. Facility names and emission quantities are available at the national emissions inventory website.

Data on area/mobile sources is available for Utah, but not Wyoming. Utah's information is available at http://www.deq.utah.gov/ProgramsServices/programs/air/emissionsinventories/inventories/11StateList.htm. These data are in tabular form by county.

Wildfire and Prescribed Fire Smoke and Dust

Wildfire smoke, particularly from large fires, is a vivid air quality impact to the Ashley National Forest on a seasonal basis. Prescribed fire is the predominant emission-producing management activity practiced by the Forest Service. Emissions from fire (wildland and prescribed) are an important episodic contributor to

[4] The Ashley Forest lies within Utah counties Daggett, Duchesne, Summit, Uintah, Utah, and Wasatch. Utah counties Davis, Morgan, and Weber are directly upwind of the Ashely and comprise much of the Wasatch Front metropolitan area. The Ashley also lies within Wyoming county Sweetwater. Wyoming county Uinta is directly upwind of the Ashely. Sweetwater County is very large; the part of the county east of Rock Springs likely has little influence on air quality on the Ashley National Forest because it is downwind and in the Great Divide Basin, a geographically closed hydrologic unit (Darla Potter, Wyoming DEQ, personal communication).

visibility-impairing aerosols, including organic carbon, elemental carbon, and particulate matter. Wildfire impacts are increasingly difficult to manage due to excessive fuel loads, history of fire exclusion, increased urban interface, and climate change (drought and increasing temperatures). Prescribed fire and fuel treatment projects include mastication (chipping), thinning, broadcast burns (area burns designed to reduce fuels in a contiguous area over a landscape) and pile burns (discrete piles of slash from timber harvest, thinning from fuel treatment projects, or both). These treatment techniques are designed to:

- reduce the size, frequency, and intensity of wildland fires and improve fire control;
- increase predictability of fire effects; and
- allow for smoke emissions management.

Dust generated in the southwestern U.S., and at a global scale, occasionally impacts the Ashley National Forest, most apparent as a dark covering of the snowpack as it melts in the spring. In the alpine zone, this dust decreases snow albedo (light reflectivity), shortens the duration of snow cover, and hastens (spring) peak runoff. Shorter snow duration can increase evapotranspiration from earlier exposure of soils and germination of plants, resulting in reduced annual water runoff (Deems et al 2013). In forested areas, the effects of dust on snowpack are reduced. The tree canopy influences snow interception and shading, overwhelming the effects of dust on snowpack albedo and radiative energy balance (Maurer and Bowling 2014). Specific to the Uinta Mountains alpine zone, dust accumulation rates are similar to values reported for the Wind River Range of Wyoming, but less than values for southwestern Colorado. This suggests a south-to-north decrease in regional dust flux (Munroe 2014). Grain analysis suggests the dust has an exotic origin and is not from local geology. There is a recording of anthropogenic change in dust composition in the Uinta Mountains, linked to settlement of surrounding lowland basins (Munroe et al 2015).

Potential Future Sources

Potential future sources of emissions that could impact the Ashley National Forest are continued growth in the Wasatch Front metropolitan area and continued energy development in the Uintah Basin and southwest Wyoming.

Air Resource Monitoring

Visibility

IMPROVE

The Interagency Monitoring of Protected Visual Environments (IMPROVE) program was established in 1985 to assist in the management of visibility in class I areas. Four objectives were identified:

- Establish current visibility and aerosol conditions in mandatory Class I areas
- Identify chemical species and emission sources responsible for existing man-made visibility impairment
- Document long-term trends for assessing progress towards the national visibility goal
- Provide regional haze monitoring as part of the enactment of the Regional Haze Rule

IMPROVE sites can be useful for non-class I areas, but unfortunately there are no existing IMPROVE sites representative of the Ashley National Forest. Historically, the Lone Peak Wilderness site on the Uinta-Wasatch-Cache National Forest was operated by the U.S. Forest Service from 1993 to 2001. Data from this site may be useful to the Ashley National Forest from a historical perspective or for comparative purposes in the event a representative site is established in the future. More information on the program can be found at http://vista.cira.colostate.edu/improve/.

The Ashley National Forest has operated a visibility camera on Lake Mountain from the 1987 through 2000 and 2010 through 2015. Historical photographs can be found at http://www.fsvisimages.com/. Analytical reports are available at: http://ars-fsairpgm.com/Documents.aspx?folder=02_Analytical%20Reports. These reports indicate visibility from Lake Mountain is excellent, with no impairment from haze. Visibility in the High Uintas is, in the big picture, similar to the Flat Tops and Mount Zirkel wilderness areas in Colorado. But visibility is not necessarily similar on an episodic basis, such as extreme dust events (Scott Copeland, IMPROVE Program, personal communication).

Deposition

Research and Monitoring

Multiple deposition research and monitoring efforts have been implemented, and continue, on the Ashley. Lake sampling in or around the Ashley National Forest has been conducted by various entities since the mid-1980s. This sampling is designed to characterize wilderness lake chemistry and sensitivity to atmospheric deposition. Some of these data is synoptic while some identify conditions and trends of air deposition in wilderness lakes. Some data may be reported as acid-neutralizing capacity or alkalinity. Lakes are generally considered sensitive to atmospheric induced acid deposition change if acid-neutralizing capacity is less than 100 microequivalents per liter and highly sensitive if the acid-neutralizing capacity is less than 50 microequivalents per liter. Lakes are considered highly sensitive if alkalinity is less than 10 milligrams per liter, moderately sensitive if alkalinity is between 10 and 20 milligrams per liter, and non-sensitive if alkalinity is over 20 milligrams per liter.

In 1985, the EPA conducted a nationwide study of acid deposition. The western lakes survey was a one-time stratified sampling effort designed to provide large scale regional information about lake chemistry throughout the United States (Eilers et al. 1987 and Landers et al. 1987). Twenty seven lakes in the Uinta Mountains were sampled. Results indicate a high percentage (93 percent) of lakes with an acid-neutralizing capacity less than or equal to 200 microequivalents per liter but a low percentage (4 percent) with an acid-neutralizing capacity less than or equal to 50 microequivalents per liter. These data suggest some lakes in the Uinta Mountains could be sensitive to acid deposition but very few are highly sensitive. Results for calcium were similar to acid-neutralizing capacity. Compared to other geomorphic units in the central Rockies, lakes in the Uintas have high concentrations of chloride and iron. Contrasting this, silicon dioxide concentration was the lowest of any geomorphic unit sampled in the central Rockies.

Designated wilderness high lake monitoring has occurred in the Uinta Mountains since the western lakes survey. Gurrieri and Mebane (2006) reported on monitoring of four lakes over 11 years. Two of the lakes had enough data to conduct trend analysis, but laboratory analysis was not sensitive enough to detect the low concentrations of many analytes in these lakes. There was adequate data for two of the four lakes to analyze calcium, which showed significant upward trend. This increase corresponded with bulk deposition data also collected in the Uinta Mountains, suggesting the lake increases are attributable to atmospheric deposition.

Although there was insufficient data for trend analysis, all four lakes had acid-neutralizing capacities under 100, confirming the western lake survey sensitivity to atmospheric deposition. Additionally, three of the four lakes showed the presence of nitrate and ammonium during periods of biological activity. This may be indicative of excess nitrogen deposition and unnatural fertilization of these lakes.

Nick and others (2012) summarized data for Dean, Fish, and Walkup Lakes, stating there is an apparent increasing trend in acid-neutralizing capacity. This suggests deposition effects may be decreasing. However, linear regression techniques were used for the trend analysis, which may not be appropriate for these data. Rather, Seasonal and regional Kendall testing techniques may be more appropriate statistical analysis (Helsel et al 2005).

The Ashley National Forest has collected lake data through 2015, but data collected after the Nick and others (2012) report is not yet available for analysis. The Ashley National Forest is encouraged to analyze these data when available, along with data already available, and use that information in the remaining steps of the Forest plan revision process. The analysis should use seasonal and regional Kendall testing techniques rather than simple linear regression.

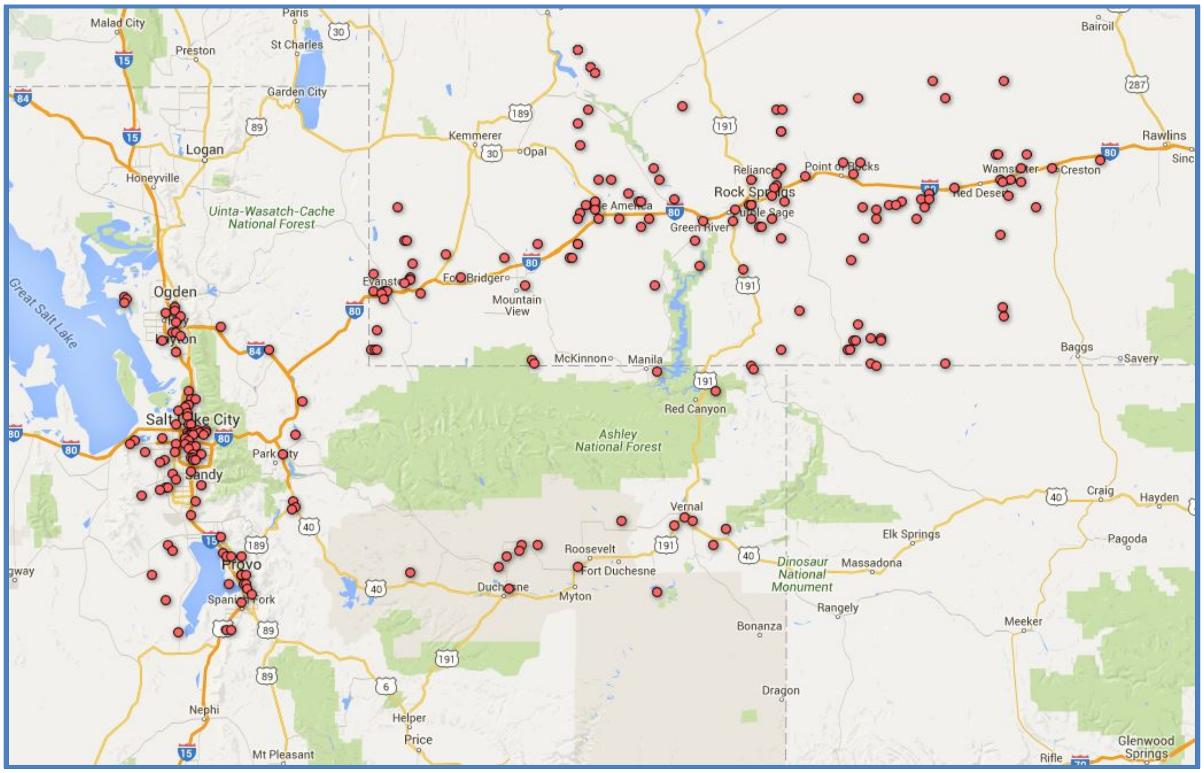

Figure 3. Sources of carbon monoxide (CO) in and around the Ashley National Forest

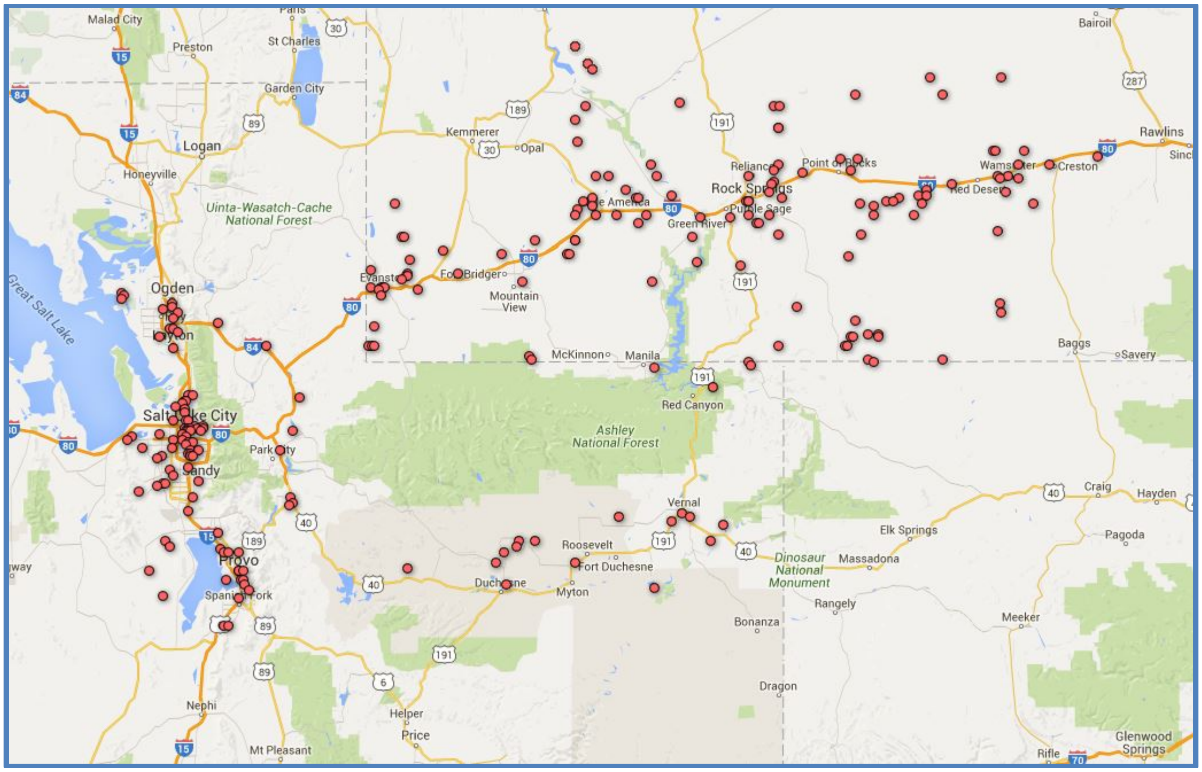

Figure 4. Sources of nitrogen oxides (NOx) in and around the Ashley National Forest

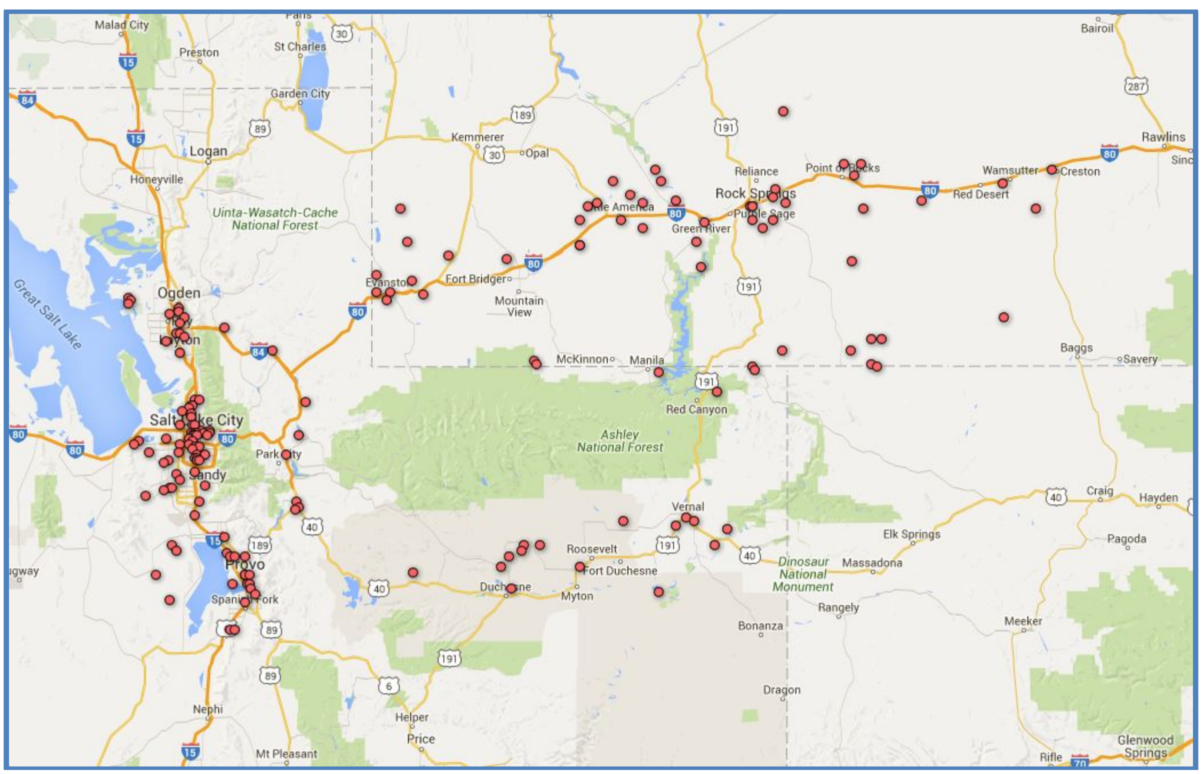

Figure 5. Sources of sulfur dioxide (SO2) in and around the Ashley National Forest

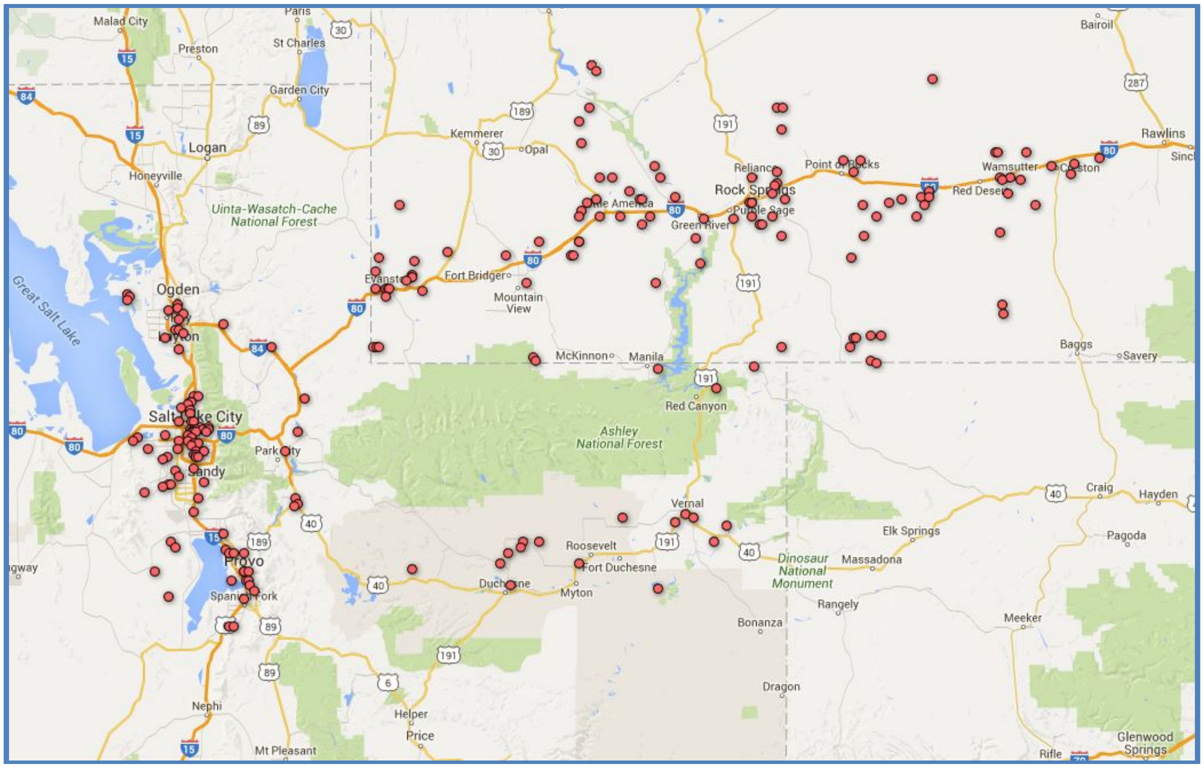

Figure 6. Sources of course particulate matter (PM10) in and around the Ashley National Forest

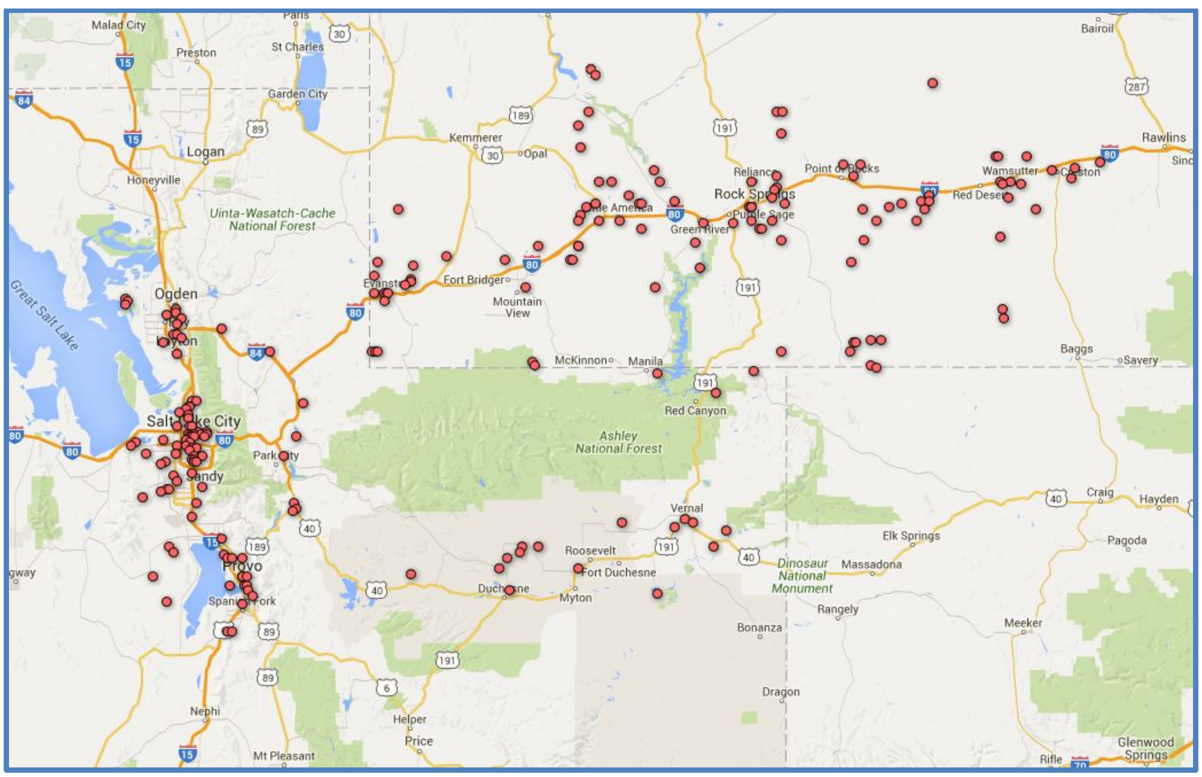

Figure 7. Sources of fine particulate matter (PM2.5) in and around the Ashley National Forest

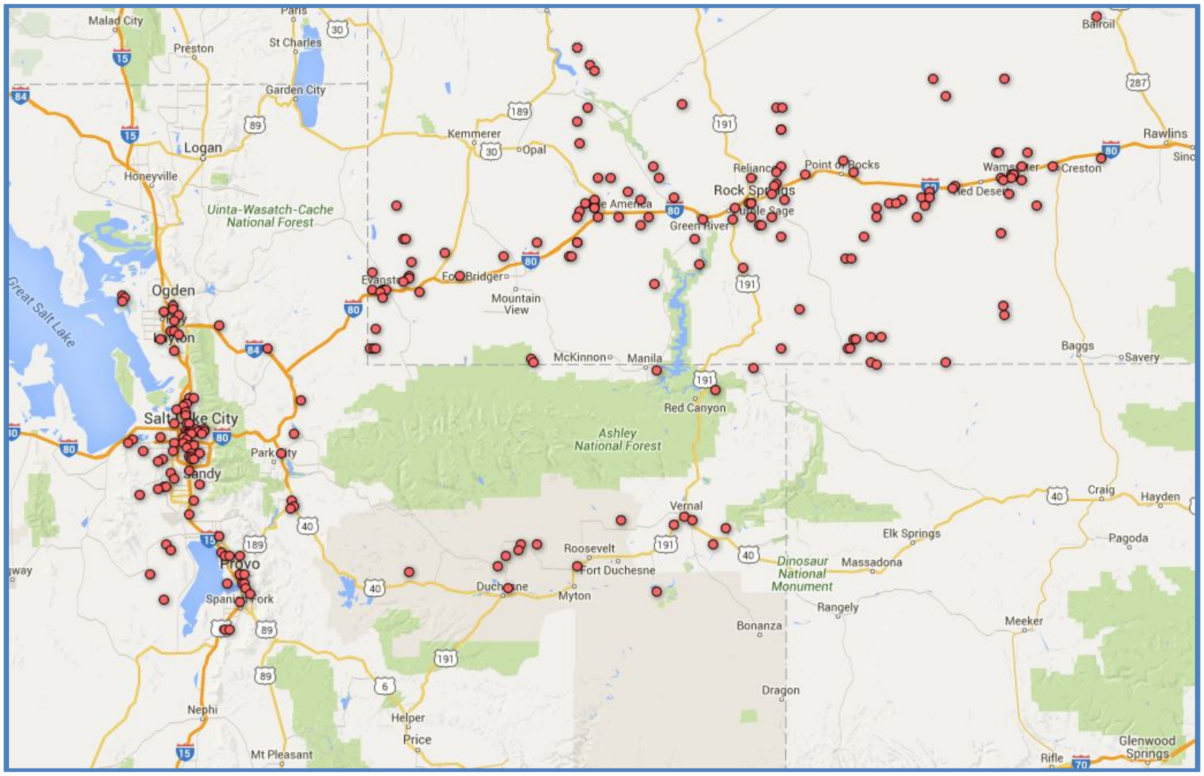

Figure 8. Sources of volatile organic compounds (VOC) in and around the Ashley National Forest

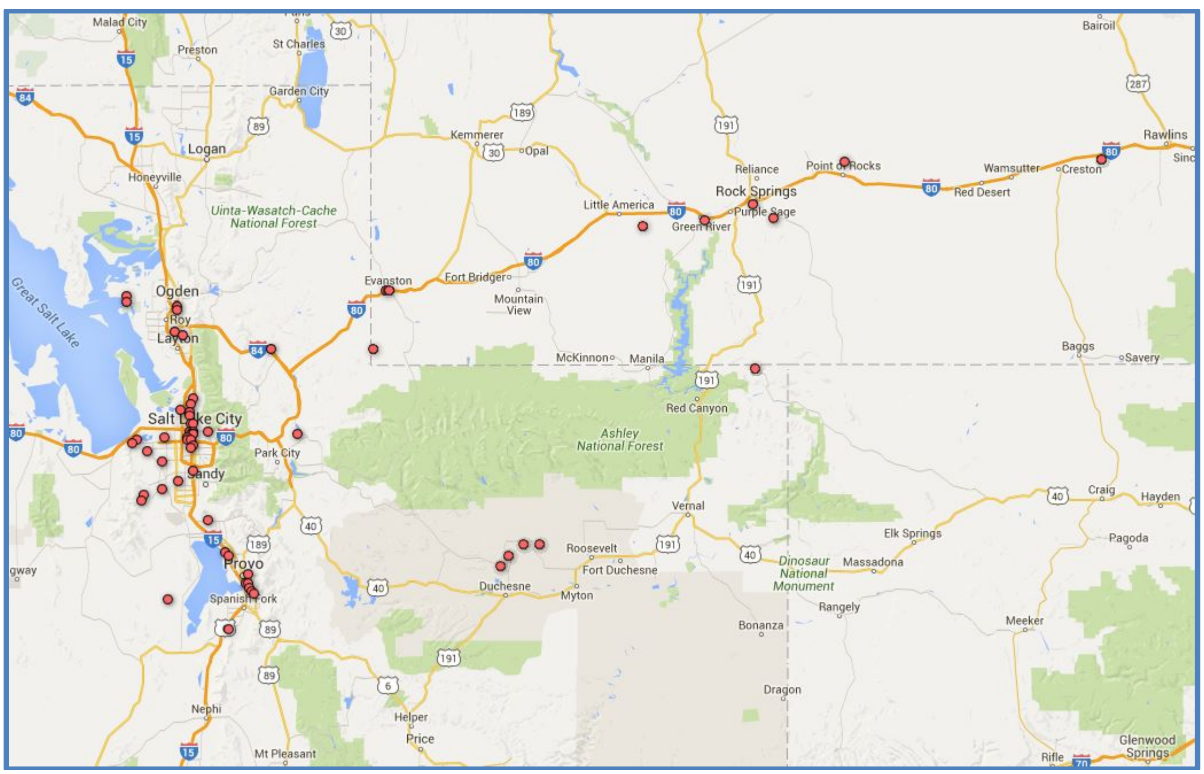

Figure 9. Sources of ammonia (NH3) in and around the Ashley National Forest

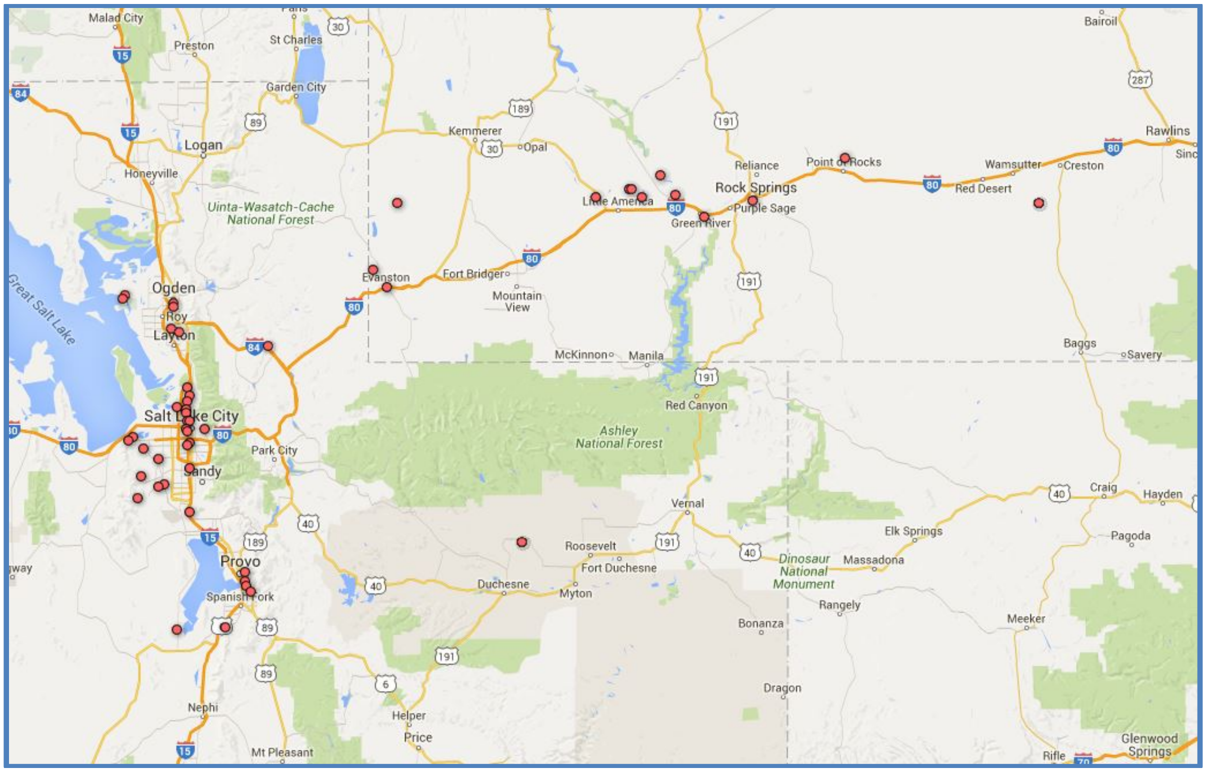

Figure 10. Sources of mercury (Hg) in and around the Ashley National Forest

Hundey and others (2014) documented that primary lake production (conversion of atmospheric carbon dioxide into organic, carbon-based compounds [i.e. plant matter]) in Uinta Mountain lakes was relatively stable for centuries until the 1950s, when increases began to occur. The study demonstrates the potential vulnerability of lakes to long-distance atmospheric transport of nutrients and the risk of lake eutrophication intensified by expansion of fossil fuel combustion, agriculture, mining activity, and climate warming. Hundey and others (2016) showed the post-1950 increases observed in these lakes have resulted from increased nitrate deposition, mainly from intensified farming and increased use of fertilizer. Stable isotope analysis of nitrogen and oxygen showed that at least 70 percent of the nitrates in Uinta Mountain aquatic systems are from regional anthropogenic activities, deposited from the atmosphere (Hundey et al. 2016). Furthermore, they showed agricultural activities, specifically nitrate and ammonium-based fertilizer use, are contributing most, i.e., 60 percent of the reactive nitrogen. In most of the lakes studied, the deposition has led to increased algal production. It was noted, however, that lakes with naturally high nitrogen concentrations are less affected by these additional nitrogen sources.

Reynolds and others (2010) showed changes in dust deposition timing and composition are related to the European settlement in western North America, including the Wasatch Front. Mining, industry, agriculture, urbanization, and transportation are potential causative factors. The changes are most pronounced in sediment deposited over the past 140 years. Squire (2012) documented atmospheric deposition of dust that is distinctly different from underlying bedrock. Thus, this dust is anthropogenic in nature. This indicates that human activities in the region are altering the chemistry of what has often been considered a primarily natural, undeveloped, and untrammeled ecosystem. Using stable isotope analysis of lead, it was shown that a main contributor of atmospheric metal deposition in Uinta Mountain lakes is the Bingham Canyon Mine on the Wasatch Front (Reynolds et al. 2010)

National Atmospheric Deposition Program

The National Atmospheric Deposition Program is a cooperative monitoring effort between many different groups and agencies. The program began as a wet precipitation chemistry network to provide data on the amounts, trends, and geographic distributions of acids, nutrients, and base cations in precipitation. Over time, the program expanded and now has five components:

- NADP national trends network (NTN)
- Atmospheric integrated research monitoring network (AIRMoN)
- Mercury deposition network (MDN)
- Atmospheric mercury network (AMNet)
- Ammonia monitoring network (AMoN)

Data for the National Atmospheric Deposition Program are available at http://nadp.sws.uiuc.edu/.

The national trends network is the original National Atmospheric Deposition Program. The mercury deposition network assesses total mercury, and at certain sites, methyl mercury. The ammonia monitoring network is similar to the national trends network in that the same chemicals are measured, but sampling is daily rather than weekly. The atmospheric mercury network measures atmospheric mercury fractions which contribute to dry and total mercury deposition. The ammonia monitoring network provides a long-term record of ammonia gas concentrations. Unfortunately, there are no National Atmospheric Deposition Program sites in, or near, the Ashley National Forest and Flaming Gorge National Recreation Area. However, there is a mercury deposition network, atmospheric mercury network, and ammonia monitoring network site in Salt Lake City. As previously discussed, this site is in certain nonattainment areas and is upwind of the Ashley National Forest. Data from these sites may prove useful to managers on the Ashley at some point in the future.

Clean Air Status and Trend Network

The clean air status and trend network (CASTNet) is a national air quality monitoring network. This network is designed to provide data for assessing trends in air quality, dry atmospheric deposition, and ecological effects due to changes in air pollutant emissions. The program provides long-term monitoring of air quality in rural areas to determine trends in regional atmospheric nitrogen, sulfur, and ozone concentrations and deposition fluxes of sulfur and nitrogen pollutants. The clean air status and trend network monitors this in order to evaluate the effectiveness of national and regional air pollution control programs. There is a site, DIN431, at Dinosaur National Monument directly east of Vernal, Utah. This site was established November 20, 2013, so the period of record is insufficient for analysis. However, data from this site may prove useful to managers on the Ashley National Forest at some point in the future. Detailed information can be found at http://epa.gov/castnet/javaweb/index.html.

Snowpack Chemistry

The U.S. Geological Survey (USGS) conducts annual snow chemistry surveys along the Rocky Mountain range from New Mexico through Montana. Annual snow packs accumulate atmospheric deposition such as nitrates and sulfates throughout the winter and offer opportunity to collect composite samples of the majority of annual precipitation. The survey network's goal is to determine annual concentrations and deposition of selected nutrients and other constituents collected in snowpack samples. The survey is also designed to assess trends, and support investigations of the effects of atmospheric deposition at local and regional levels. Detailed information can be found at http://co.water.usgs.gov/projects/RM_snowpack/.

There are two monitoring sites within the Ashley National Forest useful for atmospheric deposition monitoring: Grizzly Ridge and Lake Fork. Grizzly Ridge is in the eastern part of the Ashley National Forest on the hydrologic divide along Highway 191. Lake Fork is in the central-western part of the Ashley, on the divide between the Yellowstone and Lake Fork watersheds. A map showing the locations of these sites is available at the above mentioned website.

Data are collected for 17 metrics at each of these three sites. Each site is sampled once per year in late March to early April, which is when annual snow packs are near their maximum. For this assessment, ammonium, nitrate, sulfate, and mercury concentrations were visually evaluated for trend. The period of record varies by site and constituent. Deposition data for these four constituents were not evaluated as a part of this assessment due to concerns with accuracy of snow water equivalent data needed to convert concentrations to deposition.

Generally speaking, there is no apparent concentration trend for either site (figure 11 through figure 14), however, the period of record is relatively short. In a few years, the Ashley National Forest should conduct statistical analysis on these data using Seasonal and Regional Kendall testing techniques rather than simple linear regression. Analysis done for the Mount Massive and Buffalo Peaks Wilderness areas on the Pike and San Isabel National Forest (Forest Service 2014) could be used as a guide.

Ozone

Ozone has become an increasing concern in the Uintah Basin in Utah and the Upper Green River Basin in Wyoming in recent years due to increased oil and gas development. As noted previously, the Wyoming ozone concern is north of the Ashley National Forest airsheds and will not be discussed further in this assessment. The Utah ozone concern is noteworthy of discussion in this assessment because the Uintah Basin is equivalent to Utah smoke management airshed 9, which contains much of the Ashley National Forest.

The Uintah Basin ozone concern is under study by the Utah Department of Environmental Quality Division of Air Quality. In recent years, wintertime ozone concentrations have reached or exceeded national ambient air quality standards, resulting in concerns for human health and environmental impacts. In addition, there is concern the Basin will be designated a nonattainment zone, requiring development of a State implementation plan and a Federal implementation plan for portions of the Basin within Indian Country. The plans would outline emissions reductions requirements to bring the area into compliance with national ambient air quality standards. Detailed information is at http://www.deq.utah.gov/locations/U/uintahbasin/index.htm.

Currently, the Utah Division of Air Quality and other partners are diligently attempting to determine the causes of the ozone formation, identifying control strategies to reduce emissions, and encouraging the oil and gas industry to take proactive steps to cut emissions. The Ashley National Forest is extremely interested in the outcome of the study because there is considerable active oil and gas development on the South Unit of the Ashley. Also, the Ashley needs to manage for wilderness air quality values in the High Uintas Wilderness and comply with previously mentioned forest plan air quality goals, objectives, and standards and guidelines. The Ashley National Forest is also concerned with potential effects nonattainment status may have on day-to-day resource management. The Ashley National Forest should stay engaged with the Division of Air Quality study as additional forest plan revision steps are undertaken.

In addition to the Division of Air Quality study, the USFS Rocky Mountain Research Station has conducted ozone monitoring at one site on the Ashley National Forest. This site was part of an ozone study of remote, non-urban mountain areas in national forests in Colorado and northeastern Utah

(Musselman and Korfmacher 2014). This site was located at Dutch John heliport near Flaming Gorge and was operated between 2010 and 2014. The results of the study indicate ozone was primarily in the mid-concentration range, rarely exceeding 100 parts per billion or dropping below 30 parts per billion. Daily changes in concentration indicated mixing of nitrogen oxides, volatile organic compounds, and ozone favor stable ozone concentrations. High ozone concentrations in the spring and at night suggest stratospheric intrusion may be contributing to ambient ozone. The highest nighttime concentrations occurred at the highest elevations, while daytime concentrations were not correlated with elevation.

Lichens

Lichens are susceptible to air pollution and are increasingly being monitored as biological indicators in remote areas such as national forests. The Forest Service forest inventory and analysis program, located at http://www.fia.fs.fed.us/program-features/indicators/lichen/index.php, provides detailed explanation of the use of lichens for air quality monitoring. Dozens of forest inventory and analysis program lichen plots are located in and around the Ashley National Forest (Story 2014). In 2014, the forest health monitoring program issued a contract to quantify existing lichen data in their database warehouse and establish lichen baselines where sufficient data exists. The Ashley National Forest should track the progress of this contract as additional forest plan revision steps are undertaken.

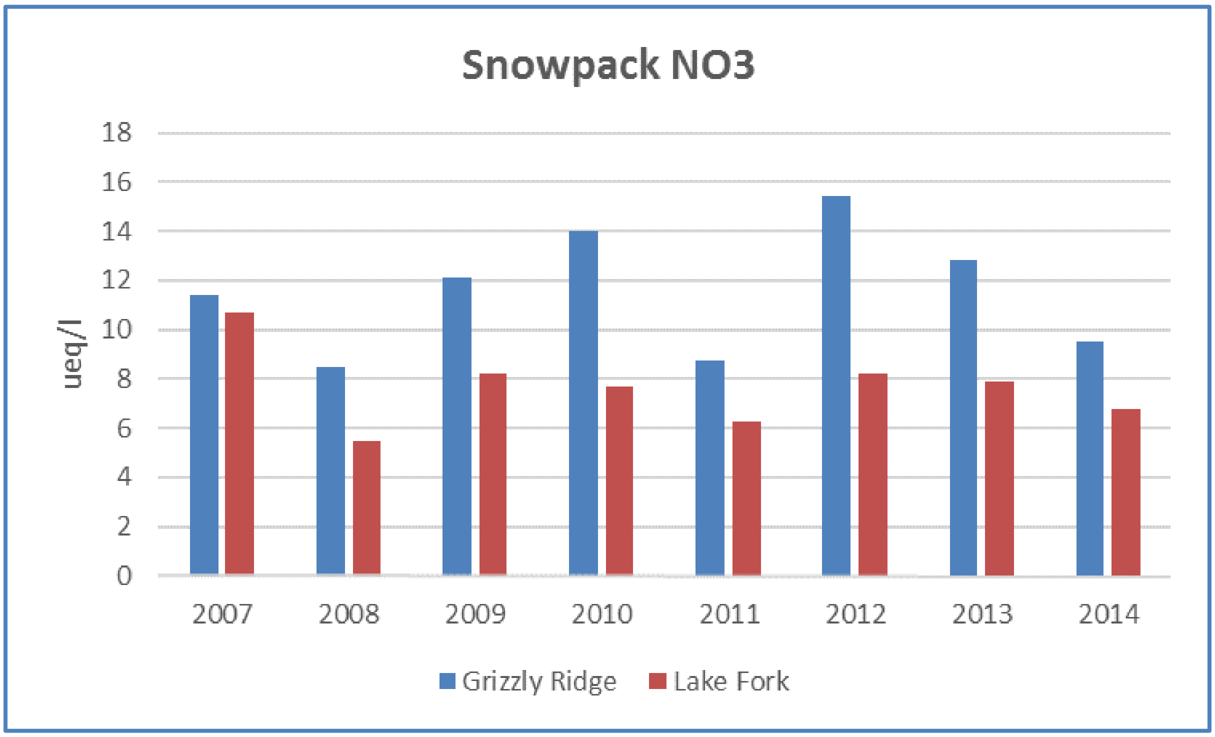

Figure 11. Annual snowpack nitrate concentration at two locations in the Ashley National Forest *(USGS snow chemistry data for Grizzly Ridge and Lake Fork sampling sites)*

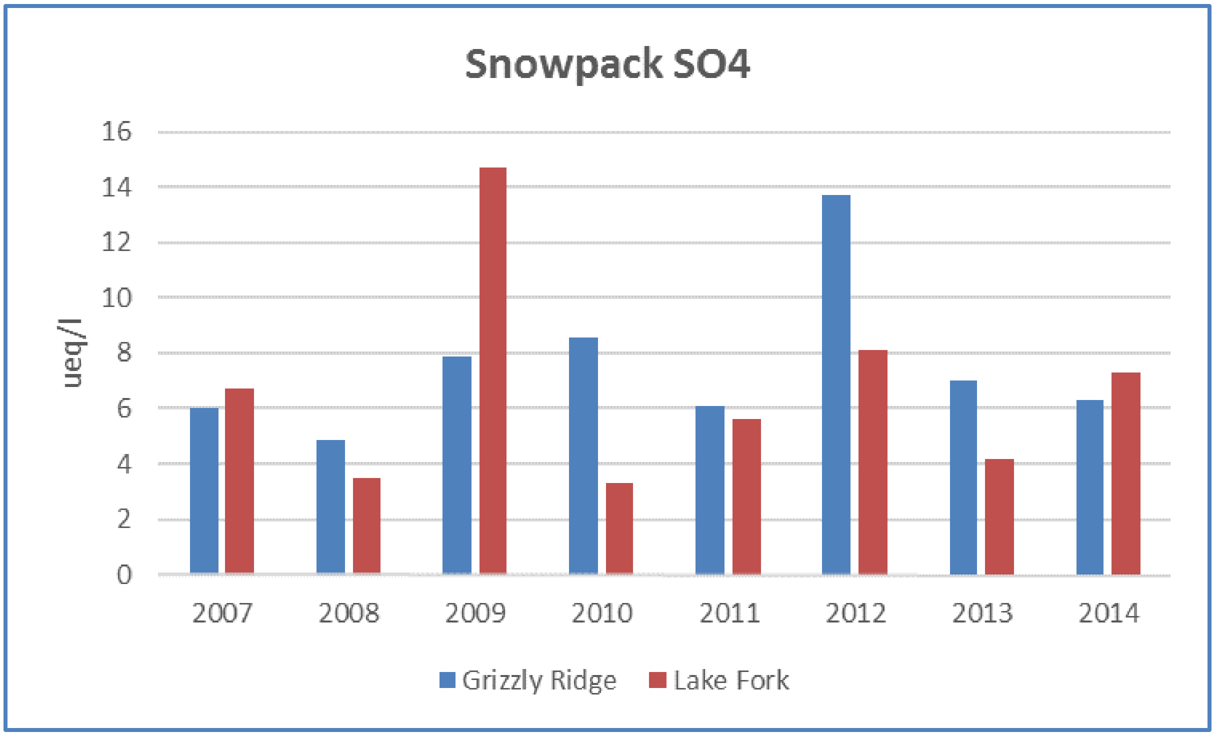

Figure 12. Annual snowpack sulfate concentration at two locations in the Ashley National Forest *(USGS snow chemistry data for Grizzly Ridge and Lake Fork sampling sites)*

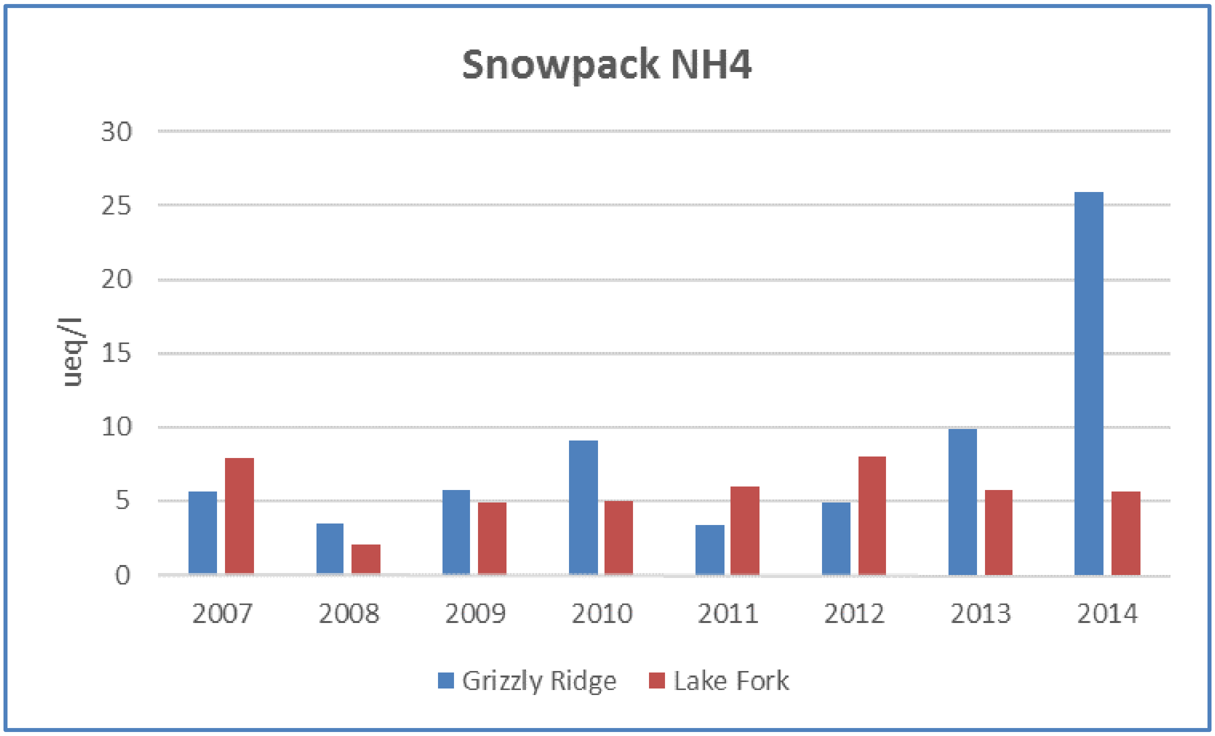

Figure 13. Annual snowpack ammonium concentration at two locations in the Ashley National Forest *(USGS snow chemistry data for Grizzly Ridge and Lake Fork sampling sites)*

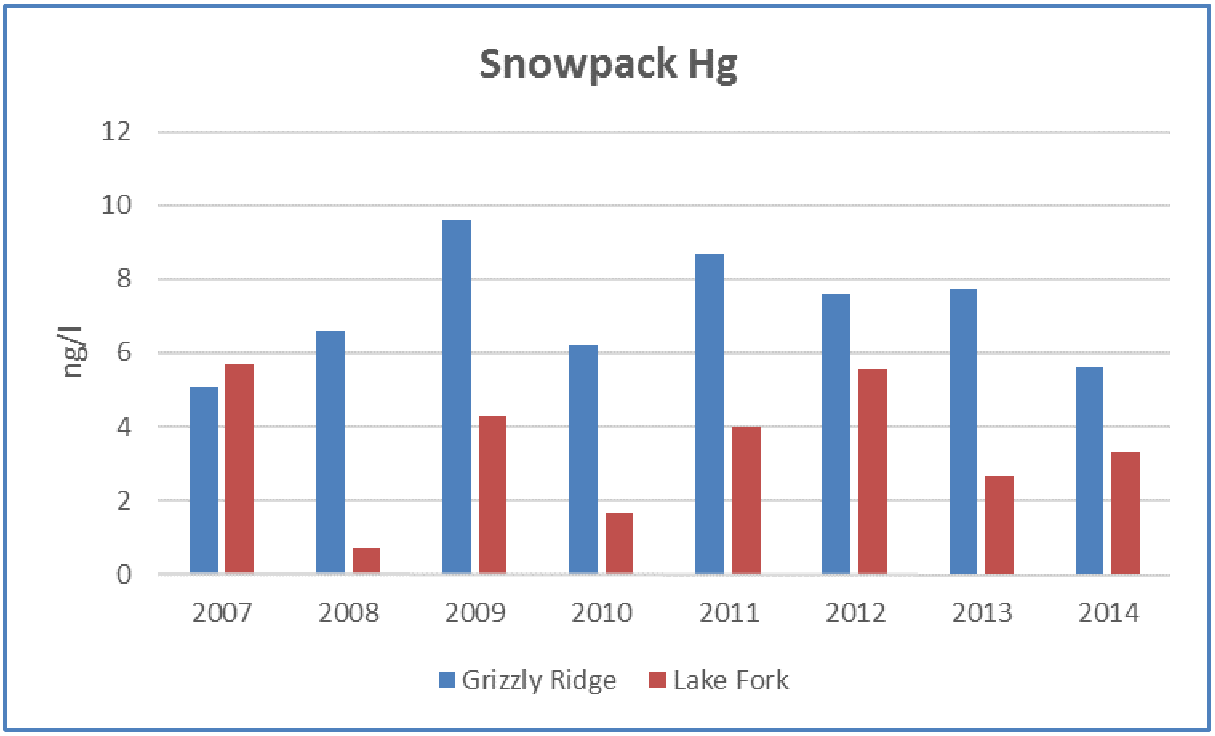

Figure 14. Annual snowpack mercury concentration at two locations in the Ashley National Forest *(USGS snow chemistry data for Grizzly Ridge and Lake Fork sampling sites)*

Dr. Larry St. Clair, Brigham Young University, monitors lichen air quality reference sites in or near the High Uintas Wilderness, in Flaming Gorge National Recreation Area, and in the South Unit of the Ashley National Forest. The High Uintas sites monitor effects on air quality related values. The national recreation area sites monitor heavy metal levels along Highway 191. The South Unit sites monitor potential impacts of fossil fuel extraction and processing activities.

In June 2011, Dr. St. Clair reported two lichen communities, northwest and northeast of the wilderness respectively, are diverse and well developed. This indicates they are intact and generally free from air pollution-related damage.

In December 2013, he reported lichen flora at all sites in the South Unit are diverse, well developed, and healthy, supported by identification of 102 species in 34 genera. Within this diversity, an average of 12.4 air pollution sensitive indicator species per reference site exists. This documents that lichen communities are intact and generally free from air pollution-related damage. Along Highway 191, follow-up monitoring of previously documented elevated levels of heavy metals. This suggests the source is most likely related to general vehicle traffic, with particular input from large trucks navigating the steep grade and commonly pulling off the highway near the Cart Creek Bridge to cool their brakes. The hypothesis is the elevated heavy metals are from idling diesel engines and overheated brakes.

In June 2015, he reported two lichen communities in or near the wilderness and one community along Highway 191 remain diverse and well developed, with no detectable differences in structure or diversity. He also reported rock, soil substrates, or both are particularly rich.

Three-State Air Quality Study

The three-state air quality study was initiated in 2011 to assess the environmental impacts of sources related to oil and gas development and production in western Colorado, eastern Utah, and southwestern

Wyoming. In particular, the study is designed to quantify the impacts of proposed oil and gas development on current and future air quality. This includes ozone and visibility in national parks and wilderness areas. Participating agencies are EPA, Bureau of Land Management, Forest Service, National Park Service, and the states of Utah, Colorado, and Wyoming. Activities include expansion of air quality monitoring to establish baseline conditions and track trends, create and operate a centralized data warehouse, and perform regional-scale modeling. Detailed information can be found at http://views.cira.colostate.edu/tsdw/. Information from this study may prove useful to managers on the Ashley National Forest during subsequent steps of forest plan revision.

Watershed Condition Framework

The watershed condition framework characterizes the health and condition of National Forest System lands. The characterization is a reconnaissance-level approach using a comprehensive set of 12 indicators and 24 attributes that are surrogate variables. This characterization represents ecological, hydrological, and geomorphic functions and processes that affect watershed condition. The primary emphasis of the classification is on aquatic and terrestrial processes and conditions that Forest Service management activities can influence. The initial or baseline characterization for the Ashley National Forest was completed in 2010.

One attribute within the forest health indicator is ozone. This attribute is rated to address forest mortality impacts to hydrologic and soil function due to air pollution. All watersheds on the Ashley National Forest were rated functioning properly relative to ozone.

Two other attributes, water quality problems and soil contamination, are rated in part using data related to air quality. A summary of these attributes is in the “Water: section of this report. A more current assessment is provided below in the critical loads discussion and should be used when the Ashley National Forest updates the watershed condition framework.

Critical Loads

Air pollution deposited into national forest ecosystems may cause ecological changes due to acidification or nutrient loading. The term critical load is used to describe the threshold of air pollution deposition below which harmful effects to sensitive resources in an ecosystem begin to occur. Critical loads are based on best available science about expected ecosystem responses to atmospheric deposition. In ecosystems where damage is already documented critical loads can be used to assist with mitigation efforts. In ecosystems where critical loads have not yet been exceeded, they can be used to set allowable pollution levels to ensure protection and maintenance of the ecosystem.

The USDA Forest Service air quality portal for land management planning, located at http://www.srs.fs.usda.gov/airqualityportal/index.php , provides guidance on assessing critical loads of air pollution. The guidance serves to determine if concerns exist with acidification, i.e., acid rain, and nutrient loading, e.g., nitrogen saturation and eutrophication, of several ecosystems components. The seven step critical load implementation strategy outlined in the guidance was followed as part of this assessment.

- Step 1, or the initial screening, shows the potential for critical load exceedance on the Ashley National Forest.
- Step 2 indicates ecosystem sensitivity to atmospheric deposition due to potentially elevated deposition of nitrogen.
- Step 3 establishes there are no published regional or local critical load estimates so national estimates should be used,

- Allowing Steps 4 and 5 to be skipped
- Steps 6 and 7 involve examination and interpretation of atmospheric pollution impacts on various ecosystem components.
- Step 6 was a detailed GIS analysis, resulting in numeric output and maps of exceedance information (table 5 and figure 34 through figure 40)[5].
- Step 7 utilizes available scientific literature, with Pardo and others (2011) being a key document.

The analysis indicates there are no concerns with acidification from atmospheric deposition. More specifically, no forested ecosystem grid cells exceeded acidification criteria built within the portal and only 4 percent of the sampled lakes exceeded acidification criteria. The reliability of these results are high for surface waters but low for forested ecosystems. However, these acidification results are consistent with previous discussions in this report that, despite apparent increases in nitrogen deposition (nitrogen oxides and ammonia), buffering due to geology minimizes concern for acid deposition.

The analysis indicates there are concerns with nutrient loading. From Pardo and others (2011), the Ashley National Forest is in the Northwestern Forested Ecoregion, where the empirically derived critical load values for nitrogen deposition varies from 2.5 to 17 kilograms per hectare per year, depending on the ecosystem component. Lichens are the most sensitive component, so deposition rates at the lower end of the range can be of concern. For the other components - herbaceous plants and shrubs, forests, alpine grasslands, mycorrhizal (group of fungi in the soil which colonize the roots of plants while providing a variety beneficial functions for the plants) fungi and soil leaching - concerns typically do not arise until nitrogen deposition rates are at the mid to higher end of the range.

The analysis indicates 68 percent of the Ashley National Forest exceeds the modeled critical load for herbaceous plants and shrubs. Exceedances range between 0.03 and 2.68 kilograms per hectare per year. Almost all (95 percent) of the grid cells exceeded the critical load for herbaceous plants and shrubs by less than 1.95 kilograms per hectare per year. Seventy percent (68 percent) of the forest exceeds the critical load for forests. Exceedances range between 0.03 and 2.68 kilograms per hectare per year. Almost all (95 percent) of the grid cells exceeded the critical load for forests by less than 1.83 kilograms per hectare per year. Thirty-one percent of the Ashley exceeds the critical load for mycorrhizal fungi. The exceedances range between 0.02 and 1.68 kilograms per hectare per year. Almost all (95 percent) of the grid cells exceed the critical load for mycorrhizal fungi by less than 1.68 kilograms per hectare per year. For nitrate leaching, 70 percent of the Ashley exceeds the critical load. Exceedance values range from 0.03 to 2.68 kilograms per hectare per year, with 95 percent of the grid cells exceeding the critical load for nitrate leaching by less than 1.83 kilograms per hectare per year. The reliability of the results from this modeling effort for these three ecosystem components is low.

Ninety five percent of the Ashley National Forest exceeds the modeled minimum critical load for lichens, while only 25 percent exceeds the maximum. Exceedances range from 0.02 to 1.65 kilograms per hectare per year for the maximum critical load and from 0.01 to 3.52 for the minimum. Almost all (95 percent) of the grid cells exceed the maximum critical load for lichens by less than 0.72 kilograms per hectare per year and the minimum by less than 2.6 kilograms per hectare per year. The reliability of the results from this modeling effort are high.

As noted previously in this report, lichens are some of the most sensitive species to nitrogen deposition and are an important early indicator of impacts from air pollution. Current lichen monitoring efforts on

[5] Note there is no data at the portal for the Wyoming portion of Flaming Gorge National Recreation Area. Because of this, the area is not a part of the critical load assessment nor a part of this discussion. Should data for that area become available, the Forest should re-run the analysis.

the Ashley National Forest indicate lichens are not currently being impacted by atmospheric deposition. However, this modeling effort suggests the Ashley should remain diligent in lichen monitoring. A large part of the Forest exceeds the minimum critical load for lichens and a sizable portion of the Ashely exceeds the maximum critical load.

Table 5. Summary of air pollution critical loads assessment. Severity – range of exceedance amount is the quantity of deposition being received above the critical load

	Acidity: Surface Waters	Acidity: Forested Ecosystems	Nutrient N: Herbaceous Plants and Shrubs	Nutrient N: Forests	Nutrient N: Lichens	Nutrient N: Mycorrhizal Fungi	Nutrient N: Nitrate Leaching
Extent	2 of 49 lakes (4%) exceed critical load	0% of forest exceeds critical load	68% of forest exceeds critical load	70% of forest exceeds critical load	25% of forest exceeds maximum critical load; 95% of forest exceeds minimum critical load	31% of forest exceeds critical load	70% of forest exceeds critical load
Severity – range of exceedance amount	0.49 to 0.77 $meq/m^2/yr$	NA	0.03 to 2.68 kg/ha/yr	0.03 to 2.68 kg/ha/yr	0.02 to 1.65 kg/ha/yr for maximum critical load; 0.01 to 3.52 kg/ha/yr for minimum critical load	0.02 to 1.68 kg/ha/yr	0.03 to 2.68 kg/ha/yr
Severity – 95% exceedance value	NA due to small sample size	NA	1.95 kg/ha/yr	1.83 kg/ha/yr	0.72 kg/ha/yr for maximum critical load; 2.6 kg/ha/yr for minimum critical load	1.68 kg/ha/yr	1.83 kg/ha/yr
Reliability	High	Low	Low	Low	High	Low	Low

N = nitrogen; kg/ha/yr = kilograms per hectare per year; $meq/m^2/yr$ = milliequivalents per square meter per year, NA = not applicable

For other ecosystem components – herbaceous plants and shrubs, forests, alpine grasslands, mycorrhizal fungi and soil leaching – the modeled deposition rates of 1.68 to 2.68 kilograms per hectare per year are not particularly high, but they are within the range of concern for the Northwestern Forested Ecoregion. Additionally, roughly 70 percent of the Ashley National Forest exceeds the critical loads for herbaceous plants, shrubs, forests, and nitrate leaching. These modeled values suggest the potential for future ecosystem maintenance issues. These issues are due to lower organic soil horizon carbon to nitrogen ratios, higher nitrogen mineralization rates, higher potential net nitrification rates and foliar nitrogen concentration, higher nitrogen to potassium, nitrogen to calcium, and nitrogen to magnesium ratios in forested areas, and changes in plant species composition in alpine ecosystems enhancing rates of nitrogen cycling, which could lead to nonlinear increases in nitrate leaching and soil acidification (Pardo et al. 2011). The results of this nutrient loading assessment, and other information provided in this report, does not support development of refined and target critical loads for these ecosystems components at this time. However, the Ashley National Forest should continue with development, adjustment, and implementation of its existing air resources program. Use of the critical loads monitoring strategy, located at http://www.srs.fs.usda.gov/airqualityportal/critical_loads/monitoring_strategy.php , provides information that may be particularly useful to the Ashley National Forest in fine-tuning its air resources program.

Implementation Plans

As mentioned previously there are State implementation plans in Utah and Wyoming, per Clean Air Act requirements. EPA-approved plans are available at http://www.epa.gov/region8/state-implementation-plan-sip. Plans for Utah's nonattainment areas are also available at http://www.deq.utah.gov/Laws_Rules/daq/sip/index.htm. Regional haze plans for each state are available at http://www.epa.gov/region8/air-program.

Natural Hazards

There are no known large, broad-scale, major geologic hazards within the Ashley National Forest that may affect air quality.

Multiple Uses and Ecosystem Services

The air resource on the Ashley National Forest, in conjunction with soil, water, and watershed resources, is part of the foundation for providing for the full suite of multiple uses available from national forests. Good to excellent air quality is a prerequisite to many National Forest uses, products, and services. For example, people recreate on the forest to enjoy clean air and view expansive vistas. Water unpolluted by atmospheric deposition provides on- and off-forest uses such as habitat for aquatic organisms, and drinking, industrial, and agricultural supply. Clean air assists in climate regulation, particularly relative to greenhouse gases.

Conditions and Trends

Compared to many areas in the country, air quality within and near the Ashley National Forest and Flaming Gorge National Recreation area is good to excellent. The area is minimally developed, has limited local emissions sources, and predominantly very robust air dispersion. The Ashley National Forest is in conformance with current national ambient air quality standards.

Wildfire emissions, depending upon the year, can be a significant source of pollution within and around the Ashley National Forest. The emissions are not controllable by management except indirectly, through fire suppression and fuels management projects such as prescribed burning. Prescribed-fire emissions in the area do occur during the spring and late fall. The amount of fuels management activity is expected to hold constant, with several thousand acres per year being treated. Smoke management is regulated by permit from the states of Utah and Wyoming. Overall smoke emissions (wildfire and prescribed) are expected to remain about the same, with the major variable being weather conditions. Air quality impacts from other resource management activities, e.g., dust from logging roads and recreational use of system roads, are generally small and inconsequential. The impacts are not a concern at the forest planning level.

The greatest threat to Ashley National Forest air quality is anthropogenic sources on lands of other ownership. Urban, industrial, and agricultural air pollution, from both upwind and surrounding source areas, have a potentially persistent impact because many of these emissions occur year-round. These sources are managed to varying degrees by air quality regulatory agencies in Utah and Wyoming, and other upwind states. There is also collaboration from the Forest Service for major source permitting through the prevention of significant deterioration process. Currently, areas around the Ashley National Forest are in attainment of all national ambient air quality standards, but there is a concern with ozone in the Uintah Basin. This concern is being actively investigated by the Utah Air Quality Division. The concern may eventually lead to nonattainment status in a portion or all of the Uintah Basin. There are nonattainment areas along the Wasatch Front, which is west and upwind of the Ashley National Forest. Implementation plans are in place for these nonattainment areas.

Monitoring indicates visibility is not being impacted by regional haze and this wilderness air quality value is being protected in the High Uintas Wilderness. There is an ever growing body of evidence from research and monitoring that atmospheric deposition is a reason for concern for managers of the Ashley National Forest. This is particularly true as related to wilderness air quality values in the High Uintas Wilderness. This evidence suggests acidification of surface waters and forested ecosystems is not a concern, but deposition of nitrogen (both nitrates and ammonium) and phosphorus are. This deposition of nutrients is traced to upwind and surrounding sources. The deposition appears to be having an effect on sensitive high elevation lake water chemistry and possibly biota. The deposition does not currently appear to be affecting herbaceous plants and shrubs, forests, lichens, mycorrhizal fungi and nitrate leaching. But critical load modeling does suggest potential concern, particularly with lichens, which are an excellent indicator of effects of air pollution on terrestrial biota. Another potential concern is deposition of dust from off-Forest sources and its effects on high elevation lakes, water yield, and timing of flows. Research in the Wasatch Range of Utah and the San Juan Mountains in Colorado indicates windblown dust can speed snowmelt and alter the timing of spring runoff. Metals and other elements can be carried long distances in the dust, with a potential to influence aquatic organisms.

Soil Resources

Inventories

The following inventories and information are available in the supervisor's office of the Ashley National Forest:

- A soil survey, certified by the National Cooperative Soil Survey, for the South Unit of the Ashley National Forest
- A land system inventory and ecosystem diversity evaluation report for the entire Ashley National Forest
- A watershed improvement needs inventory (hard copy). In more recent times, the inventory is being managed electronically in the natural resource information system watershed improvement tracking module and watershed condition framework database.
- A watershed condition framework which characterizes the health and condition of National Forest System lands

Important Attributes, Characteristics, and Processes

Physiography[6]

The Ashley National Forest, which includes the Flaming Gorge National Recreation Area, is a large geographical area in northeastern Utah and southwestern Wyoming. The dominant physiographic features include the Uinta Mountains, Tavaputs Plateau, a very small portion of the Uintah Basin, and the southern end of the Upper Green River Basin.

The Uinta Mountains are an east-west trending mountain range, lying parallel with the southern border of Wyoming. The mountains extend from Kamas, Utah eastward to the Colorado border. The Uinta

[6] A detailed discussion of geology will be provided in another assessment, being written by the forest geologist.

Mountains comprise three significantly different sections: High Uintas Subsection, Eastern Uintas Subsection, and Marginal Benches Subsection (Stokes 1986).

- The High Uintas Subsection is the highest elevation portion of the Uinta Mountains and comprises the western half of the mountain range. This area is topographically different from lower elevation areas surrounding it, but also from the eastern extension of the mountain range. Kings Peak, Utah's highest at 13,528 feet, is located in the High Uintas Subsection. Rocks that make up the central core are quartzites, with inclusions of shale. The area has distinctive glacial topography, with cirque valleys separated by steep-walled aretes. There are hundreds of lakes, above and below timberline, which is at about 11,500 feet.
- The Eastern Uintas Subsection comprises the eastern half of the mountain range and lacks the glacial features of the High Uintas Subsection. Rather, there are wide shallow valleys that cross the crest of the mountain range. Lakes are almost non-existent. Browns Hole, which lies in this subsection along the Utah-Colorado border, is believed to be responsible for lowering the former crest of the range creating the depression the Green River follows from Wyoming into Utah.
- The Marginal Benches Subsection lies on the north and south side of the mountain range. On the south side, benches rise and merge with the other two subsections. On the north side, the benches abruptly descend toward adjacent lowlands. The Green River cuts across the bench surfaces and Eastern Uintas Subsection from north to south. The river basically divides the Green River drainage into the Upper Green and Lower Green River basins. Flaming Gorge National Recreation Area lies in the lower elevations of the southern end of the Upper Green River Basin and Eastern Uintas Subsection, directly along the Green River itself. Rocks that make up this subsection are mostly limestones, with inclusions of conglomerates.

The Tavaputs Plateau contains the South Unit of the Ashley National Forest and is at the northern end of the Colorado Plateau. Rocks are predominately shales, limestones, sandstones, and siltstones. The small portion of the Uintah Basin that contains National Forest System lands is directly adjacent to the Tavaputs Plateau and is comprised of sedimentary rocks similar to the plateau. The southern end of the Upper Green River Basin, where much of the Flaming Gorge National Recreation Area is located, is a structurally complex geologic depression of extensive faulting and folding of sedimentary layers. Rocks are conglomerates, sandstones, siltstones, shales, and Quaternary age sand dunes and loess.

Soils

The Ashley National Forest is fortunate to have a land systems inventory and a draft ecosystem diversity evaluation report (Forest Service 2009a). These two documents are useful in describing important attributes, characteristics, and processes for the soil resource. The ecosystem diversity evaluation report was developed as both a top-down and bottom-up approach to describing ecosystems across the Ashley. A full description of the approach is described in the draft ecosystem diversity evaluation report.

The ecosystems found on the Ashley National Forest are defined from the top-down using four sections and 15 subsections defined by the National Hierarchical Framework for Ecological Units, and from the bottom-up using166 land types and 24 land type associations from the land systems inventory. Land type associations are the scale most useful for forest wide planning and will be the focus of the remaining discussion (figure 15). Land types are more appropriate for project level use and thus are only casually mentioned in this report. For the South Unit, at the project level, the soil survey that is available should be used rather than the land type information.

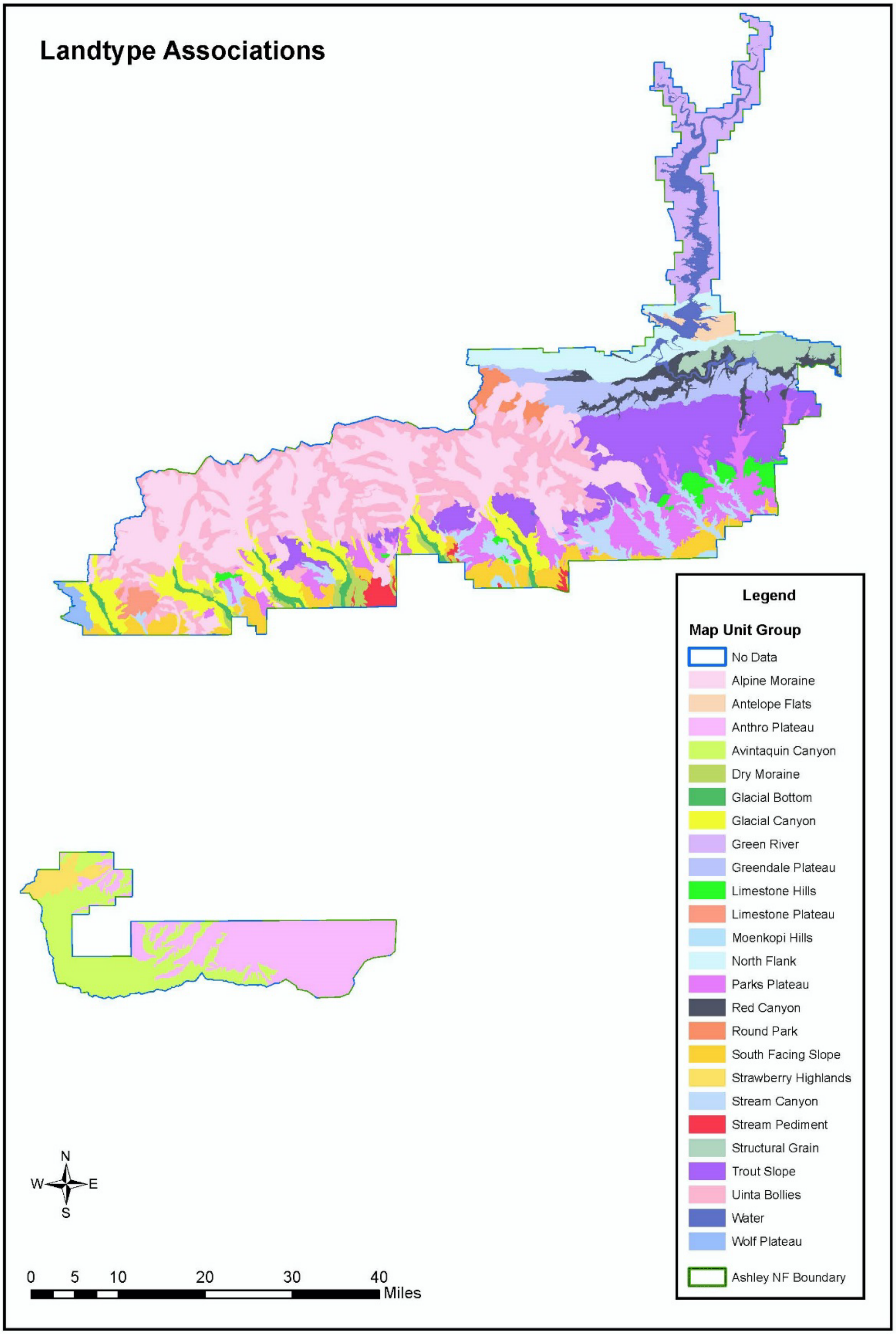

Figure 15. Land type associations on the Ashley National Forest

Each land type association is unique in terms of its geology, geomorphology, and soils characteristics as described below. Each land type association is also unique in terms of vegetation composition and structure. The vegetation narrative for each land type association is too lengthy to summarize in this report. However, the understanding of the narrative is paramount to the understanding of soils. Thus, the narrative should be referenced as necessary as plan revision proceeds.

It is noteworthy that information for some land type associations is much more complete, and thus better described, than for other land type associations. Additional information for less well-described associations is available in various venues and could be utilized as forest plan revision efforts move forward. This additional information is not necessarily readily available however, so a decision will need to be made whether the additional workload is justified.

Alpine Moraine Land Type Association

Geology and Geomorphology

Glaciated lands, predominately in the Uinta Mountain Group, characterize the Alpine Moraine land type association. They consist of alpine glaciated cirques and scoured and depositional basins at the heads of drainages. These include glaciated valley bottoms consisting of lakes, meadows, seeps and springs, steep glaciated sideslopes with surficial deposits of glacial material, and steep inner gorges. They are characterized by nonconsolidated soils of recent age consisting of gravels, sands, and sandy loams, and finer textured soils in the wet areas. Landform characteristics include ground moraines, wet and dry meadows, scoured and depositional basins, potholes, rock debris, steep glacial side-slopes, exposed bedrock with shallow soils, and deep gorges of exposed bedrock. Slopes range from about two percent to near vertical in the gorges.

Soils

Soils in this land type association are shallow to deep, depending on deposition over bedrock. In many places, bedrock exposure shows the striations of the glacial movement. Here, the soils are shallow, sandy, cobbly sandy loams and loamy sands. For much of the ground moraine, they are deep loamy sands. These soils are subject to erosion until the coarse fragments establish an armor surface. The soils that occur in the depressions are poorly drained and ponded during the wetter parts of the season. These soils are clay and clay loams and have a reduced amount of coarse fragments and cobbles. The soils in the riparian area are generally poorly drained and subject to ponding or overland seepage. There are also many stratified layers of sandy materials.

Antelope Flat Land Type Association

Geology and Geomorphology

The Antelope Flats land type association includes sandy and gravelly quaternary pediments, associated with the Green River and gypsum-bearing, alkaline, or saline sediments of Mancos Shale. Topography is generally flat with escarpments of Mancos shale.

Soils

Soils in this land type association have formed on eolian (windblown, wind-deposited) sand deposits derived from Green River floodplains and bars, sandstone formations, and quartzite from the Uinta Mountains. The remaining soils formed in alluvium and residuum from saline marine shale. The eolian soils fall in the sandy and loamy soil texture groups, have low rock fragment content, and are well drained with rapid permeability. Limited soil sampling shows these soils are deep (100 to 150 centimeters). Soil texture is often sandy loam over a subsoil of loamy sand. Calcium carbonate accumulations begin around a depth of 28 centimeters and the amount of cementation and secondary carbonates increases with depth in the soil profile. There are few rock fragments in the upper portion of the soil profile, but in the lower profile there are layers of gravel, possibly bench gravels where the sand was initially deposited.

Anthro Plateau Land Type Association

Geology and Geomorphology

The Anthro Plateau land type association consists of plateau lands dissected by long, canyons with comparatively wide, flat bottoms. Canyons are cut through calcareous sandstones and marly, shale-like mudstones of the Green River and Uinta Formations.

Soils

Soils in this land type association have formed from erodible parent materials derived from shales, sandstones, and siltstones of the Green River and Uinta Formations. Debris flows on steep slopes are common especially during summer storm events.

Avintaquin Canyon Land Type Association

Geology and Geomorphology

The Avintaquin Canyon land type association is composed of dendritically dissected plateau lands. These lands are underlain by marly, shale-like mudstones of the Green River and Uinta Formations with narrow or moderately wide, flat ridges and northerly gradients of about five percent. The dendritic canyons (most common river drainage pattern, containing many contributing streams and tributaries) have steep walls and very narrow drainage bottoms.

Soils

Soils in this land type association have formed from erodible parent materials derived from shales, sandstones, and siltstones of the Green River and Uinta Formations.

Dry Moraine Land Type Association

Geology and Geomorphology

The Dry Moraine land type association is comprised of steep escarpments (long steep slope - especially along the edge of a plateau - separating land areas of different heights) of sandy, bouldery lateral moraines of glaciated canyons of the south slope of the Uinta Mountains that are being fluvially dissected. Some of these lateral moraines have a well-expressed constructional topography composed of a ridge and trough system that roughly parallels the main valley. The basin-ward extension of the Dry Moraine land type association consists of extensive moraine deposits, mainly off the Ashley. Landforms of this land type association also reflect older glacial periods.

Soils

Soils in this land type association have formed primarily on lateral and end glacial moraines. These soils are coarse-textured with surface textures of sandy loam and subsurface textures of sandy loam or loamy sand. Rock fragment content ranges from 10 to 70 percent and is dominated by cobbles.

Glacial Bottom Land Type Association

Geology and Geomorphology

The Glacial Bottom land type association typically dominates the western portion of the south slope of the Uinta Mountains, while the Stream Canyon land type association dominates the eastern portion, reflecting two different geomorphic formation processes. The Glacial Bottom land type association consists of current floodplains, fans, stream bottomlands, and terraces along the lower reaches of the major canyons of the south slope of the Uinta Mountains. Fans are a major component and have been built by active side canyon streams that have deposited material over the glacial drift of the main canyon. Much of this material is in the form of debris flows. The main stream bottoms are highly diverse and are composed of wet stream bottomlands, floodplains, and lower terraces. These main channels are subject to flooding with channel migration. The higher terraces are dry because of the stream down-cutting to its present level. Red Pine Shale outcrops along the base of the glacial canyons produce mudflows over the glacial bottoms, leaving some highly erosive fine textured areas. Slope ranges are from three to 20 percent for most of the land type association.

Soils

Soils in this land type association are variable, but fall in the loamy or sandy soil texture groups, with a high content of quartzite rock fragments. Soils are formed from colluvium (unconsolidated sediments deposited at base of hillslopes by rain wash, sheet wash, or downslope creep) and alluvium (river deposited sediment) and are typically deep (100 to 150 centimeters). Poorly drained soils are found in valley bottom positions where water tables are high, and moderately well drained soils are present on terraces and side slopes.

Glacial Canyon Land Type Association

Geology and Geomorphology

The Glacial Canyon land type association consists of steep (i.e., gradients between 45 to 75 percent) fluvial cut tributary and main valley side-slopes underlain by a variety of competent sedimentary rock types. Many of the canyon slopes are covered by talus and colluvium from glacial deposits. But, for the most part, the canyon side-slopes lack the colluvium found higher up in the Alpine Moraine land type association. This land type association also includes post-glacial mudflow areas underlain by shale, back rotational paleo slumps, and canyon slopes mantled by cobbly and bouldery quartzite, frequently underlain by shale. The areas underlain by shale that are fluvially dissected are highly erosive. The areas produce high amounts of sediments that are often deposited into streams.

Soils

Soils in this land type association have formed on glacial outwash and glacial slumps and are composed of very gravelly and very cobbly sand deposits. Soils can be very deep (more than 150 centimeters) and surface horizons often have high cobble and stone rock fragment content. Steeper side slopes tend to have low soil development due to the colluvium movement of soil materials downslope.

Green River Land Type Association

Geology and Geomorphology

The Green River land type association consists of flats, hills, and canyons underlain by the Green River Formation, primarily the Laney Shale member, with the Wilkins Peak and Tipton Shale members north of the Blacks Fork confluence. All three members consist of shale, organic mudstone and marlstone, tuffaceous sandstone, limestone, and oil shale (Sprinkel and others 2000). Other landforms include wind-sand, slopewash colluvium, pediments of old streams, benches or plateaus, saline or alkaline flats, moderately to highly dissected slopes, and scarps. The sandy soils of this land type association are loamy with many coarse fragments, and are well drained with rapid permeability.

Soils

Soils in this land type association fall in the loamy soil texture group and have a high content of rock fragments, making them well drained with rapid permeability.

Greendale Plateau Land Type Association

Geology and Geomorphology

The Greendale Plateau land type association consists of plateau lands of the eastern Uinta Mountains, underlain by gently to moderately sloping quartzitic sandstone. This land type association is part of the Bear Mountain erosional surface and slopes gently to the north and east. It is underlain by quartzites and shales of the Uinta Mountain Group that have chemically weathered to form a soil that is not very thick in most areas. Since the different rock types in the Uinta Mountain Formation weather at different rates, there is a series of east-west trending ridges of bedrock that stand 10 to 20 feet (3 to 6 meters) higher than the adjacent swales. Large, flaggy, or angular boulders, as well as bedrock, are common at and near the surface for most of the area. At several places, the outcrops are pitted indicating chemical solution.

Soils

Soils in this land type association have formed on dissected and un-dissected rolling uplands, with ridges, swales, and broad level surfaces underlain by quartzite bedrock. Soils on broad surfaces and ridges are shallow (25 to 50 centimeters) over residuum, with textures that fall in the sandy soil texture group and a high rock fragment content. Areas with shale beds at or close to the surface have deeper soils with finer textures. Swale positions and meadows commonly have deep soils (100 to 150 centimeters). Soils in these positions have variable textures and rock fragment content, but commonly have loam and sandy clay loam textures and are well drained.

Limestone Hills Land Type Association

Geology and Geomorphology

The Limestone Hills land type association consists of scarp and dip slopes of Mississippian Limestone on the south slope of the Uinta Mountains. This is part of the limestone “donut” that interrupted surfaces around the Uinta Mountains. The land types are limestone dip slopes. Karst topography including depressions of internal drainage is also included in this land type association.

Soils

Soils in this land type association have formed on strongly sloping to moderately steep and thinly mantled scarp and dip slopes. Soil depth ranges from very shallow (less than 25 centimeters) on ridge tops to deep (100 to 150 centimeters) on lower slopes and in concave draws. Surface soils commonly have loam or silt loam textures, and subsurface textures are commonly clay or silt loam. Gravel and cobble rock fragment content ranges from 5 to 70 percent, and increases with depth in the soil profile.

Limestone Plateau Land Type Association

Geology and Geomorphology

The Limestone Plateau land type association consists of plateau lands underlain by Mississippian Limestones on the south slope of the Uinta Mountains just below the Uinta Bollie land type association.

This association has karst topography of hummocky bedrock controlled mounds with interspersed depressions of internal drainage, steep rugged canyons, and broad sloping side-slopes that were formed during the uplift of the Uinta Mountains. Paleo-karst areas are also common on the broad uplifted plateau area. The mounds are shallow to bedrock with many horizontal and faulted exposures. The depressions have deep soils with internal drainage. Steep rugged canyons and outcrops are common where cut into the plateau, and lack external drainage for most of the year. Slopes from the ridge dipping south were formed from depositional materials with the uplift of the Uinta Mountains. A small section has patterned ground from frost action, which is the only area in limestone with these features on the Ashley National Forest. The patterned ground area in limestone is rare on the Ashley and rare in limestone areas.

Soils

Soils in this land type association commonly have loam and silt loam surface textures and subsurface textures are commonly clay or silt loam. Gravel and cobble rock fragment content ranges from 5 to 70 percent, and increases with depth in the soil profile. Depressional areas have deep soils with no rock fragments that fall in the loamy soil texture group. Side slopes have deep soils (100 to 150 centimeters) with silt and clay loam textures and high rock fragment content. These soils formed from colluvium and alluvium deposited during the uplift of the Uinta Mountains

Moenkopi Hills Land Type Association

Geology and Geomorphology

The Moenkopi Hills land type association consists of foothills of the Uinta Mountains, underlain by the Moenkopi Formation. They are dip and scarp slopes that formed with the uplift of the Uinta Mountains. The land type association includes slopes eroding to badlands, all of which are down-slope of the South Face land type association. Vegetation of these highly dissected, steep, scarp slopes of the exposed and naturally eroding Moenkopi Formation is relatively sparse.

Soils

Soils in this land type association have formed primarily on steep and very steep scarp slopes with inclusions of gentle dip slopes. The soils are shallow (25 to 50 centimeters) to very deep (more than 150 centimeters) over lithic or paralithic materials and are well drained. Soils commonly have loam over sandy clay loam textures, and gravel and cobble rock fragment content ranges from 30 to 70 percent. In many areas, large boulders are scattered on the soil surface.

North Flank Land Type Association

Geology and Geomorphology

The North Flank land type association is composed of diverse landscapes that include dip and scarp slopes with intervening valleys of the north slope of the Uinta Mountains. This land type association is underlain by a number of geologic formations, including the Park City, Weber, and Mississippian Limestone. Slopes are typically steep, and are near vertical on some of the canyon walls. This land type association is comprised of some of the youngest deposits and oldest rocks in Utah. This land type association also contains the classic faults and folds of Laramide orogeny that uplifted the Uinta Mountains about 70 to 40 million years ago. The units are dip and scarp slopes in east trending bands that dip north and consist of sedimentary rocks of limestone, sandstones, and shales separated from the Uinta Mountain Group by the Uinta Fault. Shales areas of clay-bearing formations and unconsolidated deposit often lead to failures in areas that are associated with minor landslide deposits. Between and at the base of many of the dip and scarp slopes are north-south dip valley-fill of low relief, colluvial deposits forming fans, and deposited slope-wash at the base of steep slopes. This land type association provides the spectacular geologic scenery of the Flaming Gorge National Recreation Area.

Soils

Soils in this land type association have formed on coarse textured, shallow to moderately deep (25 to 100 centimeters) colluvium and alluvium, lacking the residual soils of old erosional surfaces. Soils commonly have sandy loam and silt loam textures, high rock fragment content, and pH ranging from slightly acid to slightly alkaline. Rock fragments are composed primarily of quartzite, limestone, and shale. Soils are generally shallow (25 to 50 centimeters) on ridges and increase in depth toward the base of slopes. Soil development is limited in steep canyon positions and where rock outcrop is a large component in the land type association

Parks Plateau Land Type Association

Geology and Geomorphology

The Parks Plateau land type association is an upland mid-elevation plateau slightly dissected by concave drainages and deeply dissected by the Stream Canyon land type association. Gradients generally range from of 2 to 10 percent although, gradients up to 20 percent occur on side-slopes. The side-slopes are dissected by wide-open drainage-ways, separated by broad, flat interfluves, with the surfaces of the interfluves being smooth and containing partially buried cobbles. The side-slopes and drainage-ways are mantled by cobbles, boulders, and some outcrops. This land type is underlain by a heterogeneous tertiary formation. This formation was derived from the material eroded off the sedimentary formations that form the core of the Uinta Mountains during uplift, and it lies un-conformably on the younger Paleozoic formations.

Soils

Soils in this land type association have formed on un-dissected rolling uplands and side slopes. Soils are predominantly deep (100 to 150 centimeters), well drained with areas of poor permeability, and have variable textures and rock fragment content. These soils are very old and have heavy clay content. Soils under aspen, and in some areas under lodge pole pine, are deep, have textures that fall in the loamy soil texture group, and are highly productive. Some soils are coarse-textured with high rock fragment content.

Red Canyon Land Type Association

Geology and Geomorphology

The Red Canyon land type association consists of very steep canyon walls cut into Uinta Mountain quartzite. Precipitous walls of Red Canyon are the central theme of this land type association. This land type association also comprises units with alluvial bottomlands in the deep, narrow canyons cut by the tributaries of the Green River, such as Cart Creek and Carter Creek.

Soils

Soils in this land type association have formed primarily on weakly expressed colluvial drainages or on small benches. A large component of this land type association consists of rock outcrop and talus with little or no soil development. Surface soils tend to have sandy loam textures with high (25 to 80 percent) rock fragment content dominated by gravel and cobbles, but including stones and boulders.

Round Park Land Type Association

Geology and Geomorphology

The Round Park land type association is equivalent to the Trout Slope land type association, but on the north slope of the Uinta Mountain range. The Round Park land type association is an uplifted residual plateau surface comprised of shales and quartzites of the Uinta Mountain Group. It extends from the Uinta Bollie LTA and has been altered by periglacial fluvial and colluvial processes. This land type association is predominantly a gently rolling upland with inclusions of steep bedrock controlled side-slopes. Alternate layers of shale and quartzite form heavy clay soils with few coarse fragments. For the most part, this is a tertiary residual surface with some alteration by glacial material forming thin layers of materials in the higher elevation meadows.

Soils

Soils in this land type association have formed on a gently rolling residual plateau, with inclusions of steep bedrock controlled side slopes. Soils are very old, deep (100 to 150 centimeters), and have clay textures with few rock fragments in the soil profile. Shale parent material and translocation have formed clayey soils, and frost wedges found in relic soils indicate formation and alteration of these soils occurred during a very cold period. Soils in meadow positions are deep (100 to 150 centimeters), and have clay textures in wet areas with sand lenses from times of glacial outwash. Soils in drier hummock positions around the meadows have sandy loam textures and high rock fragment content.

South Face Land Type Association

Geology and Geomorphology

The South Face land type association consists of slopes on the south face of the Uinta Mountains that are moderately to steeply dissected. There is a steep scarp face on the eastern end of the range that becomes more subdued toward the west. Below the scarp face there is much evidence of past block failure and widespread slumping. Gravel and cobble debris washed from the Parks Plateau land type association covers large areas. It also includes dip slopes of the Park City Formation, mountain side-slopes covered with a thin veneer of mixed colluvium, and underlying Mesozoic sandstones and shales.

Soils

Soils in this land type association have formed on mildly sloping to steep slopes. Soils are predominantly shallow (25 to 50 centimeters), but inclusions have moderately deep to deep soils. Soil surface textures are mainly loam, silt loam or sandy loam, and subsoil textures are mainly sandy loam with clayey or silty components in some units. Rock fragment content ranges from 10 to 70 percent and is dominated by gravel and cobbles. Soils under aspen and mountain big sagebrush are commonly deeper with higher silt and clay content.

Strawberry Highlands Land Type Association

Geology and Geomorphology

The Strawberry Highlands land type association is characterized by high plateau lands dissected by long canyons with narrow to moderately wide bottoms underlain by calcareous sandstones and marly, shale-like mudstones of the Green River and Uinta Formations. Sandstones are more dominant in the Strawberry Highlands than in the Avintaquin Canyon or Anthro Plateau land type associations. The upper reaches of leeward slopes of the canyons support snow beds or snow banks that commonly persist until July or perhaps August in years following heavy snow accumulations.

Soils

Soils in this land type association have formed on highly erodible parent materials derived from shales, sandstones, and siltstones from the Green River and Uinta Formations.

Stream Canyon Land Type Association

Geology and Geomorphology

The Stream Canyon land type association is located east of the glacial canyons on the south slope of the Uinta Mountains. These canyons are fluvially dissected canyon side-slopes and bottoms with relatively smooth steep, to extremely steep, colluvial canyon side-slopes and occasionally vertical cliffs. Geologic strata are variable and include Mississippian Limestone and Weber Sandstone. Slumps form where shale is the underlying member or where heavy clays discharge water along a planar surface. Paleo slumps, including glacial slumps, are also a common component.

This land type association includes glacial outwash of Uinta Mountain Quartzite and alluvial and colluvial slopewash, derived from the Weber and Morgan Formations, much of which is deposited over limestone sink areas. A large karst system exists and conducts cross drainage subsurface water flows. Debris flows are common and are associated with heavy storms. Valley bottoms narrow toward the east and consist of very steep to vertical bedrock side-slopes. These canyons form the backdrop for the Ashley Valley, with Ashley Gorge being the most prominent.

Soils

Soils in this land type association have formed on variable parent materials. Soils in canyon bottom positions have formed on glacial outwash and slump deposits. These soils can be very deep (more than 150 centimeters), with textures of sand and loam, and high gravel and cobble rock fragment content. Very steep slopes have low soil development due to the colluvial movement of soil materials downslope. Soils on moderately steep slope positions are highly variable and range from moderately deep (50 to 100 centimeters) to deep (100 to 150 centimeters), with soil instability reflected in the horizonation of the soil profiles. Soils in these positions commonly have loam and clay loam textures with some coarse-textured soils, and variable rock fragment content that can range up to 75 percent.

Stream Pediment Land Type Association

Geology and Geomorphology

The Stream Pediment land type association consists of gravel, cobble, and boulder pediments associated with streams at lower elevations on the south slope of the Uinta Mountains. Coarse fragments are mostly quartzitic sandstone. These pediments are typically found in the stream bottoms and on concave slopes. These pediments are porous deposits overlying impervious sedimentary rocks.

Soils

Soils in this land type association have formed on pediments associated with lower elevation streams. Soils are variable but are dominantly deep (100 to 150 centimeters), have mollic epipedons, have loam and cobbly loam textures, and are moderately well to somewhat poorly drained. Soils in wet meadow positions associated with springs have clay loam and loam textures, and are poorly and somewhat poorly drained. Soils in swale positions have fewer rock fragments in the upper (25 to 50 centimeters) portion of the soil profile and often a substantial increase in clay in the subsoil.

Structural Grain Land Type Association

Geology and Geomorphology

The Structural Grain land type association is composed of the Uinta Mountain Group located on the North Flank of the Uinta Mountains. This includes high angle north dipping slopes set in Paleozoic through Mesozoic rocks with an east west strike of the beds. These beds are the result of earlier faulting that were reactivated during the Laramide and recent Basin and Range extension of Tertiary time. These reworked faults are often capped with materials from the Browns Park Formation deposited and reworked during Tertiary time. Dip slopes and scarp slopes, or questas, of Precambrian quartzitic sandstone and shale of the Uinta Mountain Group occur frequently. Since the different beds in the Uinta Mountain Group weather differently, there is a series of south-facing questas running east west across the land type association.

Soils

Soils in the land type association have formed on the parent materials of a gently sloping plateau and on a series of questas - and alternating swales. Soils commonly have sandy loam texture, and clay texture where they have developed on the Browns Park Formation. Areas of soil deposition have deeper soils, including swales between questas and in valley and bench positions created by faulting. Soils near the crest of questas are shallow. Soils formed on sloping plateau areas are predominantly moderately deep (50 to 100 centimeters) with surface textures of loam and flaggy loam and subsurface textures of flaggy loam or clay loam. Rock fragment content of these soils is highly variable, ranging from 25 to 75 percent. Rock outcrop is common and depth to bedrock is highly variable.

Trout Slope Land Type Association

Geology and Geomorphology

The Trout Slope land type association is an uplifted residual plateau surface comprised of shales and quartzites of the Uinta Mountain Group. This unit produced colluvial materials to the Parks Plateau land type association directly below it during uplift of the Uinta Mountains. It extends from the Uinta Bollie land type association and has been altered by periglacial, fluvial, and colluvial processes. This land type association is predominantly a gently rolling upland with inclusions of steep bedrock controlled side-slopes. Alternate layers of shale and quartzite form heavy clay soils with few coarse fragments. For the most part, this is a tertiary residual surface with some alteration by glacial material forming thin layers of materials in the higher elevation meadows.

Soils

Soils in this land type association have formed on a gently rolling residual plateau, with inclusions of steep bedrock controlled side slopes. Soils are very old, deep (100 to 150 centimeters), and have clay textures with few rock fragments in the soil profile. Shale parent material and translocation have formed clayey soils, and frost wedges found in relic soils indicate formation and alteration of these soils occurred during a very cold period. Soils in meadow positions are deep (100 to 150 centimeters), and have clay textures in wet areas, with sand lenses from times of glacial outwash. Soils in drier hummock positions around the meadows have sandy loam textures and high rock fragment content.

Uinta Bollie Land Type Association

Geology and Geomorphology

The Uinta Bollie land type association forms the ridge of the Uinta Mountains, which is an erosional surface affected by glacial and periglacial processes. The landforms are characterized by gently rolling topography on the ridges, glaciated cirque headwalls, and side-slopes at the heads of the drainages. The glaciated cirque headwalls and side-slopes are characterized by debris flows, talus, and relic rock glaciers. The alpine summits and slopes above glaciation include Matterhorn type peaks, rounded bollies (treeless, high-elevation, domed tops of the Uinta Mountains), low gradient benches, and exposed bedrock of the Precambrian quartzitic sandstones and shales of the Uinta Mountain Group. From east to west, the topography becomes more rugged where glacial processes were more dominant than periglacial processes.

The major portion of this land type association is comprised of the Uinta Mountain Group, with a minor inclusion of limestone in the western portion of the forest. Patterned ground, rock stripes, and solifluction lobes are common features. A loess cap, or topsoil, comprised of silts and clays formed from wind deposition after the last glacial period. The majority of the land type association is above tree line with inclusions of tree-covered areas on old residual surfaces of the Uinta Mountain Group.

Soils

Soils in this land type association have formed on a variety of landforms formed by glacial and periglacial processes. Soils toward the western portion of the range are young and poorly developed (Entisol and Inceptisol soil orders). These soils range from shallow (25 to 50 centimeters) to deep (100 to 150 centimeters), depending on the positon on the landscape, and have cobbly sand and sandy loam textures. Soils toward the east on periglacial surfaces are well developed (Mollic and Typic Haplocryalfs) with surface loess deposits, soil textures in the loamy soil texture group, and cobbles in the soil profile. Some soils indicate the tree line was once much higher than it currently is and these soils are deep (100 to 150 centimeters) and have limited rock fragments in the subsoil. Biological soil crusts (thin surface layer or mat composed of living material such as algae, cyanobacteria, moss, and lichen) protect soils from erosion and occur in areas where disturbance has not removed them. These crusts are an important factor in the establishment of alpine plant communities. Steep headwall and side slope positions have shallow soils (25 to 50 centimeters) and bedrock.

Wolf Plateau Land Type Association

Geology and Geomorphology

The Wolf Plateau land type association is limited to the far western corner of the Ashley National Forest. The largest portion is an upland plateau underlain by a variety of sandstones and some shales. The topography is nearly level to rolling. A significant, but smaller, component consists of steep colluvial mantled sandstone and limestone canyon sides (Studies 34-7F, 34-7H). These slopes are commonly tree covered. Soils are skeletal but include areas of bare scree and short cliffs. The canyons at the base of these slopes were once occupied by glaciers, but the slopes do not show evidence of glacial action. Mass wasting processes (process by which sediment, soil, sand, rock, etc. move down a slope), including creep, are active on these slopes. Gullies appear to be absent, which is probably due to the stony nature of the soil and material moving into these gullies as soon as they are formed. There are also notable areas with large slumps, scarps, and talus boulder fields.

Soils

Soils in this land type association have formed on gently rolling plateaus and steep side slopes of the Weber Formation on parent materials of colluvium and glacial till. Soils are predominantly deep (100 to 150 centimeters) with minor inclusions of moderately deep (50 to 100 centimeters) to shallow soils (25 to 50 centimeters). Surface soils typically have find sandy loam texture and subsoils textures are commonly loamy sand or fine sand with flagstone rock fragments. Rock fragment content ranges from 25 to 50 percent.

Watershed Condition Framework

The watershed condition framework characterizes the health and condition of National Forest System lands. The characterization is a reconnaissance-level approach using a comprehensive set of 12 indicators and 24 attributes that are surrogate variables. The variables represent ecological, hydrological, and geomorphic functions and processes that affect watershed condition. The primary emphasis of the classification is on aquatic and terrestrial processes, and conditions that Forest Service management activities can influence. The initial or baseline characterization for the Ashley National Forest was completed in 2010. There are multiple indicators and attributes in the watershed condition framework related to soils. Summary information for these indicators and attributes is in the “Air” and “Watersheds and Water Resources” sections of this assessment.

Multiple Uses and Ecosystem Services

The soil resource on the Ashley National Forest is part of the foundation for providing for the full suite of multiple uses available from national forests. This is in conjunction with air, water, and watershed resources. Productive and stable soils are the building blocks for most all uses, products, and services the Forest provides. For example, soils provide the growth medium for vegetation found on timber and rangelands. Soils are important in nutrient cycling and providing carbon sinks, which helps with climate regulation. Soils also filter, purify and store water for on-Forest and downstream uses.

The health of soils and vegetation are closely tied. When vegetation is damaged or replaced by invasive species, the corresponding changes in plant cover, roots, and organic additions can alter soil properties. Plant cover protects soil from erosion, regulates soil temperatures, and adds organic materials to the soil surface. Plant roots add organic materials, increase soil stability, and provide sites for microorganisms and nutrient cycling. Changes or damage to vegetation will impact the soil and its ability to support productive plant communities.

Conditions and Trends

During the previous forest plan revision effort, i.e., mid-2000s, the following management activities were identified as having an effect on soil quality:

- Road, trail, and landing construction in support of vegetation management
- Increased cross-country use of off-road vehicles outside of established roads and trails
- Dispersed and heavily concentrated recreation activities causing soil and vegetation damage in forested, riparian, and meadow areas
- Cattle and sheep use, especially along riparian corridors and at concentrated use areas like bedding grounds, watering troughs and stock driveways
- Wildfires and the exclusion of natural fire, particularly in areas of juniper invasion and decadent sagebrush stands
- Debris flows and slope failures in conjunction with fires and irrigation ditches

The 2009 draft ecosystem diversity evaluation report discusses geomorphic conditions and trends. The list of concerns identified during the previous revision effort remain as concerns in the current revision effort. These concerns include the geomorphic conditions and trends discussion by land type association listed below. Additional soil quality concerns include the following:

- Burning large slash piles during fuel reduction projects

- Land areas becoming dominated by monocultures of invasive weeds, particularly cheatgrass and *Halogeton*.
- Oil and gas development road density impacts, unknown success of interim and final reclamation of well pads and roads, loss of soil structure, dilution of biologically active surface soil by mixing and disturbance of soils, and invasive plants brought in by traffic and spreading to undisturbed sites
- Surface soil loss in old lodgepole pine clearcuts due to insufficient effective ground cover and lack of organic matter on the soil surface
- Surface soil loss in more recent severely burned areas
- Management activities damaging saturated soils and ground water flow in areas of seasonal or permanent high water tables
- Management activities damaging vegetation and soil crusts in rangelands and desert shrub lands
- Atmospheric deposition of elements in alpine areas, increasing levels of metals, salts and nutrients, including nitrogen and phosphorus, that effect soil chemistry and productivity.

Protecting soil resource to maintain soil quality on the Ashley National Forest will mainly depend on three factors: protecting the health of native plant communities, maintaining organic additions to soils, and preventing erosion loss of the biologically active surface soil. Adequate protection of soil quality and productivity exists in the form of best management practices. The practices are proven measures that protect the soil resource if properly implemented and monitored. The concern is that formal and informal monitoring indicates the practices are not always being fully and properly implemented at the project level.

Alpine Moraine Land Type Association

Many small reservoirs are located in the High Uintas Wilderness. These reservoirs have changed the hydrology of the watershed in which they occur by changing flow regimes in the streams, thereby inundating or creating wet meadows. Reservoirs have also altered sediment transport processes, generally resulting in an upstream fining and downstream coarsening (general shift in the type of material present in a stream/river channel after installation of a reservoir) of sediments. These reservoirs are often connected to constructed canal systems that start and flow through large segments of this land type association. In many cases, the canal system artificially distributes water out of the natural drainage. Due to the loose, unconsolidated materials in these glaciated landforms, piping and failure are common. Teepee Lakes (i.e., Carter Creek Arm of Sheep Creek Canal), Sheep Creek, and Mosby Canal are a few examples of canal failures in this association. The canal systems also artificially distribute water out of the natural watershed system, and in some cases transfer water to drainage, or change underground karst flows and flushing regimes with the removal of water from one drainage to the next. Springs that have been developed for livestock or domestic use have also altered the hydrologic processes on this land type association.

There are few roads because a majority of this land type association is in the High Uintas Wilderness. However, the roads that have been constructed are a source of large amounts of sediment to streams, especially if the shale component of the Uinta Mountain Group is present and the roads run parallel to the streams. Roads often capture runoff and transport the flow, along with sediment, into nearby streams. The sandy nature of the sediment contributes to early deposition. As a result, many streams, such as Rock Creek, have sediment fans in the stream just below the road. Small streams from springs also show considerable amounts of deposited sediment. All-terrain vehicle use is occurring off designated trails on the western and eastern portions of this land type association, which is also contributing to erosion and sedimentation of nearby streams.

Past and present patterns of grazing -including sheep, cattle, and wildlife such as elk and mountain goats - have opened the area to soil loss and increased erosion from wind and water especially in the alpine moraine 4 land type. Grazing that has occurred in meadows has degraded some meadow streams, especially channel morphology (i.e., widening, shallowing, and destabilizing banks), likely degrading water quality due to increased sedimentation. Loss of biotic soil crust has reduced the amount of ground cover in the alpine area.

Antelope Flat Land Type Association

Three canal systems, including the main stem of the Peoples Canal, pass through this land type association and terminate in the Flaming Gorge Reservoir. This canal has altered the flow of water. There are a few impoundments, mostly stock ponds, that are less than an acre in size that have also affected water flow. There are two constructed wetlands in the land type association. One is maintained by return flows from the Peoples Canal, the other is maintained by flows from Henry's Fork Creek. Both of these wetlands, which are adjacent to the Flaming Gorge Reservoir, have likely altered the flow of water on this land type association. Springs that have been developed for livestock or domestic use have also altered the hydrologic processes. Stream channels have also been altered and soils have been compacted in the riparian areas, especially at springs and along stream corridors. These impacts are likely due to increased use of these areas by domestic livestock and an increase in wild ungulate numbers.

Anthro Plateau Land Type Association

Vegetation stabilizing some of the more erodible soils on this land type association is dramatically influenced by fluctuations of seasonal precipitation. During drought, vegetation cover may be reduced or eliminated. These results, combined with impacts from heavy grazing or other uses, have been dramatic in places. The south facing slopes have generally been the most affected by these combined disturbances. Severe gullying has occurred on overgrazed slopes and on cattle trails. Historic flooding and debris flows have altered stream channel morphology and floodplain characteristics in the canyon bottoms. Debris flows have repeatedly covered U.S. Highway 191 in Left Fork Indian Canyon (Study 69-9G1). Springs that have been developed for livestock or domestic use have also altered the hydrologic processes on this land type association. The majority of the oil and gas development on the Ashley occurs in this land type association. This development has affected soils at localized sites where this development has occurred.

Avintaquin Canyon Land Type Association

Vegetation that has stabilized some of the more erodible soils on this land type association is dramatically influenced by fluctuations of seasonal precipitation. During drought, vegetation cover may be reduced. These results, combined with impacts from heavy grazing or other uses, have been dramatic in places. Severe gullying has occurred on overgrazed slopes and on cattle trails. The south-facing slopes have generally been the most affected by these combined disturbances.

Historic grazing use has also been heavy in the canyon bottoms, especially those that are off-forest on private lands. Heavy grazing on these private lands has contributed to historic flooding and debris flows that have affected stream channel morphology and floodplain characteristics of the canyon bottoms on both private land, and lands administered by the Forest Service. Springs that have been developed for livestock or domestic use have also altered the hydrologic processes on this land type association.

Dry Moraine Land Type Association

Due to sandy soils, this land type association is particularly susceptible to erosion from management activities. Road surfaces have concentrated water flow along road surfaces, creating substantial gullies in some areas. Other management activities have led to more uniform sheet wash erosion (detachment and removal of soil particles from water flowing overland as a broad sheet instead of in channels or rills) that has removed the fine soil particles off the surface. Springs that have been developed for livestock or domestic use have also altered the hydrologic processes on this land type association.

Glacial Bottom Land Type Association

There are several diversions, canals, or impoundments on this land type association that also may be contributing to increased sedimentation to streams, as well as affecting the historical hydrologic regime. These include two reservoirs; Upper Stillwater and Moon Lake, and three canals; Lake Fork, Yellowstone River Aqueduct, and Uinta River. High erosion and mass wasting rates from adjacent Glacial Canyon land type association slopes could pose accelerated sedimentation/infilling problems for the reservoirs, especially if erosion rates are exacerbated by management activities. Reservoirs have greatly changed the hydrology in this land type association due to water being exported from the Uinta Mountains to the Wasatch front and stored in Strawberry Reservoir. Springs that have been developed for livestock or domestic use have also altered the hydrologic processes on this land type association.

Channel migration and avulsion, as well as flooding, debris torrents (from upslope areas outside the land type association), and mudflows have occurred facilitated by several roads that follow watercourses up the canyons. Soil erosion has occurred due to unauthorized all-terrain vehicle use occurring on the western and eastern portions of this land type association.

Glacial Canyon Land Type Association

Steep terrain has limited access on this land type association. Therefore, the typical management activities that have occurred on other land type associations have for the most part not occurred here, allowing the geomorphic processes to function in the historic range of variation. The exception is the Duchesne portal that goes through a portion of this land type association. The portal transfers water from Stillwater Reservoir, located in the Glacial Bottom land type association, to Strawberry Reservoir and the Provo River drainage. Springs that have been developed for livestock or domestic use have also altered the hydrologic processes on this land type association.

Green River Land Type Association

The Flaming Gorge Reservoir has inundated a majority of this land type association, which has completely altered natural hydrologic function, riparian conditions, and aquatic habitats. In addition, springs that have been developed for livestock or domestic use have also altered the hydrologic processes on this land type association.

There are natural gas liquids pipelines that cross through the western portion of this land type association. Soils have been disturbed and ground cover has increased during the construction of these pipelines. Also, the numerous and popular system roads crossing saline soils of this land type association have contributed to and concentrated the flow of salt to the Flaming Gorge Reservoir.

Riparian areas have been impacted by grazing, especially at springs and along stream corridors. Where riparian areas have been impacted by livestock, common effects include decreased streambank stability due to unvegetated and eroding banks, widening and shallowing of stream dimensions, and increased sedimentation. These effects are similar to the effects observed elsewhere across the West (Platts 1991).

Greendale Plateau Land Type Association

There are several canals within this land type association, which include Sheep Creek Canal, Sheep Creek Lake Canal, Greendale Canal, and Lodgepole Canal. Because these canals are in formations underlain by fractured bedrock, infiltration to groundwater is known to be a significant process. The canals are also known to be “leaky,” resulting in return-flow to streams downstream of the point where stream flows are intercepted by the canal (e.g., Beaver Creek, within 300 to 600 feet or 91-182 meters). There are also several reservoirs within this land type association. The three largest reservoirs are Long Park Reservoir, Browne Lake, and Sheep Creek Lake. These reservoirs and canals have altered the historic hydrologic flows on this land type association In addition, irrigated lands associated with Swett Ranch and private lands of the Greendale area have altered water flow on this land type association. Springs that have been developed for livestock or domestic use have also altered the hydrologic processes on this land type association.

Due to the amount of fine sands in the soils of this land type association, trails and roads that intersect with streams are often areas where sediment is delivered into streams. In addition, although clay subsoils are not that common in this land type association, heavy rains can produce a high water table where clay subsoils do occur. All terrain and 4-wheel drive vehicle use during these conditions has produced considerable rutting and damage to roads, especially some of the less traveled roads with low maintenance levels and those that pass through wet and dry meadows. However, due to the inherent relative stability of the soils of this land type association, relatively few road-influenced soil problems have occurred compared to other associations.

Timber harvesting has historically produced increases in water yield and has increased peak flows during spring snowmelt. This is similar to the effects observed in a paired watershed study at Brownie Creek and North Fork Dry Fork (Burton 1997). In addition, the practice of piling and burning following harvest has generally resulted in loss of soil biota and productivity.

Grazing has had impacts in some areas on this land type association, such as compaction of soils in the riparian areas, especially in the open meadows and along stream corridors. However, problem areas are relatively localized to the few streams and wet meadows within the land type association.

Rangeland trend in meadows of this land type association is demonstrated by a 42-year study (2-1B1) in Hickerson Park. The first photos and notes of this study were taken in 1959 following about five to six decades of livestock grazing. This 42-year photo record indicates that ground cover, desired species, and productivity increased under the changes associated with increased monitoring and management of livestock. The six 3x3 plots in this study begin in the drier part of the park and then cross into the wetter part of the park as they approach the end of the transect. In 1959, bare ground averaged 20 to 40 percent along this transect. Common dandelion, long-foot clover, and other tap-rooted forbs dominated the plots mixed with some grasses. In 2001, bare ground averaged less than five percent along this same transect, and sheep fescue and other grasses were the dominant species in the plots. In addition, water sedge (*Carex aquatilis*) was common in only plot 6 in 1959. By 2001, water sedge was common in plot 3 and dominant in plot 4, indicating expansion of the wetter areas of this park.

Limestone Hills Land Type Association

There are no reservoirs within the land type association. However, there is a water diversion that begins at the Oaks Park Reservoir and runs through this land type association to Ashley Creek. Because this canal was underlain by limestone, there had been considerable leakage from the canal to downslope springs and stream channels. Since 2007, this open canal was converted into a pipeline which has stopped leakage and redistributed surface flows. Springs that have been developed for livestock or domestic use have also altered the hydrologic processes on this land type association.

There is a large amount of dispersed camping within this land type association that tends to be more seasonal (i.e., associated with fall hunting and fall foliage). This has compacted soils and increase bare ground in localized areas. The increased unregulated use of all-terrain vehicles is also evident throughout the land type association, which has caused soil erosion in some areas. Likewise, all-terrain vehicle and 4-

wheel drive vehicle use during heavy rains has produced rutting and damage to low volume roads with low maintenance levels. This is most apparent in areas that produce a high water table where there is a clay surface and subsoil, creating a perched water table.

There has been some, but not extensive, timber harvesting in this land type association. Harvesting in these areas has historically produced increases in water yield and increased peak flows during spring snowmelt. This is similar to the effects observed in a paired watershed study at Brownie Creek and North Fork Dry Fork (Burton 1997). Practices of piling and burning of slash following harvesting have resulted in loss of soil, soil biota, and productivity and have increased the spread of noxious weeds.

Limestone Plateau Land Type Association

The increased unregulated use of all-terrain vehicles has caused an increase in bare ground and subsequent soil erosion on this land type association. A major factor that has facilitated an increase in unauthorized all-terrain vehicle use off trails is a lack of trees on this land type association. Because few trees exist, this land type association has few impediments to all-terrain vehicle travel. Consequently, additional unauthorized routes are showing up each year. Likewise, all-terrain and 4-wheel drive vehicle use during heavy rains has produced rutting and damage to low volume roads with low maintenance levels. This is most apparent in areas that produce a high water table where there is a clay surface and subsoil, creating a perched water table. In addition, late hanging snowbeds prevent road travel until later in the summer season. As a result, all-terrain vehicles go around and up slopes, creating bare soils followed by soil erosion in these areas.

Areas highly selected by pocket gophers (*Thomomys talpoides*) have shown little change other than annual variations that are likely consistent with the timing and amount of precipitation and other weather related events. This is demonstrated by a 47-year interval with repeat photography at study 34-1.

Grazing has had impacts on both the riparian areas and in the uplands. Where riparian areas have been impacted by livestock, common effects include: decreased streambank stability, widening and shallowing of stream dimensions, and increased sedimentation. These effects are similar to those observed elsewhere across the West (Platts 1991). Where pocket gophers have already disturbed surface soil conditions, livestock grazing has created additional disturbances in some places. Springs that have been developed for livestock or domestic use have also altered the hydrologic processes on this land type association.

Moenkopi Hills Land Type Association

There are no system roads and trails mapped in this land type association. However, limited trails and old roads do exist and increased unregulated use of all-terrain vehicles in these areas is evident. The raw eroding slopes of this unit are sometimes attractive to dirt bike enthusiasts. Potential for dirt bike access is somewhat limited by natural barriers. However, there are some places where dirt-bike trails have channeled water that has created gullies on steep slopes. This land type association is located at elevations where high intensity summer thunderstorms can produce debris flows, undermining cap rock, which influences the high erosion rate. Springs that have been developed for livestock or domestic use have also altered the hydrologic processes on this land type association.

North Flank Land Type Association

Water flow on this land type association has been altered by the Sheep Creek and Lodgepole Canals. The Sheep Creek Canal carries flows into Long Park Reservoir. Flows from the reservoir are then piped through Sols Canyon and canaled north off the Forest. The Lodgepole Canal occupies the entire length of the natural position of Lodgepole Creek through the land type association. Because this canal is routed through a steep, narrow canyon underlain by limestone, infiltration to groundwater is likely a significant process. There are also two constructed wetlands within this land type association that are located in Wyoming adjacent to Henry's Fork Creek. Both are maintained by flows diverted and piped from Henry's Fork Creek. In the alluvial bottomlands, there are debris dams and beaver ponds that often create usable fisheries or aquatic habitat. Springs that have been developed for livestock or domestic use have also altered the hydrologic processes on this land type association.

About five percent of the timber on the North Flank land type association has been harvested. Almost all of these timber harvests have occurred in the higher elevation areas to the west in the North Flank 1 and North Flank 2 land types (17 percent and 39 percent respectively). Harvesting in these areas has historically produced increases in water yield and has increased peak flows during spring snowmelt. This is similar to the effects observed in a paired watershed study at Brownie Creek and North Fork Dry Fork (Burton 1997). Practices of piling and burning of slash following harvesting have resulted in loss of soil, soil biota, and productivity. The practices have also increased spread of invasive plants.

Grazing has had impacts on both the riparian areas, where they exist in this land type association, and in the uplands. Where riparian areas have been impacted by livestock, common effects include decreased streambank stability, widening and shallowing of stream dimensions, and increased sedimentation. These effects are similar to those observed elsewhere across the West (Platts 1991).

Parks Plateau Land Type Association

Julius Park is currently the only active dam/reservoir in this land type association. Water is diverted by sections of pipeline and open ditch, through the Mosby Canal system and by a pipeline system originating at Oaks Park Reservoir. These two diversion systems have increased flows into Mill Canyon and Ashley Creek and have reduced flows into Dry Fork Creek and Big Brush Creek. Risk from breaching has largely been eliminated by installation of pipeline in breach-prone segments of canal. Springs that have been developed for livestock or domestic use have also altered the hydrologic processes on this land type association.

Although there are numerous systems roads in this land type association, due to the inherent soil stability, there relatively few soil problems related to roads. Roads tend to be on ridges and across plateau areas, resulting in minor erosion problems. However, all-terrain vehicle use is increasing and there are some watershed concerns. For instance, trails without proper drainage act as conduits for sediment, originating from side-slopes and the numerous side drainages to adjacent streams. Likewise, where roads intersect with streams, sediment is delivered directly into the stream. In addition, heavy rains can produce a high water table where there is clay subsoil, which creates a perched water table. All-terrain and 4-wheel drive vehicle use during these conditions has produced considerable rutting and damage to two-track roads. This use, consequently, has increased soil erosion in these areas.

Timber has been harvested at numerous sites on this land type association. Harvesting in these areas has historically produced increases in water yield and has increased peak flows during spring snowmelt. This is similar to the effects observed in a paired watershed study at Brownie Creek and North Fork Dry Fork (Burton 1997). In addition, timber harvesting activities with heavy equipment, in areas with a high water table, have resulted in rutting, puddling, and compaction. The practice of piling and burning following harvesting has resulted in loss of soil, soil biota, and productivity, and has increased the spread of invasive plants.

Livestock grazing occurs throughout this land type association, and there are numerous spring developments to water livestock. Problem areas are relatively few and are localized to the few streams and wet meadows within the land type association. The soils in the dry meadow component of the Parks Plateau land types are subject to compaction and erosion from use by wildlife and livestock. Some common effects in problem areas include streambank instability caused by bare eroding banks, channel widening and shallowing, and increased sedimentation. This is consistent with the effects of livestock grazing observed in other areas across the West (Platts 1991).

Red Canyon Land Type Association

The most obvious human-caused alteration of this land type association is the Flaming Gorge Reservoir that flooded the lower elevations of Red Canyon after the construction of the Flaming Gorge Dam. Besides the dam, effects to watersheds and soils have generally been minimal due to the lack of management activities on this land type association. The lack of management activities is due in part to the topography, such as steep slopes. Likewise, soils are generally stable. Consequently, there are relatively few road-related problems. In addition, roads and trails tend to be on ridges, resulting in fewer erosion problems. Stream crossings are generally rare.

There have been some effects to the canyon bottoms from grazing and recreation use where livestock have access to the dry meadows, and where roads and developed campgrounds have been constructed. These effects include decreased streambank stability due to unvegetated and eroding banks, widening and shallowing of stream dimensions, and increased sedimentation. Springs that have been developed for livestock or domestic use have also altered the hydrologic processes on this land type association.

Round Park Land Type Association

Impacts to riparian areas, such as stream channel alteration, soil compaction, and erosion have occurred due to grazing, unregulated all-terrain vehicle use, and dispersed camping. The impacts are especially seen in the open meadows and along stream corridors. Springs that have been developed for livestock or domestic use have also altered the hydrologic processes on this land type association.

South Face Land Type Association

There are several diversions, impoundments, and canals within this land type association. A majority of these water developments divert and store water for the Uinta and Ouray Indian Reservation. Many of these water developments capture surface flows, altering natural drainage patterns. During snowmelt and storm events, for example, the risk of canal breaches and slumping increases. This often causes increased erosion and sedimentation. There are also numerous spring and seep developments that are used to water livestock and wildlife. These developments have also altered the natural flow patterns and affected unique aquatic habitats. Springs that have been developed for livestock or domestic use have also altered the hydrologic processes on this land type association.

Livestock grazing generally occurs throughout this land type association. Grazing has had impacts on both the riparian areas along stream corridors, springs, and in the open dry meadows. Where riparian areas have been impacted by livestock, common effects include: decreased streambank stability, widening and shallowing of streams and streambanks, and increased sedimentation. These effects are similar to those observed elsewhere across the West (Platts 1991). Where pocket gophers have already disturbed surface soil conditions, livestock grazing has created additional disturbance in some places.

Strawberry Highlands Land Type Association

The current conditions and trends of management activities affecting geomorphic processes in the Strawberry Highlands land type association are very similar to what has been described in the Avintaquin Canyon land type association

Stream Canyon Land Type Association

There are no reservoirs or canals within the land type association. However, a canal system on the Parks Plateau land type association diverts water from the Big Brush Creek drainage, located below the Oaks Park Reservoir, into the Ashley Creek Drainage. Generally, the effects of this canal system are increased flows in Ashley Creek and decreased flows in Big Brush Creek. Springs that have been developed for livestock or domestic use have also altered the hydrologic processes on this land type association.

There are very few roads within this land type association, with the exception of the Red Cloud Loop Road and the Pole Creek Sinks Road. Roads tend to be on ridges, resulting in fewer erosion problems and relatively few stream crossings. Slumps, however, have formed where roads have cut into the side-slopes and shale is the underlying member or where heavy clays discharge water along a planar surface.

Where roads in valley bottoms do occur, they generally run parallel to the stream. The exception is in Pole Creek, where the road acts as a drainage bottom in high water years. Due to the inherent stability of this land type association, relatively few road-related problems occur in comparison with other land type associations. The sheet erosion rate is low to moderately high (i.e., 0.01 inches or 0.03 centimeters) per year. Roads and trails without water bars and other drainage features, tend to loose fine-grained material leaving the larger, leaving the larger rocks behind.

Recreation areas in this land type association have generally been limited to areas where roads have been built, especially along canyon bottoms and in developed campgrounds (e.g., Deep Creek Campground). Activities such as all-terrain vehicle use and dispersed camping have compacted soils and increased rill erosion in some areas.

Stream Pediment Land Type Association

Although the geomorphic setting of this land type association indicates major influence of flooding or stream action in the past, the pediments are currently relatively inactive. Flooding associated with Timothy Creek is likely. However, the flooding appears to be a minor influence on most of the land type association.

The numerous roads and trails have caused sedimentation of adjacent streams. In some cases, such as Dry Gulch Creek, roads are concomitant with perennial creeks, which has funneled water down these roads and increased sedimentation into streams through erosion.

Livestock grazing in some places has altered stream channel morphology and caused soil compaction in the riparian areas, especially at springs and along stream corridors. Where riparian areas have been impacted by livestock, common effects include: decreased streambank stability due to un-vegetated and eroding banks, widening and shallowing of stream dimensions, and increased sedimentation. These effects are similar to those observed elsewhere across the West (Platts 1991). Springs that have been developed for livestock or domestic use have also altered the hydrologic processes on this land type association.

Structural Grain Land Type Association

There are numerous system roads in this land type association. However, due to the inherent soil stability, relatively few road related problems affect soil and water resources in comparison to other associations. Where road related problems do occur, soil compaction and sedimentation are the main effects.

Livestock effects on soil and water are relatively few and localized to the few streams and wet springs within the land type association. Where riparian areas have been impacted by livestock, common effects include: decreased streambank stability due to un-vegetated or eroding banks, widening and shallowing of stream dimensions, and increased sedimentation. Springs that have been developed for livestock or domestic use have also altered the hydrologic processes on this land type association.

Trout Slope Land Type Association

The Greendale Canal intercepts flow from numerous streams on the North Slope that flow along Utah State Highway 44, on the Flaming Gorge Ranger District. There are also three reservoirs in the Vernal Ranger District. These reservoirs include East Park, Paradise Park, and Oaks Park Reservoirs. The Oaks Park Reservoir transfers water from the Brush Creek drainage to the Ashley Creek drainage. These water conveyance and storage systems have altered the water flow on this land type association.

A canal system, beginning below the Oaks Park Reservoir on the Parks Plateau land type association, diverts water from the Big Brush Creek drainage and transfers it to the Ashley Creek Drainage. This diversion has increased flows in Ashley Creek and decreased flows in Big Brush Creek. The main effects of this canal system to the Trout Slope land type association, especially the Trout Slope 9 land type, have been: capturing overland flow, augmenting flow in a 100-yard stretch of Government Creek, and dewatering Government Creek below the augmented section. These effects have been minimized or eliminated with the installation of a new pipeline in 2007. Springs that have been developed for livestock or domestic use have also altered the hydrologic processes on this land type association.

Roads and trails currently contribute large amounts of sediment to streams, especially the road crossing Ashley Creek by Big Park and Trout Creek. Where road drainage structures are inadequate, soil erosion and sedimentation have been exacerbated. Increased dispersed recreation and all-terrain vehicle use in the meadows has also resulted in soil compaction and rutting, causing increased erosion and sedimentation. Places that have been affected include, but are not limited to: Round Park, Government Park, Twin Parks, Big Park, Trout Creek Park, Windy Park, Center Park, and Mill Park. If meadows have a shale component resulting in clayey soil textures, they are more susceptible to disturbance than meadows with sandy textures of quartzitic-derived soils. The effects from dispersed recreation and all-terrain vehicle use are generally concentrated along transportation corridors.

Timber harvesting has historically produced increases in water yield and has increased peak flows during spring snowmelt. This is similar to the effects observed in a paired watershed study at Brownie Creek and North Fork Dry Fork (Burton 1997). Windthrow and windbreak are common in this land type association where selection harvesting was used. Practices of piling and burning following harvesting have resulted in the loss of soil, soil biota, and productivity.

There have been some impacts to meadows and riparian areas from grazing, especially in the open meadows and along stream corridors. Where riparian areas have been impacted by livestock grazing, common effects include: decreased streambank stability due to un-vegetated and eroding banks, widening and shallowing of stream dimensions, and increased sedimentation. These effects are similar to the effects observed elsewhere across the West (Platts 1991). The TS9 land type can be particularly susceptible to the effects of grazing.

Uinta Bollie Land Type Association

There is one small cross-drainage diversion and canal near Leidy Peak that alters natural drainage patterns. This leads to Longs Park Reservoir, which eventually leads to North Fork Ashley Creek in the Uinta Bollie 6 land type. Springs that have been developed for livestock or domestic use have also altered the hydrologic processes on this land type association.

There are very few permanent roads, but many trails within the land type association. Seeps and springs, which are common, create challenges for trail maintenance and location. Many sections of trail intercept flows from seeps or springs, altering natural drainage patterns and increasing soil erosion and sedimentation. Unauthorized all-terrain vehicle use is occurring on the western and eastern portions. In some places, vehicle use in alpine areas has removed groundcover and broken down sensitive soils. These crust and soils have been very slow to recover.

The majority of this land type association is in the High Uintas Wilderness. Therefore, there is no active timber harvesting in this area. Past harvests were limited to a few units in the Trout Creek area of the Uinta Bollie 6 land type. No noticeable increases in water yield or sediment erosion have occurred from timber harvesting in this land type association.

The soil crust component of the alpine area has been altered by grazing of both wildlife and domestic sheep. Past and present patterns of grazing (i.e., sheep) have opened some areas to soil loss and increased erosion from wind and water. Loss of biotic soil crust has reduced the amount of groundcover protection in the alpine area.

Wolf Plateau Land Type Association

Roads and trails located on the steep slopes of this land type association have contributed to slumping or other mass wasting features (i.e., talus), which have increased erosion and sedimentation in places.

During the 1970s and 1980s, about 20 percent of this land type association was affected by timber harvest. Elsewhere on the Ashley National Forest, extensive harvesting has been observed to produce increases in water yield and has increased peak flows during spring snowmelt similar to the effects observed in a paired watershed study at Brownie Creek and North Fork Dry Fork (Burton 1997).

Livestock grazing occurs throughout most of this land type association. The problem areas are relatively few and localized to the few streams and springs. Where riparian areas have been impacted by livestock, common effects include: decreased streambank stability due to un-vegetated and eroding banks, widening and shallowing of stream dimensions, and increased sedimentation. These effects are similar to the effects observed elsewhere across the West (Platts 1991). Springs that have been developed for livestock or domestic use have also altered the hydrologic processes on this land type association.

Water and Watershed Resources

Inventories

There is land system inventory and ecosystem diversity evaluation report for the entire Ashley National Forest. Information is available at the Supervisor’s Office.

There is the watershed condition framework, which characterizes the health and condition of all National Forest System lands.

There is a watershed improvement needs inventory in hard copy at the Supervisor’s Office. In more recent times, the inventory is being managed electronically in the natural resource information system watershed improvement tracking module and Watershed Condition Framework database.

There is a water rights inventory, which contains information on Forest Service water uses and rights.

There are stream health surveys for a limited number of stream segments across the Ashley National Forest. All major streams were inventoried in the 1990s for stream type, particle size distribution, and channel stability. Reference reach inventories were conducted on streams in the northern slope area of the Uinta Mountains in the early 2000s, using Region 1 and Region 4 protocols.

There are water quality monitoring sites operated in cooperation with the Utah Department of Environmental Quality Division of Water Quality. The sites are used primarily by Division of Water Quality staff for assessment of beneficial uses.

Repeat photo points have been established across the Ashley National Forest. Some are in riparian areas and along streams. Accompanying some of the photo points are Winward greenline inventories and surveys of greenline widths.

There are multiple repeat macroinvertebrate inventory sites across the Ashley National Forest, as well as fish population surveys for some streams.

There are proper functioning condition assessments and Multiple Indicator Monitoring (MIM) sites for a few locations on the Vernal and Flaming Gorge Ranger Districts.

There are a couple hundred level I groundwater-dependent ecosystem inventories. Related to this is a Weber State University study on a pair of fens in Reader Creek and Dry Fork. The study is characterizing wetland form, chemistry, and cover type.

There are site-specific channel morphology and floodplain studies in various drainages on the Ashley National Forest.

Important Attributes, Characteristics, and Processes

To reiterate the narrative in the air and soil resources section of this report, the Ashley National Forest, which includes the Flaming Gorge National Recreation Area, is a large geographical area in northeastern Utah and southwestern Wyoming. The Uinta Mountains, the Tavaputs Plateau, a very small portion of the Uintah Basin, and the southern end of the Upper Green River Basin are the dominant physiographic features.

Specific to hydrography, the Ashley National Forest is in the Green River drainage, a major tributary to the Colorado River. The Green River drainage begins at the Continental Divide, in the Wind River Range in northwest Wyoming, and joins the Colorado River in Canyonlands National Park in south-central Utah. The drainage is comprised of the upper and lower Green River basin, being divided by the Uinta Mountain Range, where much of the Ashley National Forest is located. The Flaming Gorge National Recreation Area is on the north side of the Uinta Mountains and in the southern end of the upper Green River basin. The South Unit of the Forest is in the Tavaputs Plateau. The Uintah Basin, generally, is between the Uinta Mountains and the Tavaputs Plateau. A description of hydrologic unit codes that contain national forest acreage was discussed previously.

Geology, soils, and vegetation are important aspects of understanding water and water resources on the Ashley National Forest. Narrative for these three key components were discussed previously in this report.

Annual precipitation across the Ashley National Forest varies from eight inches at lower elevations of the Flaming Gorge National Recreation Area, to more than 60 inches at higher elevations of the Uinta Mountains. Generally, precipitation increases four to six inches for each 1,000-foot gain in elevation. In areas of the Ashley receiving less than 18-inches annual precipitation, most, if not all, the precipitation goes to satisfying evapotranspiration demands so little to no runoff is generated. An exception can be when summer thunderstorm rainfall intensity exceeds the soil infiltration rate. This results in overland water flow potentially reaching stream channels. At and above the 18-inch zones, the Ashley National Forest is considered a snow dominated system, in that the majority of the annual precipitation falls as snow, while the remainder is from late spring to early fall rains. Summer thunderstorms can produce short-duration, high-intensity precipitation.

Precipitation regimes across the South Unit and the lower elevation portions of Flaming Gorge National Recreation Area contrast with that of the higher elevation Uinta Mountains. Regimes also differ between the western and eastern halves of the Uinta Mountains, at approximately the Whiterocks River drainage. This is because the western half has a more pronounced snow dominated hydrology and the eastern half has a stronger summer thunderstorm component. Figure 16 through figure 18 illustrate the variability of monthly and annual precipitation, as well as snowpack snow water equivalent across the Ashley.

Snowfall typically begins in October and extends through May. The snowpack builds through this time period, acting as a water storage reservoir that begins to melt in April. This snowmelt causes streams to rise accordingly. By early to mid-June, the majority of the snowpack has melted out, but elevated streamflow continues into August.

The Uinta Mountains periodically experience rain-on-snow events that can result in catastrophic flooding. These events are a function of the amount of land base above 9,000 feet, and the west to east orientation of the Uinta Mountains. This allows for snow to remain on the ground well into the summer thunderstorm season. This phenomenon is most significant in years when annual snowpack is above normal.

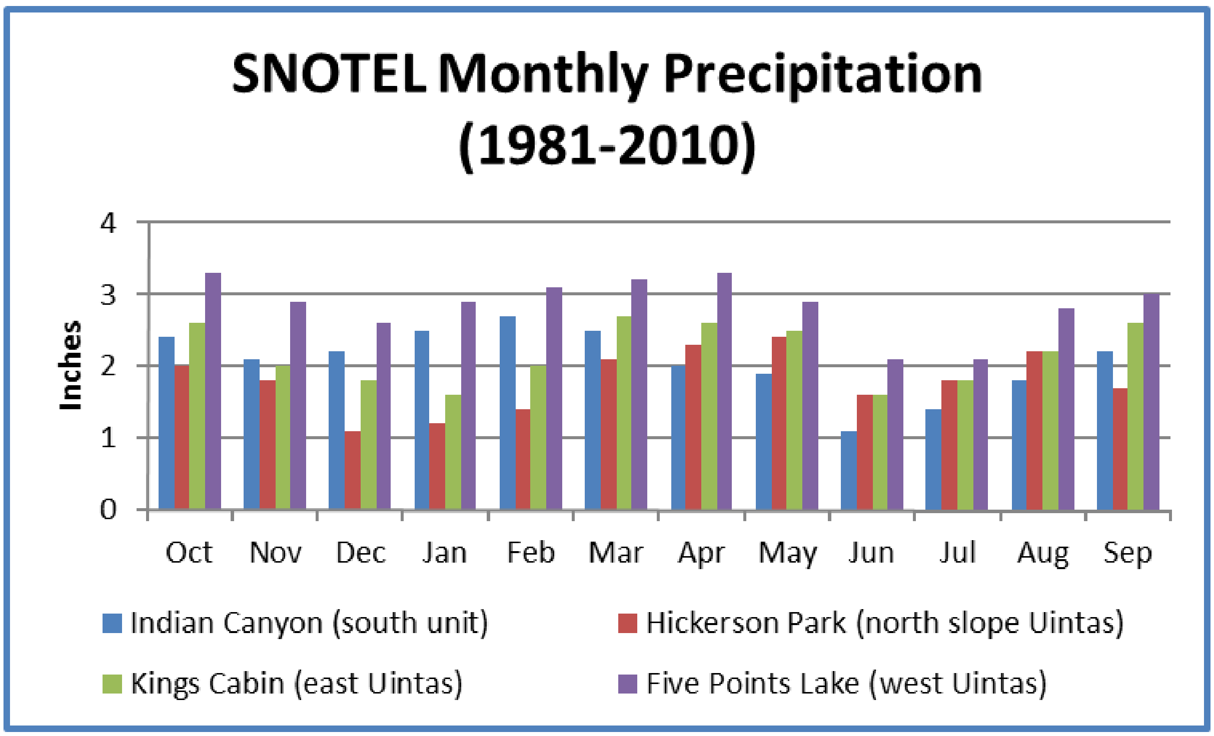

Figure 16. Monthly precipitation at four locations on the Ashley National Forest

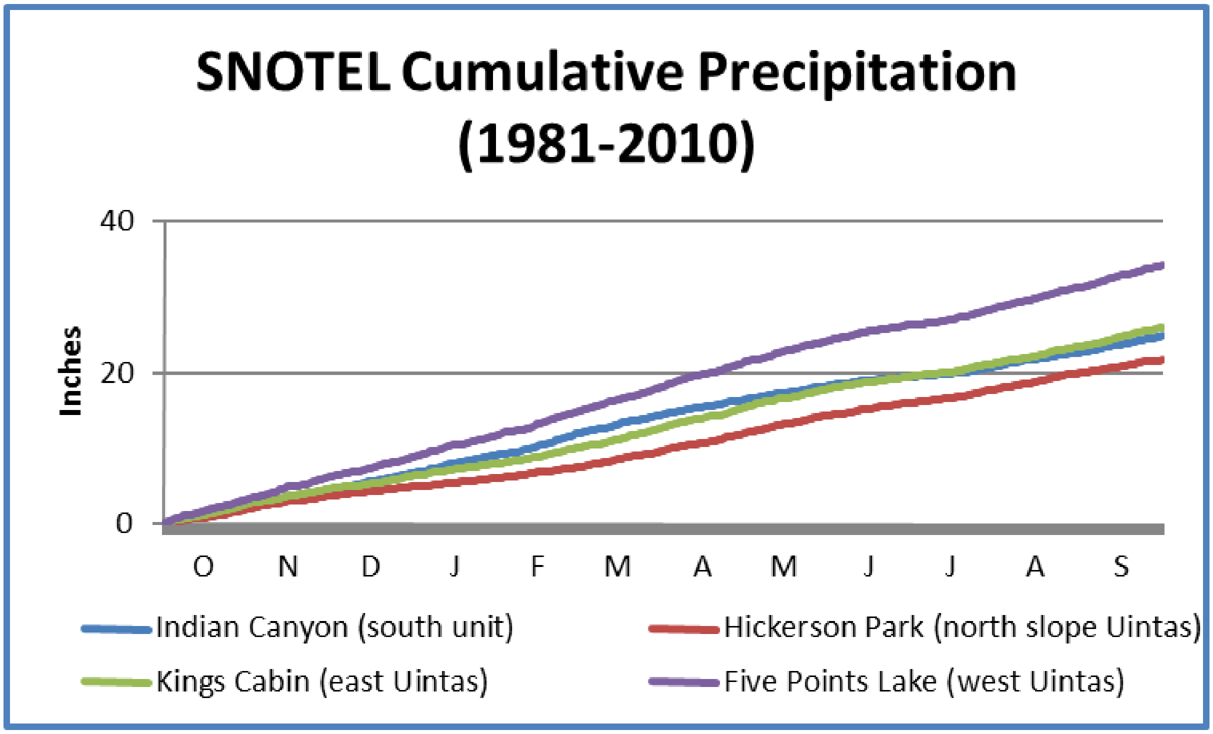

Figure 17. Cumulative precipitation at four locations across the Ashley National Forest

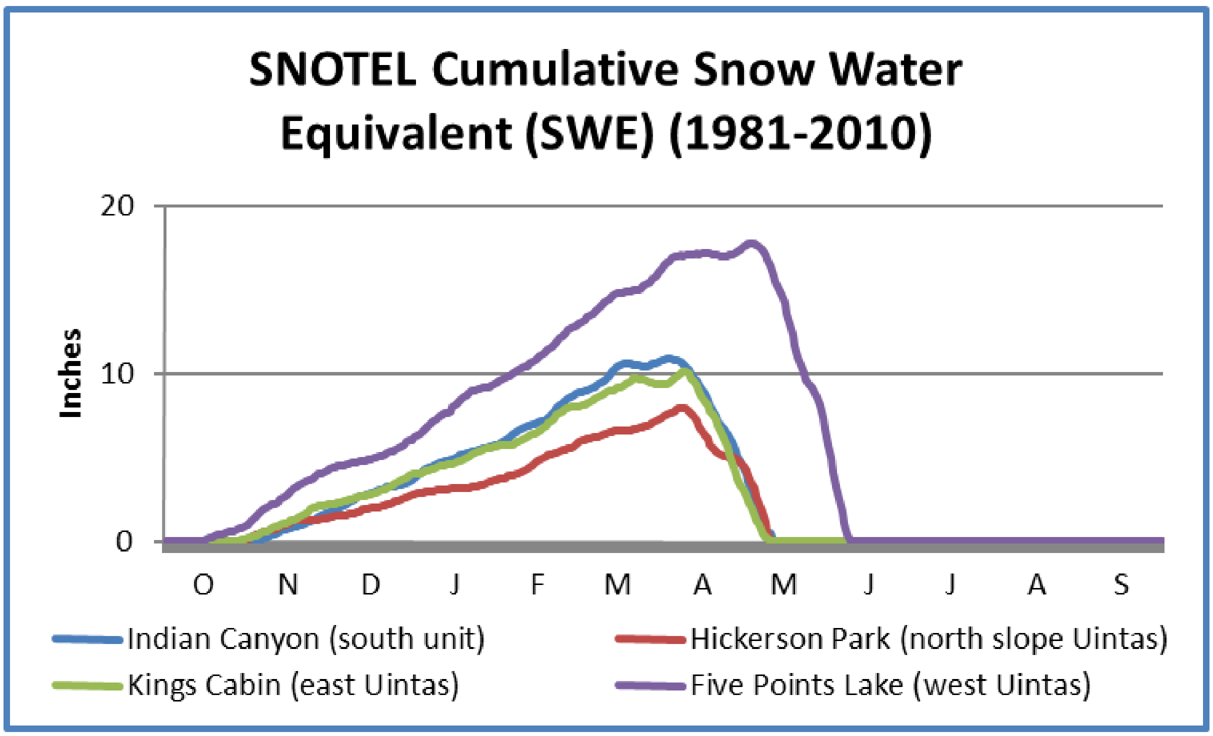

Figure 18. Cumulative snow water equivalent at four locations across the Ashley National Forest

Flow regimes across the Ashley National Forest are as variable as the precipitation regimes. Streamflow is predominately from annual snowmelt runoff. But there can be small increases in flow for short periods of time due to summer thunderstorm activity, particularly in the South Unit (figure 20). The volume of water contained within these spikes, with the exception of some precipitation-runoff events in the South Unit, typically represents only a small percentage of the thunderstorm precipitation total, roughly equivalent to the watershed area occupied by stream channels (Troendle and Bevenger 1996). Annual snowmelt flows typically start to increase in late March to early April, peak in late May to early June, and return to baseflow levels in August. There is considerable year-to-year variability in the shape of the annual hydrograph and the number of instantaneous peak flows during the snowmelt period (figure 20). The magnitude of annual peaks also exhibits considerable variability (figure 22 and figure 23). Flow duration for perennial streams on the Ashley is typical of snowmelt dominated areas where the high flow period is relatively short and gradual release of groundwater maintains a base flow for the remainder of the water year (figure 21). Flow duration in the South Unit however is different than other areas of the Ashley National Forest, where in some years there can be no surface flow in stream channels late in the year. The flow regimes described here are critical for sustaining current ecosystems across the Forest and prescribing best management practices to mitigate land management activities. Conversely, the current ecosystems also result in and sustain the current flow regimes across the Forest. In other words, a change in one results in a corresponding change to the other.

The Ashley National Forest lies within all or part of 147 6^{th}-level size watersheds or hydrologic units (figure 2). These watersheds on average generate 1.0 million acre-feet of water per year. There are 3,313 miles of perennial and intermittent stream and an undetermined mileage of ephemeral stream, across the Forest (table 6 and figure 19). There are thousands of waterbodies that total 51,035 acres (table 7 and figure 19).

Table 6. Miles of stream on the Ashley National Forest by type and ranger district[7]

District	Intermittent Stream	Perennial Stream	River	Total
Duchesne – South Unit	636	54	0	690
Duchesne - Uintas	171	129	3	303
Flaming Gorge - Utah	366	274	10	650
Flaming Gorge – Wyoming	182		8	190
Roosevelt	311	363	34	708
Vernal	476	287	9	772
Total	2142	1107	64	3313

Table 7. Acres of waterbodies on the Ashley National Forest by type and ranger district

District	Intermittent	Perennial	Total
Duchesne – South Unit	42	0	42
Duchesne – Uintas	0	1746	1746
Flaming Gorge – Utah	4	14616	14620
Flaming Gorge – Wyoming	5	28178	28183
Roosevelt	120	4060	4180
Vernal	16	2248	2264
Total	187	50848	51035

[7] These numbers represent flowlines outside of waterbodies such as lakes and reservoirs. There is no mileage in the Wyoming portion of the Flaming Gorge Ranger District because of Flaming Gorge reservoir.

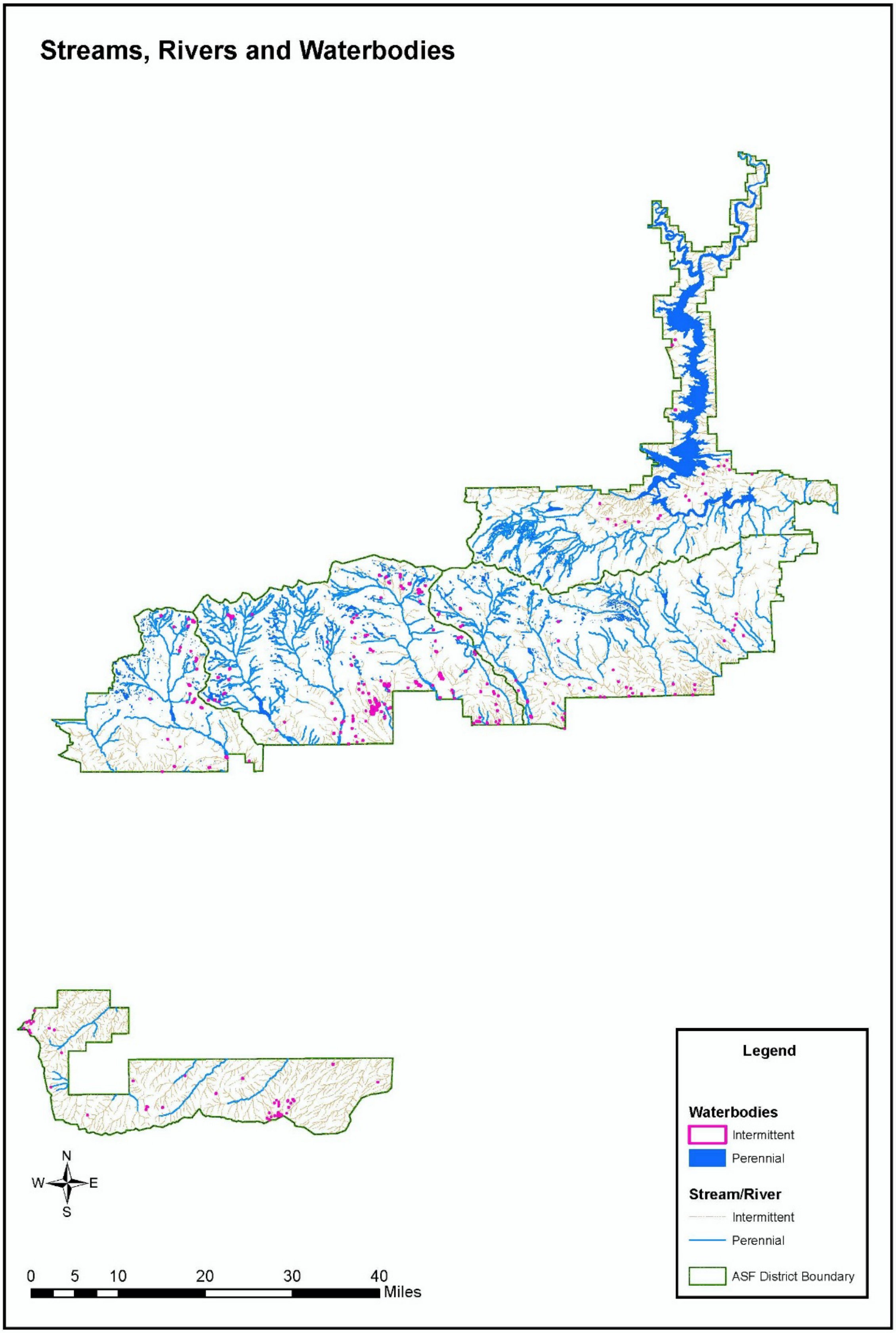

Figure 19. Streams, rivers, and waterbodies on the Ashley National Forest

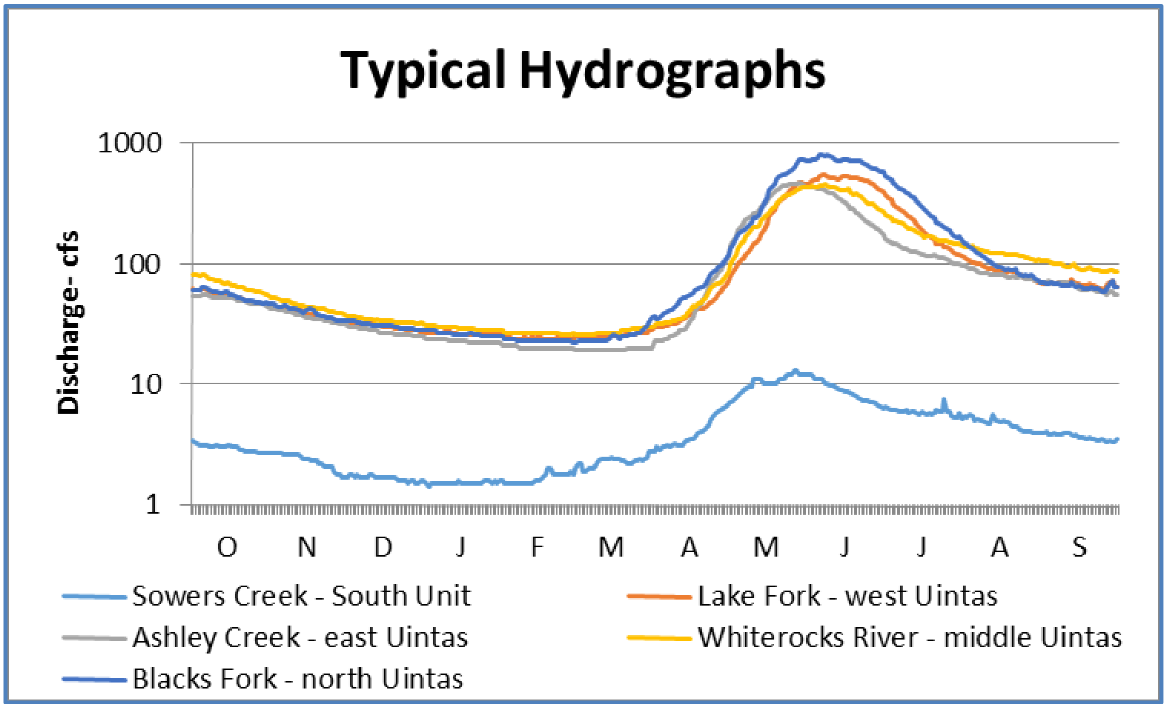

Figure 20. Typical hydrographs for various locations on the Ashley National Forest

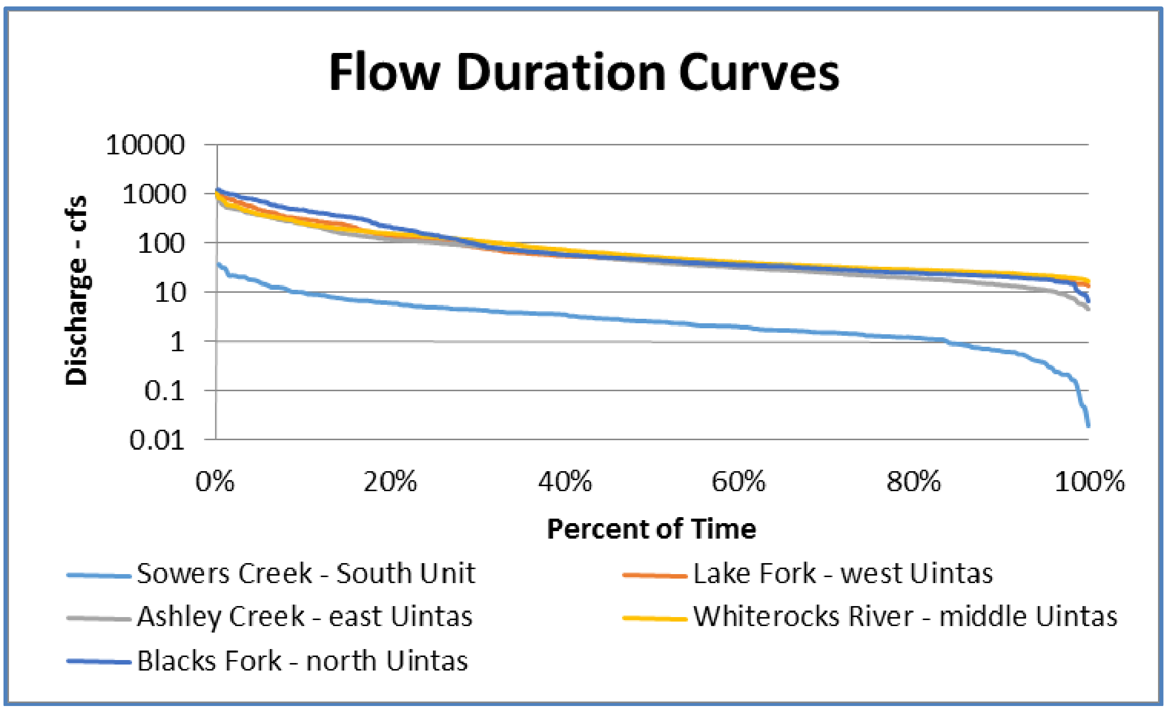

Figure 21. Typical flow duration curves for various locations on the Ashley National Forest

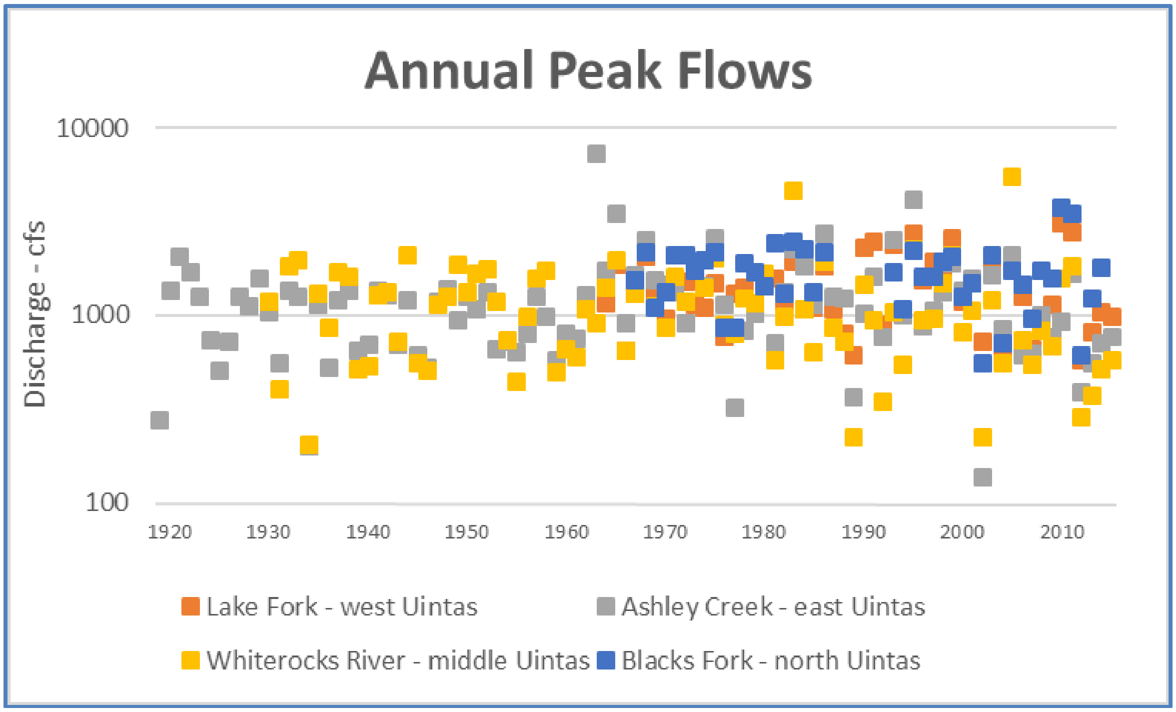

Figure 22. Annual peak flows for various locations in the Uinta Mountains area of the Ashley National Forest

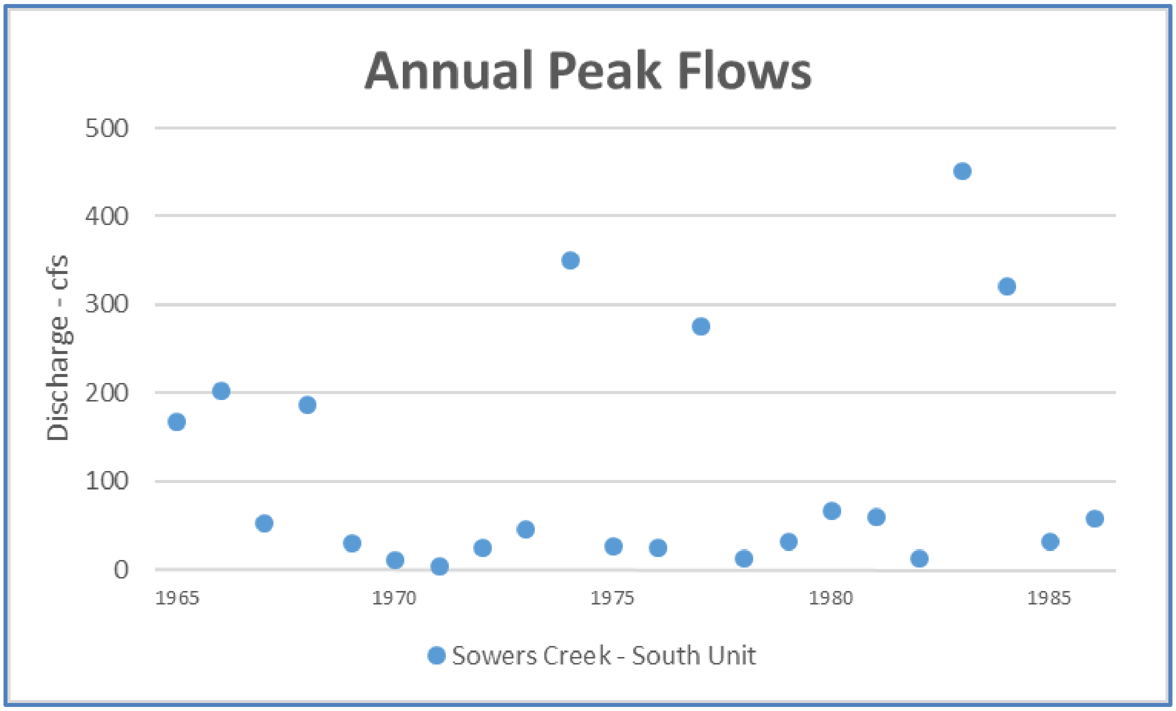

Figure 23. Annual peak flows for the South Unit area of the Ashley National Forest

Streams across the Ashley National Forest have a low-flow channel, a high-flow or bankfull channel, and a floodplain to handle above bankfull flows. Flooding is a natural part of the hydrologic cycle and access to the floodplain is critical. The width of the flood-prone area varies by stream and valley type and can be relatively narrow to very wide, i.e., tens of feet to hundreds of feet.

Floodplains and their associated riparian areas are very important in regulating water quality and how water is distributed over time. Healthy stream and riparian systems dissipate flood energy and recharge alluvial aquifers. Water is then slowly released from the aquifers back to the channel during drier periods of the year.

The streams across the Ashley National Forest transport the water and sediment delivered to them from the watershed, meaning they are self-formed and self-maintained. Increases or decreases in either the amount of water or sediment can result in stream channel aggradation or degradation, resulting in stream widening or down-cutting, leading to a whole host of negative effects on stream and riparian area health. Human occupancy and use along the channel or in the floodplain can upset water and sediment transport. This could also result in stream widening or down-cutting, leading to a whole host of negative effects on stream and riparian area health.

The Ashley National Forest contains groundwater resources that are very important to local ecosystems, as well as agriculture and local communities. Most notable are multiple springs, some very large, associated with carbonate rocks along the northern and southern boundaries of the Uinta Mountains (figure 24). In essence, streams at higher elevations lose water into the carbonate rocks through karst features at lower elevations (Spangler 2005). Karst features include sinking and losing streams, caves, sinkholes, and springs. Water then resurfaces at large springs at lower elevations. Seven of the largest springs have been dye-tested. The results show that the time period between when the flows go subsurface and when they resurface ranges from a few days to a few weeks over linear distances of a few to tens of miles.

Figure 24. Karst hydrology locations across the Ashley National Forest

Groundwater supports many wetlands, springs, and seeps across the Ashley National Forest. A portion of these are groundwater-dependent ecosystems, which are communities of plants, animals, and other organisms whose existence and distribution depends on availability of groundwater. While there is some inventory of groundwater-dependent ecosystems on the Ashley, the National Hydrography Dataset and the

National Wetlands Inventory provide information about potential extent (figure 25, figure 26, and table 8). More specifically, springs and seeps in the National Hydrography Dataset and palustrine emergent bed wetland types in the National Wetlands Inventory serve as representations for groundwater-dependent ecosystems. Springs and seeps are classified as points where water issues from the ground naturally. Palustrine emergent bed wetlands are saturated, non-tidal areas characterized by erect, rooted, herbaceous hydrophytes where the substrate is saturated to the surface for extended periods during the growing season but no surface water is typically present. Examples of this wetland type include marshes, fens, potholes, and wet meadows. A query of the National Hydrography Dataset indicates there are 427 springs and seeps across the Ashley National Forest. A query of the National Wetlands Inventory indicates there are 17,903 acres of palustrine emergent wetlands across the Ashley National Forest; this equates to 1.3 percent of the Ashley.

An excellent summary of hydrology and geomorphic processes is provided in the Ashley National Forest land systems inventory through the ecosystem diversity and evaluation report (see attachment A, table 26).

Table 8. Potential extent of groundwater-dependent ecosystems[8]

District	Palustrine emergent bed wetlands (acres)	Springs and seeps
Duchesne – South Unit	8	48
Duchesne – Uintas	1903	23
Flaming Gorge – Utah	2535	44
Roosevelt	6142	107
Vernal	7315	205
Total	17903	427

[8] There are no springs/seeps or PEMB wetlands in the Wyoming portion of the Flaming Gorge Ranger District.

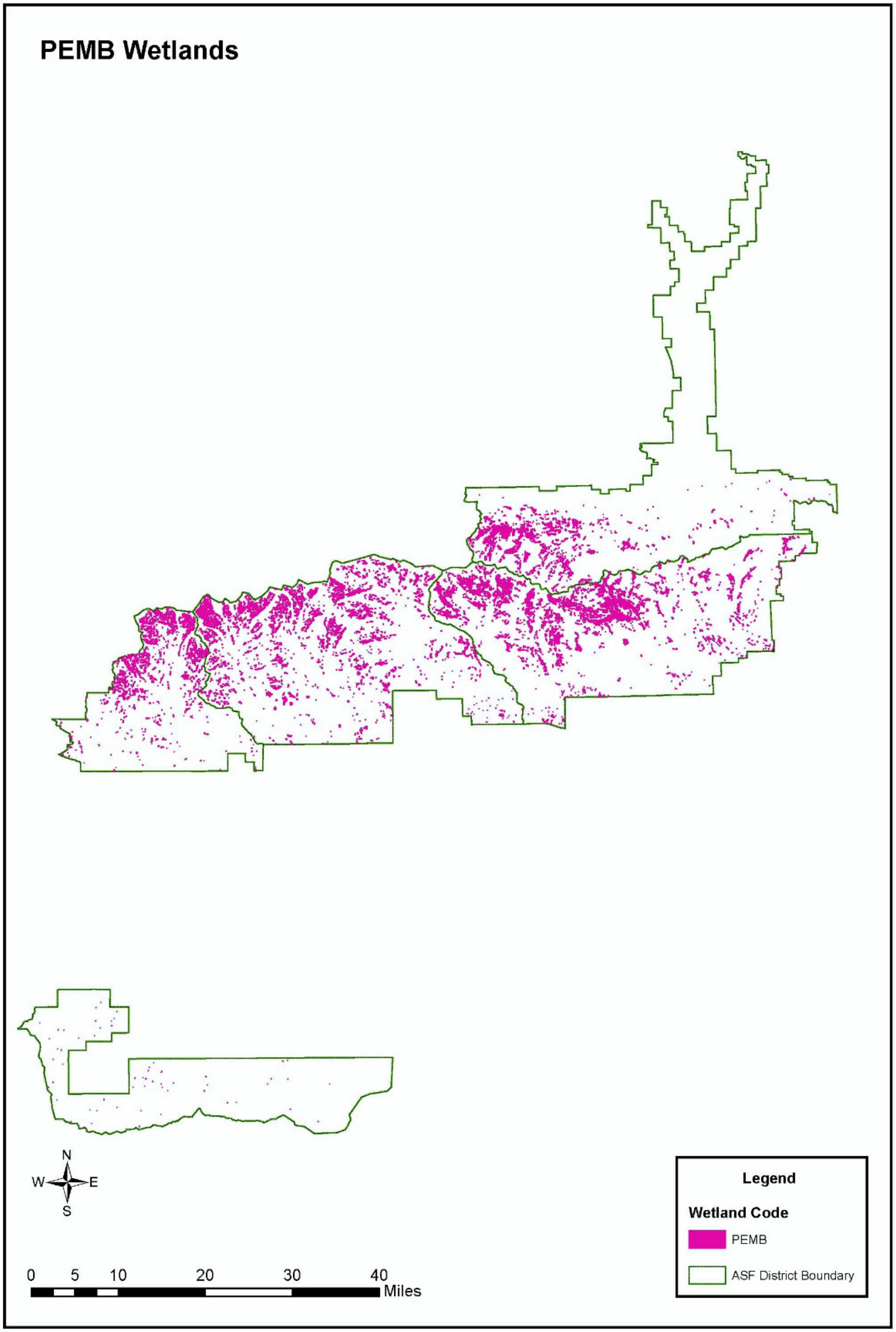

Figure 25. Palustrine emergent bed wetlands on the Ashley National Forest

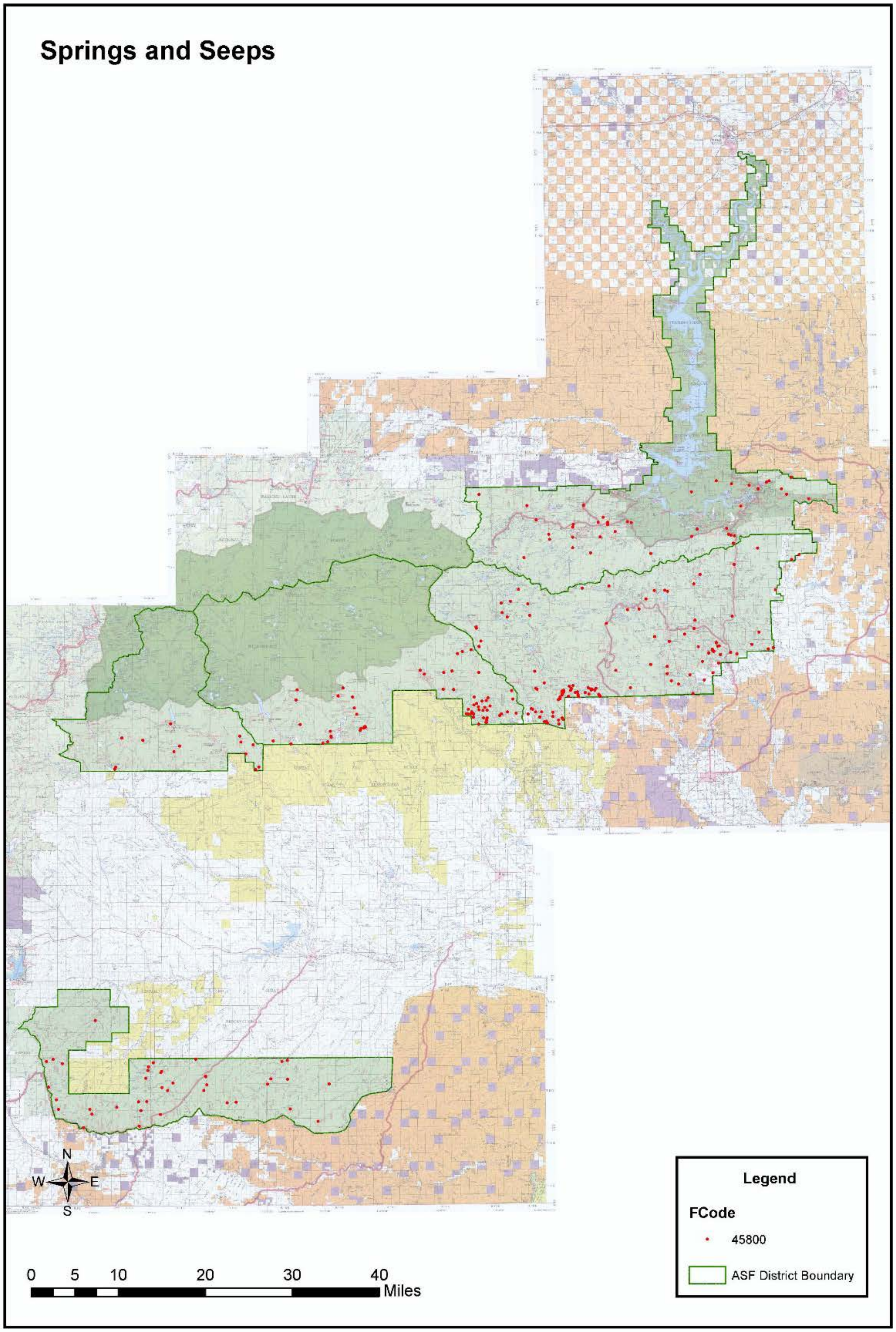

Figure 26. Springs and seeps on the Ashley National Forest

Consumptive and Nonconsumptive Water Uses

The Ashley National Forest generates approximately 1.0 million acre-feet of water annually to streamflow and contributes a large, but unmeasured, quantity of water to multiple groundwater aquifers. A portion of this water is used by wildlife, livestock, the recreating public and administrative uses across the Forest, but the majority of the water flows downstream and off the Ashley National Forest. A small portion of the water is used on private lands, i.e., in-holdings, interior to the Forest administrative boundary.

The Ashley National Forest is located entirely in the Colorado River Basin. Use of water, both on and off the Forest, is managed and operated under numerous compacts, federal laws, court decisions and decrees, contracts, and regulatory guidelines collectively known as the "Law of the River". These documents apportion water and regulate use and management among seven basin states, including Utah and Wyoming, and Mexico. The drainage is divided into the Upper and Lower Basins; the Ashley National Forest and Flaming Gorge National Recreation Area are in the Upper Basin.

Both Utah and Wyoming are divided into water divisions. The Flaming Gorge National Recreation Area is in Wyoming Water Division 4. Water rights in Wyoming are managed by the Wyoming State Engineer's Office. Detailed information can be found at http://seo.wyo.gov/home. The Ashley National Forest is in Utah water areas 41, 43, and 45. Area 41 is the north slope of the Uinta Mountains. Area 43 is the Duchesne and Strawberry River drainages. Area 45 is the Ashley and Brush Creek drainages. Water rights in Utah are managed by the Utah Division of Water Rights. Detailed information can be found at http://www.waterrights.utah.gov/. Each of Utah's areas has specific and detailed policy on water management and procedures for uses and rights. This explicit information is accessible by selecting the water area of interest on the interactive map at the above mentioned website.

There are 3,313 inventoried water sources on the Ashley National Forest. During the 1970s and 1980s, the Ashley National Forest began a process to file claims on many of these uses with the State of Utah. The process however was never completed.

Presently, there are 32 dams on the Ashley National Forest, with one dam scheduled for decommissioning in 2017. There are 14 pipelines that traverse parts of the Ashley; three are used for electricity generation. There are 30 irrigation pipelines and canals used for off-Forest irrigation. Some of the water development infrastructure mentioned here is associated with the Central Utah Project and Flaming Gorge Dam. Detailed information on these water development projects can be found at http://www.cupcao.gov/index.html and http://www.usbr.gov/uc/rm/crsp/fg/.

Water Rights

The Ashley National Forest has water rights in both Utah and Wyoming. In Utah there are 1,590 perfected water rights: 1,401 for stock water, 129 for domestic use, 41 for irrigation use, and 19 for miscellaneous uses. The Forest also possesses three sub basin claims, with plans to file for additional claims. Sub-basin claims consolidate stock water uses so that individual water rights are not needed for each and every one, allowing for simplified management. In Wyoming there are 12 domestic, miscellaneous, and stock watering rights associated with the Flaming Gorge National Recreation Area.

Municipal Watersheds, Sole Source Aquifers, and Source Water Protection Areas

Water from the Ashley National Forest serves drinking water administrative needs of the Forest Service and the public (both on and off-forest) for domestic, recreation, and municipal purposes. For example, the city of Green River, even though it is well downstream of the Ashley National Forest, obtains its drinking water in part from waters that flow off the Forest into the Green River. As other examples, Red

Fleet Reservoir and Ashley Spring, both directly downstream from the Ashley National Forest boundary, are considered municipal sources.

Wyoming is the only state in the country where public water systems are not required to complete source water assessments. However, the State encourages water systems entities to participate in voluntary assessments. More than 385 public water systems in Wyoming have participated. Utah requires source protection plans for all sources. Drinking water data and other information on source water assessments are not openly public by either state agency due to homeland security concerns, but are available to planners and other officials. This includes GIS information. As plan revision progresses, the Ashley National Forest is encouraged to work directly with both the Wyoming and Utah Departments of Environmental Quality for necessary and pertinent information needed to ensure protection of municipal watersheds, sole source aquifers, and source water protection areas. Specific information can be found at http://www.deq.utah.gov/ProgramsServices/programs/water/sourceprotection/index.htm and http://deq.wyoming.gov/wqd/water-wastewater/.

Multiple Uses/Ecosystem Services

As has been noted throughout this assessment, watersheds and water resources, in conjunction with air and soil resources, support multiple uses on the Ashley National Forest. Healthy watersheds, and the associated properly functioning hydrologic cycle, provide ecological sustainability, which in turn provides for the socio-economic setting of the forest plan area and communities downstream. Watersheds and the quantity and quality of water, as well as the timing of stream flows on the Ashley National Forest, are an important part of the lower end of the Upper Green River basin and all of the lower Green River basin, particularly for the Uintah Basin. As examples: people recreate on the Ashley National Forest to enjoy clean water, flowing streams, and high elevation scenic lakes. Streamflow fed by annual snowmelt provides unpolluted water for on- and off-Forest uses such as: habitat for wildlife and aquatic organisms, public drinking water, industrial, and agricultural supply. Healthy watersheds assist in climate regulation, and serve as a sponge and filter system for delivery of late-season water. Additionally, Ashley National Forest watersheds provide important ecosystems services to the Wasatch Front through trans basin diversions.

Conditions and Trends

During the previous forest plan revision effort, i.e., mid-2000s timeframe, the following management activities were identified as having an effect on water and watersheds:

- Domestic water, irrigation and livestock developments impacting both surface and groundwater flow regimes and water quality
- Oil and gas activity impacting water quality
- Harvest of conifer vegetation affecting peak flows and altering channel function, and construction of timber roads and skid trails affecting sediment delivery
- Increased road, trail, and off-road vehicle use affecting sediment delivery
- Historic and present livestock use affecting stream channels, riparian areas, upland areas, and water quality

The 2009 draft ecosystem diversity evaluation report discusses geomorphic conditions and trends. The list of concerns identified during the previous forest plan revision effort, and the geomorphic conditions and trends discussion (starting on page 62) remain as concerns in the current revision effort.

Additional water and watershed concerns include:

- Trans basin water diversions altering flow regimes, channel form and function in both the losing and gaining watersheds
- Increasing use of all-terrain vehicles and other off-road vehicles increasing interconnected areas of ground disturbance with potential effects on stream flow regimes sediment delivery and transport
- Oil and gas development road and well densities increasing interconnected areas of ground disturbance with potential effects on flow regimes and sediment delivery and transport
- Flood response and effects in recent severely burned areas
- Atmospheric deposition of nutrients, particularly nitrogen and phosphorus, and its effects on water chemistry and aquatic biota

Adequate protection of water and watersheds exists in the form of best management practices. These practices are proven measures that protect the water and watershed resources if properly implemented and monitored. The concern is that formal and informal monitoring indicates the practices are not always being fully and properly implemented at the project level.

State Integrated Reports

The State of Wyoming 2012 Integrated Water Quality Monitoring and Assessment Report, commonly called the 303(d)/305(b) report, is located at http://sgirt.webfactional.com/wqd/water-quality-assessment/resources/reports/. The report indicates there are no listed waterbodies within the Flaming Gorge National Recreation Area. There are listed waterbodies upstream of the national recreation area, which may be influencing water quality in the national recreation area, e.g., Bitter Creek. The 2014 report is in draft form, awaiting EPA approval. The 2014 report should be referenced rather than the 2012 report, if it becomes available as the forest plan revision progresses. At that time the Ashley National Forest should also reference http://deq.wyoming.gov/wqd/tmdl/ for additions of total maximum daily loads and watershed-based plans that may be pertinent or useful in plan revision.

The State of Utah 2010 Integrated Water Quality Monitoring and Assessment Report, located at http://www.deq.utah.gov/ProgramsServices/programs/water/wqmanagement/assessment/PreviousIR.htm#2010, indicates there are listed waterbodies for the Uinta watershed management unit, which includes the Ashley National Forest. Listed waterbodies are almost exclusively on the South Unit. Specific location, cause, source, concern, and total maximum daily load status is available at http://www.deq.utah.gov/ProgramsServices/programs/water/wqmanagement/assessment/docs/2010/11Nov/IR2010/Part2/Chapter7_Uinta_Basin.pdf. As plan revision progresses, the Ashley National Forest needs to pay particular attention to draft and approved total maximum daily loads to ensure compliance with them as plan components are developed. Approved total maximum daily load information is available at http://www.deq.utah.gov/ProgramsServices/programs/water/watersheds/approvedtmdls.htm. There are multiple watershed plans and documentation associated with water quality studies within the Uinta watershed management unit that the Ashley National Forest should peruse during revision efforts. This information is available at http://www.deq.utah.gov/ProgramsServices/programs/water/watersheds/index.htm#owqs.

Utah's 2012-2014 integrated report was approved by EPA and is available at https://deq.utah.gov/ProgramsServices/programs/water/wqmanagement/assessment/currentIR2014.htm#updates. The 2012-2014 report should be referenced rather than the 2010 report. The report suggests there may be an increase in listed waterbodies in the Uinta Mountains, including waterbodies in the High Uintas Wilderness. These waterbodies are being evaluated for concerns with metals, for which source or sources are not known. The Ashley needs to pay particular attention to this potential listing as plan revision progresses.

Integrated reports have a tendency to focus on chemical and biological quality of waterbodies and not on physical quality. Therefore, physical quality, i.e., stream pattern, profile, and dimension, may be under-represented in the State reports discussed above. Monitoring by Ashley National Forest staff suggests historical land uses, e.g., grazing, water development, roading, is negatively affecting stream physical function. The watershed condition framework, discussed next in this report, is a better reflection of waterbody physical condition across the Ashley.

Landscape-scale Disturbances

Ecosystems across the Ashley National Forest operate within a range of natural variation. The ecosystems experience periodic, but necessary, disturbances. The most recognized landscape-scale disturbances are insect epidemics and wildfire. Other disturbance processes, such as rain-on-snow events and floods, are also important relative to water and watersheds across the Ashley.

Bark Beetles

Bark beetles are native to the Ashley National Forest and generally influence forested ecosystems at endemic levels. Occasionally various species, e.g., Douglas-fir bark beetle, mountain pine beetle, and spruce beetle, reach epidemic levels resulting in landscape-scale change. Spruce stands grow in areas of the Forest with the greatest precipitation. Because evapotranspiration rates are greater in spruce than other conifer types, there is potential for increased stream flow from this bark beetle activity. The effects on streamflow in other conifer types would be expected to be less but not necessarily. Recent watershed studies, mostly conducted in Colorado, have failed to detect consistent changes in streamflow (Gordon and Ojima 2015). However, much of this work has been in lodgepole pine stands, which grow in areas of lower precipitation. Additionally, evapotranspiration demands of this forest type are less. Modeling efforts of bark beetle infestation indicate there may be a 5 to 10 percent increase in runoff. Such a small change may be real, but watershed studies have repeatedly shown that an increase of at least 15 percent is necessary to be able to detect, i.e., measure with statistical certainty, the change at the sub-watershed scale (MacDonald and Stednick 2003). Without specific studies on the Ashley National Forest, it is unknown if insect activity has changed evapotranspiration, and thus streamflow.

Historical watershed studies have shown that manipulation of conifer vegetation, e.g., timber harvest, can lead to measurable, i.e., detectable, increases in streamflow at the sub-watershed scale (MacDonald and Stednick 2003)[9]. However, timber harvest results in the removal of woody biomass, so comparing beetle kill to timber harvest is not entirely appropriate. In other words, both types of disturbance change the evapotranspiration component of the water cycle, but interception and evaporation processes change less under beetle kill.

Wildfire

Fire is an important component of almost every ecosystem, albeit in varying degrees, on the Ashley National Forest (USDA Forest Service 2009a). Some historic fires burned thousands of acres. Wildfire has also been suppressed across the Ashley National Forest over the last 100+ years, increasing the fire return interval and fuel loads in coniferous forests, and increasing conifer encroachment in shrub lands and grasslands. While the Ashley is actively implementing fuel reduction projects, with several thousand acres being treated per year, these trends may continue. The degree of departure from historical fire return

[9] Even though timber harvest can increase streamflow the Intermountain Region of the Forest Service, the Forest Service has determined purposefully doing so is not a management emphasis. Rather, any water yield increase that results from timber harvest is a by-product of the harvest. See regional forester letter dated 2002.

intervals and the amount of fuel that historically existed in vegetation communities has been assessed across the Ashley using the fire regime condition class protocol. This assessment conducted during the 2011 watershed condition framework analysis suggests roughly 90 percent of sub-watersheds are fire regime condition class 2, defined as a having a moderate departure from a reference or natural fire regime. The watershed condition framework captures this important watershed management information (table 21).

Watershed studies and post-fire monitoring in snow-dominated hydrologic systems indicate wildfire can result in increases in annual water yield proportional to that seen from timber harvest (Troendle and Bevenger 1996). Wildfire can also change, sometimes significantly, the response to short-duration, high-intensity summer thunderstorms. This could result in considerable soil erosion, sediment delivery, flash floods, higher peak flows, and down cutting of stream channels (Carlson 2008). High-severity fire consumes groundcover and alters the soil surface, creating water repellency. The water repellency reduces infiltration rates, resulting in erosion and overland flow to channels. The increased delivery of sediment and streamflow produces debris flows and floods that downcut channels and produce floods. These responses are typically a part of the ecosystem, but can result in issues and concerns in the wildland-urban interface. Such responses and associated effects, however, are usually only seen for the first three to five years after a significant high-severity fire. This is due to vegetative recovery and its ability to assimilate thunderstorm intensity, duration, and volume.

Dust

As discussed in the air resource section of this report, in recent years, late-spring snowpack across the Ashley National Forest occasionally has a brownish color, due to heavy deposition of windblown dust from distant and regional sources. Field studies indicate this dust alters the energy balance, resulting in enhanced snowmelt rates and earlier melt of the snowpack (Gordon and Ojima 2015). Modeling indicates the annual peak stream flows from melting snow occur about three weeks earlier than average in moderately dusty years. Years with extreme dust loading can add another three weeks, or a total of six weeks of earlier snow melt and peak flows. Modeling also indicates overall runoff can be reduced by roughly 5 percent due to changes in evapotranspiration. Extreme dust can increase evapotranspiration 6 percent. Even though the amount of dust is substantial, evapotranspiration change is minor because the energy of the sun in early spring is not sufficient to drive additional evapotranspiration. Gordon and Ojima suggest the spatial and year-to-year variability in dust loading, and resulting impacts on the water cycle, complicate watershed management. Complicating the dust issue is the interaction of climate change effects on the water cycle.

Floods

The Uinta Mountains periodically experience rain-on-snow events that can result in catastrophic flooding. These events are a function of the amount of land base above 9,000 feet and the west-to-east orientation of the Uinta Mountains. These factors allow snow to remain on the ground well into the summer thunderstorm season. This phenomenon is most significant in years when annual snowpack is above normal and spring temperatures are cooler than normal.

Floods are also of significance in the South Unit of the Ashley National Forest. Geologic, soil, and vegetative characteristics allow for considerable hydrologic response to short-duration, high-intensity summer thunderstorms. These flood events result from overland flow of storm water, produced when rainfall intensity exceeds soil infiltration rates.

Watershed Condition Framework

The watershed condition framework is a comprehensive six-step approach for proactively implementing integrated restoration on priority watersheds on national forests and grasslands. The first step of the framework characterizes the health and condition of watersheds at the 6^{th}-level hydrologic unit code scale. The classification uses a comprehensive set of four process categories, 12 indicators and 24 attributes. These are surrogate variables that represent ecological, hydrological, and geomorphic functions and processes that affect watershed condition. The primary emphasis of the classification is on aquatic and terrestrial processes and conditions Forest Service management activities can influence. The classification provides a consistent way to evaluate watershed conditions at the forest level, making it especially useful for forest planning. The initial or baseline characterization for the Ashley National Forest was completed in 2011. Only watersheds that have five percent or more National Forest System lands were rated. For the Ashley National Forest, 107 of the 147 6^{th}-level watersheds were characterized.

The Forest Service uses three classes to describe watershed condition:

- Class 1 or good condition watersheds are functioning properly because they exhibit high geomorphic, hydrologic, and biotic integrity relative to their natural potential condition
- Class 2 or fair condition watersheds are functioning at-risk because they exhibit moderate geomorphic, hydrologic, and biotic integrity relative to their natural potential condition
- Class 3 or poor condition watersheds are at impaired function because they exhibit low geomorphic, hydrologic, and biotic integrity relative to their natural potential condition

Each of the 24 attributes for each of the 107 watersheds were assigned a score of 1 (good), 2 (fair), or 3 (poor) by an Ashley National Forest interdisciplinary team. Scores were then aggregated by watershed into indicator scores, process category scores, and an overall condition score. Indicator and process category scores, as well as the overall score, were then assigned condition ratings. Scores between 1.0 and 1.6 are properly functioning watersheds. Scores between 1.7 and 2.2 are functioning at-risk watersheds. Scores between 2.3 and 3.0 are impaired function watersheds.

Overall Watershed Condition and Process Category Summary

Overall, 57 (53 percent) of the 107 watersheds are functioning properly. Another 50 (47 percent) are functioning at risk. No watersheds have impaired function (table 9, figure 27, figure 28, figure 41, figure 42). In most of the tables, the first number represents the number of watersheds rated as such; the second number represents the percent of the 107 watersheds on the Ashley rated as such.

Interestingly, the distribution of overall scores follows a bell-shaped curve, with 75 (70 percent) of the 107 watersheds straddling the break, i.e., scoring as 1.5 to 1.8 (or plus or minus 0.2 units) between properly functioning and functioning at-risk watershed condition (figure 28). What this implies is that changes in one or more attributes could cause a functioning-at-risk watershed to be reclassified to properly functioning, or a properly functioning watershed to be reclassified to functioning at-risk. These changes could be caused through either improved land management or through mismanagement

From a process category standpoint, a majority of the 107 watersheds are functioning properly relative to aquatic physical, aquatic biological, and terrestrial biological indicators (table 9, figure 29 through figure 31, figure 33, figure 43 through figure 46, figure 49, figure 50). Relative to terrestrial physical processes, a majority of the watersheds are functioning at-risk (table 9, figure 29, figure 32, figure 47, figure 48). There are no watersheds with impaired aquatic physical and terrestrial biological function. There is one watershed, Marsh Creek, with impaired aquatic biological function. The concerns in the Marsh Creek watershed are riparian condition and loss of native species. There are 22 watersheds with impaired terrestrial physical function. The concerns in these watersheds are open road density, lack of road and trail maintenance, and proximity of roads and trails to water.

Table 9. Watershed condition framework overall watershed condition and process category summary

	Watershed Condition Class	Watershed Condition Process Categories			
	Forest wide	Aquatic Physical	Aquatic Biological	Terrestrial Physical	Terrestrial Biological
Good	57 (53%)	72 (67%)	67 (63%)	7 (7%)	105 (98%)
Fair	50 (47%)	35 (33%)	39 (36%)	78 (73%)	2 (2%)
Poor	0 (0%)	0 (0%)	1 (1%)	22 (20%)	0 (0%)

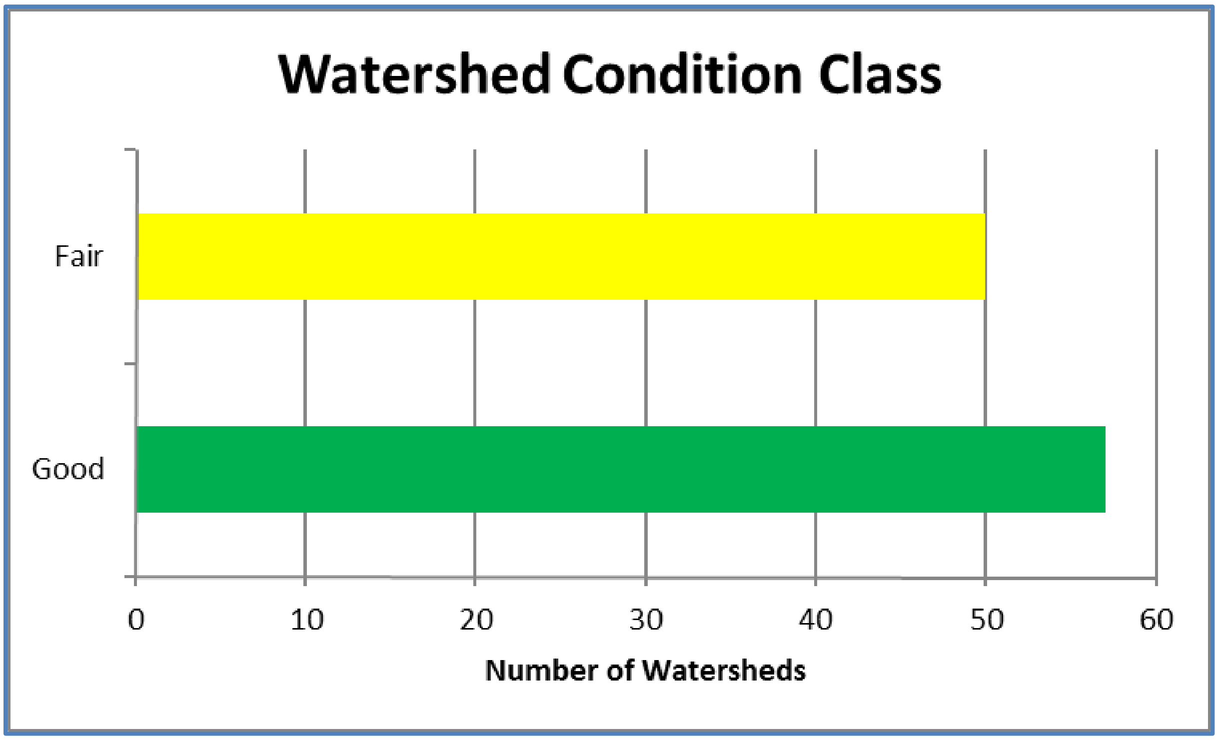

Figure 27. Watershed condition framework overall watershed condition class

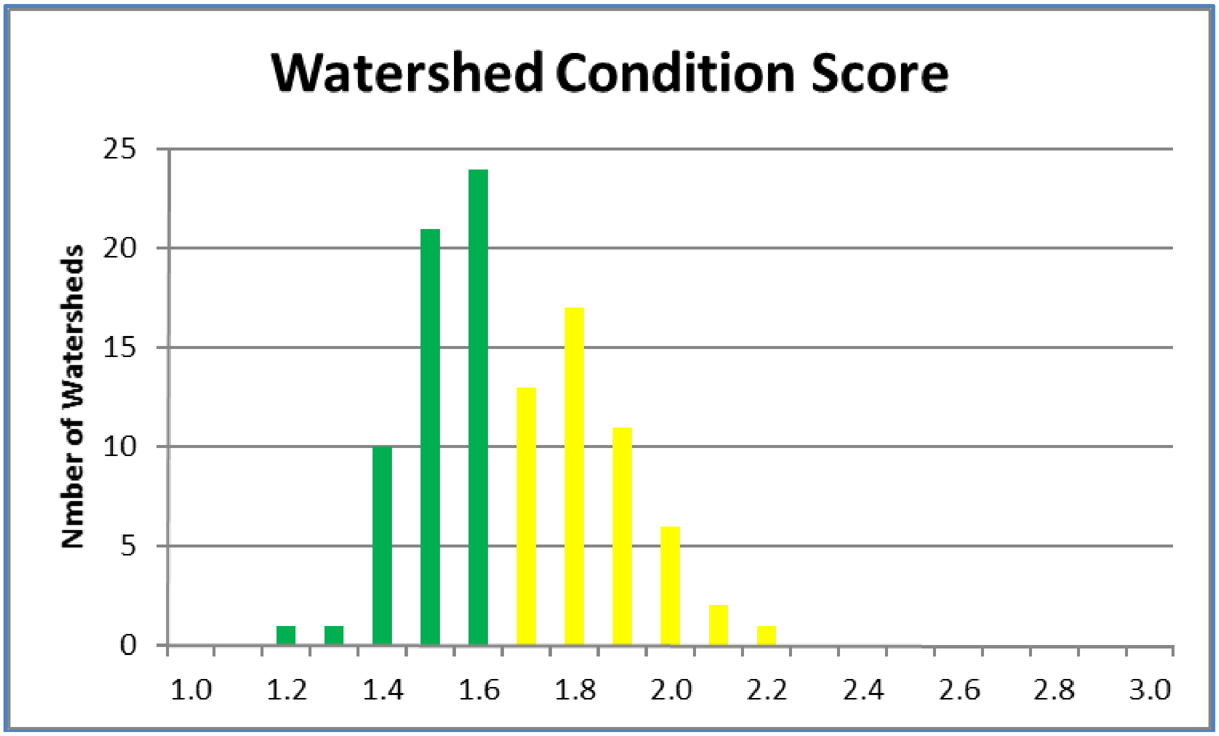

Figure 28. Watershed condition framework overall watershed condition scores

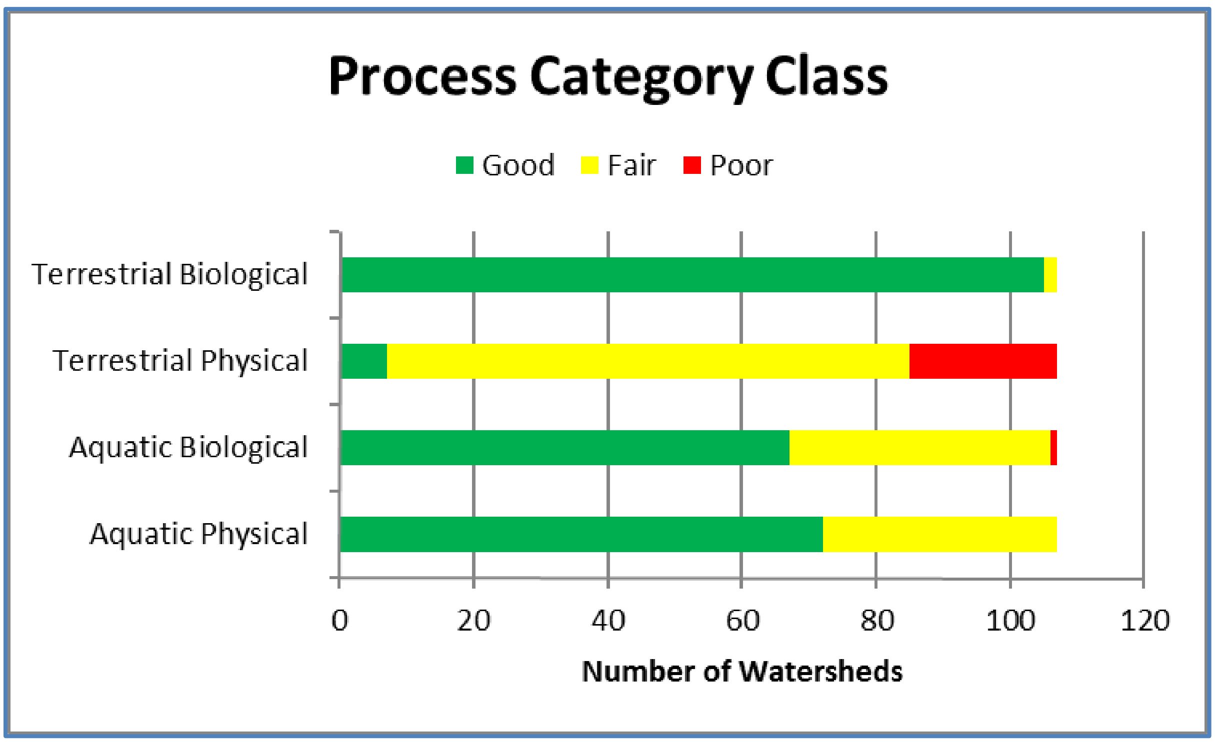

Figure 29. Watershed condition framework process category class

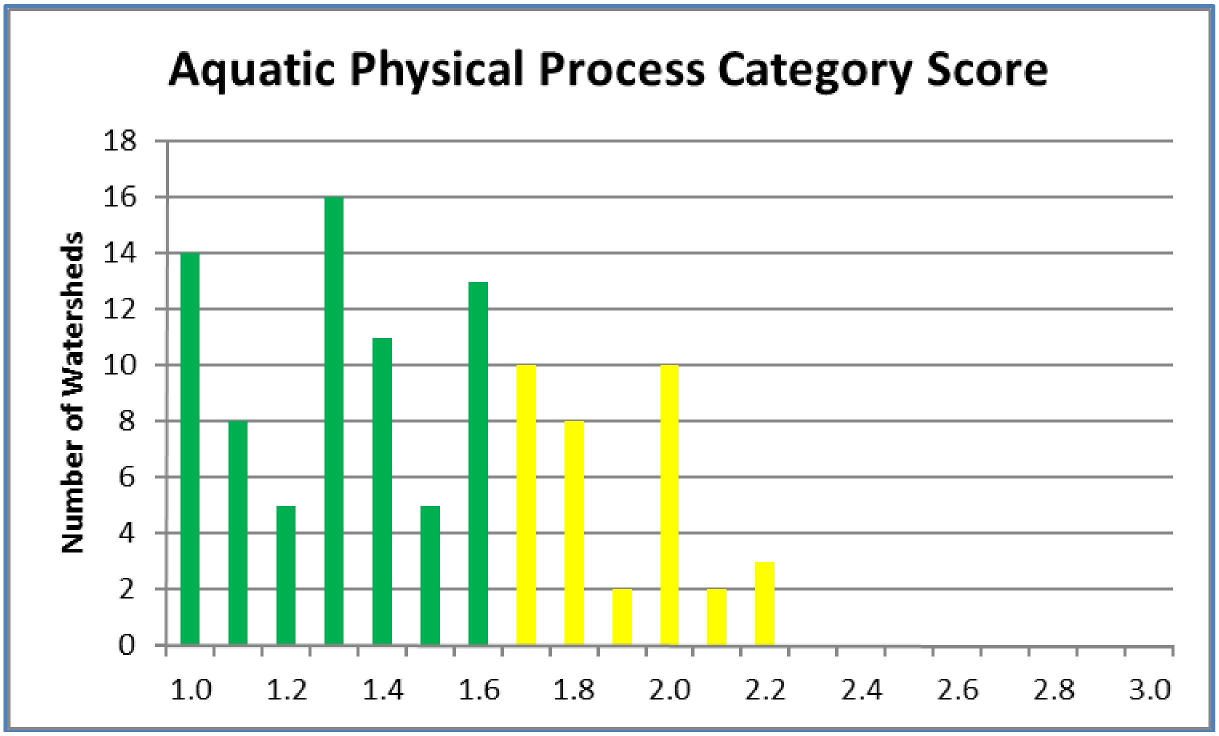

Figure 30. Watershed condition framework aquatic physical process category scores

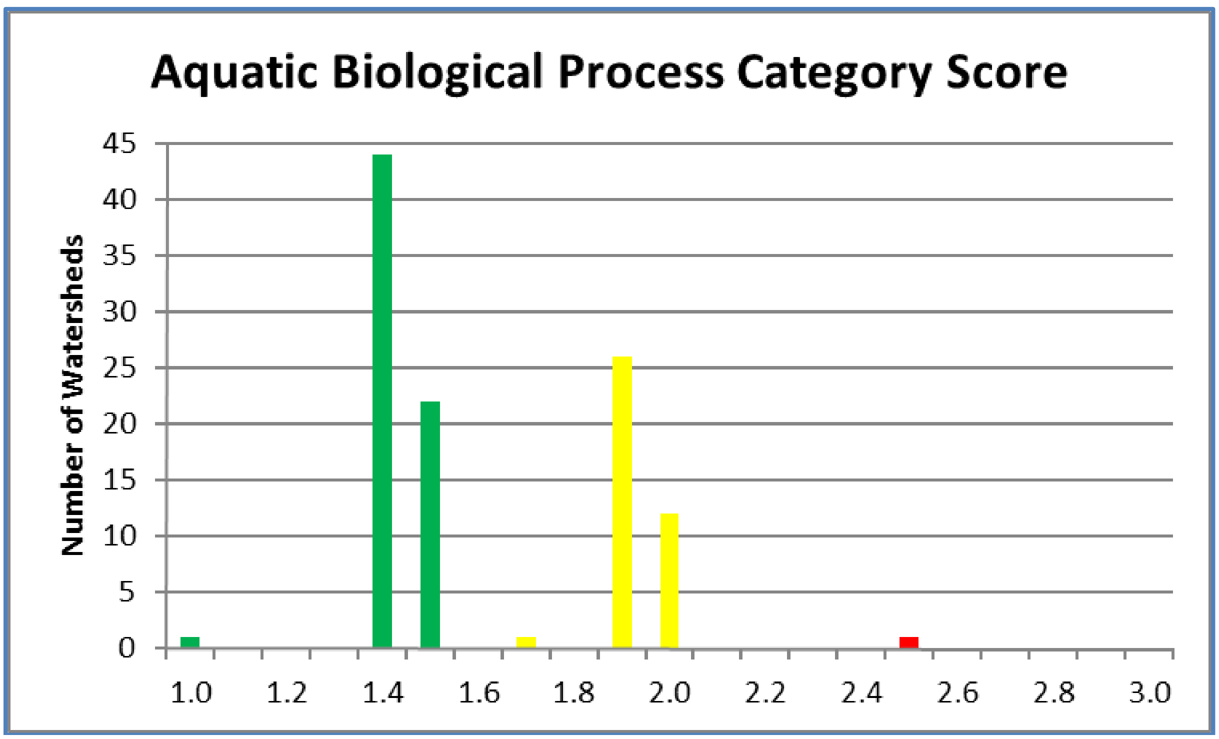

Figure 31. Watershed condition framework aquatic biological process category scores

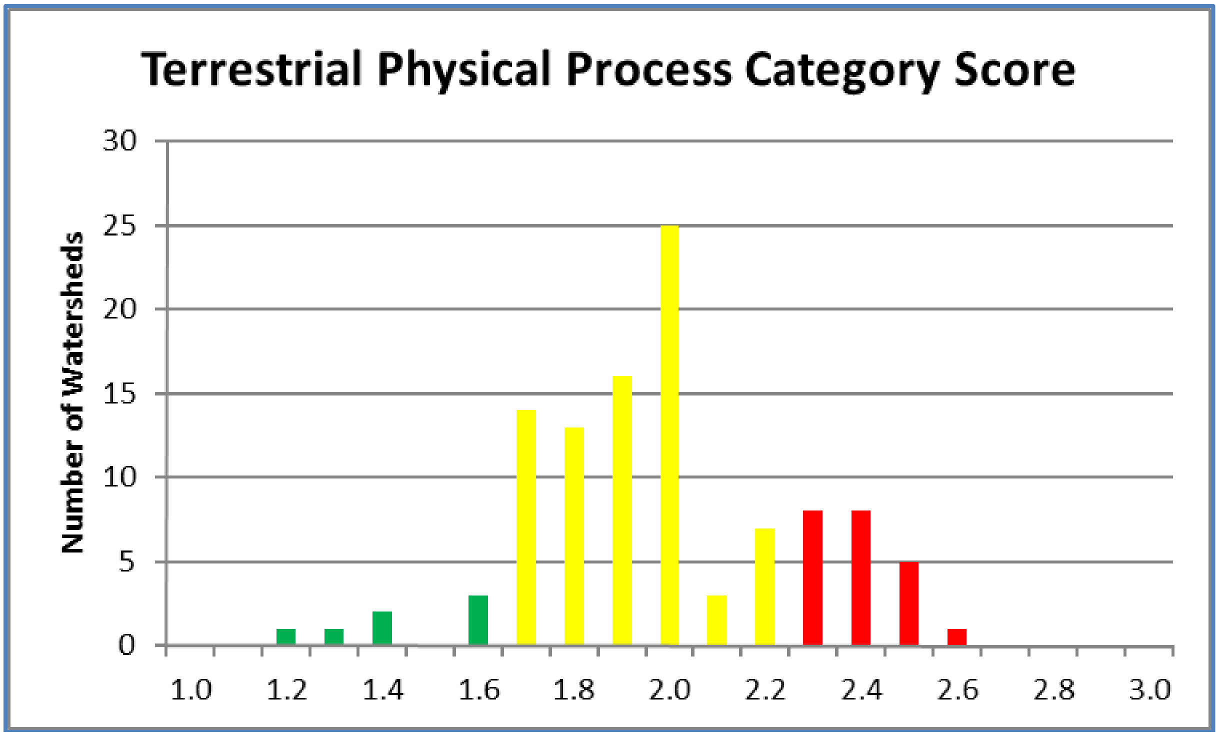

Figure 32. Watershed condition framework terrestrial physical process category scores

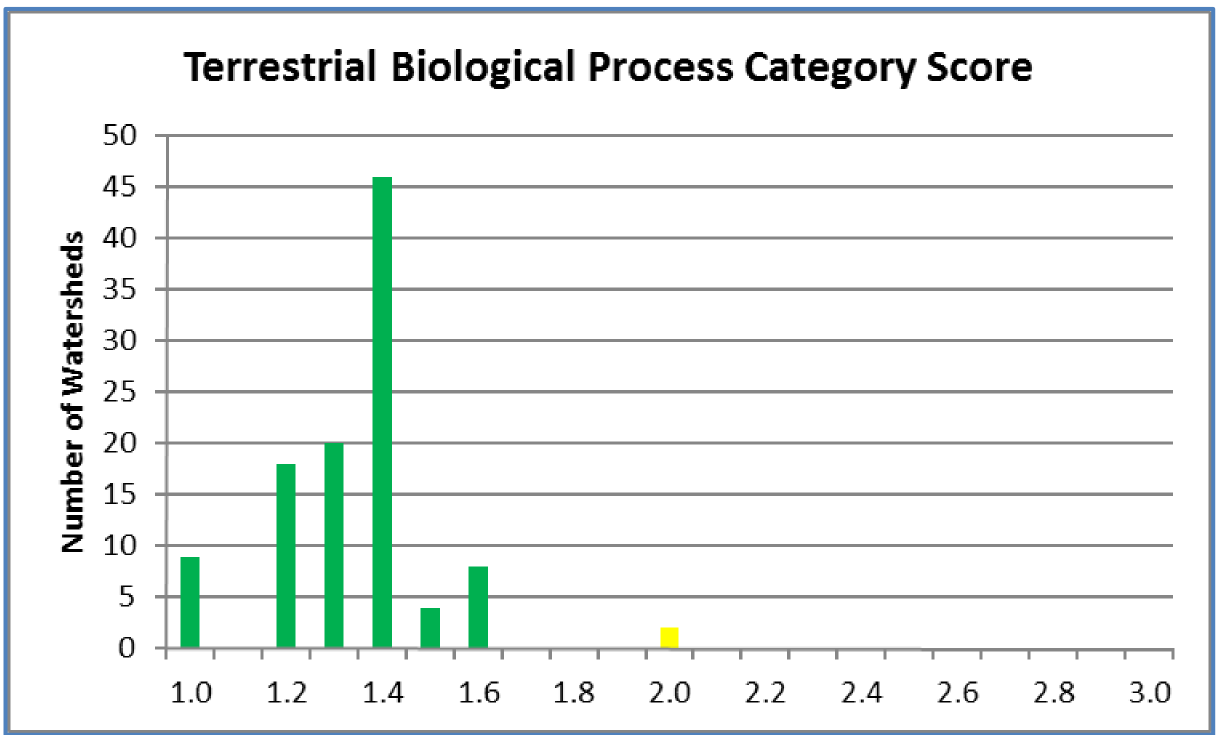

Figure 33. Watershed condition framework terrestrial biological process category scores

Process Categories, Indicators, and Attributes Summary

The majority of watersheds are functioning properly relative to the water quality and aquatic habitat indicators (table 10, table 14 through table 16). Slightly more than half of the watersheds are functioning properly relative to the water quantity indicator. The remaining roughly half are evenly split between functioning at-risk or at impaired function, with the concern primarily centered on flow characteristics. Roughly 20 percent of the watersheds are listed as either functioning at-risk or impaired function relative to the water quality indicator, due to un-listed and listed water quality segments. Roughly 1/3 of the watersheds are functioning at-risk relative to the aquatic habitat indicator, with the concerns primarily related to habitat fragmentation and channel shape and function. Large woody debris is good.

Table 10. Watershed condition framework aquatic physical indicator class

	Aquatic Physical Process Category	Aquatic Physical Indicators		
	Forest wide	Water Quality	Water Quantity	Aquatic Habitat
Good	72 (67%)	84 (79%)	57 (53%)	76 (71%)
Fair	35 (33%)	15 (14%)	26 (24%)	31 (29%)
Poor	0 (0%)	8 (7%)	24 (22%)	0 (0%)

Most watersheds across the Ashley National Forest are functioning at-risk relative to the aquatic biota indicator (table 11, table 16 through table 18). Life form presence is good. Lack of native aquatic species and presence of exotic invasive species, aquatic invasive species, or both are the driving concerns. Roughly 1/3 of the watersheds are functioning at-ask relative to the riparian and wetland vegetation indicator, with vegetation condition being the driving concern.

Table 11. Watershed condition framework aquatic biological indicator class

	Aquatic Biological Process Category	Aquatic Biological Indicators	
	Forest wide	Aquatic Biota	Riparian/Wetland Vegetation
Good	67 (63%)	2 (2%)	67 (63%)
Fair	39 (36%)	104 (97%)	39 (36%)
Poor	1 (1%)	1 (1%)	1 (1%)

The majority of the watersheds are functioning at-risk relative to the road and trails and soils indicators (table 12, table 19, table 20). Open road density, lack of road and trail maintenance, proximity to water, mass wasting, soil productivity, soil erosion, and chemical contamination are the drivers. Roughly 1/4 of the watersheds are at impaired function relative to the roads and trails and soils indicators.

The majority of watersheds are functioning properly relative to forest cover, rangeland vegetation, terrestrial invasive species and forest health terrestrial biological indicators (table 13, table 21 through table 25). Most watersheds are functioning at-risk relative to the fire regime and wildfire indicators. There are fire regime condition class concerns in 94 watersheds and wildfire concerns in two watersheds.

Table 12. Watershed condition framework terrestrial physical indicator class

	Terrestrial Physical Process Category	Terrestrial Physical Indicators	
	Forest wide	Roads and Trails	Soils
Good	7 (7%)	16 (15%)	23 (22%)
Fair	78 (73%)	67 (63%)	56 (52%)
Poor	22 (20%)	24 (22%)	28 (26%)

Only a few watersheds are functioning at-risk due to rangeland vegetation condition concerns. Two watersheds are at impaired function due to rangeland vegetation condition concerns. There are 26 watersheds functioning at-risk due to concerns with the extent and spread of terrestrial invasive species. There are two watersheds at impaired function due to concerns with the extent and spread of terrestrial invasive species. There are 34 watersheds functioning at-risk due to concerns with insects and disease effects on forest health.

Table 13. Watershed condition framework terrestrial biological indicator class

	Terrestrial Biological Process Category	Terrestrial Biological Indicators				
	Forest wide	Fire Regime or Wildfire	Forest Cover	Rangeland Vegetation	Terrestrial Invasive Species	Forest Health
Good	105 (98%)	11 (10%)	107 (100%)	97 (91%)	79 (74%)	73 (68%)
Fair	2 (2%)	96 (90%)	0 (0%)	8 (7%)	26 (24%)	34 (32%)
Poor	0 (0%)	0 (0%)	0 (0%)	2 (2%)	2 (2%)	0 (0%)

Table 14. Watershed condition framework water quality condition attributes class

	Indicator	Attributes	
	Water Quality Condition	Impaired Waters (303(d) listed)	Water Quality Problems (not listed)
Good	84 (79%)	82 (77%)	73 (68%)
Fair	15 (14%)	3 (3%)	34 (32%)
Poor	8 (7%)	22 (20%)	0 (0%)

Table 15. Watershed condition framework water quantity attribute class

	Indicator	Attributes
	Water Quantity	Flow Characteristics
Good	57 (53%)	57 (53%)
Fair	26 (24%)	26 (24%)
Poor	24 (22%)	24 (22%)

Table 16. Watershed condition framework aquatic habitat attributes class

	Indicator	Attributes		
	Aquatic Habitat	Habitat Fragmentation	Large Woody Debris[10]	Channel Shape and Function
Good	76 (71%)	78 (73%)	76 (97%)	36 (34%)
Fair	31 (29%)	29 (27%)	2 (3%)	64 (60%)
Poor	0 (0%)	0 (0%)	0 (0%)	7 (6%)

Table 17. Watershed condition framework aquatic biota attributes class

	Indicator	Attributes		
	Aquatic Biota	Life Form Presence	Native Species	Exotic and/or Aquatic Invasive Species
Good	2 (2%)	102 (95%)	2 (2%)	2 (2%)
Fair	104 (97%)	5 (5%)	74 (69%)	105 (98%)
Poor	1 (1%)	0 (0%)	31 (29%)	0 (0%)

Table 18. Watershed condition framework riparian/wetland vegetation attribute class

	Indicator	Attributes
	Riparian/Wetland Vegetation	Vegetation Condition
Good	67 (63%)	67 (63%)
Fair	39 (36%)	39 (36%)
Poor	1 (1%)	1 (1%)

Table 19. Watershed condition framework roads and trails attributes class

	Indicator	Attributes			
	Roads and Trails	Open Road Density	Road and Trail Maintenance	Proximity to Water	Mass Wasting
Good	16 (15%)	27 (25%)	9 (8%)	50 (47%)	68 (64%)
Fair	67 (63%)	58 (54%)	27 (25%)	33 (31%)	32 (30%)
Poor	24 (22%)	22 (21%)	71 (66%)	24 (22%)	7 (6%)

Table 20. Watershed condition framework soils condition attributes class

	Indicator	Attributes		
	Soils Condition	Productivity	Erosion	Chemical Contamination
Good	23 (22%)	25 (23%)	35 (33%)	0 (0%)
Fair	56 (52%)	57 (54%)	49 (46%)	107 (100%)
Poor	28 (26%)	25 (23%)	23 (21%)	0 (0%)

[10] This attribute is not applicable if the aquatic and riparian systems in the watershed evolved without wood and if the presence of wood is not an important component of the aquatic ecosystem. For the Ashley National Forest, only 78 of 107 watersheds were rated.

Table 21. Watershed condition framework fire regime or wildfire attribute class

	Indicator	Attributes	
	Fire Regime or Wildfire[11]	Fire Regime Condition Class	Wildfire Effects
Good	11 (10%)	11 (10%)	0 (0%)
Fair	96 (90%)	94 (90%)	2 (100%)
Poor	0 (0%)	0 (0%)	0 (0%)

Table 22. Watershed condition framework forest cover attribute class

	Indicator	Attributes
	Forest Cover	Loss of Forest Cover
Good	107 (100%)	107 (100%)
Fair	0 (0%)	0 (0%)
Poor	0 (0%)	0 (0%)

Table 23. Watershed condition framework rangeland vegetation attribute class

	Indicator	Attributes
	Rangeland Vegetation	Rangeland Vegetation Condition
Good	97 (91%)	97 (91%)
Fair	8 (7%)	8 (7%)
Poor	2 (2%)	2 (2%)

Table 24. Watershed condition framework terrestrial invasive species attribute class

	Indicator	Attributes
	Terrestrial Invasive Species	Extent and Ratio of Spread
Good	79 (74%)	79 (74%)
Fair	26 (24%)	26 (24%)
Poor	2 (2%)	2 (2%)

Table 25. Watershed condition framework forest health attribute class

	Indicator	Attributes	
	Forest Health	Insects and Disease	Ozone
Good	73 (68%)	49 (46%)	107 (100%)
Fair	34 (32%)	24 (22%)	0 (0%)
Poor	0 (0%)	34 (32%)	0 (0%)

Watershed Condition Framework Summary

When looking at overall watershed condition across the Ashley National Forest, 53 percent of the 107 watersheds rated in 2011 are functioning properly, 47 percent are functioning at-risk, and no watersheds have impaired function. Attribute and indicator ratings for three of the four process categories – aquatic physical, aquatic biological, and terrestrial physical – are the driving influences behind the overall

[11] Only one of the two attributes are scored, not both.

condition ratings and scores. Attribute and indicator ratings for the terrestrial biological process category are less influential.

Seventy five of the 107 watersheds straddle the break, i.e., scoring as 1.5 to 1.8 (or plus or minus 0.2 units), between properly functioning and functioning at-risk watershed condition. This implies that changes in one or more attributes could cause a functioning-at-risk watershed to be reclassified to properly functioning or a properly functioning watershed to be reclassified to functioning at-risk. The changes could come through either improved land management or through mismanagement. The Ashley National Forest may want to consider this inference as priority watersheds are selected in the plan revision process.

Further dissection of the classification shows summed and averaged attribute ratings for nine of the 12 indicators are influencing watershed condition across the Ashley National Forest most significantly. These indicators are water quality, water quantity, aquatic habitat, aquatic biota, riparian and wetland vegetation, roads and trails, soils, terrestrial invasive species, and forest health.

Eighteen of the 24 attributes are the major influences on overall watershed condition.

- State of Utah impaired waters (303(d) listed)
- Water quality problems (not listed)
- Flow characteristics
- Aquatic habitat fragmentation
- Channel shape and function
- Aquatic native species
- Exotic and/or aquatic invasive species
- Riparian vegetation condition
- Open road density
- Road and trail maintenance
- Road proximity to water
- Road mass wasting
- Soil productivity
- Soil erosion
- Soil chemical contamination
- Fire regime condition class
- Terrestrial invasive species, extent and ratio of spread
- Forest insects and disease

Land use and activities that are influencing these attributes the most are:

- domestic water supply (including trans-basin diversions);
- irrigation;
- stock water development;
- road, trail, and off-road motorized recreation;
- foot and horse trail recreation;
- historical and current livestock grazing in both uplands and riparian areas/wetlands;
- lack of road and trail maintenance;
- introduction of exotic and invasive aquatic and terrestrial species;
- atmospheric deposition of nitrates; and
- natural range of variability issues relative to fire regimes and insect and disease activity.

As a critical part of the watershed condition framework, i.e., step three of six, two watershed restoration action plans have been prepared by the Ashley National Forest to address watershed condition. These completed watershed restoration action plans are for the Swift Creek and Cart Creek watersheds. Essential projects in Swift Creek are complete. Essential projects in Cart Creek are in various stages of implementation. A watershed restoration action plan for Middle Sheep Creek is in preparation.

Effects from Land Use and Places at Risk

In short, the following surface-disturbing activities are the greatest current and potential threats to loss of watershed and water resources integrity across the Ashley National Forest:

- Domestic water development
- Ungulate grazing
- Oil and gas development
- Dispersed recreation use
- Road construction
- Off-road motorized use

The effects, many of which have been described throughout this assessment, can be direct, indirect, or cumulative. The scientific literature that supports this is voluminous but can be summarized by stating the effects are due primarily to:

- soil erosion and compaction in uplands and riparian areas;
- changes in the amount of water and sediment delivery to streams and wetlands; and
- associated adjustments then made by the stream systems.

The literature also clearly shows that application of soil and water conservation practices, also known as best management practices, mitigate the effects of land use, allowing for watershed protection.

As stated earlier, the use of water, both on and off the Ashley National Forest, is governed by treaty, compact, decree, and State-level policy. Because of this, future water uses and withdrawal and diversion opportunities, as well as water storage opportunities, within the Ashley National Forest are limited.

Potential Effects of a Changing Climate

The effects of a changing climate on air, soil, and water and watershed resources on national forests are becoming better understand as time passes. There are multiple on-going research and development activities in climate change science that are painting this picture. Relative to the Ashley National Forest, there are many sources of information available to managers to better understand potential effects. Key websites include:

- Intergovernmental Panel on Climate Change at http://ipcc.ch/
- National Center for Atmospheric Research at http://ncar.ucar.edu/
- Western Water Assessment at http://wwa.colorado.edu/
- USDA Forest Service at http://www.fs.fed.us/climatechange/
- Utah Climate Center at https://climate.usurf.usu.edu/
- Wyoming State Climate Office at http://www.wrds.uwyo.edu/sco/climate_office.html

Draft Watershed Vulnerability to Climate Change Assessment

While information at the above websites is pertinent and should be consulted as forest plan revision progresses, it is also voluminous and convoluted. Despite this, Ashley National Forest decision makers and staff are fortunate to have a Forest-specific assessment of watershed vulnerability to climate change (Rice et al. 2017). The assessment should prove extremely useful as forest plan revision efforts proceed. The assessment combines information from the scientific literature and opinion from climate change researchers to describe watershed vulnerability, sensitivity, and exposure to climate change and the capacity of Forest watersheds to adapt to the expected changes. The following paragraphs are over-simplified summary statements of the assessment relative to air, soil, and water and watershed resources on the Ashley National Forest. To repeat, the assessment, rather than the following summary statements, should be consulted as the forest plan revision progresses due to the assessment's very thorough and detailed narrative.

For the Ashley National Forest, watershed vulnerability is scored moderate to high. Sensitivity to projected increases in drought, heat, flooding, greater evaporation, snowpack loss, and earlier snowmelt shifting runoff timing and reduction in streamflow is high. Coupled with this watershed vulnerability and sensitivity, climate change effects may be compounded by fire, insect epidemics, invasive biota, and human land and water uses.

Relative to Forest air, soil, and water resources, air temperature has increased over the past century in northeastern Utah (Utah Climate Division 5), particularly since 1970, i.e., average increases of 0.2 degrees Fahrenheit per decade since 1900 and 0.5 degrees Fahrenheit since 1970. Annual precipitation records show no long-term trend in either seasonal or annual amounts. However, studies do indicate more precipitation falling as rain, rather than snow, with resultant decreases in snow depth and snow-water equivalent, and earlier snow-water equivalent peak and melting.

Down-scaled climate modeling of the Ashley National Forest suggests that annual temperatures will increase an average of 3.7 degrees Fahrenheit for years 2035-2064, compared to 1981 to 2010. The modeling predicts annual precipitation to increases by 4.2 percent. Nighttime low temperatures may rise as much as daytime highs, and summer temperatures may warm slightly more than winter and spring temperatures. Statistical confidence banding suggests temperatures in all seasons will continue increasing (i.e., 2.2 degrees Fahrenheit at the 10^{th} percentile and 4.9 degrees Fahrenheit at the 90^{th} percentile). Precipitation changes, due to less statistical confidence, could decrease or increase, i.e., minus 5.8 percent at the 10^{th} percentile and plus15.1 percent at the 90^{th} percentile. Expected warmer temperatures, discounting possible changes in precipitation, are expected to result in earlier runoff and a decrease in annual runoff, due to increases in evapotranspiration. Multiple literature citations in the report lead to a conclusion there may be enhanced risk of both flood and drought if the climate continues warming.

Upland vegetation vulnerability is very high in the alpine zone, but low at lower elevations. Elevated atmospheric deposition of nitrogen has a potential to change species composition in alpine areas. This change could reduce diversity and favor nitrophilic (nitrogen-loving plants that thrive under, or readily utilize, high nitrogen conditions) plant species in what has been a nitrogen limited environment. Warming temperatures could have an additive effect by increasing nutrient supply, lengthening growing season, and making alpine zones more inevasible to lower elevation species (Porter et al. 2013). Upland vegetation species, in general, are projected to progress upward in elevation, with associated reduction in areal extent. Conifer acreage is expected to diminish as lower elevation plants migrate upward. Topography, soils, geology, and invasive species will play a role in the extent and severity of change. Riparian vegetation vulnerability ranges from low to high. Lower elevation riparian areas have a high vulnerability due to drying, warming, snowpack loss, and land uses. Higher elevation areas are similarly vulnerable but human influences would likely be less of a factor. Riparian vegetation response will likely vary due to elevational gradients, localized hydrologic change, and adaptive capacity and tolerance of plant species. Groundwater dependent wetlands will likely have lower vulnerability than precipitation-driven wetlands.

Ashley National Forest watersheds have moderate to very high vulnerability to drought, heat, and floods. These watersheds are likely to have very high sensitivity to drought, with decreasing sensitivity as elevation increases. Watersheds are likely to have a moderate sensitivity to extreme heat, but like drought, decreasing sensitivity as elevation increases. Groundwater outflows may lower the sensitivity due to cooler water temperatures decreasing surface-flow water temperatures. Watersheds are likely to have moderate sensitivity to change in flood regimes. This is due to a combination of physiography and geology, coupled with expected changes in precipitation and vegetation.

The intrinsic capacity of Ashley National Forest watersheds to adapt to climate change is moderate. Most watersheds are inherently resilient because they are in good functioning condition at the present. Watersheds functioning at-risk are more vulnerable to climate change effects, with the degree being a function of upland cover, health of aquatic habitats, and riparian and wetland conditions.

Forest vulnerability for climate change to exacerbate the effects of non-climate stressors, or vice versa, is high. Moderate vulnerability is assigned to climate change effects on fire as warming, drying, and decreases in snowpack could raise fire potential and lengthen fire seasons. Increases in fire could increase erosion and mass movements, and affect water quality. High vulnerability is assigned to climate change effects on insect activity, due to warmer temperatures and drought stressing trees. Insect outbreaks could alter runoff and water chemistry, but the existing literature indicates change could be variable. Very high vulnerability is assigned to climate change and human water use, because warming and drying will further reduce and alter already limited water availability. Very high vulnerability is also assigned to climate change and invasive species, as climate change could create new environments for spread and thus affect watershed condition and health. High vulnerability is assigned to climate change and air pollution. This is because air pollution effects from surrounding, particularly upwind areas, could be exacerbated by warmer temperatures and changes in precipitation patterns. Increases in dust-on-snow events could result in earlier snowmelt and a shift in runoff timing. Additional research shows that climate warming may affect lake water temperatures. This could result in stronger thermal stratification and extended ice-free periods for biological activity (Ngai 2014, Moser et al. 2015). Along with warming temperatures atmospheric deposition of nutrients and metals may increase, potentially affecting the water quality and biota of high elevation lakes. High vulnerability is also assigned to climate change and recreation, grazing, roads and trails, and energy development. This is because the effects of these activities are a function of potential changes in hydrologic regimes, soil productivity, and vegetation discussed earlier.

The Ashley National Forest has high vulnerability relative to the likelihood of managing or alleviating climate change effects. This is because management activities currently exist that could reduce stressors. However, their effectiveness is untested, so they may not be completely effective. Additionally, management activities or mitigating effects of management may simply be overwhelmed by the changes in climate. The bottom line, relative to air, soil, and water and watershed resources on the Ashley National Forest, is that adaptation to climate change is enhanced when watersheds are healthy and resilient.

Carbon Sequestration

A changing climate also has potential effects on the soil resource, which is not addressed to a great degree in the Rice et al. 2017 document discussed above. For example, carbon sequestration, nutrient cycling, soil formation, and soil biology can be positively or negatively affected by changes in climate. The 2012 Planning Rule requires assessment of carbon stocks. Specifically, requirements included baseline assessment, how the plan area plays a role in sequestering and storing carbon, how disturbance and management affects carbon stocks past and future, and trends in soil carbon.

This present assessment, while addressing soil resources, does not address this part of the Planning Rule. Rather, the Intermountain Region of the Forest Service has made arrangements with the Rocky Mountain Research Station to assess above- and below-ground carbon stocks for all national forests in the region involved in forest plan revisions. The Ashley National Forest should consult that information, when it becomes available, as forest plan revision efforts move forward.

Data Gaps

Air Resources

As demonstrated in this report, there is a plethora of information for the air resource. Accordingly, there is sufficient information available to proceed with Forest Plan revision.

Given the ever growing body of evidence of air quality impacts across the Ashley, the Ashley National Forest should conduct statistical analysis of lake and snowpack chemistry data sets, consider setting limits of acceptable change, and begin dialogue on the need to develop local critical and target loads. While not needed for Plan revision, this workload could be a part of the revision or added to annual work plans.

Soil Resources

This report demonstrates there is considerable qualitative information on current soil resource condition and trend, but there is a lack of quantitative data, particularly related to soil productivity. While additional quantitative data would be ideal, the qualitative information is sufficient to proceed with forest plan revision. The data gap between what is known qualitatively and what is needed quantitatively for future management of soil resources across the Ashley can be addressed. This can be done through the establishment of clear and concise statements of desired condition, goals, objectives, and standards and guidelines, followed by a monitoring program that collects and evaluates requisite information.

Water and Watershed Resources

This report demonstrates there is considerable quantitative and qualitative information on current water and watershed resource condition and trend. Additional quantitative data would be ideal, particularly related to stream health physical function, i.e., stream pattern, profile, and dimension, and groundwater-dependent ecosystems. However, there is sufficient information to proceed with Plan revision. The data gap between what is known and what is needed for future management of water and watershed resources across the Ashley National Forest can be addressed. This can be done through the establishment of clear and concise statements of desired condition, goals, objectives, and standards and guidelines, followed by a monitoring program that collects and evaluates requisite information.

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Attachment A – Supporting Information

In the following table, LTA = land type association, LWD = large woody debris

Table 26. Ashley National Forest land type associations hydrology/riparian structure and geomorphic processes (from Forest Service 2009a). Literature citations in the text are formerly cited in the ecosystem diversity evaluation report

Landtype Association	Symbol	Hydrology/Riparian	Geomorphic Processes
Alpine Moraine	AM	In general, the stream types that form in this LTA are characterized by the following channel morphology descriptions: 1) Bedrock controlled streams with bedrock, boulder, and cobble steps on steeper channel gradients (>5 percent), where large woody debris (LWD) has a limited function in creating grade control and aquatic habitats. 2) Low gradient, meandering streams that are narrow and deep with banks that are anchored together by deep-rooted hydric species. In these stream systems, the substrate composition is mostly silt and sand. Riparian areas are an important component of this LTA. Most riparian areas are in the valleys of the AM3 land type, and are lakes in various stages of evolution toward wet meadows. Riparian areas associated with lakes and streams generally have shallow water tables, ranging from the surface to 10 inches (25 cm) deep. The steeper slopes and valley bottoms of this LTA have numerous seeps and springs.	Climatic conditions of this LTA are harsh, with current processes of wind erosion, freezing and thawing, and fluvial being the most active. Although highly variable, the soils are subject to erosion, and where disturbance is evident, much erosion is produced as sedimentation into nearby streams. Seeps and springs are common, often at the interface between surficial materials and bedrock. Snowfields and talus slopes are important for late season water production. Lakes, ponds, and meadows range from oligotrophic to eutrophic and the filling in of lakes and ponds over time is an important process. Potholes without external drainage are common, particularly in the AM1 land type where ground moraines (till covered areas with irregular topography, often forming rolling hills or plains) are interspersed with potholes. During the spring melt period, water is perched above the surface, with the surface soils being saturated well into the summer. Seeps and springs along steep slopes and in valley bottoms are often the result of water running on the plane of bedrock, which is then discharged from the side-slope where the surficial till overlays bedrock or other impermeable layers of clay from older surfaces.
Antelope Flat	AF	Even though this LTA has very few perennial channels, it is highly dissected by ephemeral channels and gullies. This is due to parent material composition being mostly erodible sands and gravels. In the areas that have gently sloping topography (e.g., Antelope Flat and Lucerne Peninsula), there are virtually no channels identified. The lack of channels in these areas is primarily due to limited annual precipitation, most of which is snowfall in the winter. Where stream channels have developed, they are steep, narrow, and V-shaped. Channel form is grade-controlled (i.e., erosion and channel depth are limited by the hillslope	In places, the shale is gypsiferous (contains high amounts of gypsum), bentonitic, (contains high amounts of bentonite clay) and high in soluble salts. Consequently, the soil has low porosity/low permeability and transmits water slowly, if at all, tends to become waterlogged, is plastic when wet, and tends to erode rapidly. Streamflow typically occurs during spring snowmelt runoff, or during summer thunderstorms. For some channels, streamflow is supplemented by springs and seeps that extends the flow duration well into the summer. The only perennial channel in the LTA is Spring Creek. Base flows in this channel are often generated by groundwater exfiltration

Landtype Association	Symbol	Hydrology/Riparian	Geomorphic Processes
		gradient) with substrate primarily of gravel and sand, having a step or cascade bedform. Bed and banks are generally unstable due to the lack of vegetation and the inherent erodibility of the parent material. In general, persistent LWD is not present in areas where channels are adjacent to brush or grass covered slopes. Since there are very few channels in the LTA, there are consequently very few riparian areas. Those that do exist are maintained by groundwater exfiltration from seeps and springs.	from seeps and springs - whereas peak flows in spring and early summer are generated from snowmelt runoff, with occasional rain-on-snow supplements. Summer and fall peaks are generated from occasional, intense thunderstorms. Community dynamics of desert shrub communities are mostly driven by variation in weather and particularly amount and timing of precipitation. These weather patterns also greatly influence the demise and recovery of shrubs and graminoid (grasses) species. Drought is typically the major disturbance process on this LTA. Severity, patch size, extent, and patterns are highly variable, depending on the severity and duration of drought. This was vividly portrayed in the drought of 2002 through 2003. During this drought, there was a major dieback of sagebrush and some native perennial grasses on the LTA that was most conspicuous in the spring and summer of 2003. In some places, winterfat (*Krasheninnikovia lanata*) replaced the native grasses that died. For the most part, Wyoming big sagebrush that appeared dead due to the drought made rapid recovery. By 2005, the sagebrush had grown back to near pre-drought canopy cover (Study 5-27E). There was high mortality of sagebrush at one location of about 40 acres (16 ha). Shadscale (*Atriplex confertifolia*) increased after the dieback of sagebrush in this area (Study 4-42B). Monitoring studies on this land type indicate high resilience of Wyoming big sagebrush/grass communities in this rather droughty environment. In areas where some species died during the most recent drought, these species either recovered or were replaced by other native plants. This was documented in studies 4-42B, 5-1, 5-3, and 5-27E. Herbaceous species tend to have greater cover and be more abundant where sagebrush cover has been reduced. The 5-27 series of studies, as well as other studies, provide examples of this relationship (AntelopeFlat.ppt). Drought also greatly influences plant cover in Gardner saltbush communities on this LTA. This was demonstrated at study site 6-16. Crown cover of Gardner saltbush was near 32 percent in 1992 and 4 percent in 2003, which was near the peak of drought, and 28 percent one year later in 2004. This wide shift in plant cover in this desert shrub community is consistent with a study spanning 40 years in Idaho. The

Landtype Association	Symbol	Hydrology/Riparian	Geomorphic Processes
			study (1990) documented wide shifts in plant composition, concurrent with drought and insect population shifts. Frequent wide variation in plant cover is also documented for desert shrub communities by Nelson and others (1989).
Anthro Plateau	AP	This LTA is highly dissected (i.e., closely spaced) by both ephemeral and perennial channels. This LTA has one of the highest stream densities of all the LTAs, however, the majority of streams are ephemeral. Since this LTA occurs at a lower-elevation than those LTAs of the Uinta Mountains Section, there is less snow accumulation in the winter and generally a lower annual precipitation. The channels in this LTA are very similar to those in the adjacent Avintaquin Canyon and Strawberry Highlands LTAs. There are two main stream types within the LTA: 1) ephemeral channels are steeper, narrow, V-shaped, and typically bedrock-controlled; a. channel gradients are typically steeper than five percent, but can be much steeper; 2) perennial channels are narrow-to-moderate width (i.e., typically less than 25 feet or eight meters wide), V- or U-shaped, and typically bedrock-controlled; a. channel gradients are typically less than five percent, but can be locally steeper or shallower; b. in the lowest elevations of this LTA, many perennial channels have become alluvial (i.e., low gradient or less than two percent) and meander with moderate sinuosity within the boundaries of the canyon walls. These channels are associated with wide floodplains (e.g., wider than the Avintaquin Canyon LTA) that are subject to flooding. The dynamic role of beaver activity can play a key role in creating and maintaining riparian and wetland areas. For both ephemeral and perennial channels, bed material is typically composed of sands to cobbles, but can have larger stones in some locations. Parent material is of the Green River Formation sandstone/shale. Because of bedrock controlling the planform, banks are often stable. For all streams in this LTA, LWD can be a major structural component, especially where the vegetation consists primarily of conifers and aspen located in the mid-slope elevations. In	For ephemeral channels, streamflow typically occurs during spring snowmelt runoff, or during summer thunderstorms. For some channels, streamflow is supplemented by springs and seeps to extend the flow duration well into the summer. There are numerous springs within this LTA indicating it is an area of groundwater discharge. For perennial channels, base flows during all seasons are often generated by groundwater exfiltration from seeps and springs within the LTA, whereas peak flows in spring and early summer are generated from snowmelt runoff with occasional rain-on-snow supplements. Summer and fall peaks are generated from occasional, intense thunderstorms that often contribute to the high erosion rate. Floods with debris flows are a common factor affecting the dynamics of vegetation on this land type. Debris flows are generated by intense thunderstorms that hit the steep, sparsely vegetated canyon walls. With high intensity thundershowers, these debris flows occur somewhere in the LTA almost every year. These flows are carried onto the canyon bottoms where they form fans. A number of native species are highly adapted to colonizing in this debris, including sagebrush, Salina wildrye, yucca, and other species. Plateau penstemon, rough paintbrush, and other specialists have also colonized on these flows (Study 67-45).

Landtype Association	Symbol	Hydrology/Riparian	Geomorphic Processes
		the steep headwall areas where vegetation is limited, or in lowland areas where a climate of low precipitation tends to favor pinyon/juniper vegetation, there is limited LWD available to be of significance in channel structure. The soils in swales of first and second order drainages are deep mollisols inhabited by sagebrush and perennial grasses that stabilize the banks. Riparian areas are generally associated with canyon bottoms and springs or seeps.	
Avintaquin Canyon	AC	This LTA is highly dissected and it has one of the highest stream densities of the LTAs on the Forest, however, the majority of streams are ephemeral or intermittent. Since this LTA occurs at a lower-elevation than those LTAs of the Uinta Mountains Section, there is generally less snow accumulation in the winter and lower annual precipitation There are two main stream types in this LTA: 1) ephemeral channels are steeper, narrow, V-shaped, and typically bedrock-controlled; a. channel gradients are typically steeper than five percent, but can be much steeper; 2) perennial channels are narrow-to-moderate width (i.e., typically less than 25 feet or eight meters wide), V- or U-shaped, and typically bedrock-controlled; a. channel gradients are typically less than five percent, but can be locally steeper or shallower; b. in the lowest elevations of this LTA, some perennial channels have become alluvial (i.e., low gradient or less than two percent) and meander with moderate sinuosity within the boundaries of the canyon walls. These channels are associated with moderately wide floodplains that are subject to flooding. The dynamic role of beaver activity can play a key role in creating and maintaining riparian and wetland areas. For both ephemeral and perennial streams, bed material is typically composed of sand to cobbles; but can have larger stones in some locations. Parent material is Green River Formation sandstone/shale. Because of bedrock controlling the planform, banks are often stable. For all streams in this LTA, LWD can be a major structural component in the mid-slope elevations, especially where the vegetation consists primarily of conifers and aspen. In the	For ephemeral channels, streamflow typically occurs during spring snowmelt runoff, or during summer thunderstorms. For some ephemeral channels, streamflow is supplemented by springs and seeps that extend the flow duration well into the summer. There are numerous springs within this LTA indicating it is an area of groundwater discharge. For perennial channels, base flows during all seasons are often generated by groundwater exfiltration from seeps and springs within the LTA, whereas peak flows in spring and early summer are generated from snowmelt runoff with occasional rain-on-snow supplements. Summer and fall peaks are generated from occasional, intense thunderstorms, which often influence the high erosion rate. Debris flows play a role in channel development and sediment transport.

Landtype Association	Symbol	Hydrology/Riparian	Geomorphic Processes
		steep headwall areas, where vegetation is limited or in lowland areas where insufficient precipitation favors pinyon/juniper vegetation, there is limited LWD available to be of significance in channel structure. The soils in swales of first and second order drainages are deep mollisols inhabited by sagebrush and perennial grasses that stabilize the banks. Riparian areas are generally associated with canyon bottoms and springs or seeps.	
Dry Moraine	DM	This LTA is weakly dissected (i.e., broadly spaced) by ephemeral channels that run perpendicular to canyon walls; there are no mapped perennial channels. Some areas on this LTA are discharge areas for groundwater, which sometimes produce springs. Stream channels in this LTA are moderate-to-steep (>5 percent slope) ephemeral channels, located along perpendicular to canyon walls, which generally have the following characteristics: 1) channel form is narrow, bedrock-controlled, having a step or cascade bedform; 2) bed and banks are generally unstable since the morainal material is deep, unconsolidated, and lacking bedrock; erosion depth is dependent on: grade of the hillslope, presence of boulders, and volume of runoff water; 3) channel depth will generally be shallow, except at the toe of steep slopes where the regolith (A layer of loose unconsolidated material (dust, soil, broken rock) that overlies solid bedrock) is deepest and there is sufficient flow volume to scour the toe material. 4) large woody debris is not a major structural component, but may be present.	Where water has been concentrated on this LTA, it has cut gullies, while more uniform sheet wash has removed surface fines. Because of the steep slopes of this LTA, the boulders and cobbles of the till roll off the slope rather than form an armor layer. In some cases, outwash and debris deposits are covering the lower portions of this LTA. Parts of this LTA are rapidly eroded by slumping and gullying due to sandy soils. However, in other areas there is a marked absence of dissection. Streamflow is usually only present during spring snowmelt runoff or during intense, summer thunderstorms. Considerable channel realignment can occur during infrequent flash floods following large-scale thunderstorms.
Glacial Bottom	GB	This LTA has a high density of streams and rivers. They range from ephemeral channels that seasonally dissect alluvial fans and terraces, to braided, multi-channel, main-stem rivers. Where bedrock is not exposed, the substrate in all watercourses ranges from sands to cobbles, with stones and boulders controlling grade. Some streams that cross Red Pine or Manning Canyon Shales have a considerably higher proportion of fine sediment (i.e., clays and silts) intermixed with coarse material. There are two general types of streams within this LTA:	In the low gradient ephemeral channels located perpendicular to abandoned terraces, streamflow is usually only present during spring snowmelt runoff or during intense summer thunderstorms. For perennial streams, base flows during all seasons are generated by groundwater flows. In low gradient valleys, high water tables are common, which results in exfiltration to streams. Peak flows in spring and early summer are generated from snowmelt runoff with occasional rain-on-snow supplements. Summer and fall peak flows are generated from occasional, intense thunderstorms. Considerable channel realignment can occur during

Landtype Association	Symbol	Hydrology/Riparian	Geomorphic Processes
		1) low gradient (i.e., less than five percent) ephemeral channels located along (perpendicular to) abandoned terraces (some channels are abandoned braids from main-stem channels); a. channel form is narrow, slope/grade-controlled, having a pool-riffle bedform (stream form that is a series of pools and riffles) b. bed and banks are generally stable due to the presence of riparian vegetation stabilizing banks with root masses. However, sediment transport rates from upslope source areas are quite high; c. typically, LWD is not a major structural component, but may be present; d. channel depth will generally be moderately deep (i.e., three to five feet or one to one and half meters) deep; 2) low gradient (<2 percent slope), perennial channels in wide, shallow gradient floodplains, or abandoned terraces (e.g., White Rocks, Uinta, Yellowstone, and Duchesne Rivers); a. channel form often has low-to-moderate width/depth ratios, with the potential to laterally migrate anywhere within the valley bottom; b. the valley bottoms adjacent to channels typically have substantial riparian vegetation, which can contribute large volumes of LWD during channel realigning events; c. channels are often slope/grade controlled, with considerable substrate formed of alluvial/colluvial/fluvial material, with sizes ranging from silt to boulders, transported from banks; side slopes, or upstream (in-channel) sources, often in pool-riffle sequences occasionally with alternating bars.	infrequent flash floods following large-scale thunderstorms or rain-on-snow events in the uplands. Flooding of the braided stream complex of the GB2 land type is an annual event. Magnitude of flooding varies with accumulation of snow higher in the drainage and with the rapid change in temperature and duration of periods of warm weather during the high runoff season. Because flooding associated with spring runoff is annual, there is hardly time for vegetation to recover between flooding events. Where flooding causes alteration of stream channels, only a few years pass before plants have colonized abandoned channels. Lateral channel migration, channel avulsion and abandonment, and development of off channel ponds from abandoned meanders are dominant processes in the valley bottom streams, which is typical of channels that are either anastomosed or braided. Beaver also play a major role in maintaining and creating riparian and wetland areas. Beavers do this by elevating water tables, connecting streams to the valley floor and floodplain, providing fish and amphibian habitat, increasing over bank floods, and dissipating flood flows. However, all beaver dams eventually fail in this setting. The dams leave exposed, nutrient rich sediments that facilitate the return of early successional plant species. This cycle affects relatively small areas. However, it is a common process that is well dispersed in the riparian forest of the canyon bottoms, especially in the GB2 land type. Flooding associated with beaver ponds also tends to kill conifers and at a small scale. This might help maintain openings where deciduous trees and other non-coniferous species can increase after beaver ponds go dry. However, this process does not seem adequate to maintain a high presence of seral species over the landscape, and it certainly does not prevent conifer advancement on uplands. Pockets of wind-thrown trees indicate wind is also a moderate process of disturbance.
Glacial Canyon	GC	This LTA is weakly dissected (i.e., broadly spaced) by both ephemeral and perennial channels that run perpendicular to canyon walls. There is higher stream density than the Uinta Bollie LTA, but much lower stream density than the Alpine Moraine LTA. This LTA has streams ranging from steep,	Historically, block and side-slope failures were common on this LTA due to glaciers cutting into the slopes, which undercut and destabilized them. Following the retreat of glaciers, fluvial and colluvial processes became dominant in this LTA. Erosion and mass wasting is a common process.

Landtype Association	Symbol	Hydrology/Riparian	Geomorphic Processes
		ephemeral channels to low gradient, moderate sinuosity meadow streams. Stream substrate depends on which subunit the stream crosses. For example, streams in limestone, sandstone, and quartzite will have coarser substrate. This ranges from sands to cobbles with stones and boulders controlling grade, where bedrock is not exposed. However, streams in Red Pine or Manning Canyon Shales will have a considerably higher proportion of fine sediment (i.e., clays and silts intermixed with coarse material). There are two general types of streams within this LTA: 1. steep (>20 percent slope), ephemeral channels located along (perpendicular to) canyon walls; a. channel form is narrow, bedrock-controlled, having a step or cascade bedform; b. bed and banks are generally stable (due to the presence of bedrock, except where bedrock is shale); c. typically, LWD is not a major structural component, but may be present; d. channel depth will generally be shallow, except at the toe of steep slopes where the regolith (layer of loose rock deposits over bedrock) is deepest and there is sufficient flow volume to scour the toe material. 2. low to moderate gradient (<5 percent slope), perennial channels at the base of steep canyon walls (e.g., Swift, Iron Mine, Hades, Rock, Brown Duck, Fish, Yellowstone, Paradise, and Lily Lake Creeks; White Rocks and Duchesne Rivers); a. channel form often has high width/depth ratios (wider than it is deep), with the potential to laterally migrate only within the valley bottom (which is usually narrow); b. the valley bottoms adjacent to channels typically have substantial riparian vegetation, which can contribute large volumes of LWD during channel realigning events; c. channels are often bedrock controlled, with considerable substrate formed of alluvial/colluvial/fluvial material (with sizes ranging from silt to boulders) transported from banks, side	Mass movement occurs by slow creep and rolling of boulders down the face of the slope, with occasional debris and mudflows. Where soils have developed, they are inherently vulnerable to erosion and mass wasting processes. Streamflow in steep, ephemeral channels is usually only present during spring snowmelt runoff or after intense, summer thunderstorms. In the perennial streams, base flows throughout the year are generated by groundwater flow and exfiltration. Peak flows in spring and early summer are generated from snowmelt runoff with occasional rain-on-snow supplements. Summer and fall peaks are generated from occasional, intense thunderstorms. Considerable channel realignment can occur in the low to moderate gradient channels during infrequent flash floods following large-scale thunderstorms. Avalanches (Studies 35-15, 36-25, 36-26, 36-26H, GlacialCanyon.ppt) and debris flows (Studies 26-16A, 26-16C, 26-17B, GlacialCanyon.ppt) are common in some areas of this LTA. Both of these disturbances typically occur in years of heavy snowfall, with debris flows likely triggered by rapid warming after heavy snow accumulations. Compared to fire, the extent of these events is small, and their effect on patch size is relatively small. However, they are more frequent than fire, and larger avalanches might cover 30 acres (12 ha) or more. Avalanche paths where frequent avalanches occur are usually relatively free of conifer and are often dominated by spindly aspen with downward curving stems. The sizes of trees in some avalanche paths indicate about 200 to 300 years between major avalanche events. This long interval is indicated for an avalanche of 2005 in South Fork Rock Creek (Study 35-15) that toppled and broke spruce trees of two to three feet (0.6 to 1 m) diameter at breast height (DBH) that were 100 feet (30 m) tall.

Landtype Association	Symbol	Hydrology/Riparian	Geomorphic Processes
		slopes, or upstream (in-channel) sources, often in pool-riffle sequences (occasionally with alternating bars); Many small seeps and springs are found in this LTA, often reflective of the underlying shale. Many ponds and springs are also found along the back rotational slump areas. Perennial streams entering the main drainage all have an associated riparian component.	
Green River	GR	This LTA is highly dissected by ephemeral channels/gullies and has few perennial channels. This is likely due to parent material composition being mostly erodible sands and gravels. In the areas that have gently sloping topography (e.g., Buckboard Marina, Anvil Draw), there are virtually no channels identified. The lack of channels is primarily due to limited annual precipitation, which is between 8 to 11 inches/year (20 to 28 cm/year), most of which is snowfall in the winter. Most channels are low-to-moderate gradient, narrow, and V-shaped. Channel form is grade-controlled (i.e., erosion and channel depth are limited by the hillslope gradient) with substrate primarily of gravel and sand, having a step or cascade bedform. Bed and banks are generally unstable due to the lack of vegetation and the inherent erodibility of the parent material. In general, persistent LWD is not present in areas where channels are adjacent to brush or grass covered slopes. Since there are very few channels in the LTA, there are consequently very few riparian areas. Those that do exist are maintained by groundwater exfiltration from seeps and springs.	In places on this LTA, the shale component is high in soluble salts and has low porosity and permeability. Hence the component transmits water slowly if at all, and tends to become waterlogged. It is also plastic when wet, and tends to erode rapidly. Landslides appear to have been of minor importance on this desert shrub dominated LTA. Except in washes, floods have likely been of little importance. For ephemeral channels, streamflow typically occurs during spring snowmelt runoff, or during summer thunderstorms. For some ephemeral channels, streamflow is supplemented by springs and seeps to extend the flow duration well into the summer. For perennial channels, base flows during all seasons are often generated by groundwater exfiltration from seeps and springs. Peak flows in spring and early summer are generated from snowmelt runoff with occasional rain-on-snow supplements. Summer and fall peaks for perennial channels are typically generated from occasional, intense thunderstorms.
Greendale Plateau	GP	The stream channel density is noticeably lower in this LTA than in adjacent LTAs (e.g., AM, RC, and NF) primarily because a large portion of the area is flat to gently sloped. This has created a situation where snowmelt and rainfall infiltrate the soil rather than concentrate flow to become surface runoff. There are three general stream types within this LTA: 1) ephemeral streams beginning within the LTA; 2) perennial streams beginning outside the LTA (from the AM land type) and passing through to the RC LTA; and 3) perennial/ephemeral streams passing through meadows.	For ephemeral channels, streamflow typically occurs during spring snowmelt runoff or during summer thunderstorms. For some ephemeral channels, streamflow is supplemented by springs and seeps that extend the flow duration well into the summer. For perennial channels, base flows during all seasons are often generated by groundwater exfiltration from seeps and springs from outside the LTA. Peak flows for perennial channels typically occur during the spring and early summer, which are generated from snowmelt runoff with occasional rain-on-snow supplements. Summer and fall

Landtype Association	Symbol	Hydrology/Riparian	Geomorphic Processes
		Ephemeral streams that begin in this LTA, and perennial streams that pass through, are often low to moderate gradient (i.e., less than five percent) but can exceed 20 percent gradient. Channels are narrow, V-shaped, and typically bedrock-controlled. Bed material is typically composed of sands to cobbles. Because of bedrock controlling the planform, banks are often stable. Large wood debris can be an important structural component because this LTA has many conifer stands adjacent to the channels. Where canals intersect these streams, a substantial portion of the streamflow is diverted and exported out of the natural drainages. However, because the canals are "leaky", exfiltration return flows are often seen in the perennial channels within about 300 to 600 feet (91 to 183 m) down-slope of the diversion. Perennial and ephemeral streams passing though meadows are typically low gradient (i.e., less than two percent and sinuous). Bed material is typically fine-grained sands and silts, with minor components of cobbles. Stream banks are stabilized by the root masses of native grasses and sedges. Large woody debris is typically not a major structural component of the channels since these channels flow through meadows rather than forests. Riparian plant communities are a complex of wet and dry meadows, willow patches, and other shrubs. The wetter areas located adjacent to the stream courses that are perpetually wet, support communities of semi-aquatic sedges, grasses, and willow. Coarse semi-aquatic sedges, water sedge, and beaked sedge often are dominant on these sites with bluegrass, bentgrass, hairgrass, lousewort, timothy, rush, woodrush, and marsh marigold species. Numerous beaver dams are present in the western portion of this LTA.	peaks are typically generated from occasional, intense thunderstorms. This LTA has drainages running from west to east, generally following dips until they enter Cart Creek. Numerous wet and dry meadows are present on this LTA. These wet meadows, such as Hickerson Park, formed by partial blocking of streams and glacial outwash. Beaver are also major geomorphic agent in the meadows or parks of this LTA. For example, the low gradient part of Hickerson Park is dominated by fine sediments, indicating that this area was often submerged. Much of this area is also covered with water and marshy vegetation as a function of beaver dams lower in the park, and is nearly devoid of willows. Willows are abundant higher in the park and gravels and cobbles dominate streambed materials.
Limestone Hills	LH	The stream channel density is noticeably lower in this LTA than in adjacent LTAs (i.e., SC, PP, and TS). This is primarily due to two factors: 1) a large portion of the area is flat to gently sloped. This creates a situation where snowmelt and rainfall infiltrate the soil rather than concentrate flow to become surface runoff, and 2) the LTA is underlain by limestone undergoing dissolution processes, which create karst or underground flow paths.	The dip slopes of this LTA are interrupted by short scarp slopes, which serve to retard erosion processes. Some portions of the LTA have slopes of talus or colluvium composed of limestone fragments of variable sizes that appear to move downslope at a slow rate. This hillslope movement is shown by trees that bend downslope and then curve upwards, as well as accumulations on the uphill sides of the trees.

Landtype Association	Symbol	Hydrology/Riparian	Geomorphic Processes
		Both ephemeral and perennial streams are often low to moderate gradient (i.e., less than five percent) but can exceed 20% gradient. Ephemeral channels are steeper, narrow, V-shaped, and typically bedrock-controlled. Perennial channels are narrow-to-moderate width (i.e., typically less than 25 feet or eight meters wide), V- or U-shaped, and typically bedrock-controlled. For these streams, bed material is typically composed of sands to cobbles; but can have considerable components of boulders in some locations. Because of bedrock controlling the planform, banks are often stable. Large woody debris can be a major structural component because this LTA has many conifer and aspen stands adjacent to channels. Relatively few surface water features create riparian areas. Where riparian areas do exist, they are generally limited to seeps, springs, and a limited amount of riparian habitat in the stream bottoms.	Soils are produced by the chemical solution of the limestone, and are thus clay rich. Although the surface soils are well drained, having a subsoil rich in clay can produce a perched water table during heavy, summer thunderstorms. For ephemeral channels, streamflow typically occurs during spring snowmelt runoff, or during summer thunderstorms. For some ephemeral channels, streamflow is supplemented by springs and seeps that extend the flow duration well into the summer. For perennial channels, base flows during all seasons are often generated by groundwater exfiltration, whereas peak flows in spring and early summer are generated from snowmelt runoff with occasional rain-on-snow supplements. Summer and fall peaks are typically generated from occasional, intense thunderstorms. Where aspen stands are adjacent to streams, there is potential for beavers to modify channels, impound water, and create or expand riparian habitat.
Limestone Plateau	LP	Stream channel density is noticeably lower in this LTA than in adjacent LTAs (e.g., AM and GC) primarily due to the flat to gently sloping topography and rapid transport of water into and through the soil, which prevents live streams from developing in most areas. Where stream channels have formed, both ephemeral and perennial channels are present. Ephemeral and perennial streams are often low to moderate gradient (i.e., less than five percent) but can exceed 20 percent. Ephemeral channels are steeper, narrow, V-shaped, and typically bedrock-controlled. Perennial channels are narrow-to-moderate width (i.e., typically less than 25 feet or eight meters wide), V- or U-shaped, and typically bedrock-controlled. For these streams, bed material is typically composed of sands to cobbles; but can have considerable components of boulders in some locations. Because of bedrock controlling the planform, banks are often stable. Large woody debris can be a major structural component because this LTA has many conifer and aspen stands adjacent to the channels. Riparian areas are limited in this LTA due to the underlying limestone geology. None of the landform features is present to pond water, and seeps and springs generally do not develop in this setting.	The low stream density in this LTA is primarily a result of two factors: 1) a large portion of the area is flat to gently sloped, which creates a setting where snowmelt and rainfall infiltrate the soil rather than concentrate flow to become surface runoff and 2) the LTA is underlain by limestone undergoing dissolution processes. These processes create karst or underground flow paths, where water is quickly moved through the limestone gravelly ground. Although the surface soils are well drained, a subsoil rich in clays can produce a perched water table during heavy, summer thunderstorms. For ephemeral channels, streamflow typically occurs during spring snowmelt runoff, or during summer thunderstorms. For some channels, streamflow is supplemented by springs and seeps to extend the flow duration well into the summer. For perennial channels, base flows during all seasons are often generated by groundwater exfiltration. Peak flows for perennial channels typically occur in spring and early summer and these peak flows are generated from snowmelt runoff with occasional rain-on-snow supplements. Summer and fall peaks are typically generated from occasional, intense thunderstorms. The main drainage in this LTA, Blind Stream, produces running water in the spring associated with spring snowmelt. For the rest of the year, the section of Blind Stream in this LTA does not have flowing water. In addition, because

Landtype Association	Symbol	Hydrology/Riparian	Geomorphic Processes
			this area is near alpine elevations, snowfields can be important for late season water production. Patterned ground that has formed in the limestone of this LTA is unique in the Uinta Mountains. Here, microclimate conditions exist in trough areas where cold air settles, which can affect vegetative growth. High elevation and open terrain create harsh weather conditions such as high winds, cold temperatures, and short growing seasons, similar to the Uinta Bollie LTA.
Moenkopi Hills	MH	This LTA is moderately to highly dissected (i.e., closely spaced) by ephemeral channels and has one of the highest stream densities of the LTAs, but there are no mapped perennial channels. Since this LTA occurs in lower-elevation foothills of the southern face of the Uinta Mountains, there is less snow accumulation in the winter and generally lower annual precipitation than upslope LTAs. The ephemeral channels in this LTA are often moderate to steep gradient (i.e., typically greater than five percent) but can exceed 20 percent. They are generally narrow, V-shaped, and typically bedrock-controlled. For these streams, bed material is typically composed of sands to cobbles, but can have larger stones in some locations. Because of bedrock controlling the planform, banks are often stable. Large woody debris is rarely a major structural component, especially where the vegetation consists primarily of pinyon/juniper and annual grasses. There is little riparian area associated with this LTA. Where riparian areas exist, they are seeps and springs toward the cap of the units.	There is active gullying and sheet wash in this LTA and, consequently, considerable sediment production. This active erosion is undermining the sandstone caprock, and blocks of this bed are sliding down the shale slopes. Streamflow typically occurs during spring snowmelt runoff, or during summer thunderstorms. For some channels, streamflow can be supplemented by springs and seeps to extend the flow duration well into the summer. The erosive nature of the Moenkopi Formation indicates high intensity thundershowers have considerable influence on slopes of this LTA.
North Flank	NF	This LTA has very few stream channels, the majority of which are ephemeral. Only Mahogany Draw, and Lodgepole, Death Valley, Spring Creeks (all tributaries of Sheep Creek), and Birch Creek are perennial. Most channels, both ephemeral and perennial, are steep (i.e., at least four percent slope but typically are greater than 20 percent slope), narrow, and V-shaped. Channel form is bedrock-controlled, with a substrate of boulders and/or cobbles (occasional, high-to-moderate gradient riffles will have cobble to sand substrate). These channels also typically have a boulder-step, cascade-chute, or step-pool bedform. Bed and banks are generally stable due to the presence of	For ephemeral channels, streamflow typically occurs during spring snowmelt runoff, or during summer thunderstorms. For some ephemeral channels, streamflow is supplemented by springs and seeps to extend the flow duration well into the summer. For perennial channels, base flows during all seasons are generated by groundwater flows through karst systems. Peak flows in spring and early summer are generated from snowmelt runoff, with occasional rain-on-snow supplements. Summer and fall perennial channel peaks are generated from occasional, intense thunderstorms. In the alluvial bottomlands, considerable natural channel

Landtype Association	Symbol	Hydrology/Riparian	Geomorphic Processes
		large boulders and bedrock. Large woody debris can be a structural component in areas where this LTA has many conifer stands adjacent to the channels. Otherwise LWD is not present in areas where channels are adjacent to brush or grass covered slopes.	realignment can occur during low-frequency flash floods following large-scale thunderstorms.
Parks Plateau	PP	The stream channel density is noticeably lower in this LTA than in adjacent LTAs (e.g., AM, RC, and NF), primarily because a large portion of the area is flat to gently sloped. This type of topography creates a situation where snowmelt and rainfall infiltrate the soil, rather than concentrate flow to become surface runoff. Both ephemeral and perennial streams are often low to moderate gradient (i.e., less than five percent), but can exceed 20 percent. Ephemeral channels are steeper, narrow, V-shaped, and typically bedrock-controlled. Perennial channels are narrow-to-moderate width (i.e., typically less than 25 feet or eight meters wide), V- or U-shaped, and typically bedrock-controlled. For these streams, bed material is typically composed of sands to cobbles, but can have substantial components of boulders in some locations. Because of bedrock controlling the planform, banks are often stable. Large woody debris can be a major structural component because this LTA has many conifer stands adjacent to the channels. Wet meadow streams are typically low gradient (i.e., less than two percent) and sinuous. Bed material is typically fine-grained sands and silts, with minor components of cobbles. Stream banks are stabilized by the root masses of native grasses and sedges, and have overhanging banks that create aquatic habitat. Large woody debris is typically not a major structural component of the channels, since these channels flow through meadows rather than forests. Riparian areas are limited in this LTA. Most wet areas are reflective of fluctuating water tables, but do not have a riparian vegetative component. The exception is along US Highway 191, where components of meadows are riparian. Alma Taylor Lake and Gull Lake are two small water bodies on this LTA and both are filled in depressional areas.	This LTA occurs in the mid-elevation zone of the Ashley National Forest. It generally has a moderate temperature, and there is comparatively greater rainfall in this LTA than in adjacent areas at similar elevations. There is also less snowpack than LTAs at higher elevations. This type of climate is very productive for vegetation, especially the production of grasses. Typically, under lodgepole pine stands, a seasonally high water table is reflective of the precipitation that occurs on this landscape. Heavy rains during the monsoon season can produce a high water table where there is clay subsoil. This creates a perched water table because the impeding clay layer restricts drainage and creates puddling. Streamflow for ephemeral channels typically occurs during spring snowmelt runoff or during summer thunderstorms. For some ephemeral channels, streamflow is supplemented by springs and seeps to extend the flow duration well into the summer. For perennial channels, base flows during all seasons are often generated by groundwater exfiltration. Peak flows in spring and early summer are generated from snowmelt runoff with occasional rain-on-snow supplements. Summer and fall peaks are generated from occasional, intense thunderstorms. Much of the water from this LTA is discharged in the seeps and springs of the South Face LTA.
Red Canyon	RC	Stream types in this LTA are composed of steep ephemeral channels and low to moderate gradient perennial channels.	Slopes are being actively eroded by subsurface water movement, freeze-thaw, exfoliation, and spalling

Landtype Association	Symbol	Hydrology/Riparian	Geomorphic Processes
		Riparian vegetation exists primarily along the perennial, bottomland, alluvial streams, (e.g., Cart Creek, Carter Creek, and Sheep Creek). Vegetation consists of willow, cottonwood, birch, dogwood, rose, and alder. In the alluvial bottomlands, there are numerous wet areas due to natural depressions, debris dams, and beaver ponds. These wet areas often provide usable fisheries or aquatic habitat. There are two general types of streams within this LTA: 1) steep (>20% slope), ephemeral channels located along the canyon walls (e.g., Red Canyon above Flaming Gorge Reservoir); a. channel form is narrow, bedrock-controlled, with substrate primarily of cobbles (where present), having a step or cascade bedform; b. bed and banks are generally stable (due to the presence of bedrock); c. typically, LWD is not a major structural component, but may be present; 2) low to moderate gradient (i.e., less than five percent slope), perennial channels at the base of steep canyon walls (e.g., Carter Creek, Cart Creek), or fault lines (e.g., Sheep Creek); a. channel form often has high width/depth ratios (i.e., wider than it is deep) with the potential to laterally migrate only within the valley bottom, which is usually narrow; b. the valley bottoms adjacent to channels typically have substantial riparian vegetation, which can contribute large volumes of LWD during channel realigning events; c. channels are often bedrock controlled, with considerable amount of substrate formed of alluvial/colluvial/fluvial material (with sizes ranging from silt to boulders) transported from banks, side slopes, or upstream (in-channel) sources.	(weathering/breakdown of a rock where large flakes are broken off). Even though slopes are steep, erosion is not rapid due to the thinness of the colluvium and soil, which prevent gullying and head-cutting. Fluvial processes are dominant in this LTA. In the alluvial bottomlands of the side canyons to the Green River, considerable natural channel realignment occurs during infrequent flash floods following large-scale thunderstorms. There are also numerous wet areas due to natural depressions, debris dams, and beaver ponds that augment aquatic habitat in these alluvial bottomlands. In steep ephemeral channels, streamflow is usually only present during spring snowmelt runoff or during intense, summer thunderstorms. For perennial streams, base flows during all seasons are generated by groundwater flows through karst systems. Peak flows for perennial springs in spring and early summer are generated from snowmelt runoff, with occasional rain-on-snow supplements. Summer and fall peaks for paraxial streams are generated from occasional, intense thunderstorms. Considerable channel realignment can occur during low-frequency flash floods, following large-scale thunderstorms.
Round Park	RP	The stream channel density is noticeably lower in this LTA than in adjacent LTAs (e.g., AM, RC, and NF), primarily because a large portion of the area is flat to gently sloped. This topography creates a situation where snowmelt and rainfall infiltrate the soil, rather than concentrate flow to become surface runoff. In the RP4 land type, funnel flows	For ephemeral channels, streamflow typically occurs during spring snowmelt runoff or during summer thunderstorms. For some ephemeral channels, streamflow is supplemented by springs and seeps that extend the flow duration well into the summer. For perennial channels, base flows during all seasons are often generated by groundwater exfiltration from

Landtype Association	Symbol	Hydrology/Riparian	Geomorphic Processes
		without well-defined drainages are located in broad, concave hillslope positions between areas with steeper slopes. Ephemeral and perennial streams are often low to moderate gradient (i.e., less than five percent), but can exceed 20 percent. Channels are narrow, V-shaped, and typically bedrock-controlled. Bed material is typically composed of sands to cobbles. Because of bedrock controlling the planform, banks are often stable. Large woody debris can be a major structural component because this LTA has many conifer stands adjacent to the channels. Wet meadow streams are typically low gradient (i.e., less than two percent) and sinuous. Bed material is typically fine-grained sands and silts, with minor components of cobbles. Stream banks are stabilized by the root masses of native grasses and sedges. Large woody debris is typically not a major structural component of the channels since these channels flow through meadows rather than forests. Where flow is not channelized, standing water is common due to shallow hillslope gradients. Riparian areas make up a small portion of this LTA but are large in area where they occur. Most have deep sinuous (having many curves and turns) streams running through wet meadows. Raised fens are common in these meadows with large components of sedge species in adjacent ponded areas. Streams have overhanging banks in the meadows. Vegetation is dominated by large stands of lodgepole pine at lower elevations and by mixed coniferous stands at higher elevations. Meadows, including Round Park are included.	seeps and springs. Peak flows in spring and early summer are generated from snowmelt runoff with occasional rain-on-snow supplements. Summer and fall peaks are generated from occasional, intense thunderstorms. Temperatures and winds can be extreme on this LTA, and freezing and thawing process are evident in the soils.
South Face	SF	This LTA is highly dissected (i.e., closely spaced) by both ephemeral and perennial channels. It has one of the highest stream densities of the LTAs, however, the majority of streams are ephemeral. Since this LTA occurs primarily on the foothills of the southern face of the Uinta Mountains and at a lower elevation, there is less snow accumulation in the winter. There is generally lower annual precipitation than upslope LTAs. Streams are often low to moderate gradient (i.e., less than five percent), but can exceed 20 percent, and are comprised of two main types: 1) ephemeral channels are steeper, narrow, V-shaped, and typically bedrock-controlled.	In most places on the South Face LTA, bedrock is at or very near the surface. This bedrock is typically mantled with a thin veneer of colluvium that is actively moving into perennial streams. Consequently, there is a relatively high sediment deposition rate into perennial streams on this LTA. The bench and step topography is common as a function of paleo (old/ancient) slumps, and subsoils of clay add to some of the stability problems in this LTA. Landslides have occurred in recent times, but these are of minor extent. Floods appear to be of minor importance to the function and processes on this LTA. For ephemeral channels, streamflow typically occurs during spring snowmelt runoff or during summer thunderstorms. For

Landtype Association	Symbol	Hydrology/Riparian	Geomorphic Processes
		2) perennial channels are narrow-to-moderate width (i.e., typically less than 25 feet or eight meters wide), V- or U-shaped, and typically bedrock-controlled. For these streams, bed material is typically composed of sands to cobbles; but can have larger stones in some locations. Because of bedrock controlling the planform, banks are often stable. Large woody debris is rarely a major structural component, especially where the vegetation consists primarily of pinyon/juniper and annual grasses. However, where this LTA has a considerable number conifer and aspen stands adjacent to the channels, LWD occasionally can be a major structural component. Where the few riparian areas of this LTA occur, there is a high density of seeps and springs. This is due to the ponding of water above stratified bedrock and clays that discharge water along the steep side slopes. Seeps and springs are also common in areas of slumping. Ponded water occurs in many of the rotational slump areas but these areas have limited riparian vegetation.	some ephemeral channels, streamflow is supplemented by springs and seeps that extend the flow duration well into the summer. There are numerous springs within this LTA indicating that it is an area of groundwater discharge. The groundwater pollution hazard is rated moderate because of the proximity of ephemeral streams. For perennial channels, base flows during all seasons are often generated by groundwater exfiltration from seeps and springs within the LTA. Flows in spring and early summer are generated from snowmelt runoff with occasional rain-on-snow supplements. Summer and fall peaks are generated from occasional, intense thunderstorms, which influence the high erosion rate
Strawberry Highlands	SH	This LTA is highly dissected (i.e., closely spaced) by ephemeral channels. Channels in this LTA are very similar to those in the adjacent Avintaquin Canyon and Anthro Plateau LTAs. However, there are no mapped perennial channels in this LTA. Ephemeral channels are steeper, narrow, V-shaped, and typically bedrock-controlled. Channel gradients are typically steeper than five percent, but can be much steeper. For these streams, bed material is typically composed of sands to cobbles; but can have larger stones in some locations. The parent material is Green River Formation sandstone/shale. Because of bedrock controlling the planform, banks are often stable. For streams in this LTA, LWD can be a major structural component (especially where the vegetation consists of primarily conifers and aspen) in the mid-slope elevations. In the steep headwall areas, where vegetation is limited or in lowland areas where a climate of low precipitation tends to favor pinyon/juniper vegetation, there is limited LWD available to be of significance in channel structure. The soils in swales of first and second order drainages are deep mollisols inhabited by sagebrush and perennial grasses	Streamflow typically occurs during spring snowmelt runoff, or during summer thunderstorms. For some channels, streamflow is supplemented by springs and seeps that extend the flow duration well into the summer. There are fewer springs in this LTA than the adjacent Avintaquin Canyon and Anthro Plateau LTAs.

Landtype Association	Symbol	Hydrology/Riparian	Geomorphic Processes
		that stabilize the banks. Riparian areas are generally associated with canyon bottoms and springs or seeps.	
Stream Canyon	SC	There are two general stream types in this LTA: 1) steep (>20 percent slope), ephemeral channels located along (perpendicular to) canyon walls, and 2) low to moderate gradient (<5 percent slope), perennial channels at the base of steep canyon walls. The structure of these two general stream types is described below: 1) steep (>20 percent slope), ephemeral channels located along (perpendicular to) canyon walls; a. channel form is narrow, bedrock-controlled, with substrate primarily of cobbles (where present), having a step or cascade bedform; b. bed and banks are generally stable (due to the presence of bedrock); c. typically, LWD is not a major structural component, but may be present; 2) low to moderate gradient (<5 percent slope), perennial channels at the base of steep canyon walls including; Little Brush, Big Brush, and Ashley Creeks; White Rocks and Uinta Rivers; Hole In the Wall and Dry Fork Canyons; a. channel form often has high width/depth ratios (wider than it is deep), with the potential to laterally migrate only within the valley bottom (which is usually narrow); b. the valley bottoms adjacent to channels typically have substantial riparian vegetation, which can contribute large volumes of LWD during channel realigning events; c. channels are often bedrock controlled, with a substantial amount of substrate formed of alluvial/colluvial/fluvial material (with sizes ranging from silt to boulders) transported from banks, side slopes, or upstream (in-channel) sources; The valley bottoms adjacent to channels typically have substantial riparian vegetation, which can contribute large volumes of LWD during channel realigning events. Species associated with these riparian areas are described in the vegetation composition section.	Flooding in the spring following spring melt is an active process in the valley bottoms of the Stream Canyon LTA (Study 43-56A). These flooding events deposit large amounts of materials in the drainage bottom, creating channel avulsions and realignment. The stream often returns to former channels with subsequent flood events. Channel realignment and avulsion can also occur during infrequent flash floods following large-scale thunderstorms. In the steep ephemeral channels, streamflow is usually only present during spring snowmelt runoff or during intense summer thunderstorms. In the perennial channels, base flows during all seasons are generated by groundwater flows through karst systems. Peak flows in spring and early summer are generated from snowmelt runoff, with occasional rain-on-snow supplements. Summer and fall peaks in the perennial channels are generated from occasional, intense thunderstorms. Floods along Dry Fork, Ashley Creek, and Brush Creek are of considerable influence along the narrow riparian bands of the canyons. Floods have scoured stream channels and toppled trees. Narrowleaf cottonwood appears particularly adapted to this disturbance, because it colonizes rocky riverbeds following floods. In the alluvial bottomlands, considerable natural channel realignment occurs during infrequent flash floods, following large-scale thunderstorms. There are also natural depressions, debris dams, and beaver ponds that often create usable fisheries or aquatic habitat. Groundwater movement through karst continues to be a significant factor in moving water between surface water drainages.

Landtype Association	Symbol	Hydrology/Riparian	Geomorphic Processes
Stream Pediment	SP	This LTA is broadly dissected (i.e., widely spaced) by both ephemeral and perennial channels. This LTA has one of the lowest stream densities of the LTAs on the Ashley National Forest. There are also some sections of meadow streams within this LTA. Since this LTA occurs in lower-elevation foothills of the southern face of the Uinta Mountains, there is less snow accumulation in the winter and generally lower annual precipitation than upslope LTAs. Streams are often low to moderate gradient (i.e., less than five percent), but can exceed 20 percent. Ephemeral channels, located on the mid-slopes of the LTA, are steeper, narrow, V-shaped, and typically bedrock-controlled. Perennial channels, located only on the lowest slopes of the LTA, are narrow-to-moderate width (i.e., typically less than 25 feet or eight meters wide), V- or U-shaped, and typically bedrock-controlled. For these streams, bed material is typically composed of sands to cobbles; but can have larger stones in some locations. Because of bedrock controlling the planform, banks are often stable. Large woody debris is rarely a major structural component, especially where the vegetation consists primarily of pinyon/juniper and annual grasses. However, where this LTA has many conifer and aspen stands adjacent to the channels, LWD occasionally can be a major structural component. Meadow streams (often perennial) are typically low gradient (i.e., less than two percent) and sinuous. Because soils are poorly drained loams and clay loams, bed material is typically fine-grained sands and silts, with minor components of cobbles. Stream banks are stabilized by the root masses of native grasses and sedges. Large woody debris is typically not a major structural component of the channels, since these channels flow through meadows rather than forests.	The geomorphic setting of this LTA indicates major influence of flooding or stream action in the past. For the most part however, landslides are unlikely or of minor influence on this LTA. The streams that flow out of the mountains rapidly lose water through infiltration into this LTA due to the porous deposits overlying impervious sedimentary rocks. This infiltration charges the shallow gravel aquifers that carry water to the springs at the edge of the benches out in the Uinta Basin, and accounts for the intermittent nature of watercourses toward the forest boundary. For ephemeral channels, streamflow typically occurs during spring snowmelt runoff or during summer thunderstorms. For some ephemeral channels, streamflow is supplemented by springs and seeps that extend the flow duration well into the summer. For perennial channels, base flows during all seasons are often generated by groundwater exfiltration from seeps and springs within the LTA. Peak flows in spring and early summer are generated from snowmelt runoff, with occasional rain-on-snow supplements. Summer and fall peaks are generated from occasional intense thunderstorms, which often influence the high erosion rate on this LTA.
Structural Grain	SG	This LTA has relatively few stream channels. In the areas that have gently sloping topography (e.g., Bear Top Mountain and Dutch John Bench), there are virtually no channels identified. Where there are channels, the majority are ephemeral. There are only a few named perennial channels (i.e., Goslin Creek, Dripping Springs, and Dutch John Draw). The lack of channels is primarily due to limited annual precipitation, which is between 10 and 16 inches/year or 25-41 centimeters/year.	For ephemeral channels, streamflow typically occurs during spring snowmelt runoff or during summer thunderstorms. For some ephemeral channels, streamflow is supplemented by springs and seeps that can extend flow duration well into the summer. For perennial channels, base flows during all seasons are often generated by groundwater exfiltration from seeps and springs (e.g., Goslin Creek, Dripping Springs, Dutch John Draw). Peak flows in spring and early summer

Landtype Association	Symbol	Hydrology/Riparian	Geomorphic Processes
		A majority of this precipitation comes in the form of snowfall during the winter. Most channels, both ephemeral and perennial, are steep (i.e., at least five percent slope), but typically >20 percent slope, narrow, and V-shaped. Channel form is bedrock-controlled, having a step or cascade bedform, with substrate primarily composed of boulders and/or cobbles. Occasional high-to-moderate gradient riffles will have cobble to sand substrate. Channel bed and banks are generally stable due to the presence of bedrock. In general, persistent LWD is not present in areas where channels are adjacent to brush or grass covered slopes. Since there are very few channels in the LTA, there are consequently very few riparian areas. Those riparian areas that do exist are maintained by groundwater exfiltration from seeps and springs.	are generated from snowmelt runoff, with occasional rain-on-snow supplements. Summer and fall peaks of perennial channels are generated from occasional, intense thunderstorms.
Trout Slope	TS	This LTA is weakly dissected (i.e., broadly spaced) by both ephemeral and perennial channels. It has a higher stream density than UB or GP, but much lower stream density than AM. This LTA has streams ranging from steep, ephemeral channels to low gradient, moderately sinuous meadow streams. Streams are often low to moderate gradient (i.e., less than five percent), but can exceed 20 percent, and are comprised of three main groups: 1) ephemeral channels are steeper, narrow, V-shaped, and typically bedrock-controlled; 2) perennial channels are narrow-to-moderate width (i.e., typically less than 25 feet or eight meters wide), V- or U-shaped, and typically bedrock-controlled. For these streams, bed material is typically composed of sands to cobbles, but can have considerable components of boulders in some locations. Because of bedrock controlling the planform, banks are often stable. Large woody debris can be a major structural component because this LTA has many conifer stands adjacent to the channels. However, for wider channels (e.g., North Fork Ashley Creek at Soldier Meadow) LWD is less of a natural structural component due to higher stream power (i.e., greater flow volume and channel gradient) in the system;	Temperatures and winds can be extreme on this LTA, and freezing and thawing processes are evident in many of the soils. Frost wedges have been found in relic soils, indicating formation and alteration during a very cold period. Trees are subject to windthrow and disturbance by pocket gophers around the meadows is evident. Soils are subject to erosion with disturbance. For ephemeral channels, streamflow typically occurs during spring snowmelt runoff or during summer thunderstorms. For some channels, streamflow is supplemented by springs and seeps to extend the flow duration well into the summer. For perennial channels, base flows during all seasons are often generated by groundwater exfiltration from seeps and springs from outside the LTA. Peakflows in spring and early summer are generated from snowmelt runoff, with occasional rain-on-snow supplements. Summer and fall peaks of perennial channels are generated from occasional, intense thunderstorms.

Landtype Association	Symbol	Hydrology/Riparian	Geomorphic Processes
		3) meadow streams are typically low gradient (i.e., less than two percent) and sinuous. Bed material is typically fine-grained sands and silts, with minor components of cobbles. Stream banks are stabilized by the root masses of native grasses and sedges, and have overhanging banks that create aquatic habitat. Large woody debris is typically not a major structural component of the channels since these channels flow through meadows rather than forests. Riparian areas are a small portion of this land type, but are large in area where they occur. Most riparian areas have deep sinuous streams running through wet meadows. Raised bogs are common in these meadows with large components of Carex in adjacent ponded areas. Seeps and springs are common in the TS2 land type, where heavy clay contributes to a high water table and marsh marigold is common.	
Uinta Bollie	UB	This LTA is typified by a low density of streams per unit area, particularly when compared with the Alpine Moraine LTA, which is down slope. There are no streams on most subunits, especially those above the timberline (e.g., cirque headwalls). Water movement is generally subsurface during snowmelt or rapid overland flow during summer thunderstorms. Where streams have formed, they are of two types: 1) shallow, narrow channels on concave slopes where thin soils have developed (UB6, UB8) and both surface runoff and groundwater exfiltration can accumulate; channels are bedrock controlled with some gravel and cobbles; 2) narrow channels on talus slopes; channels can be narrow-to-deep depending on runoff volume; channels are boulder-step and can rapidly change configuration with movement of hillslope material (i.e., rockfall and solifluction). Riparian habitat is limited in this LTA. Few lakes and streams exist, and where they do, the extent of the accompanying riparian vegetation is limited. The UB6 land type has a high ground water discharge component. Areas in this land type dominated by species such as marsh marigold are indicators of the important riparian component. Seeps and springs associated with ground water discharge occur across the LTA, and are most common at the boundary or intersection with the Alpine Moraine LTA.	The erosional surfaces of the Uinta Bollie LTA have been shaped by glacial and periglacial processes. From east to west, the topography becomes more rugged as glacial processes dominate over periglacial, where the process of freezing and thawing plays a key role. The Uinta Bollies are the source and storage area for water delivered to all other down slope LTAs, and are a driving factor in the timing, duration and magnitude of downstream flows. Groundwater movement is more important than surface water movement, since the area is typified by high elevation alpine terrain, extreme weather, limited vegetation, minimal soil development, and solifluction (type of downslope soil/sediment creep often associated with cold (periglacial) environments driven by a combination of gravity, water-saturated soils, and frequent cycles of freezing and thawing). North facing cirques typically have snowdrifts, ice pockets, and snowfields that slowly release water throughout the year and are important for late season water production. Portions of the tree covered residual surface have many springs and considerable underground discharge onto the slopes. This shallow ground water discharge area typically produces water throughout the year. Particulate matter that is fractured during the winter freeze-thaw cycle is transported down-slope to lakes, ponds, and meadows of the Alpine Moraine LTA. This results in the filling

Landtype Association	Symbol	Hydrology/Riparian	Geomorphic Processes
			in of ponds and shallow lakes, eventually changing these sites to meadows. Rockfalls and debris flows are also important processes in the cirque headwalls and side slopes. Rock glaciers are active in some areas, and the turbid (cloudy, milky, opaque, thick with suspended sediment) water of lakes and ponds is a characteristic of these active rock glaciers (Munroe 2005). Snow duration and freezing/thawing processes affect vegetative communities and soil structure. Soil crusts form more readily on finely textured soils (i.e., silts and clays), compared to coarse textured soils (i.e., sands). Consequently, when soil crusts and the associated vegetation are removed by disturbance processes, the loess cap or topsoil becomes more susceptible to erosion, leaving coarse textured material or bedrock exposed. The removal of the loess cap generally results in a loss of soil productivity and biodiversity. This could be an influential factor in carbon-nitrogen ratios in alpine areas. Turf exfoliation or removal of vegetative turf cover decreases biological activity at the surface under snow cover and may be a factor in increased bare ground and expanding snow banks (Helga Vandenberg, personal communication; Munroe 1997). Snow generally melts faster over turf because of increased temperatures from biological activity. Some of the soils are very old and reflect processes that have changed over long periods. Alpine soils are subject to erosion from wind and water when turf exfoliation from the breaking of the vegetative cover or loss of soil crusts occurs. Bare soils with coarse fragments tend to extend (i.e., become larger in surface area), with the freezing and thawing processes occurring at these elevations. Duration of snow cover, as determined by wind and topography, is the dominant controlling factor in the development and dynamics of alpine plant communities (Komarkova 1979; Willard 1979). Succession is extremely slow in comparison to lower elevations and, in many alpine communities, is not expected without climate change (Komarkova 1979).
Wolf Plateau	WP	The stream channel density is noticeably lower in this LTA than in adjacent LTAs (e.g., AM, GS) primarily due to two factors. First, a large portion of the area is flat to gently	For ephemeral channels, streamflow typically occurs during spring snowmelt runoff, or during summer thunderstorms. For some ephemeral channels, streamflow is supplemented by

Landtype Association	Symbol	Hydrology/Riparian	Geomorphic Processes
		sloped. This creates situation where snowmelt and rainfall infiltrate the soil, rather than concentrate flow to become surface runoff. Second, the LTA is underlain by limestone undergoing dissolution processes that create karst systems, where water is quickly moved through the limestone gravelly ground in areas other than concave pockets. Rapid transport of water into and through the soil has prevented live streams from developing in most areas. Both ephemeral and perennial streams are often low to moderate gradient (i.e., less than five percent), but can exceed 20 percent. Ephemeral channels are steeper, narrow, V-shaped, and typically bedrock-controlled. Perennial channels are narrow-to-moderate width (i.e., typically less than 25 feet or eight meters wide), V- or U-shaped, and typically bedrock-controlled. For these streams, bed material is typically composed of sands to cobbles, but can have considerable components of boulders in some locations. Because of bedrock controlling the planform, banks are often stable. Large woody debris can be a major structural component because this LTA has many conifer and aspen stands adjacent to the channels.	springs and seeps that extend the flow duration well into the summer. For perennial channels, base flows during all seasons are often generated by groundwater exfiltration. Peak flows in spring and early summer are generated from snowmelt runoff, with occasional rain-on-snow supplements. Summer and fall peaks for perennial streams are typically generated from occasional, intense thunderstorms. Because this area is near alpine elevations, snowfields can be important for late season water production.

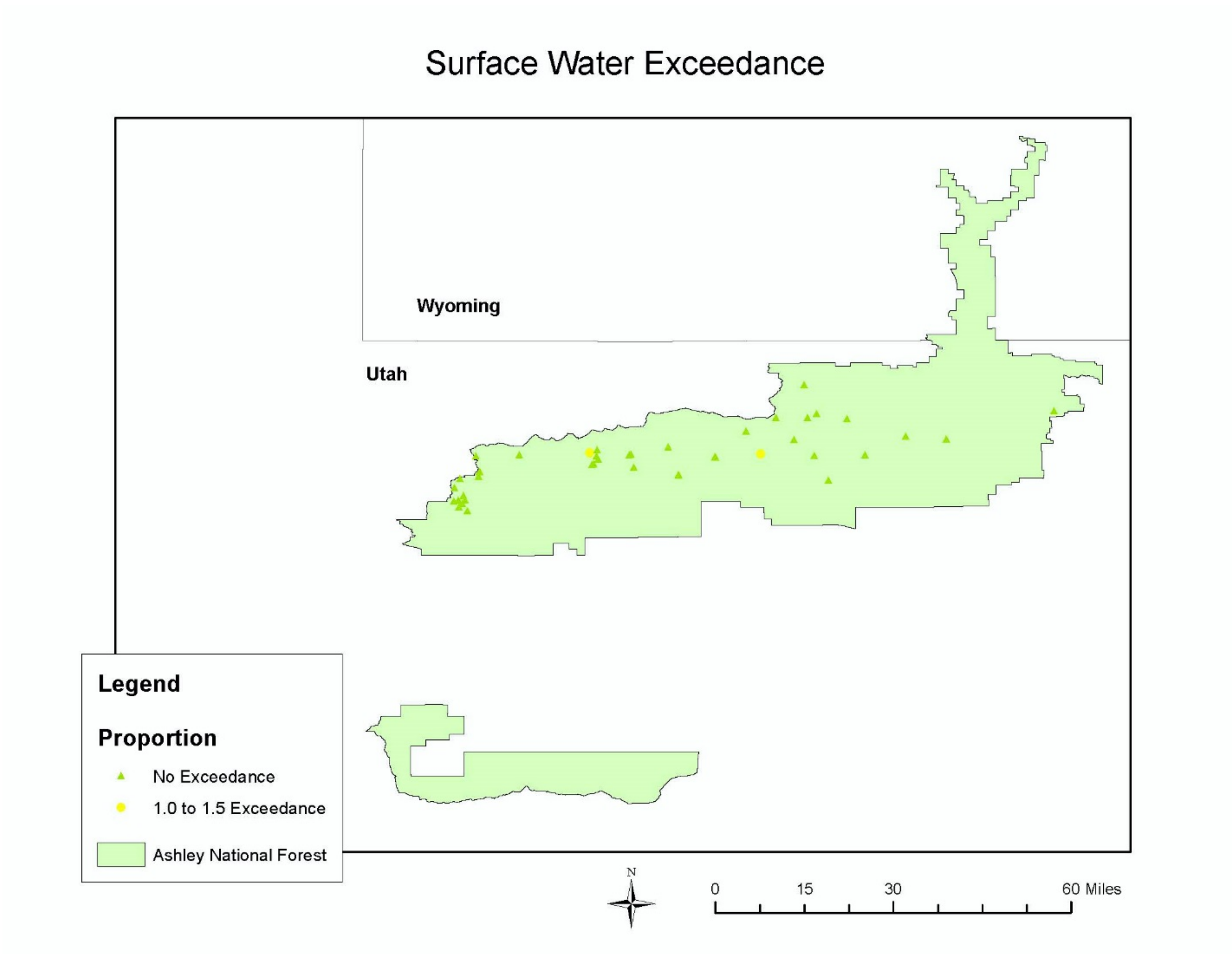

Figure 34. Surface water exceedance for the Ashley National Forest

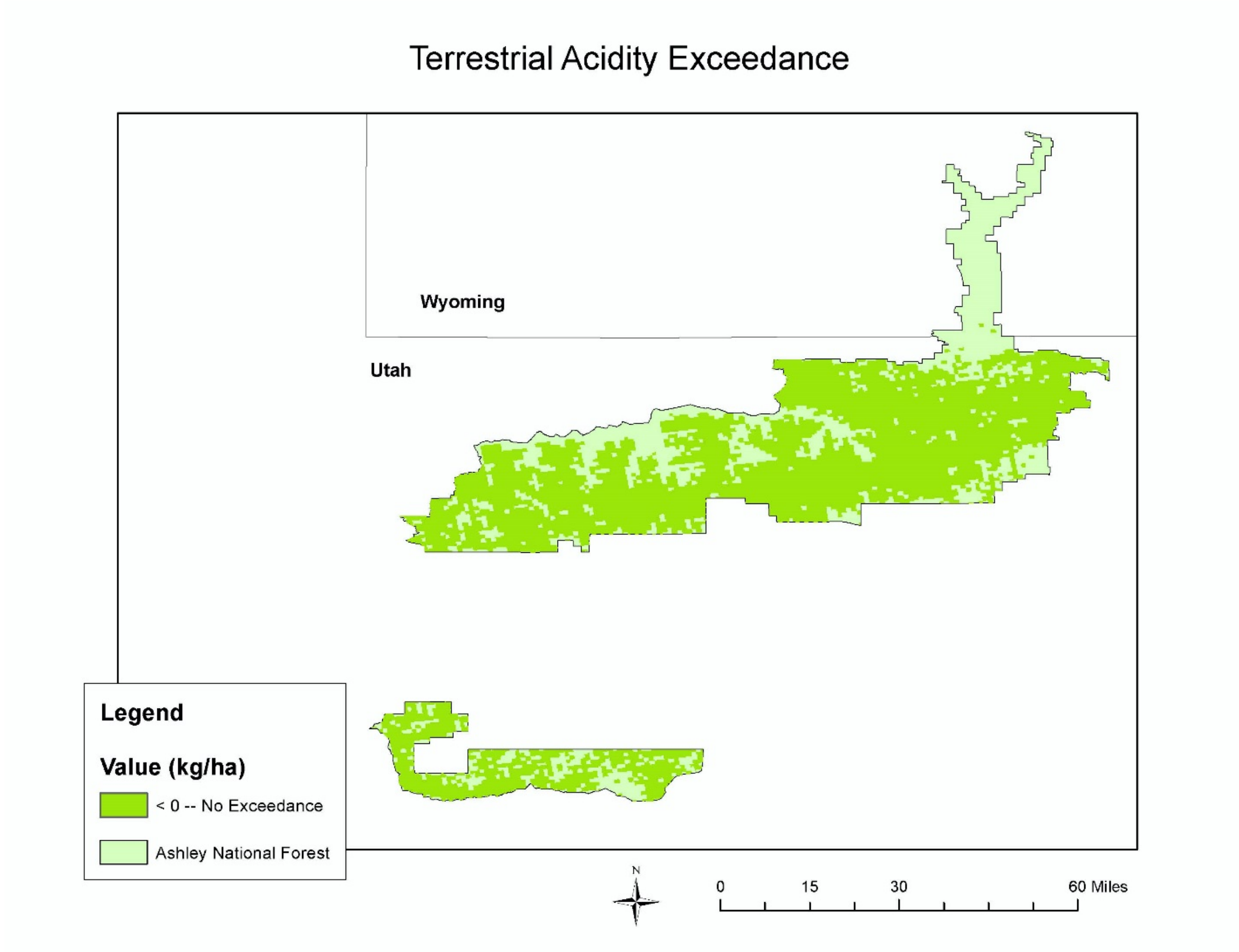

Figure 35. Terrestrial acidity exceedance for the Ashley National Forest

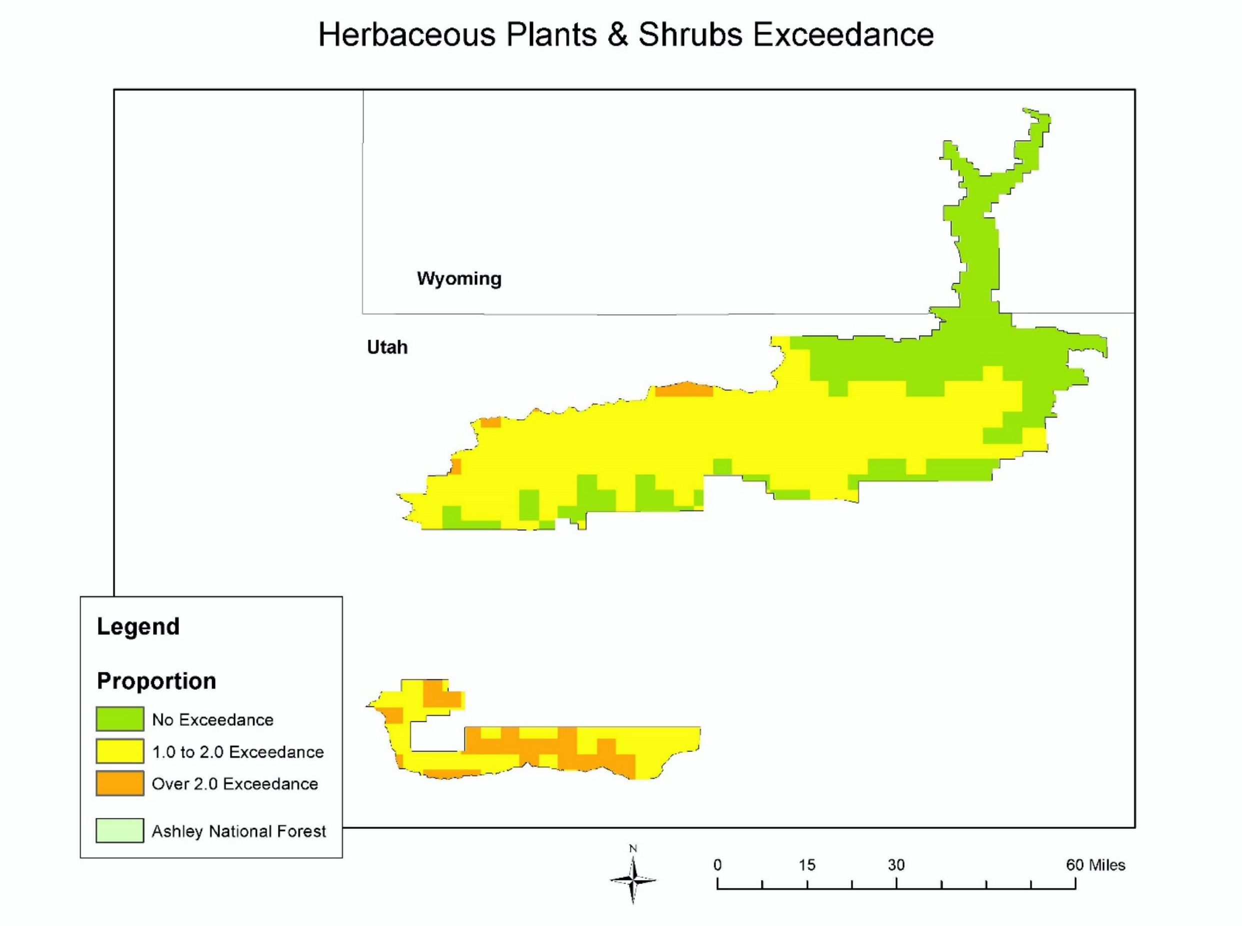

Figure 36. Herbaceous plants and shrubs exceedance for the Ashley National Forest

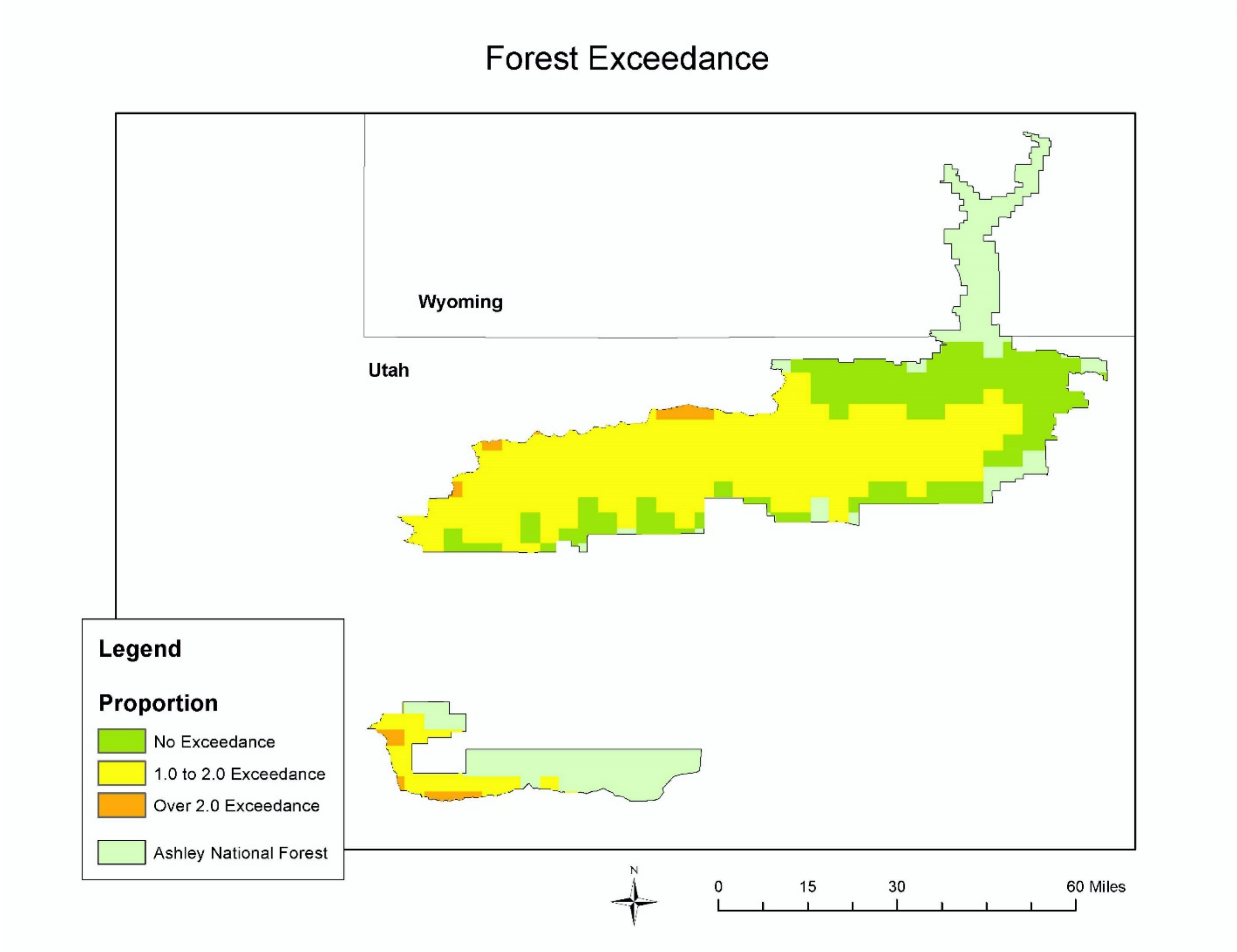

Figure 37. Forest exceedance for the Ashley National Forest

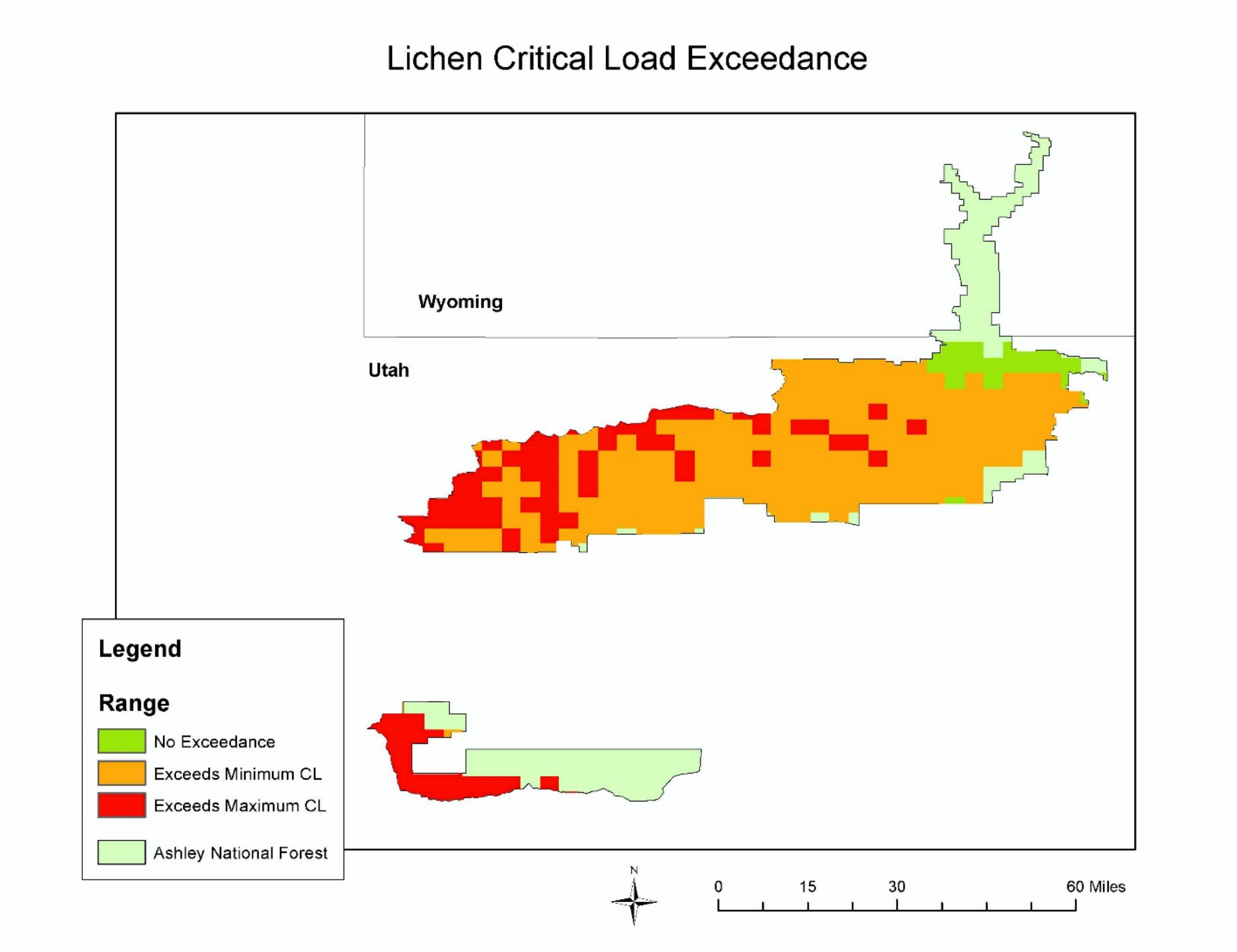

Figure 38. Lichen critical load exceedance for the Ashley National Forest

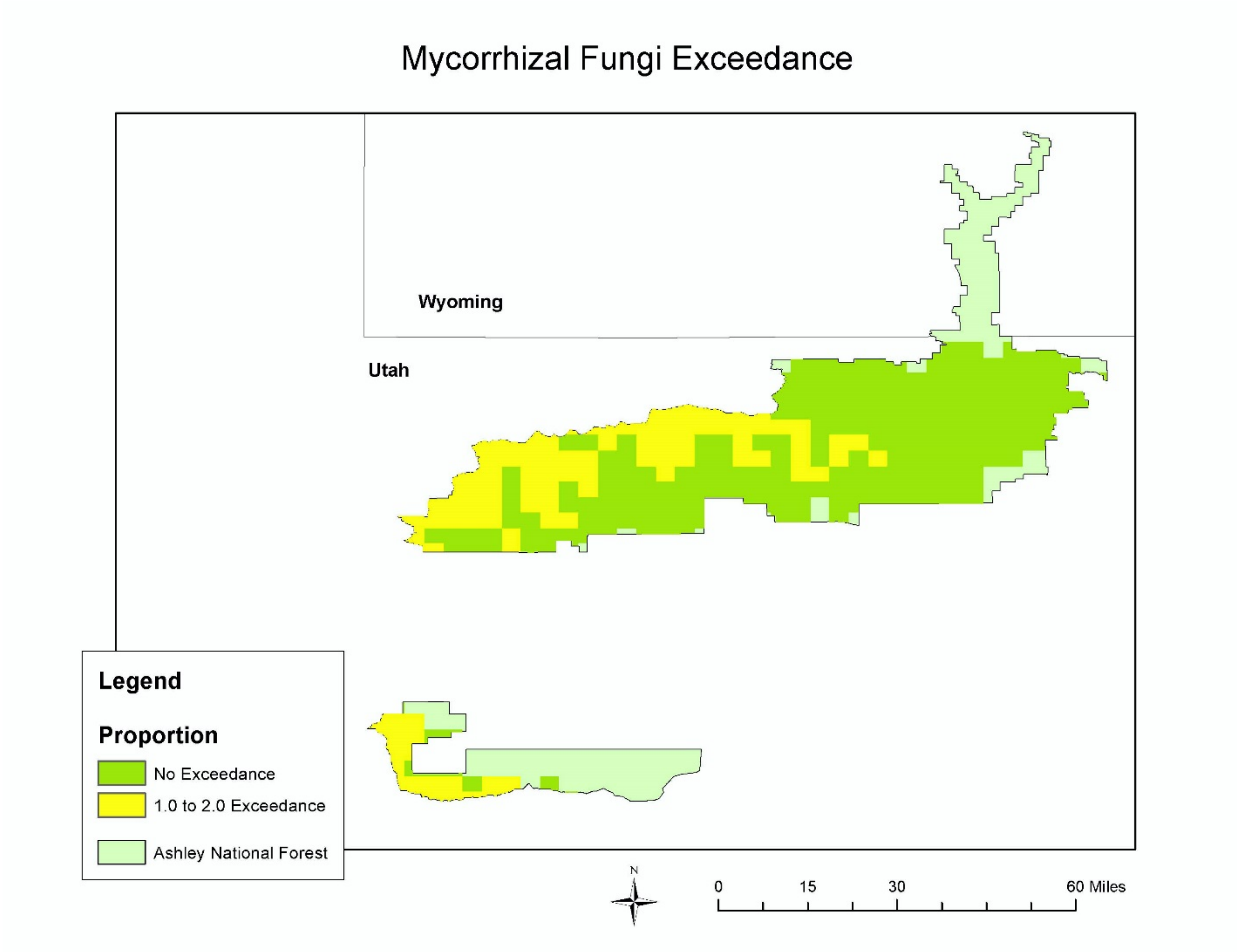

Figure 39. Mycorrhizal fungi exceedance for the Ashley National Forest

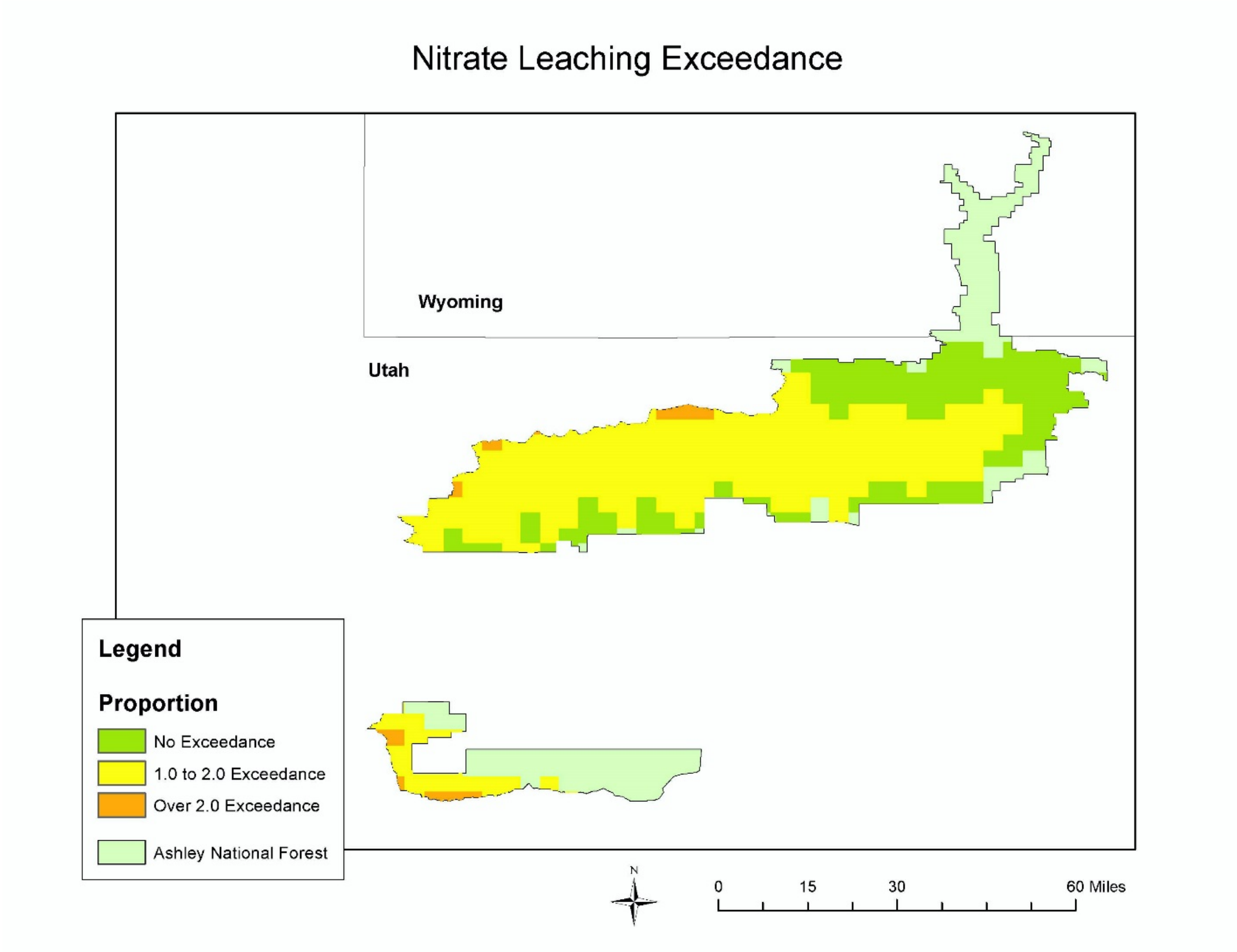

Figure 40. Nitrate leaching exceedance for the Ashley National Forest

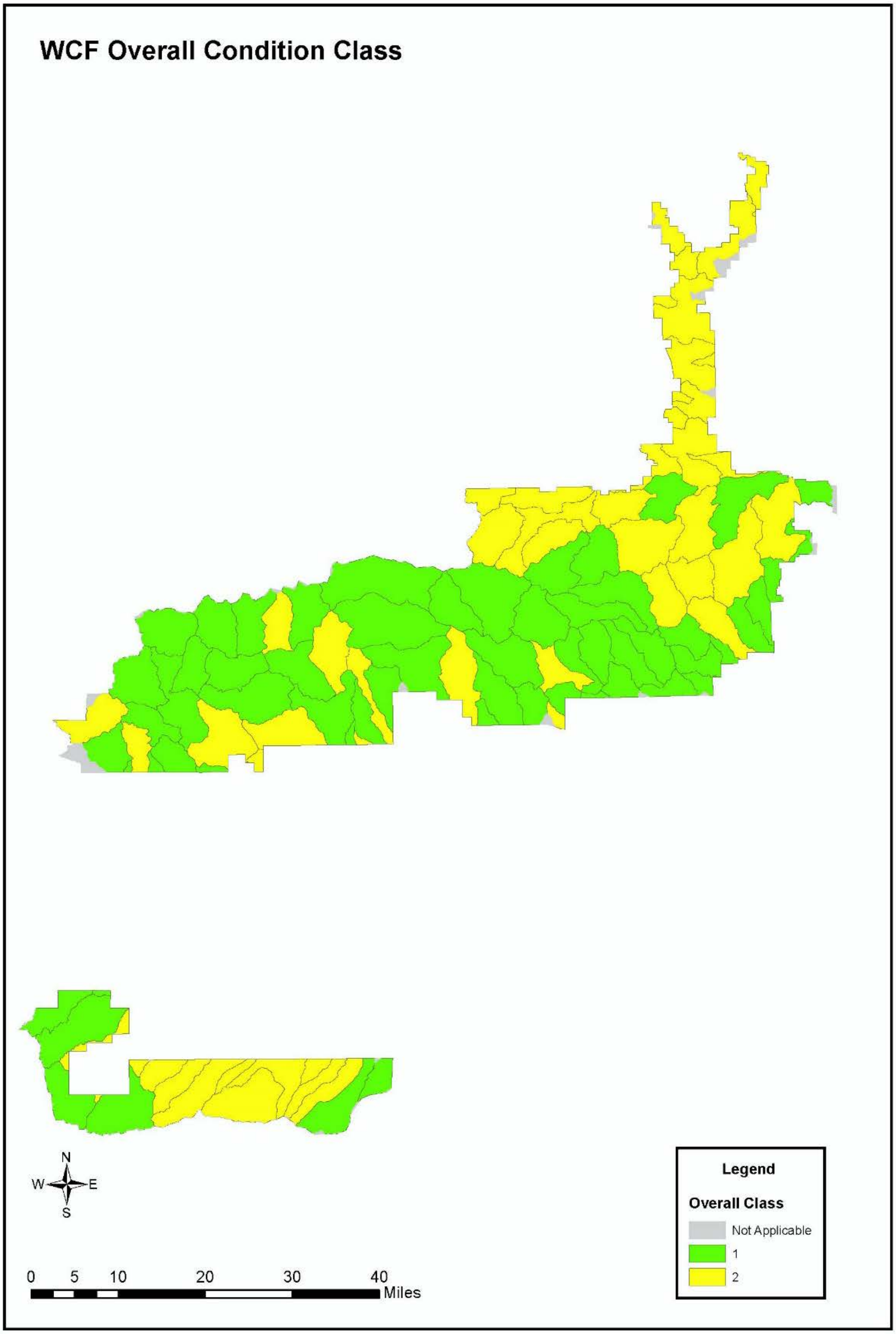

Figure 41. Watershed condition framework overall condition class on the Ashley National Forest

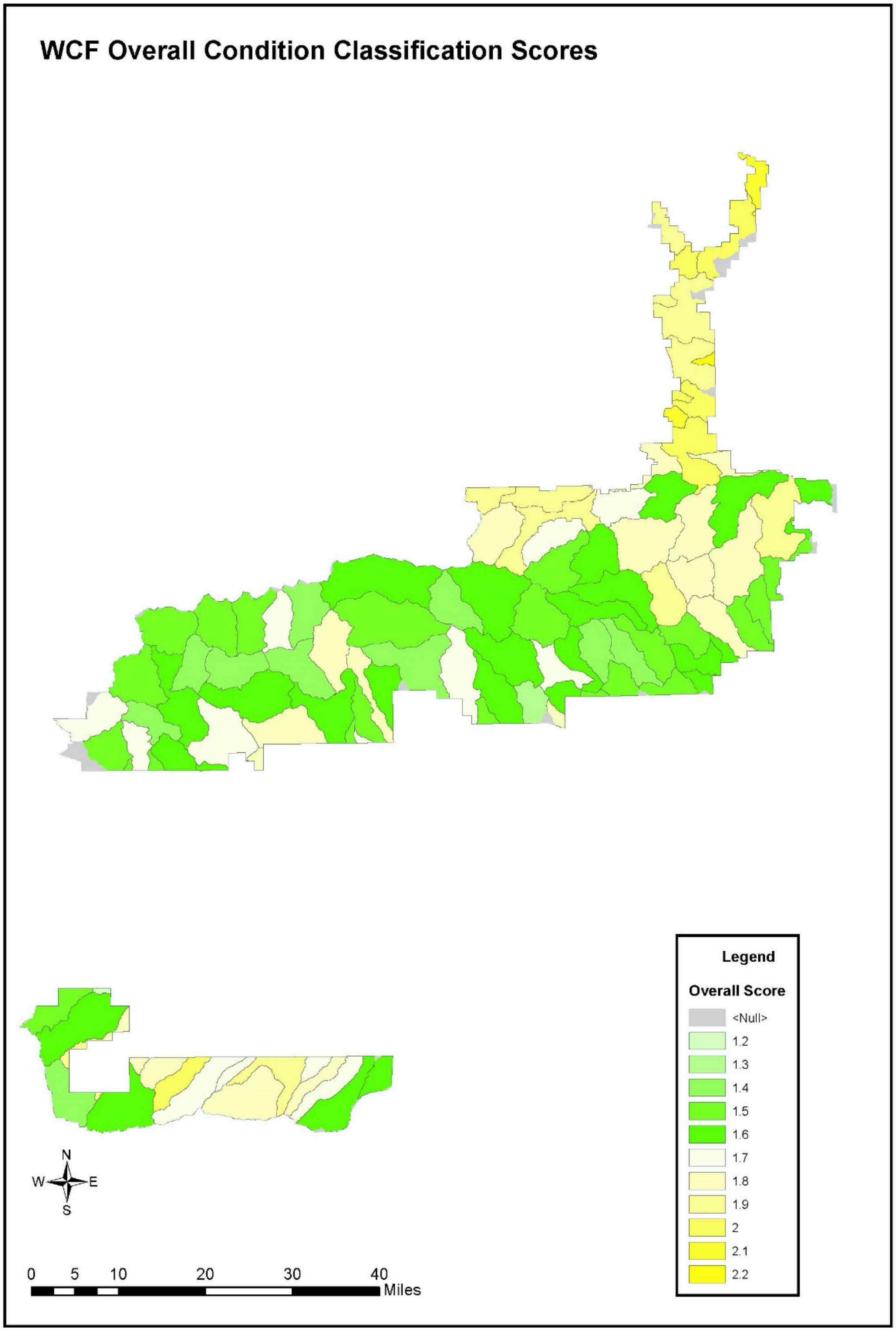

Figure 42. Watershed condition framework overall condition class scores

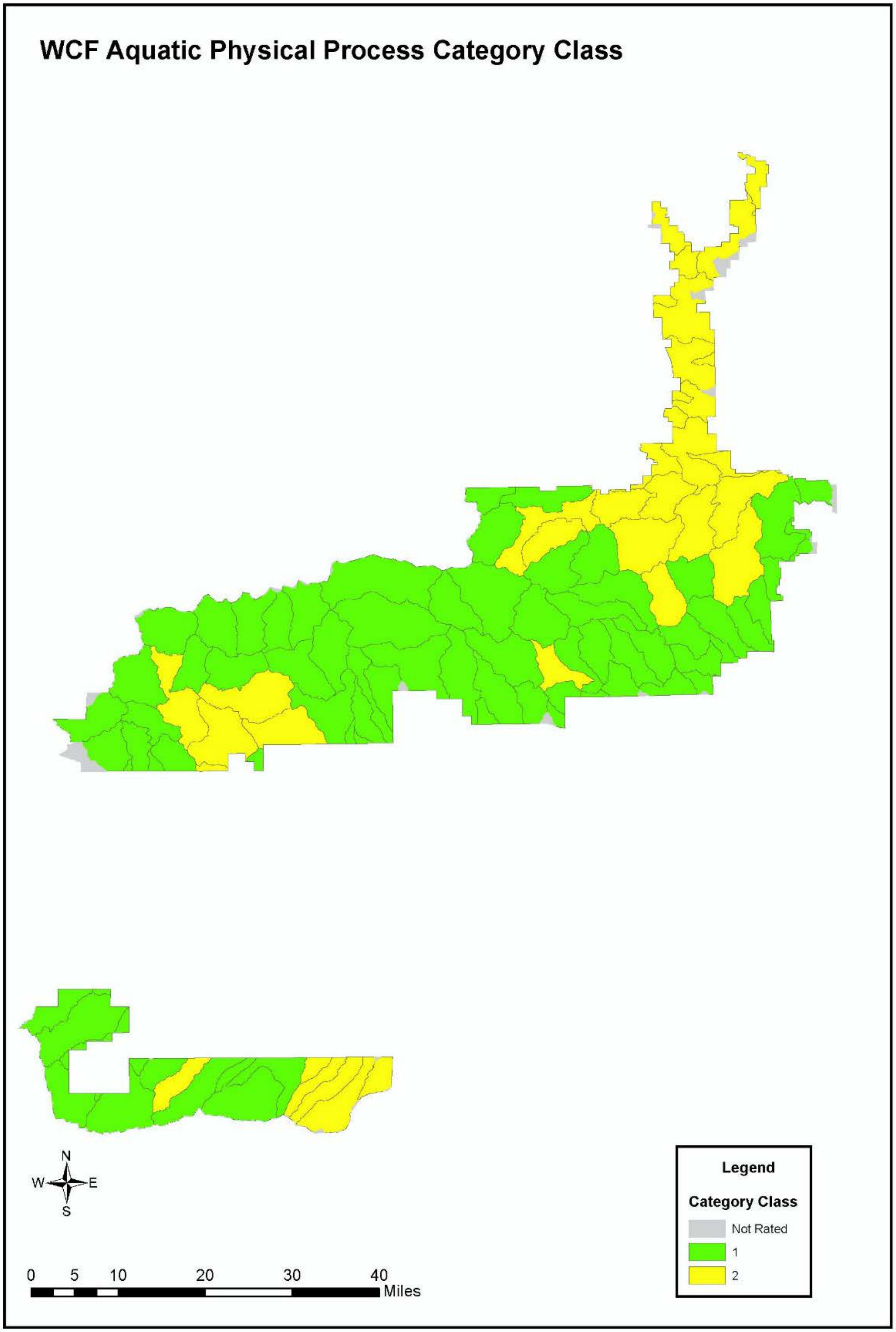

Figure 43. Watershed condition framework aquatic physical process category class

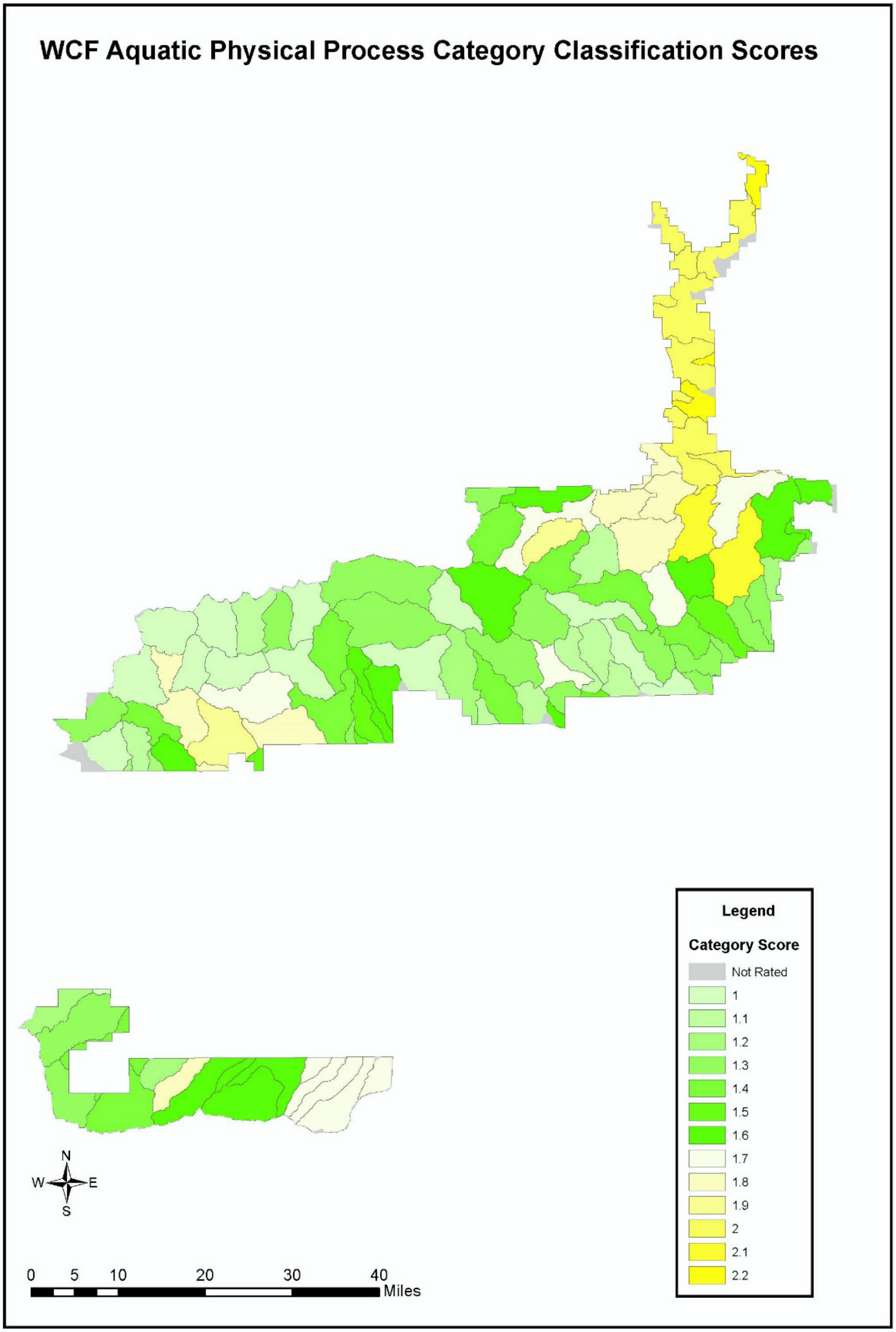

Figure 44. Watershed condition framework aquatic physical process category classification scores

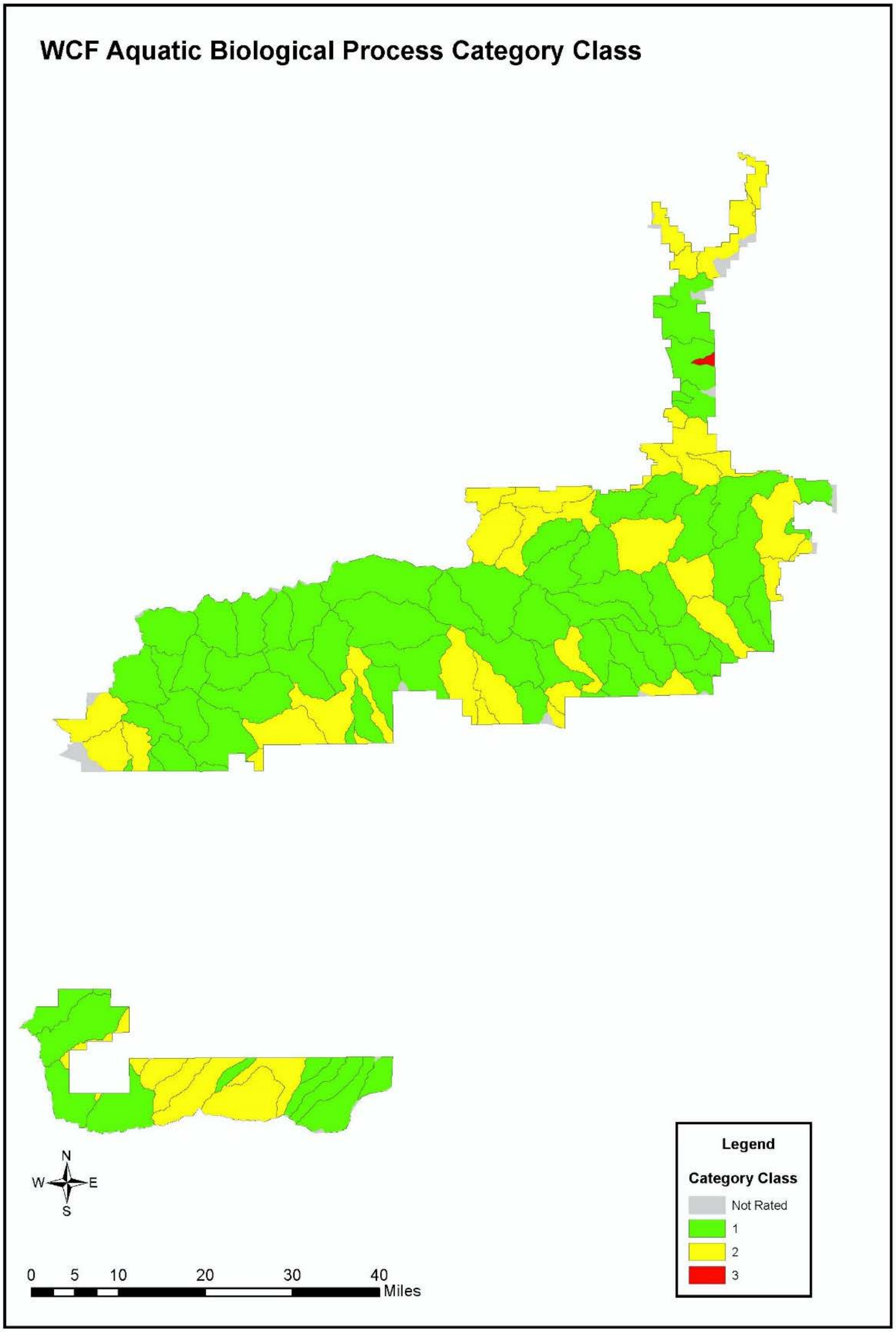

Figure 45. Watershed condition framework aquatic biological process category class

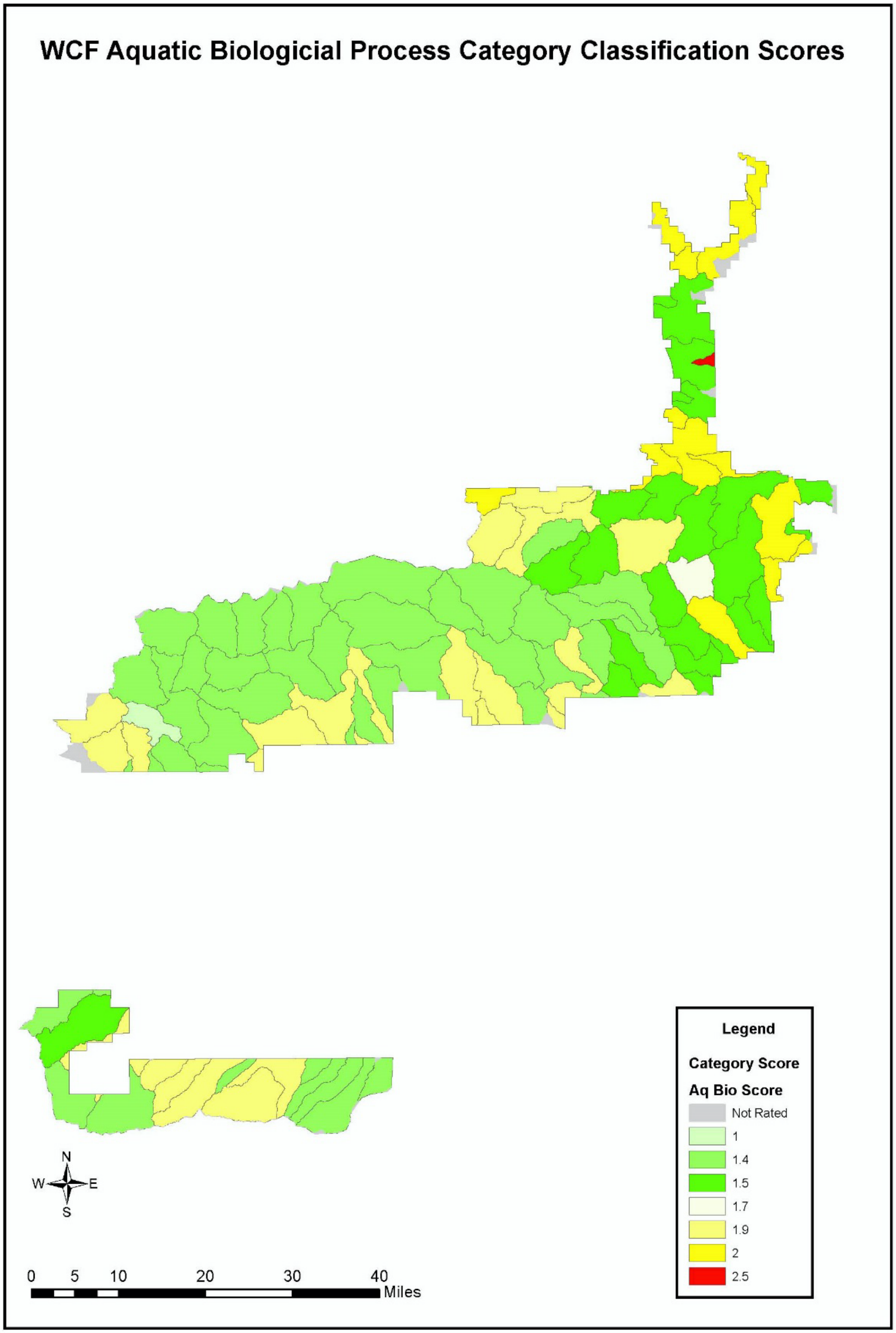

Figure 46. Watershed condition framework aquatic biological process category classification scores

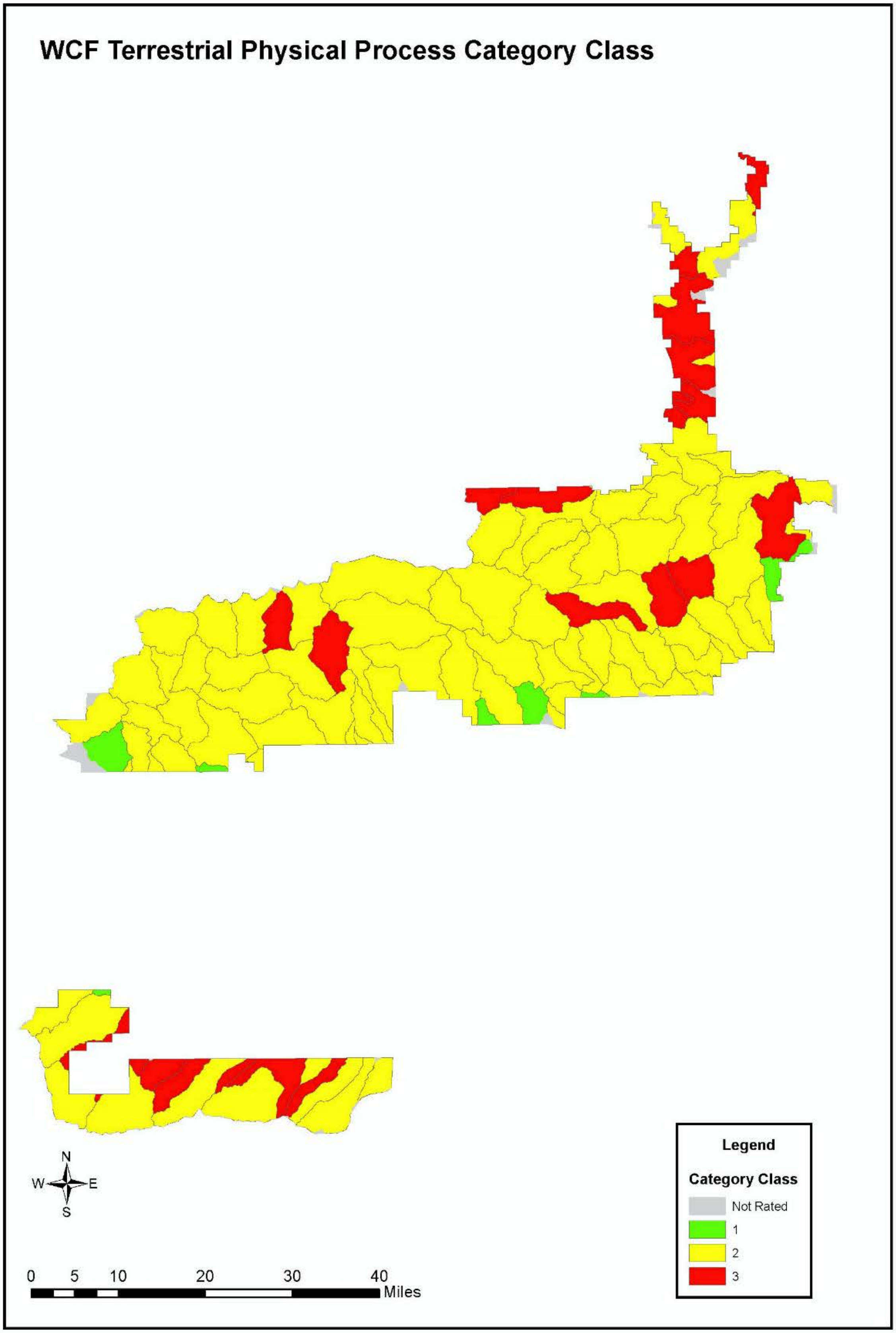

Figure 47. Watershed condition framework terrestrial physical process category class

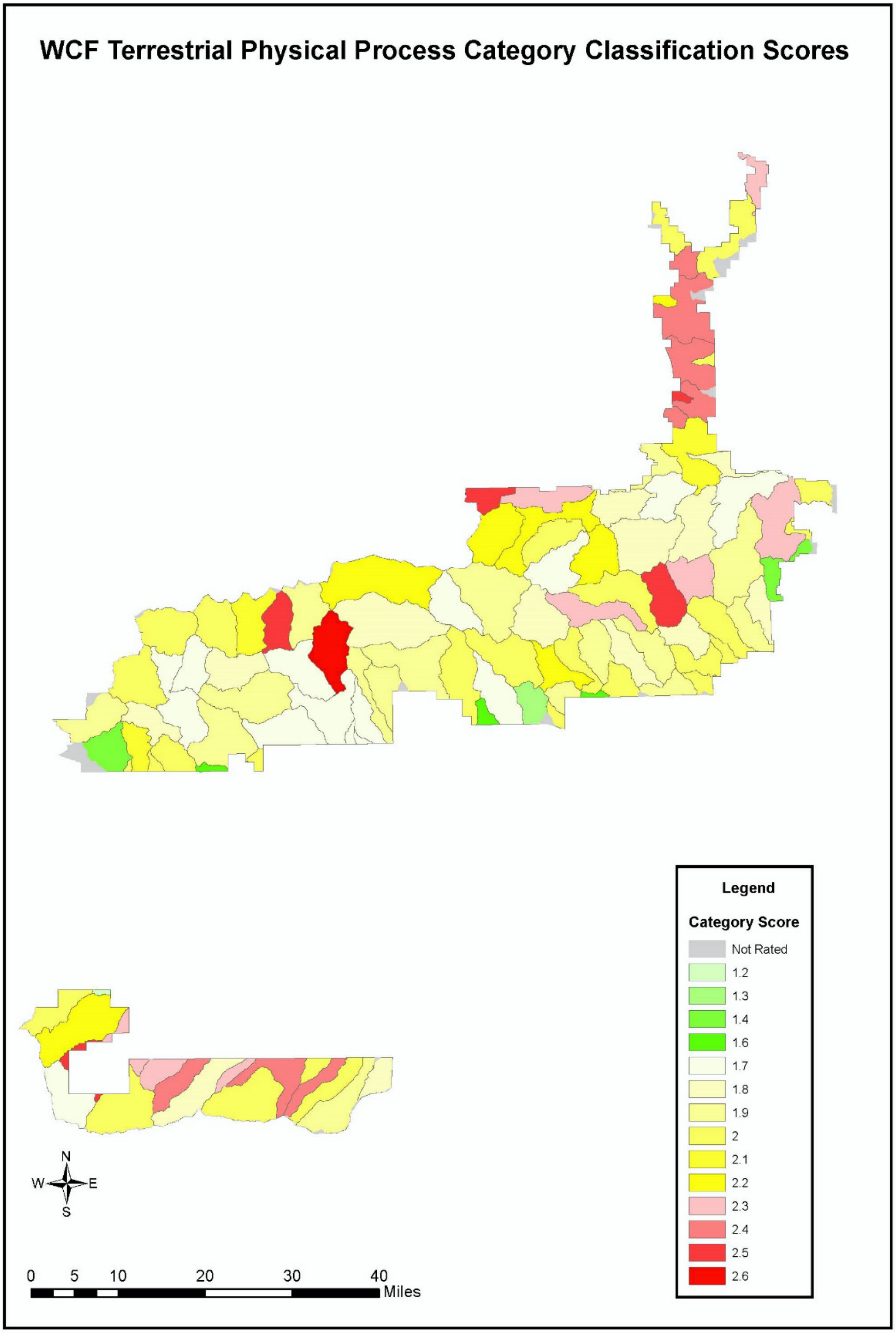

Figure 48. Watershed condition framework terrestrial physical process category classification scores

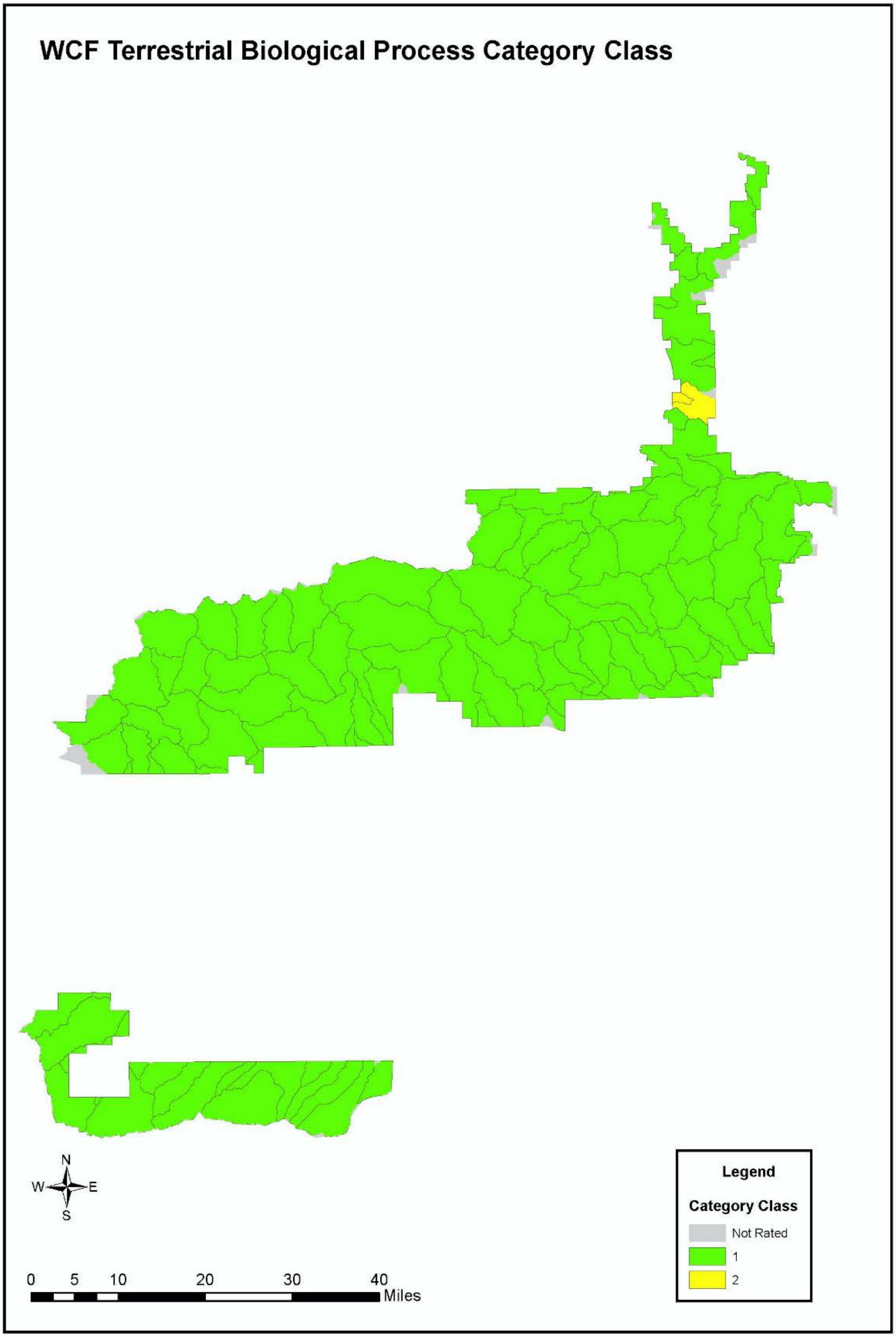

Figure 49. Watershed condition framework terrestrial biological process category class

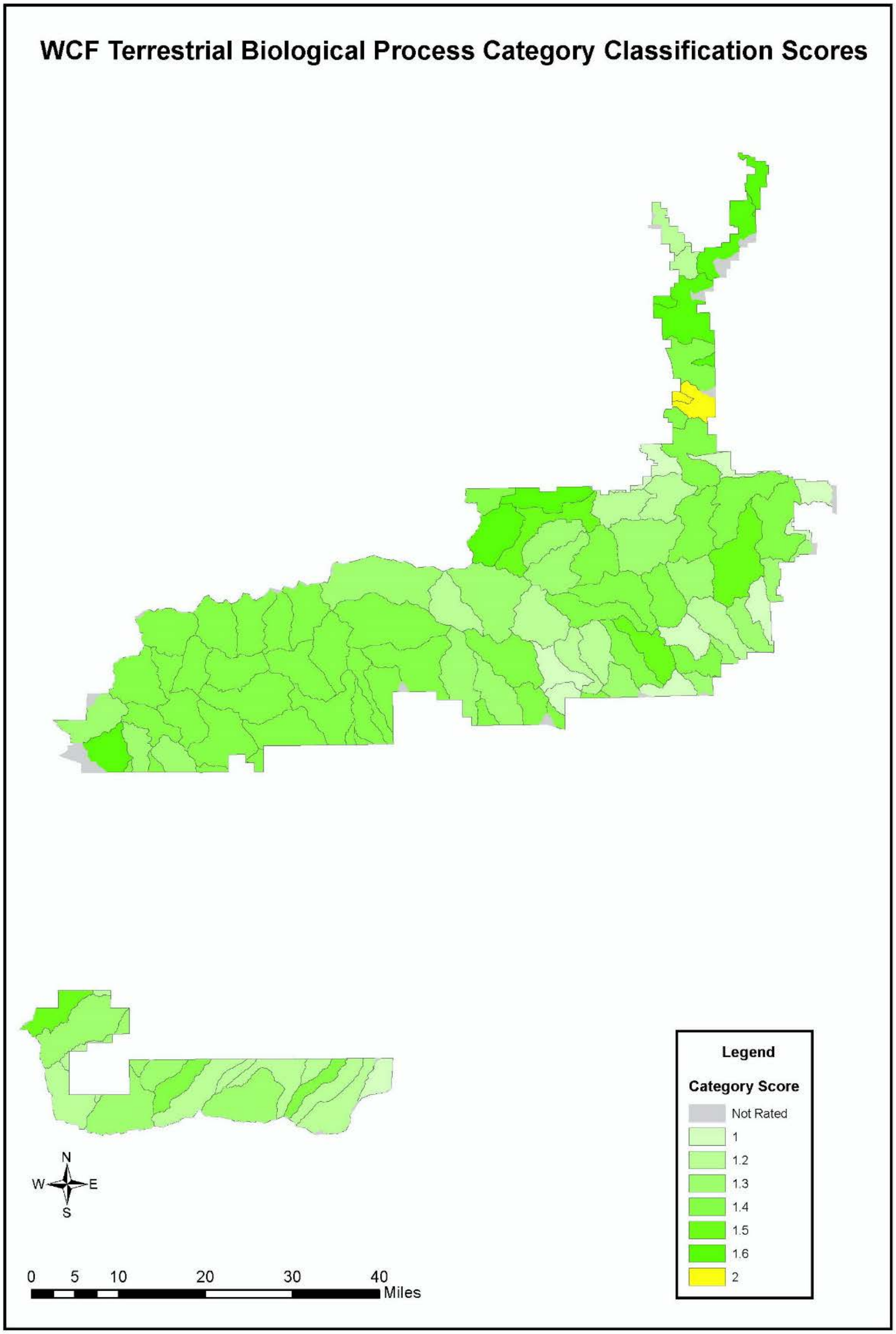

Figure 50. Watershed condition framework terrestrial biological process category classification scores