Aquatic, Riparian, and Wetland Ecosystem Assessment

San Juan National Forest, Colorado

USDA Forest Service - Rocky Mountain Region
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Report 1 of 3

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EXECUTIVE SUMMARY

This ecological assessment is the product of a cooperative effort by the USDA Forest Service and scientists from Colorado State University and the University of Wyoming. A synthesis of the best available information about aquatic, riparian, and wetland ecosystems associated with the San Juan National Forests, and the anthropogenic influences from Euro-American settlers and more recent human activities on these resources is documented.

The assessment responds to direction from the Regional Leadership Team of the USDA Forest Service Rocky Mountain Region (Region 2) to improve the quality and consistency of forest and project planning, and overall resource management. The Leadership Team recognized that this was a difficult task given the numerous laws and directives the USFS follows and the complexity of resource management related to species viability and ecosystem integrity. As a result, the Region 2 Species Conservation Team, consisting of ecologists, botanists, and biologists, were charged with developing and implementing a process to address species conservation and ecological sustainability. This ecosystem assessment is the component of the Species Conservation Project that focuses on the ecological characteristics, influences, and condition of aquatic, riparian, and wetland resources on the San Juan NF.

The development of a classification scheme, which provides an understanding of the sensitivity, abundance, and unique characteristics of aquatic, riparian, and wetland ecosystems within the San Juan NF, the surrounding landscape, and across Region 2, is defined in this assessment. The assessment includes an analysis, which classifies small watersheds into distinct groups that differ in aquatic, riparian, and wetland resource productivity, abundance, and response to disturbance. This "ecological driver" concept provides a sound stratification of aquatic, riparian, and wetland resources in the GMUG landscape as well as potentially across Region 2. A total of 24 historic and current anthropogenic influences were also analyzed in a rigorous and regionally consistent manner. Such analysis promotes consistent and efficient comparisons of influences between watersheds within a forest, among several forests, and among multiple land ownerships. A synthesis of ecological drivers and anthropogenic influences was also conducted to assess the sensitivity, importance, and management risks associated with aquatic, riparian, and wetland resources. These analyses will be valuable to help identify priority areas for restoration and monitoring, as well as development of reference conditions, program development, and refinement of management direction.

At the request of the Species Conservation Steering Committee and SJNF staff, key management implications for these sensitive aquatic resources are discussed. However, specific decisions concerning management of any lands within the SJNF or future management needs are not presented. Instead, the document and its conclusions should stimulate interdisciplinary discussion, enhance future analysis and monitoring efforts, and clarify resource management, and restoration opportunities.

The data used for this assessment will not only be distributed to the SJNF, but also incorporated into a regional and national database for future comparisons among administrative units. Therefore this assessment provides a solid foundation of data

related to aquatic, riparian, and wetland resources for all SJNF employees to use that will improve consistency in data collection and management focus in the future. The SJNF Aquatic, Riparian and Wetland Assessment are presented in three separate reports: Report 1: Introduction and Ecological Driver Analysis; Report 2: Anthropogenic Influences Report; and Report 3: Ecological Driver Analysis and Anthropogenic Influence Results: Synthesis and Discussion.

Finally, the assessment results will support more effective, efficient, and consistent watershed assessments and cumulative effects analysis on the San Juan NF and throughout Region 2. We believe that this assessment provides a common scientific foundation that the SJNF and other agencies such as the Colorado Division of Wildlife can rely on for future management and planning activities. Through this effort, Region 2 and university scientists have developed a valuable partnership that will continue to pursue meaningful ecosystem studies to address key management issues throughout Region 2.

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Chapter 1 Introduction

The Aquatic, Riparian, and Wetland Assessment (ARWA) and Current Landscape Condition (CLC) Assessments describe the aquatic and terrestrial ecological characteristics of lands influenced directly and indirectly by Forest planning and management on the San Juan and Grand Mesa, Uncompahgre, and Gunnison (GMUG) National Forests of western Colorado. In addition, this assessment describes the anthropogenic influences from European settlers and their relationship to these ecological characteristics (Winters et al. 2004a).

These two national forests encompass approximately 8,195 square miles (5.2 million acres) of the Rocky Mountain Region (Region 2) of the U.S. Department of Agriculture, Forest Service (Table 1-1). The analysis area is located near the geographic center of five western states: Wyoming, Utah, Colorado, Arizona, and New Mexico (Figure 1-1).

Table 1-1. Area and relative distribution for the GMUG and San Juan National Forests.

Forest Name	Acres	Sq. Miles	Percent
Grand Mesa	351,194	548	6.7%
Gunnison	1,796,022	2,806	34.0%
Uncompahgre	1,040,553	1,625	19.7%
GMUG Total	3,187,769	4,980	60.4%
San Juan	2,093,085	3,270	39.6%
Total	5,280,854	8,251	100.0%

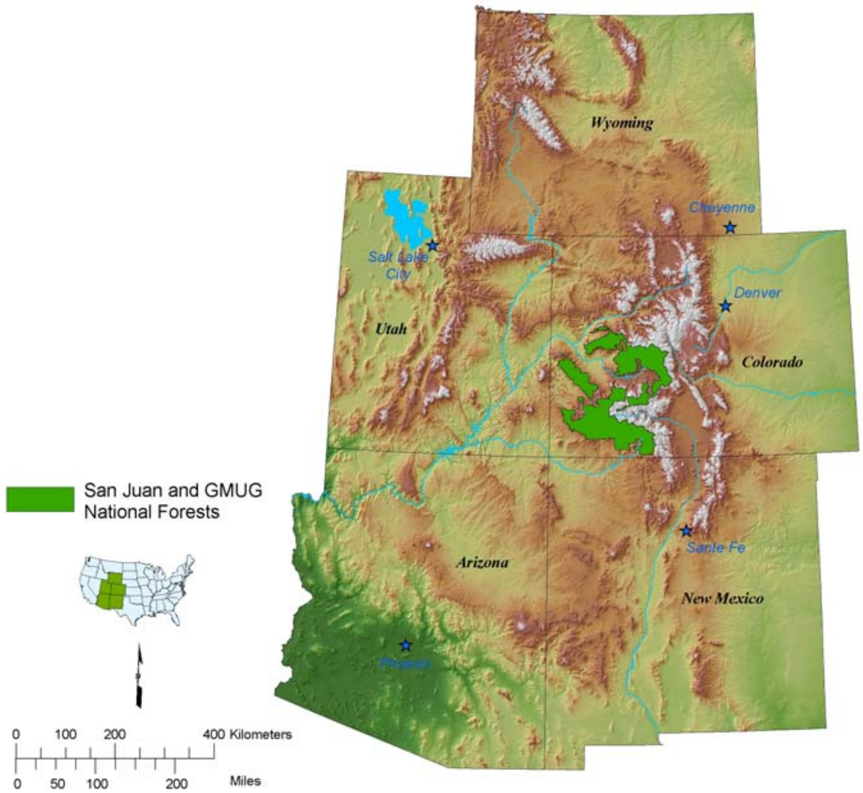

Figure 1-1. The San Juan/GMUG National Forests cover approximately 8,195 square miles (5.2 million acres) of high desert plateau, montane, and alpine areas of southwestern Colorado.

ARWA Goals and Objectives

In general, ecosystem assessments are conducted in order to portray historic and current ecosystem conditions and the effects of natural and human disturbances. The San Juan and GMUG aquatic, riparian, and wetland assessment is specifically organized to answer detailed questions about the ecological environment, natural disturbance regimes, and ecosystem dynamics, effects of human disturbances, assessment limitations, data gaps, and inventory and monitoring principles. The explicit goal is to give the Forests solid information that will enhance the analysis of ecological effects, the effectiveness of conservation efforts, and the design of future studies. The main objectives are to identify critical resource values to manage degraded or threatened resources we need to restore, and to guide where we need apply our management decisions. A list of specific questions that are answered by this assessment include:

1) What are the keystone ecosystem elements (e.g., geology, climate, landform, etc.) that influence the form and function of aquatic, riparian, and wetland ecosystems?
2) What are the physical, biological, and ecological characteristics and trends of the current environment?
3) What and where are the watersheds with important and unique aquatic, riparian, and wetland characteristics? And how do they relate to the surrounding landscape?

4) What anthropogenic factors individually and cumulatively have altered aquatic, riparian, and wetland ecosystems?
5) Where do we expect the highest risk from future management activities?
6) What are the limits in application and interpretation of the assessments?
7) What major information gaps are revealed by the assessments?

The Species Conservation Project Assessment Process

Together, both the ARWA and CLC Assessment are constituents of the comprehensive Region 2 Species Conservation Project (SCP). The SCP process combines the results of Forest aquatic, riparian, wetland, and terrestrial assessments in the region with species assessments to show species-ecosystem relationships and thus enhance immediate and long term species conservation efforts, both locally and regionally (Figure 1-2). It is important to note that the ecosystem assessments are a valuable management tool independent of the species assessments, and will be more apparent as the reader understands the results. Of primary importance in this process is the idea of providing a consistent and defensible process to be used for Forest Plan level as well as project level decisions.

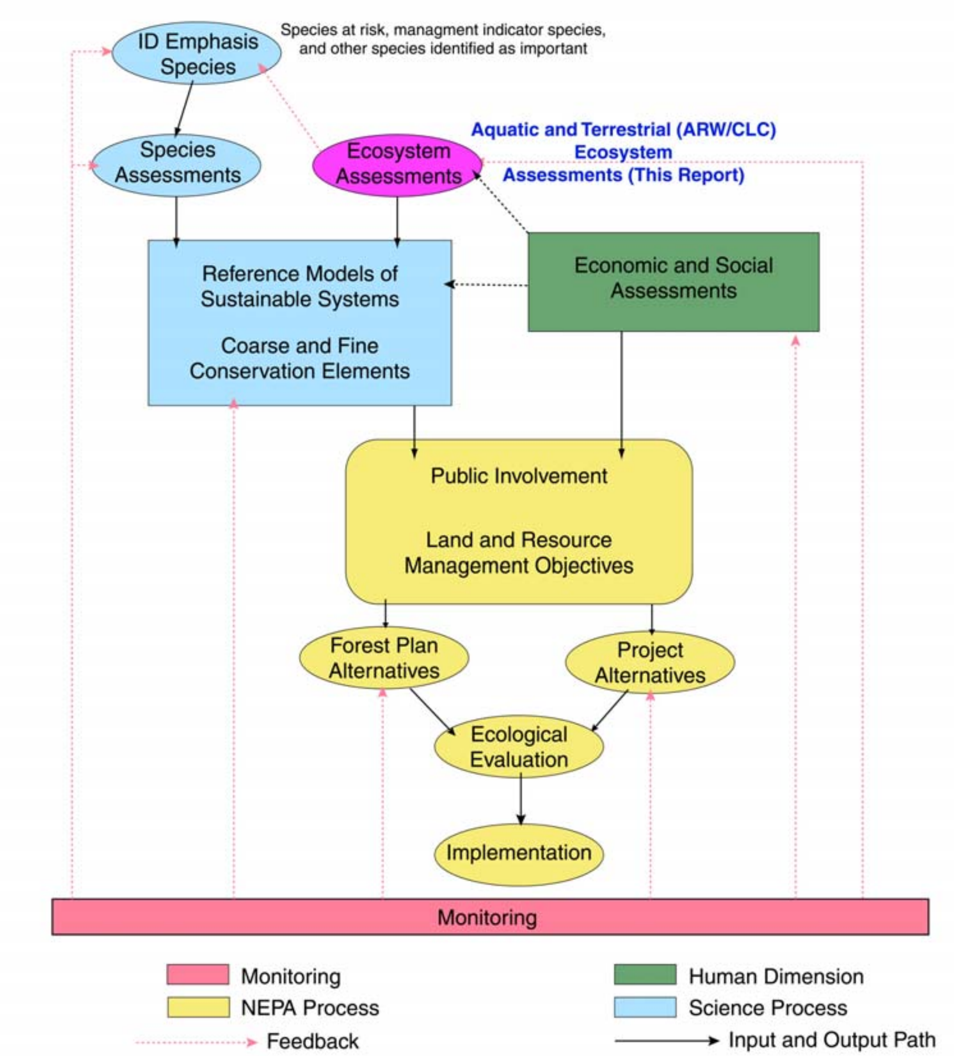

Figure 1-2. The Species Conservation Project (SCP) conceptual model. The ARWA and CLC Ecosystem Assessment are one element of the overall SCP model in Region 2.

Relationship to Forest Planning

The National Forest Management Act of 1976 (90 Stat 2949 et seq; 16 U.S.C. 1601-1614, 1976) provides the basis for the development of the SCP process, and supporting elements and integration into both forest and project planning. The Act, in part, requires the Forest Service to "…provide for diversity of plant and animal communities based on the suitability and capability of the specific land area in order to meet overall multiple-use objectives." In addition "…fish and wildlife habitat shall be managed to maintain viable populations of existing native and desired non-native vertebrate species in the planning area." The assessment process provides an approach that allows us to measure, evaluate, and interpret both natural processes and human influences that support these goals. The resulting assessment documents are not planning documents because they do not resolve issues or determine policy (Jensen et al. 2001). Instead, the ARWA and CLC Assessment are intended to contribute to the resolution of issues and provide a foundation for policy discussion and determination. Therefore the ARWA and CLC Assessment for the San Juan and GMUG Forests will include:

1) Summaries of existing condition (CLC) and ecological characterization (ARWA).
2) Identification of important and unique habitat(s) that may influence the development of plan alternatives.
3) Identification of risks and sensitivity of watersheds and vegetation communities.
4) Delineate the distribution of habitats and ecological communities from regional ecosystem perspectives.
5) Identification of areas suitable or critical for the maintenance and/or improvement of rare habitat and communities.

In addition, The ARWA will provide valuable information for the Forest Plan revision process, including to:

1) Summarize existing condition information, including databases for further analysis.
2) Identify important and unique aquatic, riparian, and wetland resources that may influence alternative development.
3) Provide important habitat distribution information for monitoring management indicator species.
4) Identification of prescription areas for rare and/or important aquatic, riparian, and wetland resources.

These assessments do not:

1) Quantify the condition of plants and animal communities at a local or site level scale.
2) Identify the thresholds for impacts.
3) Provide results suitable to application at local or site-level project scales.
4) Make changes in land allocation as specified by existing forest plans and area resource plans.
5) Serve as a decision document.

Relationship to Program and Project Development

The assessment presented here may further amplify Forest activities by creation of a multi-scale approach that directly assists with prioritization of ecological land units including watersheds, vegetative communities, and geomorphic settings.
Aquatic, riparian, and wetland assessments can:

1) Identify the highest priority watersheds for restoration and reintroduction of native species.
2) Identify reference watersheds and conditions to support monitoring.
3) Characterize relative impacts to important resource values.
4) Assist in the development of funding requirements at the watershed level.
5) Identify watersheds at risk and sensitive watersheds, and critical aquatic, riparian and wetland areas suitable for program level planning and activity.

The terrestrial CLC assessments can:

1) Provide common baseline information of terrestrial vegetation dynamics and conditions.
2) Provide a scientific basis for discussions with community leaders at local, state and federal levels regarding ecological processes and how they influence the landscape.
3) Increase the effectiveness of the Accelerated Watershed Restoration Program by:
    (a) Improving fire risk classifications.
    (b) Providing a sound basis for management activity prioritization.
    (c) Enhancing understanding of native disturbance processes that affect ecological processes.
    (d) Providing scientific basis for planning.
4) Provide multi-scale baseline information for project planning and provide mechanism to prioritize restoration work on the Forest.

The ARWA and CLC Assessment

Forest Service specialists and outside collaborators have developed protocols to guide the preparation of both the ARWA and CLC Assessment that are elements of SCP (Winters et al. 2004 and Regan et al 2004). These protocols describe the structure of assessments and their goals. ARWA are designed to characterize the influence of current and historic management activities on aquatic, riparian, and wetland ecosystems that include and extend beyond Forest Service administrative areas. The ARWA relate anthropogenic influences to specific variables that drive the function of aquatic, riparian, and wetland systems. It provides managers with important insights into the sensitivity of ecosystem components to both natural and human disturbances. It reveals areas of opportunity and areas at risk.

The GMUG National Forest has chosen to augment the ARWA by applying a watershed sensitivity rating (WSR) to the analysis. The WSR is intended to supplement the ecological driver analysis according to the ARWA protocols. The WSR attempts to categorize physical factors or ecological drivers (e.g., geology, precipitation, soils) that determine how a watershed responds to disturbance (natural or management related). The WSR will be used in Forest and project planning to prioritize potential risks land management activities may pose to watershed health.

Current Landscape Condition (CLC) assessments examine current social, physical, biological, and disturbance settings for a given area. These characteristics may be measured against historic settings to understand the influence of current and historic anthropogenic activities and their influence on terrestrial ecosystems. The measures also provide insight into opportunities for ecosystem maintenance and restoration.

CLC assessments are divided into four chapters:

1) Chapter 1 provides an introduction describing concepts, setting and key components.
2) Chapter 2 describes the geographic, physiographic and ecological settings, the assessment approach and scale.
3) Chapter 3 provides an overview of assessment modules, assessment of specific ecological factors along with descriptions of data sources and analytical methods.

4) Chapter 4 describes implementation criteria, interagency involvement, data management and timelines.

The GMUG Geographic Area Assessments

The GMUG Forest Plan revision process currently includes the development of Geographic Area Assessments (GAA). These assessments include five geographic areas that were based on watershed and socio-economic boundaries (Figure 1-3). The GAA areas were developed strictly for the Forest Planning process prior to the ARWA analysis, and are retained to maintain consistency with that process. They do not coincide with the watershed concept described previously, because they incorporate boundaries that include social values. GAA's provided a description of the current conditions of lands and resources within each area and include a comparison of these conditions to desirable conditions. GAAs will:

1) Identifies key socio-political and management issues to focus the analysis.
2) Describe current conditions relating to key issues within the Geographic Areas (GA).
3) Outline historic conditions to help identify the type of changes within the GA.
4) Outline important trend and likely future conditions within the GA.
5) Synthesize and interpret information within the GA.
6) Define opportunities and include recommendations for the respective GA.

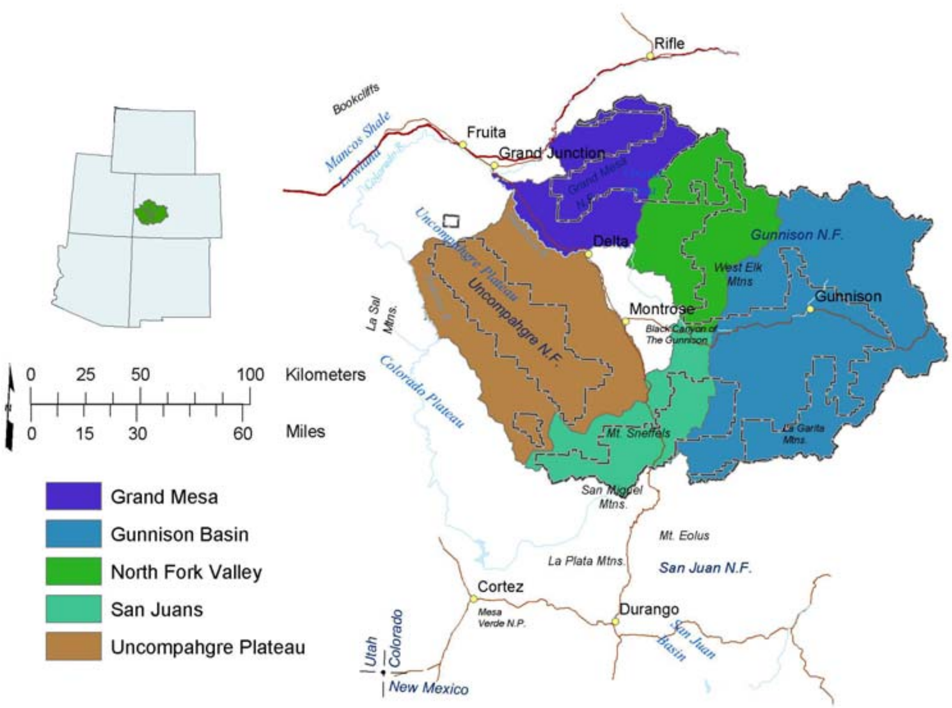

Figure 1-3. GMUG forest plan revision Geographic Areas (GA).

Integration of ARWA, CLC, and GAA Elements

In some cases the ARWA, CLC, and GAA protocols consider ecological characteristics common to both aquatic and terrestrial ecosystems. Where these characteristics are common a single umbrella document has been prepared. In other instances, a given protocol may call for the reporting of characteristics that are distinct to that protocol and will be dealt with separately. One important difference between the GAA and the ARWA and CLC Assessment is the ARWA and the CLC goals include consistency across geographic areas for comparisons at various scales. In addition, they are based on important landscape boundaries and do not include other more culturally based delineations.

The ARWA, CLC and GAA Multi-scale Geographic Setting

Both the ARWA and CLC Assessment are organized by geographic scale. Concepts of scale provide important variation in perspective and understanding of ecosystem function by following a broad scale approach that characterizes local to regional ecological settings. The ARWA protocol is based on a hierarchical arrangement of hydrologic units (Maxwell et al. 1995), and the CLC protocol is based on a hierarchical arrangement of land-cover based ecological units (e.g., vegetation). These two scale frameworks are generally complimentary, although their goals are not necessarily the same. The GAA are unique to the GMUG and incorporate watershed boundaries as well as socio/political boundaries

The ARWA Scale Framework: Ecological Scales

The ARWA protocol follows concepts defined by the National Hierarchical Framework of Aquatic Ecological Units in North America (Maxwell et al. 1995) and the National Watershed Boundary Dataset's Federal Standards for Delineation of Hydrologic Unit Boundaries (FGDC 2002).

The aquatic ecological unit hierarchy delineates aquatic ecosystems into seven hierarchical categories including: sub zones, regions, subregions, basins, sub basins, watersheds, and subwatersheds. The National Watershed Boundary Dataset defines hydrologic unit boundaries that may be adapted to fit the National Hierarchical Framework by defining four hierarchical scales. These four scale categories include, in descending order: basin, landscape, management, and reach scales (Figure 1-4).

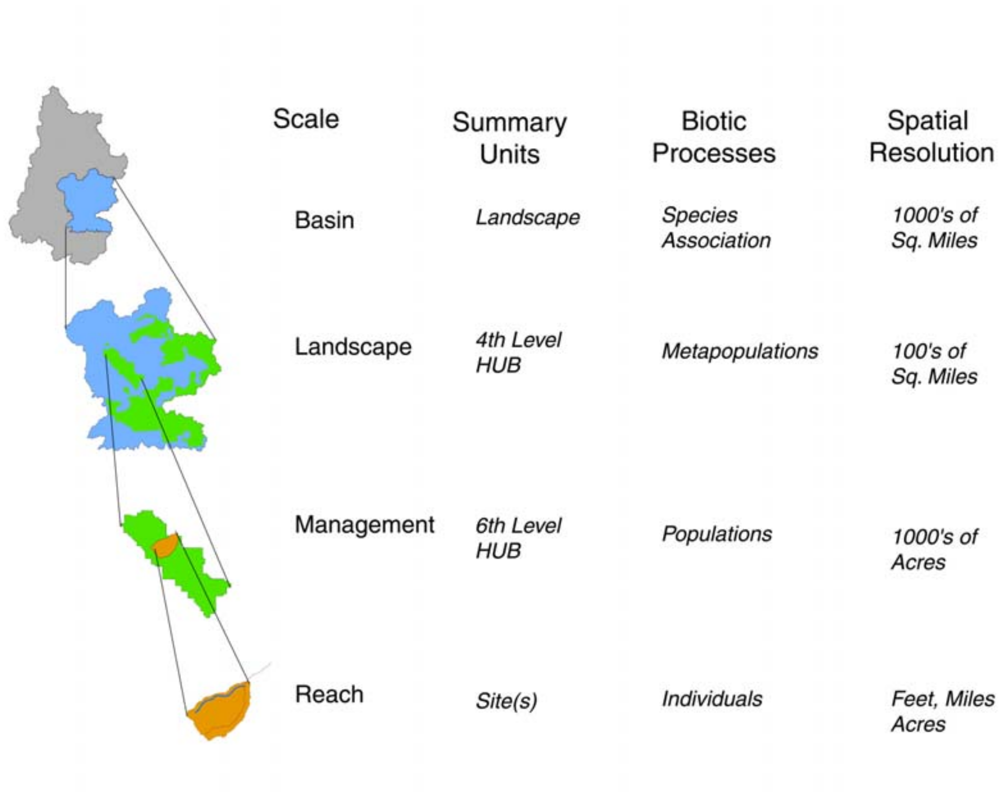

Figure 1-4. The watershed-based broad-scale configuration for aquatic, riparian, and wetland assessments.

Basin Scale

The San Juan and GMUG National Forests are located completely within the approximately 114,000 square miles of the Upper Colorado River Basin (Steeves and Nebert 1994) (Figure 1-5). Principal rivers that drain the basin include the Colorado, Green, Gunnison, San Juan, and Dolores Rivers. River basins are ecologically distinguished mainly by differences in aquatic, riparian, and wetland species assemblages and hydrologic relationships. For example, the rivers in the mountains of the Upper Missouri River Basin contain Yellowstone cutthroat trout, while the Middle Missouri and Upper Colorado River basins have greenback and Colorado River cutthroat trout, respectively. Similar distinctions apply to mollusks, invertebrates, warmwater plains fishes, and some riparian and wetland plants. All the river systems in this basin eventually flow into the Colorado River. The river basin assessment in this report constitutes a template for conducting this and future assessments. Results from the ARWA across the National Forest system will be comparable and provide a context for managing native species across the entire basin (e.g. Colorado River Cutthroat trout).

Figure 1-5. The San Juan and GMUG National Forests are located completely within the approximately 114,000 square miles of the Upper Colorado River Basin. The area comprises the basin scale.

Landscape Scale

The landscape scale is the aggregation of 4th level hydrologic unit boundaries (HUBs) that intersect the San Juan and GMUG National Forests (Figure 1-6). Analysis at this scale considers the magnitude of anthropogenic influences, summarized to each of the eighteen 4th level HUBs that comprise the landscape (Table 1-2). In total, the area includes approximately 22,258 square miles of high desert, montane and alpine uplands of Western Colorado and Eastern Utah. Principal rivers that drain these lands include the Gunnison, San Juan, Uncompahgre, San Miguel, Mancos, Animas, Piedra, and Dolores Rivers. Each river drains ultimately into the Colorado River (Figure 1-7). We can make two important comparisons at this scale, including:

1) The relative abundance of ecological conditions within the National Forest boundary as opposed to outside.
2) The relative amount of management activity within and outside of the National Forest boundary.

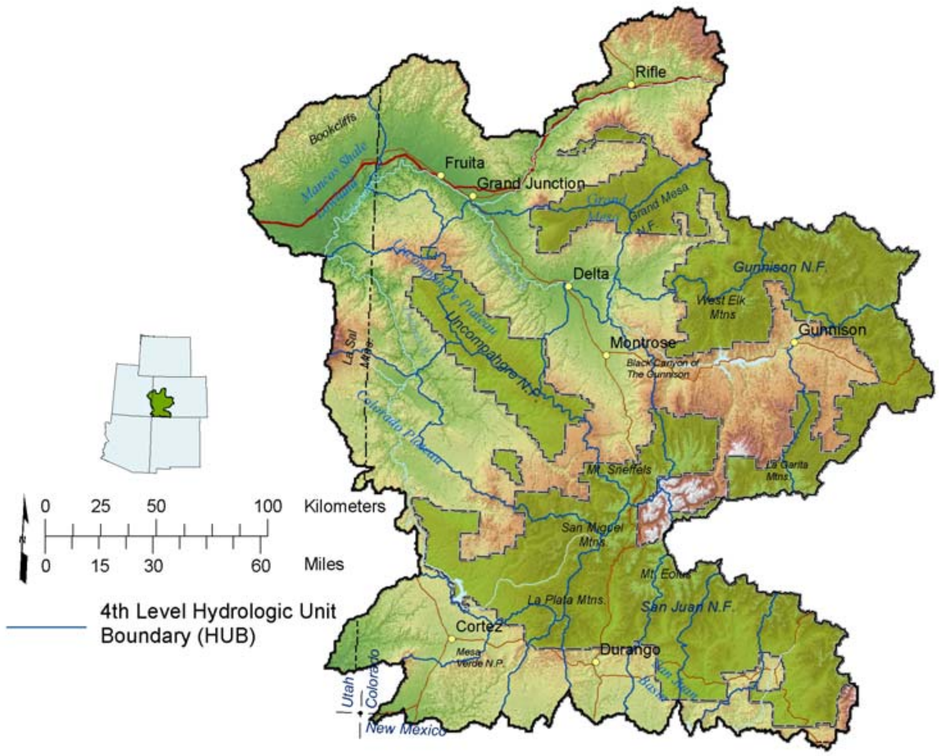

Figure 1-6. The aquatic, riparian, and wetland landscape scale for the San Juan and GMUG National Forests includes approximately 22,258 square miles (14,245,187 acres). The area is defined by aggregating eighteen 4th level watersheds that intersect the administrative areas of the GMUG NF.

Table 1-2. Eighteen 4th level HUBs comprise the San Juan and GMUG ARWA landscape scale.

Rank	4th level HUB	National Forest	4th level HUB Name	Acres	Sq. Miles	Percent
1	14010005		Colorado Headwaters-Plateau	1,998,348	3,122	14.0%
2	14020002	GMUG	Upper Gunnison	1,543,036	2,411	10.8%
3	14030002	GMUG	Upper Dolores	1,381,647	2,159	9.7%
4	14020005	GMUG	Lower Gunnison	1,064,086	1,663	7.5%
5	14030003	GMUG	San Miguel	995,742	1,556	7.0%
6	14030001	GMUG	Westwater Canyon	933,861	1,459	6.6%
7	14020006	GMUG	Uncompahgre	714,738	1,117	5.0%
8	14020003	GMUG	Tomichi	705,059	1,102	4.9%
9	14080104	SJ	Animas. Colorado	702,036	1,097	4.9%
10	14020004	GMUG	North Fork Gunnison	620,473	969	4.4%
11	14030004	SJ	Lower Dolores	591,992	925	4.2%
12	14080101	SJ	Upper San Juan	583,052	911	4.1%
13	14020001	SJ	East-Taylor	490,726	767	3.4%
14	14080202	SJ	Mcelmo	459,777	718	3.2%
15	14080107	SJ	Mancos	448,023	700	3.1%
16	14080102	SJ	Piedra	432,475	676	3.0%
17	14080101	SJ	Upper San Juan	370,102	578	2.6%
18	14080105	SJ	Middle San Juan	210,014	328	1.5%
	Total			14,245,187	22,258	100.0%

Management Scale

The ARWA management scale is based on 6th level sub-watersheds or HUBs. The gross management scale area is defined by the collection of 6th level watersheds that fall entirely within, or have a portion of their area, intersect the National Forest boundary.

Three hundred eighty-one 6th level HUBs intersect or are adjacent to HUBs intersecting the Forests (Table 1-3 and Figure 1-7). These 381 HUBs comprise the management scale for the Forests. These 381 HUBS range in size from a maximum area of 109,340 acres (170.8 sq. miles) to a minimum area of 1,736 acres (2.7 sq. miles). The average HUB area is 21,875 acres (34.2 sq. miles).

In cases where data simply do not exist, the assessment team will create or obtain the data from external sources. Where this is not possible, important data gaps are documented in the assessment.

Table 1-3. The 381 HUBs that define the ARWA management scale include HUBs distinct to each Forest, three common to each and one external HUB. The HUB 140801010501 (East Fork Navajo River) falls between the eastern-most edge of the San Juan Forest and the Continental Divide.

Forest	Count	Acres	Hectares	Sq. Miles
San Juan	151	2,781,672	1,125,703	4,346
GMUG	226	5,431,815	2,198,177	8,487
Common to Both	3	107,822	43,634	168
External but Included	1	13,268	5,369	21
Total	**381**	**8,334,577**	**3,372,883**	**13,023**

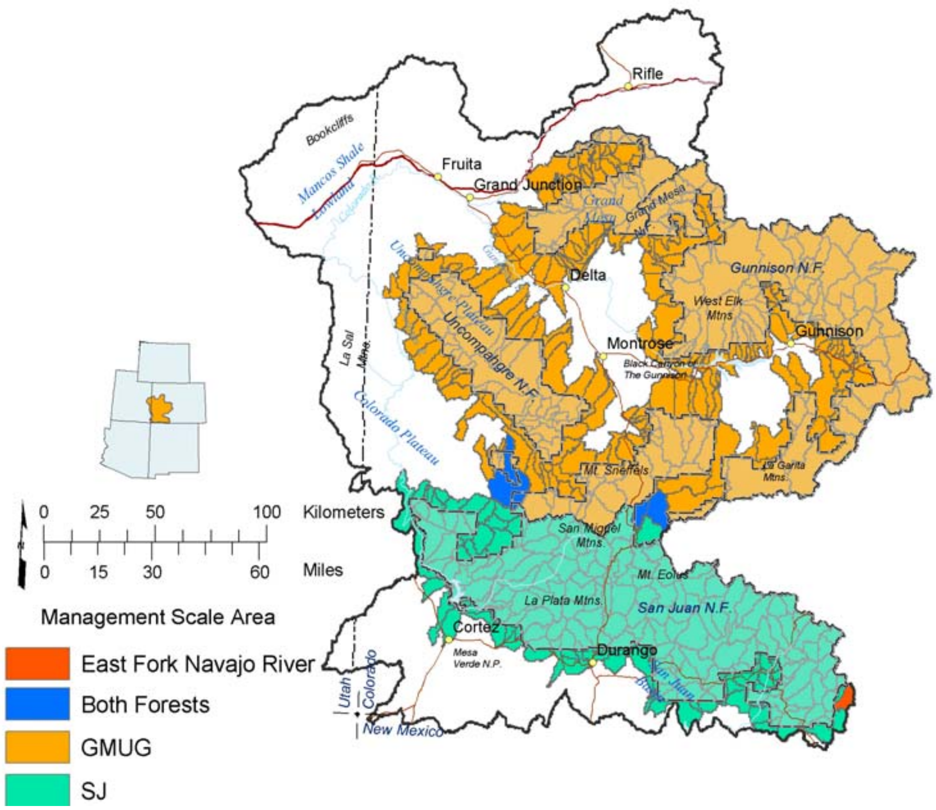

Figure 1-7. 381 6th level HUBs make up the combined the San Juan and GMUG ARWA management scale area.

At the management scale, the aquatic, riparian, and wetland assessment refines the analysis conducted at the landscape scale, and is the most intensive of this process. This scale constitutes the appropriate scale for addressing the relationship of ecological drivers at a "management" size as well as quantifying the distribution of anthropogenic activities related Forest service activities. Preliminary assessments of risk, sensitivity and abundance related to ecological conditions are also most appropriate at this scale. Other ecological drivers, such as extent of glacial activity and stream gradient, are added to the climate and geology drivers to extend the analysis, and additional data are integrated to better understand the following:

1) Distribution of high-value aquatic, riparian, and wetland ecosystems such as major wetland complexes;
2) Sensitivity of watersheds and their aquatic, riparian, and wetland ecosystems to disturbances;
3) Extent of natural and human disturbances and their effects on aquatic, riparian, and wetland ecosystems;
4) Historic and current conditions of aquatic, riparian, and wetland ecosystems; and
5) Physical and biological restoration priorities for degraded aquatic, riparian, and wetland ecosystems.

Reach/Site Scale

Because of the intensive effort needed to collect and synthesize data, this aquatic, riparian, and wetland assessment does not include analyses at the reach/site scale. However, the conditions identified at the landscape and in particular the management scale set the "context" for stratifying reach/site analysis. The identification of clusters of similar 6th level watersheds should provide the basis for stratification of inventory and monitoring programs at the reach/site level. The identification of the range of anthropogenic influences within a cluster, both independently and cumulatively should also help focus efforts in determining the reach/site effects of management activities on ARW resources. We are also conducting validation studies at the reach/site scale to test the assumptions and measurements developed at larger scales. This assessment provides specific questions that should be considered when addressing site/reach level analysis in the context of the larger scales. We have included these questions in an attempt to introduce a "consistent" thought process across administrative units when addressing management issues.

Recently, Pyne (2006) conducted a study of the relationships between ARW assessment results at the 6th level HUB and site level populations of brook char (*salvelinus fontinalis*), and benthic macroinvertebrates in the Bighorn Mountains. His results showed a significant relationship between char and benthic macroinvertebrate populations and the results of the assessments we conducted. In addition, similar studies are being conducted for wetland abundance and sediment characteristics. These results will strengthen the relationship between these scales and should help identify key inventory and monitoring programs.

The CLC Scale Framework: Ecological Scales

The CLC assessment protocol also uses a multi-scale hierarchical analysis framework of ecological units (ECOMAP 1993). The ECOMAP mapping framework was designed to assist with forest-level analysis and planning (Bailey 2004). This framework defines ecological units based on biotic and environmental factors that affect or express energy, moisture, and nutrient gradients that regulate the structure and function of ecosystems. The descending hierarchy of region, sub-region, landscape, and land-unit define the CLC scale framework applied in this assessment. These scales roughly correspond to the basin, landscape, management, and reach/site scales used in the ARWA scale framework. The CLC landscape scale should not be confused with the ARWA landscape scale. Figure 1-8 illustrates the hierarchical arrangement of scales that define CLC scale framework.

Regional Scale

Provinces are similar in scope to the basin scale of the ARWA protocol and they provide further subdivision below the province unit (Figure 1-9). Provinces typically cover areas from 1,000 to 10,000 square miles.

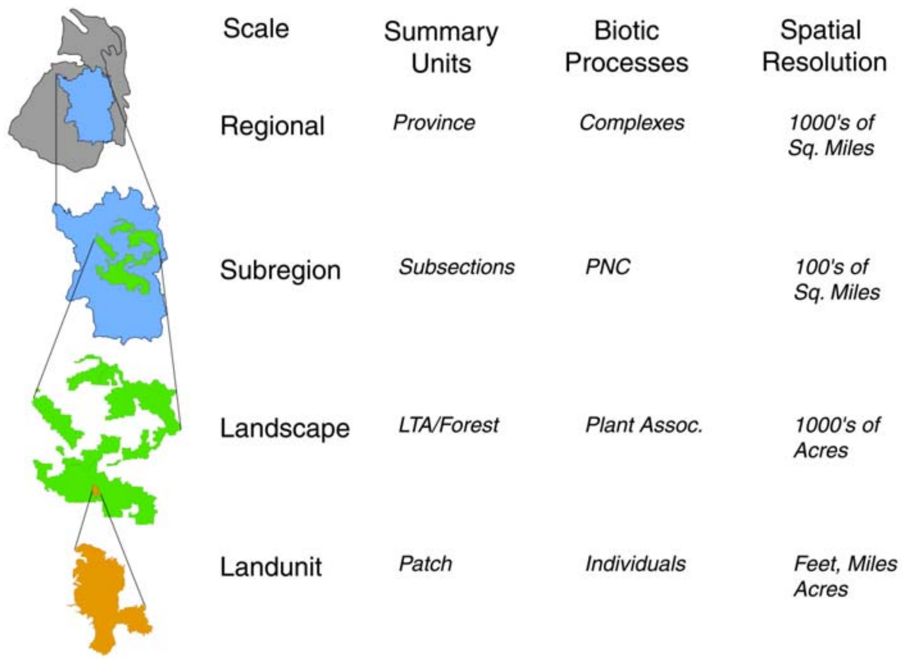

Figure 1-8. The ECOMAP based hierarchical scale arrangement for the GMUG and San Juan CLC Assessment. The regional scale includes the Colorado Plateau and the Southern Rocky Mountains provinces. The subregion scale provides regional context for analysis and the l landscape scale sharpens the focus to analysis at the forest level (similar in scope to the ARWA management scale). Site level activity is applied at the land unit scale.

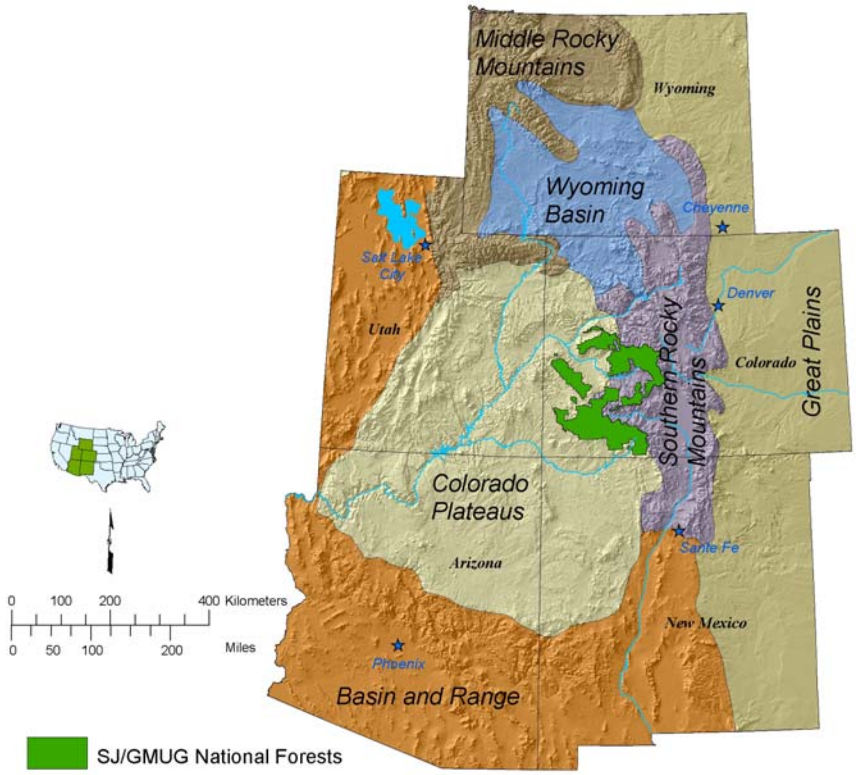

Figure 1-9. The San Juan and GMUG National Forests are included in the Colorado Plateau and Southern Rocky Mountains ECOMAP (1993) provinces.

Subregion Scale

The CLC subregion for the Forests is based on ECOMAP sections that intersect these Forests and some contiguous sections that do not. The aim is to build an ecosystem unit similar in scale and utility to the ARWA landscape scale.

Sections are the first terrestrial scale below the ECOMAP province and typically cover areas up to about 1,000 square miles. They are described by characteristic geomorphology, geology, climate, soils, potential natural vegetation, and potential natural communities. Forest management and other anthropogenic activities along with natural disturbance can affect the character and function of sections.

Six ECOMAP sections intersect the San Juan and GMUG National Forests (Figure 1-10). ECOMAP subsections are defined by the characteristics of geomorphology, geology, and potential communities as sections, but subsections as ecological entities, are more responsive to changes in climate, soils, vegetative, and animal community than sections. The area spanned by these six sections is more than adequate to the needs of most wide-ranging terrestrial species and brings into focus the larger complex of dry to wet vegetation communities of the Colorado Plateau and Southern Rocky Mountains provinces.

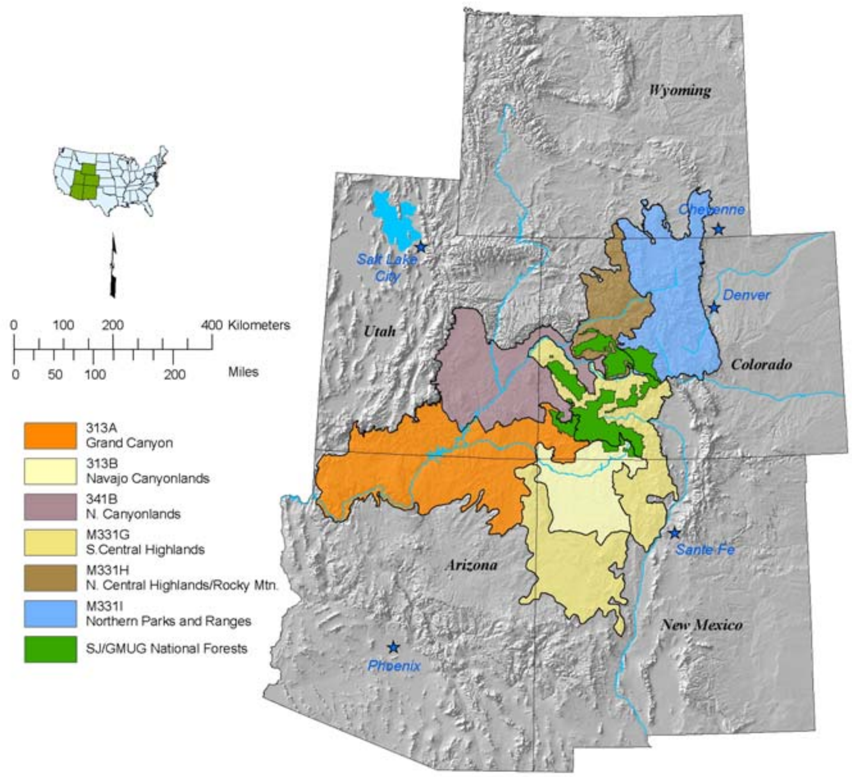

Figure 1-10. Six ECOMAP sections intersect the San Juan and GMUG National Forests. The portions of sections far from these National Forests are minimally influenced by management on those Forests.

The broad geographic setting formed by the six sections intersecting the Forests requires some approach to trim away the portions of sections minimally influenced by Forest management and well beyond the scope of the analysis. As a consequence the assessment team aggregated the relevant subsections to form a subregion scale.
Twenty-seven subsections intersect the Forests (Figure 1-11). These 27 subsections are constituents of the sections and more directly relevant to National Forest management.

The resulting region defined by these subsections is broad enough to provide adequate ecological context for the consideration of wide-ranging terrestrial species and ecological processes that could influence management of the Forests. The team added an additional 19 subsections to ensure adequate consideration of systems that both influence the Forests and are influenced by Forest management. Just as the aggregation of 4th level watersheds in the ARWA forms a landscape scale, these 27 subsections plus the additional 19 subsections, form a subregion scale for this CLC Assessment (Figure 1-12 and Table 1-4).

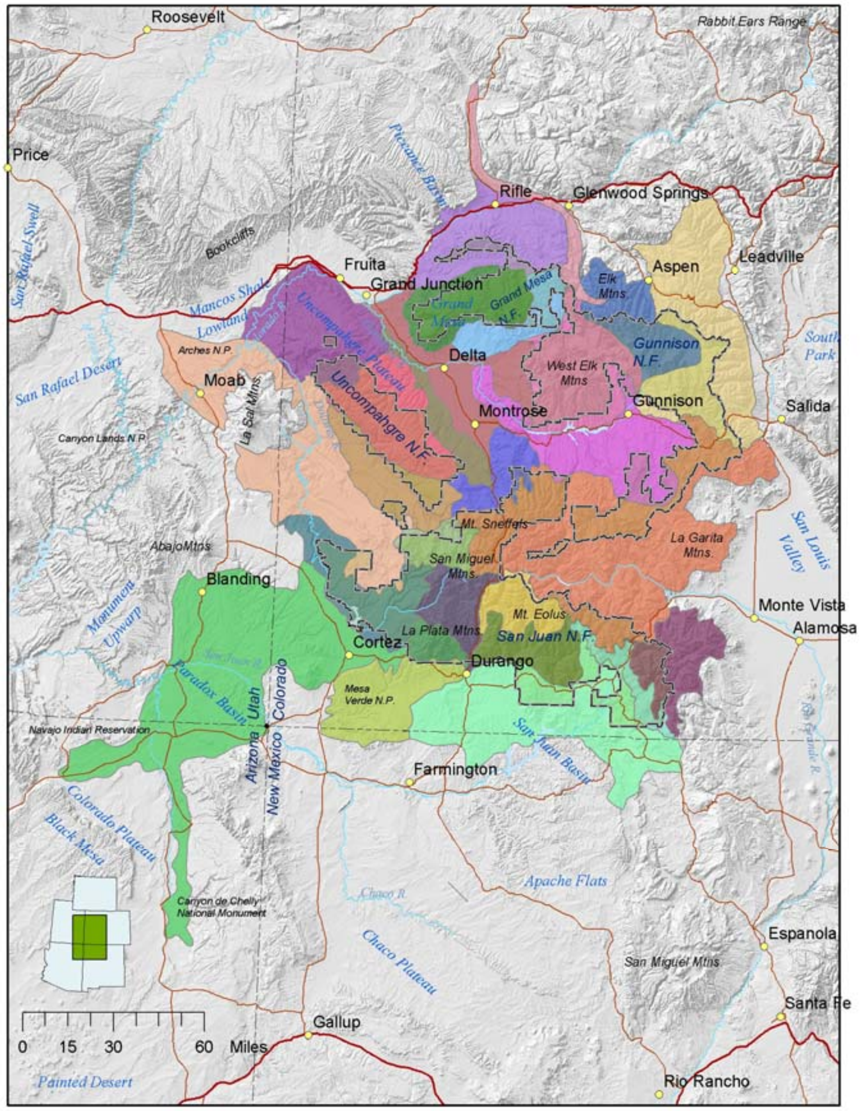

Figure 1-11. Twenty-seven subsections intersect the San Juan and GMUG National Forests.

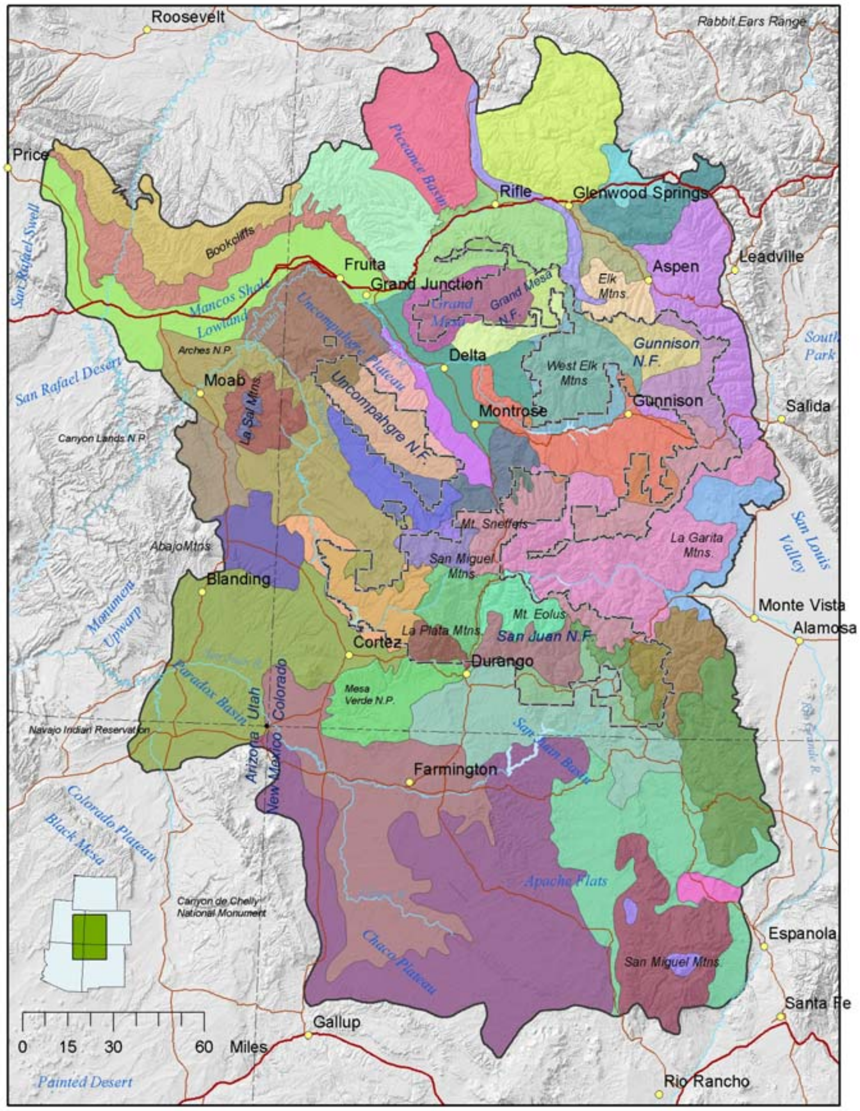

Figure 1-12. Nineteen subsections have been added to the 27 subsections that intersect the San Juan and GMUG Forests. The 19 subsections were added to take in important subsections and provide a comprehensive geographic context.

Table 1-4. The forty-six ECOMAP subsections aggregated to form the CLC subregion scale for the GMUG and San Juan CLC Assessment.

Subsection	Section Name	Acres	Hectares	Sq Miles
313Aa	Grand Canyon	535,102	216,548	836
313Ab		1,995,409	807,513	3,118
313Ac		536,428	217,085	838
313Bc	Navajo Canyon lands	2,082,085	842,590	3,253
313Bd		3,516,363	1,423,022	5,494
313Bm		1,384,139	560,141	2,163
331J	Northern Rio Grande Basin	105,031	42,505	164
341Ba	Northern Canyon Lands	543,149	219,805	849
341Bb		46	18	0
341Bd		1,436,402	581,291	2,244
341Be		385,636	156,062	603
341Bg		229,280	92,786	358
341Bk		282,563	114,349	442
341Bl		48,827	19,760	76
341Bn		337,233	136,473	527
341Bo		1,233,952	499,363	1,928
M331Ga	South-Central Highlands	776,028	314,048	1,213
M331Gb		432,022	174,833	675
M331Gc		808,651	327,249	1,264
M331Gd		350,179	141,713	547
M331Gf		272,207	110,158	425
M331Gi		594,165	240,450	928
M331Gk		875,042	354,117	1,367
M331Gm		1,011,198	409,217	1,580
M331Gn		262,894	106,389	411
M331Go		1,749,144	707,853	2,733
M331Gq		259,061	104,838	405
M331Gr		307,765	124,548	481
M331Gt		161,396	65,314	252
M331Gu		2,270,872	918,989	3,548
M331Gv		433,767	175,539	678
M331Hd	North-Central Highlands and Rocky Mountains	1,101,687	445,837	1,721
M331Hf		153,117	61,964	239
M331Hg		216,024	87,422	338
M331Hh		368,854	149,270	576
M331Hj		179,684	72,715	281
M331Hl		702,537	284,307	1,098
M331Hm		298,311	120,722	466
M331Hn		720,772	291,686	1,126
M331Hp		484,514	196,076	757
M331Ik	Northern Parks and Ranges	1,219,353	493,455	1,905
M331Iw		474,395	191,981	741
M341Bb	Northern Canyon lands	761,659	308,232	1,190
M341Bc		893,921	361,757	1,397
M341Bd		699,305	282,999	1,093
M341Bg		631,752	255,661	987
Total		34,121,920	13,808,650	53,316

Landunit Scale

Forest planning and management at the Forest level requires a finer scale than subsections. Landtype Associations (LTAs) typically ranging in area from 10 to 1,000 acres providing a suitable summary unit for analysis at the landunit scale.

LTAs in this assessment will be used to provide a broad context for plant associations but they will not be used as a primary summary unit. Instead, landunit scale analysis on the Forests will use alternative approaches to LTAs. At the same time, LTAs will be used in the CLC Assessment to define broad contexts for plant associations and communities. The San Juan Forest has defined a landunit scale equivalent referred to as the San Juan CLC landscape scale area (Figure 1-13). The GMUG National Forest defines their geographic area as a landunit scale equivalent (Figure 1-3).

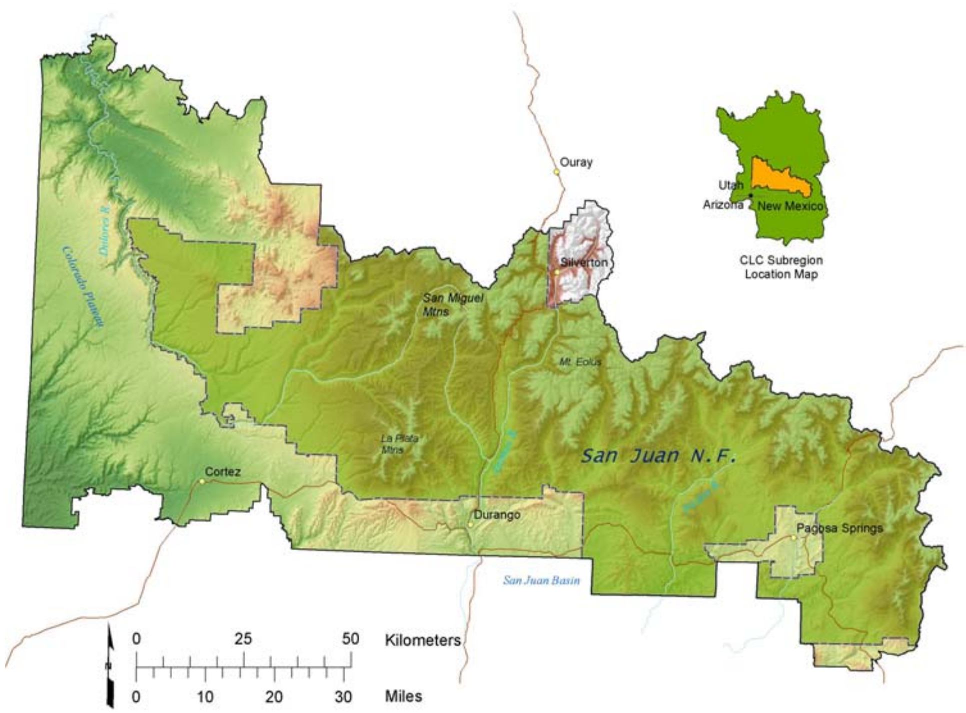

Figure 1-13. The San Juan National Forest CLC landscape scale area.

Stand Scale

The stand scale is a fine-scale level beyond the scope of the CLC Assessment.

GMUG Geographic Area Assessment Framework

Geographic Area Assessment (GAA) on the GMUG is an additional way of portraying the link between the broad-scale forest assessment and project-level analysis. Under the CLC portion of the assessment, current vegetation conditions, wildlife habitat structural stages, Potential Natural Vegetation (PNV), and natural and management influences on vegetation will be described. Natural disturbance regimes and management influences will be described by dominate cover-type in the geographic areas and then relate to how those influences are affecting current vegetative and wildlife habitat conditions and trends in the future. Based upon current conditions and future trends, potential effects to various wildlife species dependent upon those habitats will be completed.

Combined Assessments and Geographic Framework

The assessment of the Greater Study Area is defined by combining the ARWA landscape scale with the CLC subregion scale (Figure 1-14). The Greater Study Area extends from the Painted Desert of northeastern Arizona to the Rabbit Ears Range of west-central Colorado. The area is about 275 miles wide and 350 miles long. This area constitutes the logical extent of the landscape needed to characterize the ecological conditions found within the National Forests addressed in these assessments.

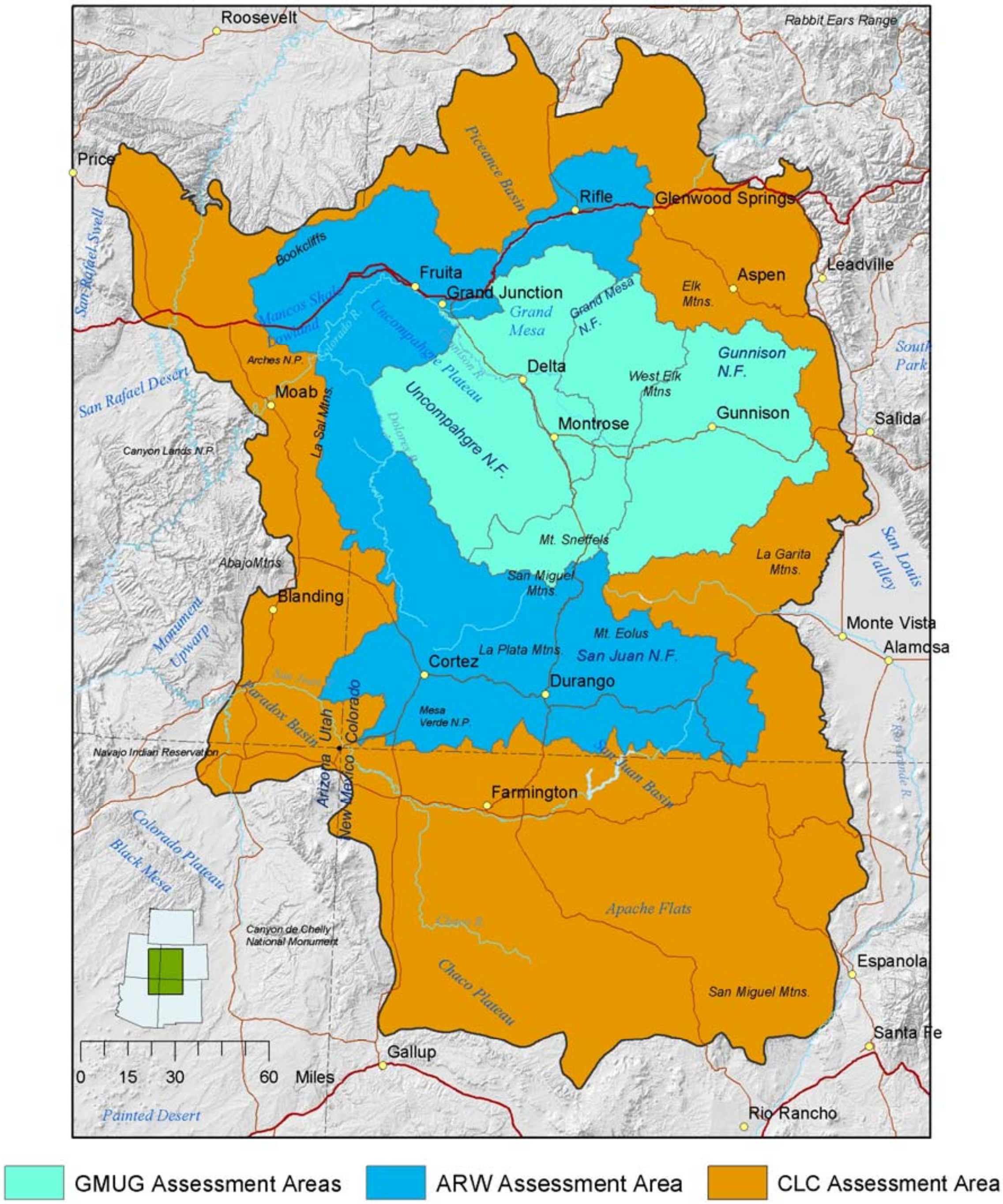

Figure 1-14. The total area encompassed by the 3 assessments. The GMUG assessment area is included in the area of the other 2.

Physiographic Setting

The physiography of the San Juan and GMUG National Forest ARWA area is complex and diverse compared to most other areas of the Rocky Mountain Region of the USDA Forest Service. This analysis encompasses portions of the Southern Rocky Mountain and Colorado Plateau physiographic provinces. The elevation in these forests ranges from approximately 4,900 feet to over 14,200 feet. The lowest elevation values are found in the western portion of the study area, and outside the GMUG and San Juan National Forests. A significant proportion of the higher elevations (e.g., > 8,000 feet) are within the GMUG and San Juan National Forests (Figure 1-15). Therefore, the management strategies on the GMUG and San Juan National Forests address issues within mostly montane, subalpine, and alpine ecosystems. The xeric lowlands to the south and west are largely outside of the management of these National Forests. Most of the lowland areas are managed by the Bureau of Land Management (BLM).

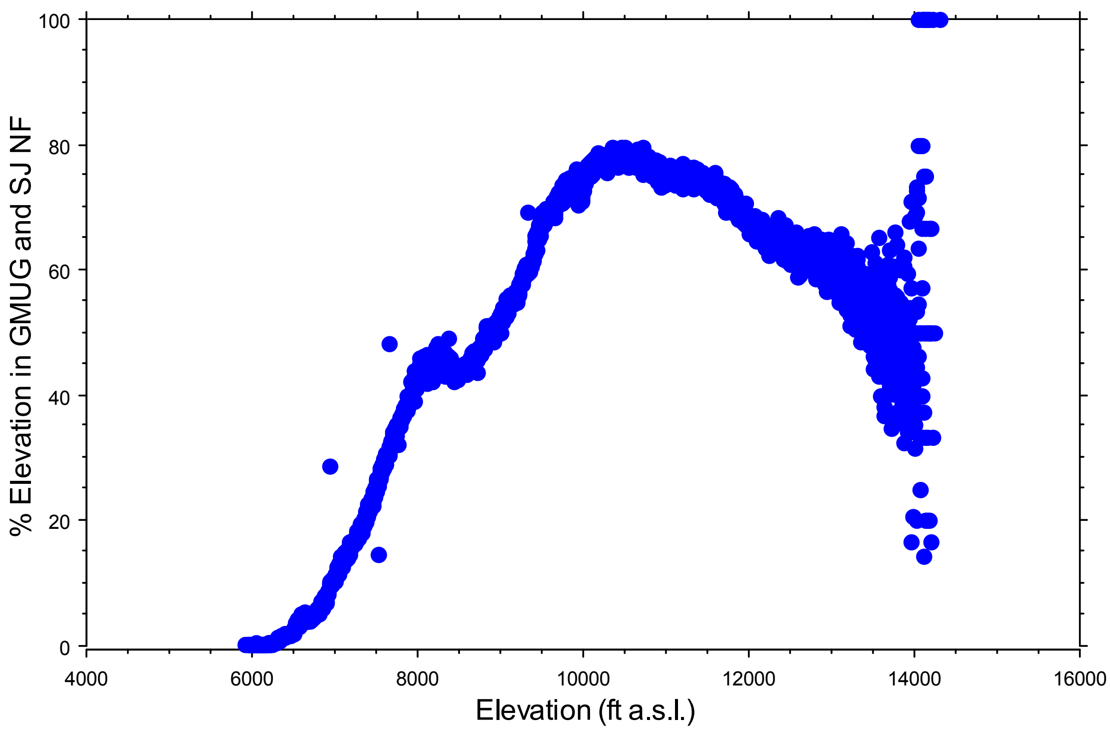

Figure 1-15. The percentage of elevational area within the GMUG and San Juan National Forests.

Differences in geology, vegetation, and climate characteristics are as dramatic as the range of elevation within the assessment area. Numerous periods of geologic uplift and erosion, volcanism, glaciation and climatic differences all contribute to this complexity.

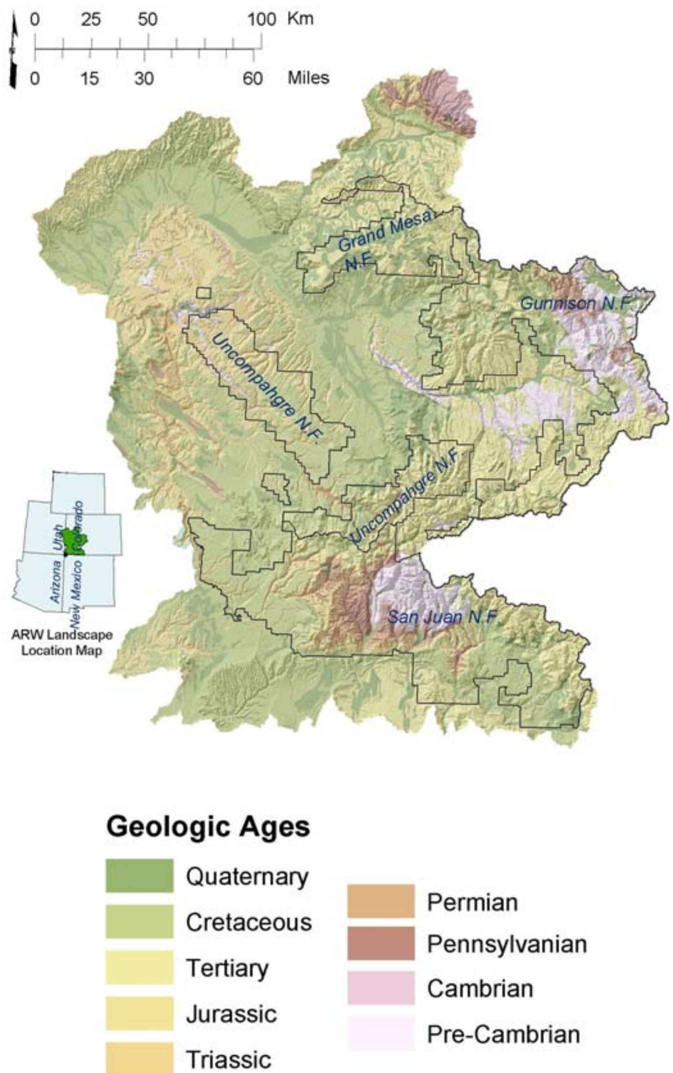

Figure 1-16. The geologic ages of rock units within the assessment area.

The ARWA area has been influenced by several periods of uplift and erosion. And is composed of rocks ranging in age from Precambrian crystalline rocks to unsorted Quaternary deposits of glacial, colluvial, and alluvial origin (Figure 1-16).

The study includes sedimentary, metamorphic, and igneous rocks (Figure 1-17). These differences in geology result in different conditions related to aquatic productivity and sediment production.

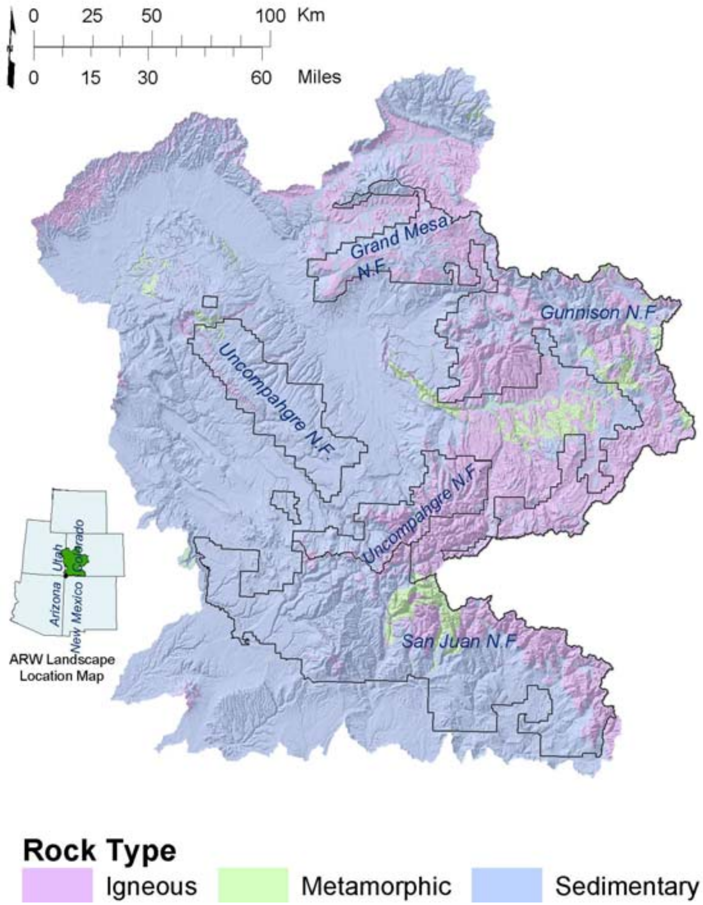

Figure 1-17. Geology of the San Juan and GMUG National Forests.

The USDA Forest Service administers 5.2 million of the 14,245,187 acres comprising the ARWA landscape scale. A majority of the lands administered by the Forest Service are located in the central and eastern portions of the landscape scale. Elevation of this portion of the landscape scale ranges from ~4,100 feet to ~14,200 feet. A majority of the area outside of the national forest administrative boundary is below 6,000 feet. The surficial rocks in this area tend to be sedimentary units with maximum ages of ~300 million years. The uplift of the Colorado Plateau during the Laramide orogeny created a varied topography of canyons, mesas, and plateaus.

Climate in this portion of the study area tends to be semi-arid, with a precipitation regime driven largely by monsoonal influence. The non-Forest Service lands have significantly less precipitation than the higher elevation areas administered by the U.S. Forest Service (Figure 1-18). Rainfall constitutes a vast majority of the annual precipitation driving the hydroclimatic regime of the non-Forest Service lands within the ARWA landscape area (Figure 1-19). However, stream systems within the National Forest boundaries are influenced to a large extent by annual snowmelt events.

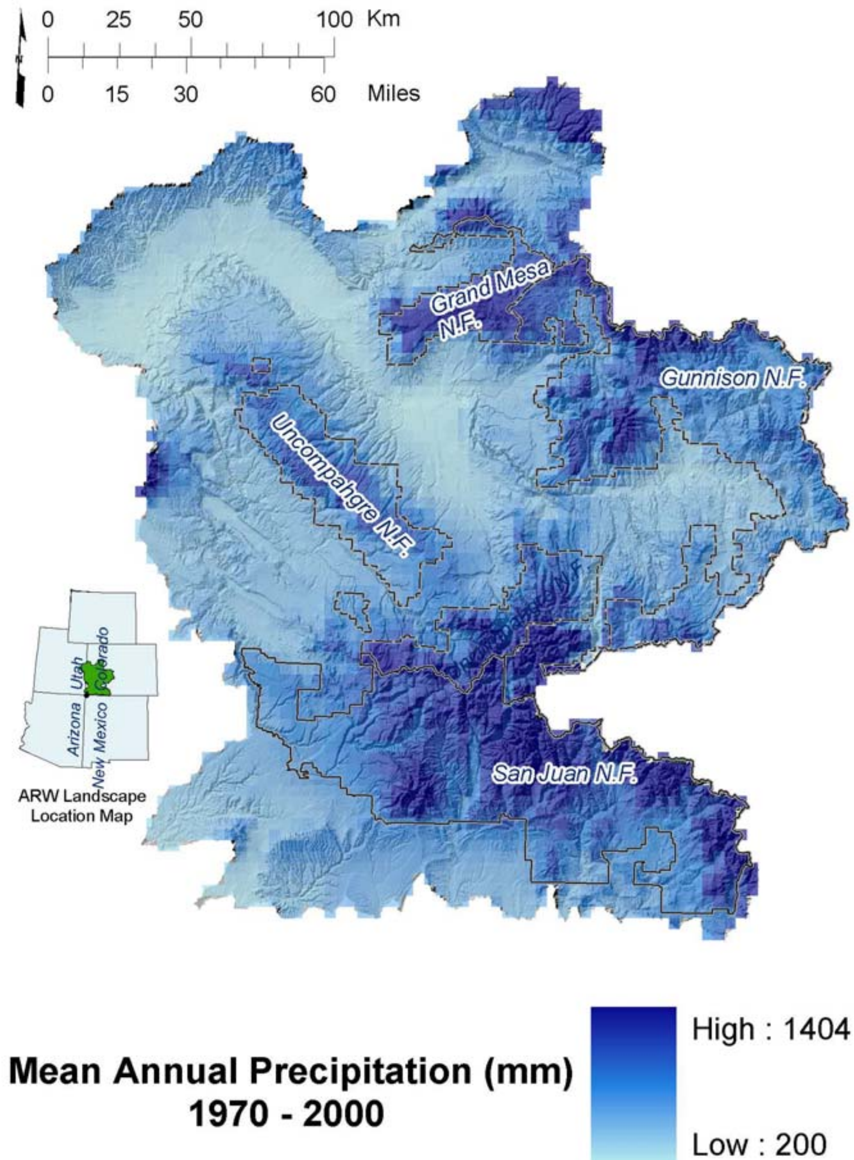

Figure 1-18. Mean annual precipitation (mm) of the San Juan and GMUG National Forests.

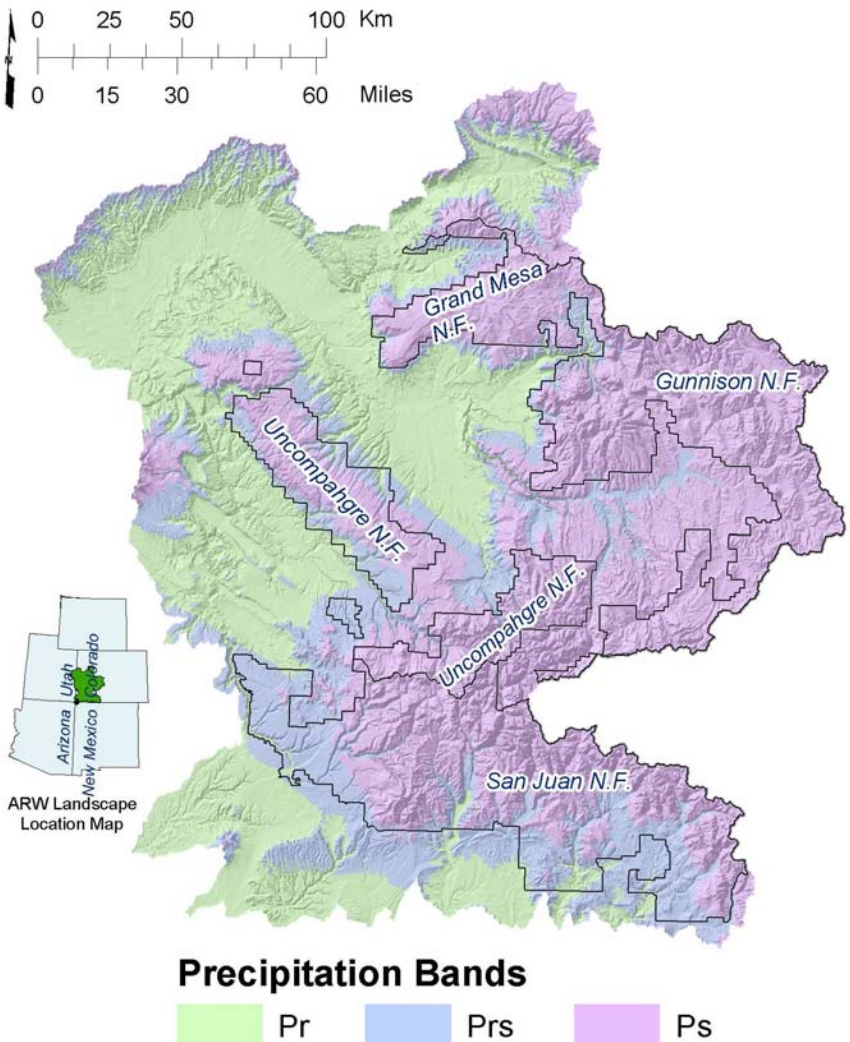

Figure 1-19. Precipitation bands of the San Juan and GMUG National Forests: Pr is rain; Prs is rain and snow; and Ps is snow.

San Juan National Forest

The San Juan National Forest comprises the mountainous southern portion of the study area (Figure 1-7). Elevation in the Forest ranges from ~6,200 to 14,200' (Figure 1-20). Dramatic peaks, rugged ridgelines, glacial valleys, and river canyons characterize the major landform features of the San Juan National Forest. The geomorphic processes associated with Pleistocene glaciation have left their signature on the San Juan National Forest. Broad, U-shaped valleys, cirques, tarns, and glacial moraines are common at higher elevations.

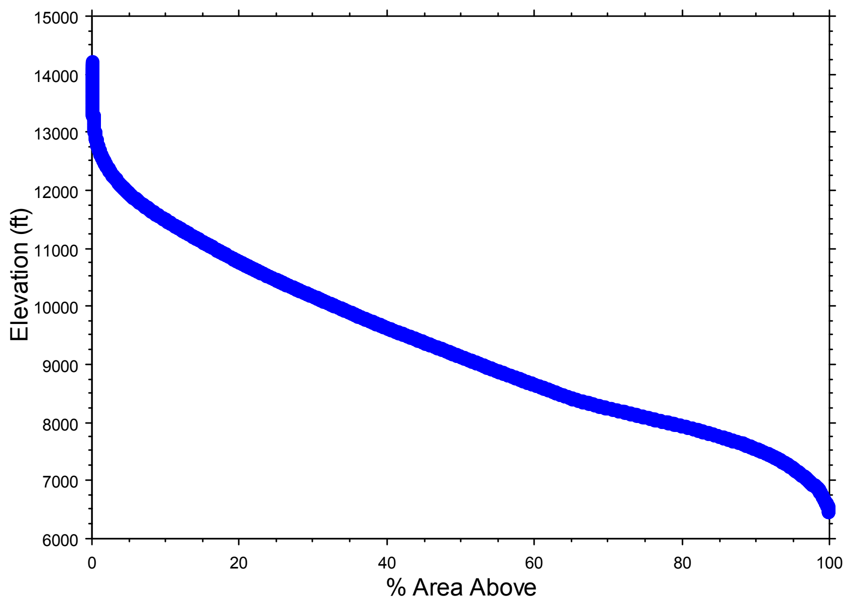

Figure 1-20. The distribution of elevation values within the San Juan National Forest.

The Forest is characterized by a complex geologic history including periods of uplift and erosion, volcanism, regional metamorphism, and Quaternary glaciation. Figure 1-21 and Figure 1-22 illustrate the geology and ages on the San Juan National Forest. Precambrian basement rocks of the Needles Mountains and central portion of the Forest have been dated to ~1.8 billion years. (Van Loenen and Gibbons 1997). Tertiary volcanic rocks flank the northern and eastern sides of the basement core. These Tertiary rocks were formed during a period of massive volcanism between 40 and 20 million years (Van Loenen and Gibbons 1997). Sedimentary rocks to the south and west were deposited beginning ~550 million years ago. These units represent the remnants of the modern and ancestral Rocky Mountains. Erosion associated with at least two periods of regional uplift contributed sediment deposited in these units. Quaternary glaciation has sculpted the higher elevations into areas characterized by broad glacial valleys bounded by dramatic mountain summits and ridgelines. Snowfall is the predominant precipitation type, which influences the hydroclimatic regime of the San Juan National Forest (Figure 1-23).

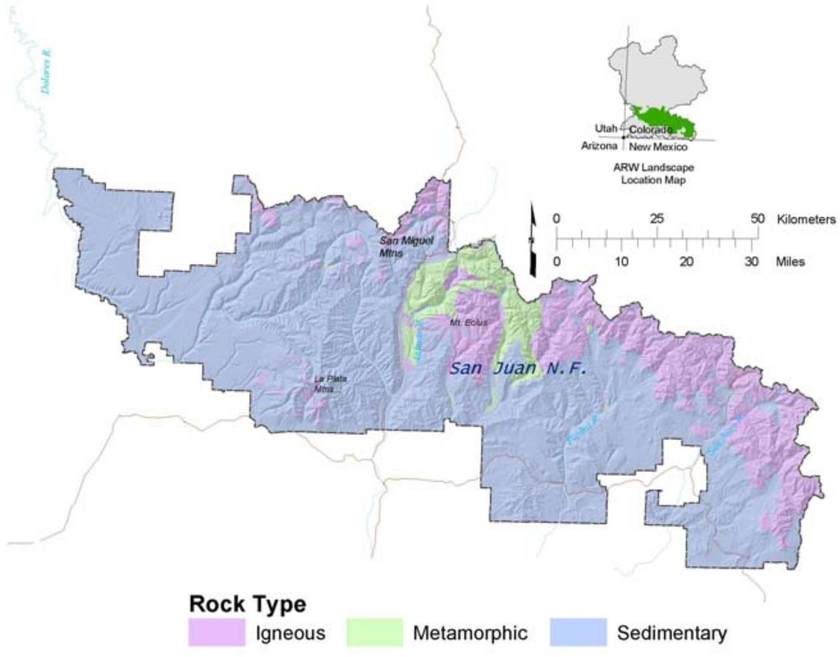

Figure 1-21. Geology of the San Juan National Forest.

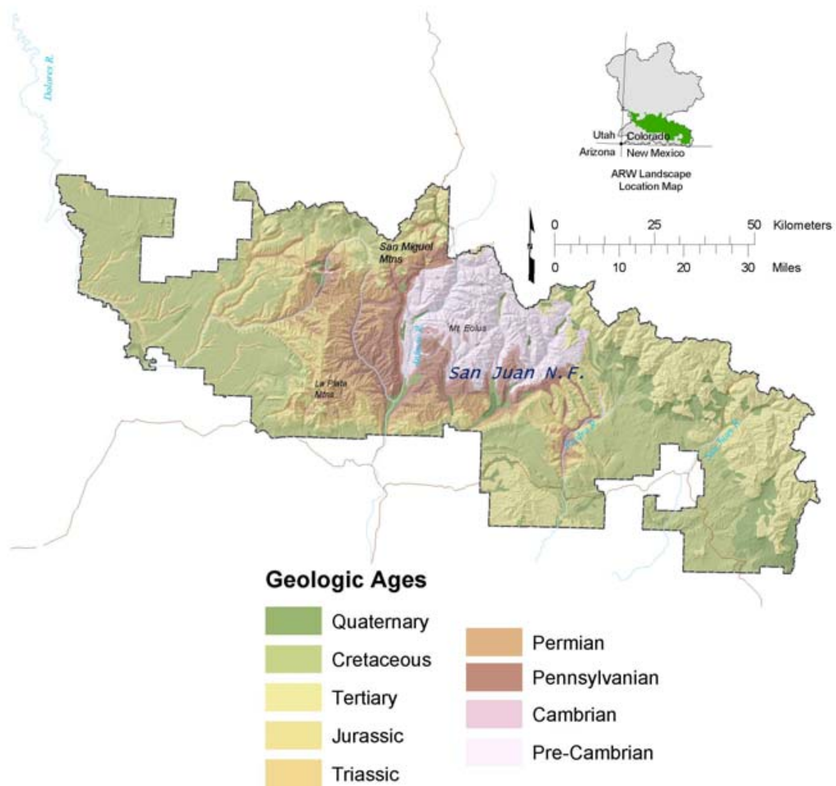

Figure 1-22. Geologic ages of bedrock in the San Juan National Forest.

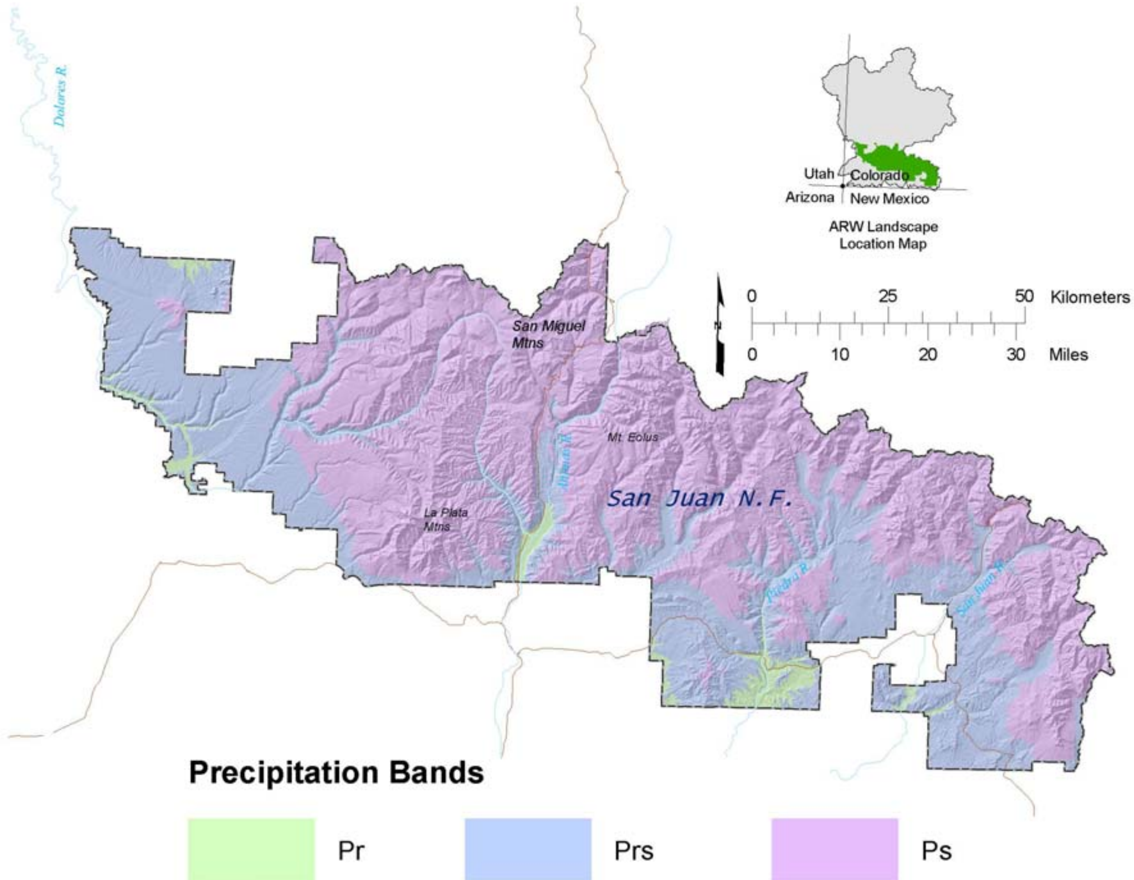

Figure 1-23. Precipitation types in the San Juan National Forest: Pr is rain; Prs is rain and snow; Ps is snow.

Grand Mesa, Uncompahgre and Gunnison National Forests

The Grand Mesa, Uncompahgre and Gunnison National Forests are administered as a single unit collectively referred to as the GMUG National Forest. These Forests comprise the central, northern and northeastern portions of the assessment area (Figure 1-7). Within these Forests, elevation ranges from 5,800 feet to 14,309 feet at the summit of Uncompahgre Peak (Figure 1-24). Figure 1-25 and Figure 1-26 illustrate the geologic distribution and relative ages on the GMUG National Forests.

The Grand Mesa National Forest is characterized by large mesas and broad valleys created by fluvial processes. Lower elevations are underlain by Cretaceous sedimentary rocks. The Grand Mesa, Battlement Mesa, and the Flattops are capped by basaltic flood lava which produces a unique topography (Day and Bove 2004). The Grand and Battlement Mesas were likely covered by small icecaps during the Quaternary (Yeend 1969).

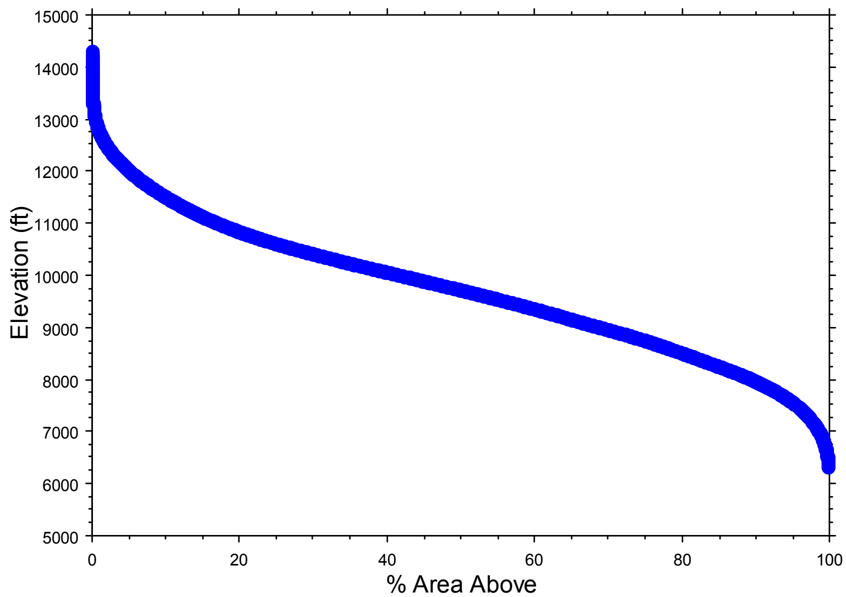

Figure 1-24. The distribution of elevation in feet within the GMUG National Forests.

The Gunnison and Uncompahgre National Forests are characterized by mountainous topography. On the Gunnison National Forest, the Laramide orogeny uplifted the Precambrian basement rock subsequently exposed by glacial and fluvial erosion processes. Permian and Pennsylvanian aged sedimentary rocks flank the Precambrian basement rock to the north and south. Igneous rocks of Tertiary age associated with post-Laramide volcanism are interbedded with Cretaceous and younger sedimentary units. This combination of rock types and ages are evident in the western and southern portions of the Gunnison National Forest and the eastern portion of the Uncompahgre National Forest (Day and Bove 2004).

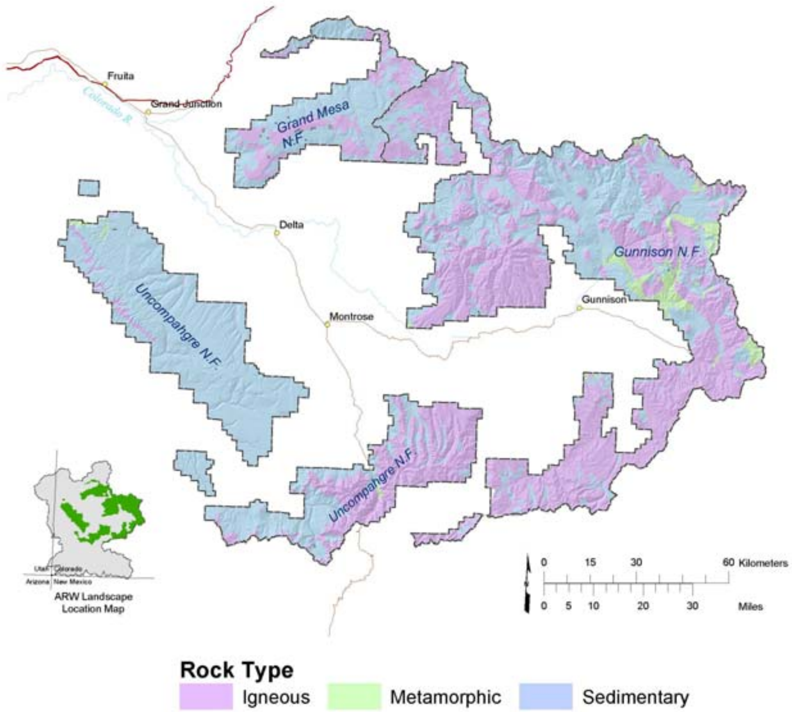

Figure 1-25. Geology of the GMUG National Forests.

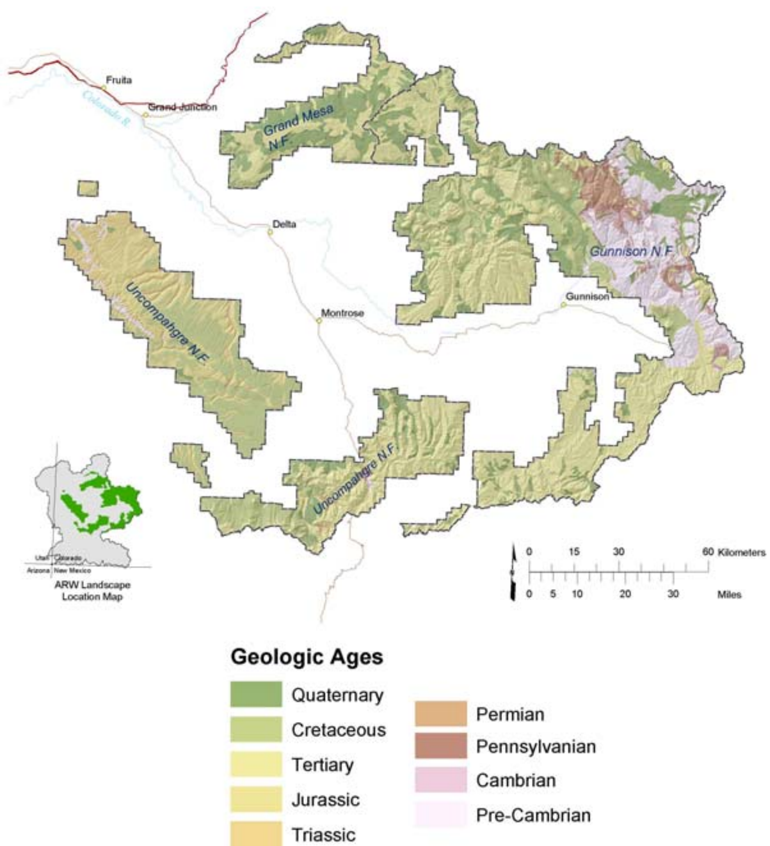

Figure 1-26. The geologic ages of rocks in the GMUG National Forests.

The Uncompahgre Plateau comprises the western portion of the Uncompahgre National Forest. This area is characterized by a narrow band of uplifted Precambrian basement rock and Tertiary volcanics on the southwestern portion of the plateau. The rest of the plateau is underlain by sedimentary units of Triassic and younger ages. Larger rivers have incised into the predominately metamorphic Precambrian basement rocks on the northeastern flanks of the plateau.

The complexity of the climate of the GMUG National Forests is reflected by the wide range of vegetation types found on these Forests. The lower elevations contain upper-Sonoran type vegetation associated with a semi-arid climate (Day and Bove 2004). Pinon-juniper vegetation is found at mid-elevations, while the higher elevations contain montane, subalpine, and alpine vegetation types. Quaternary glaciation has influenced many of the valleys at higher elevations. Snowfall is the predominant precipitation type influencing the hydroclimatic regime of the GMUG National Forest (Figure 1-27).

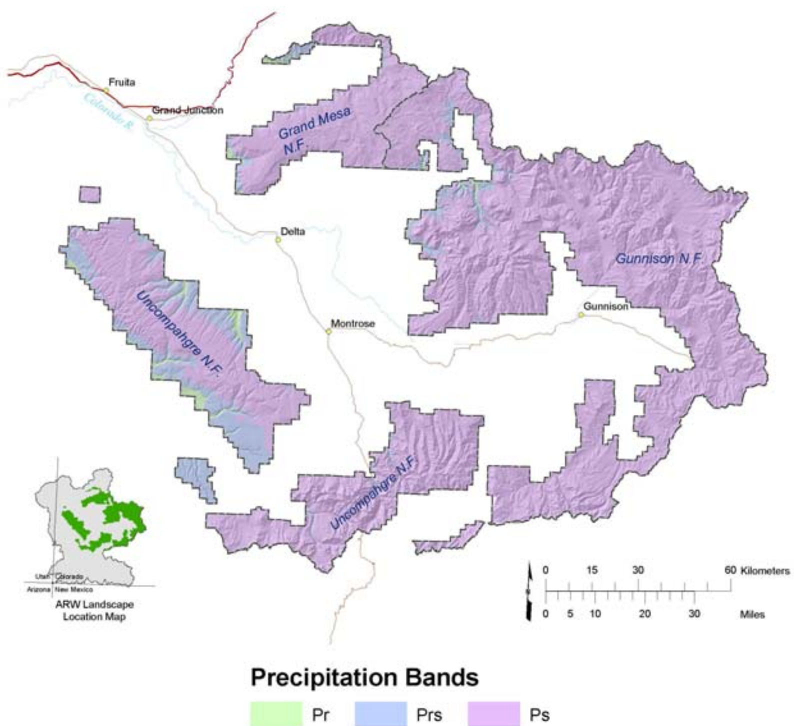

Figure 1-27. The precipitation types in the GMUG National Forest: Pr is rain; Prs is rain and snow; and Ps is snow.

Chapter 2 Ecological Driver Analysis

The Importance of Ecological Drivers in Determining Aquatic, Riparian, and Wetland Resources

Ecological drivers are environmental factors that exert a major influence on aquatic, riparian, and wetland ecosystems and ultimately on the fitness of individuals and species population size. These drivers can be considered as comprising the physico-chemical "template" of an ecosystem (Poff and Ward 1990), and the dominant expression of species and community composition at that scale (Poff 1997). Thus, characterizing the expression of drivers for particular spatial units (e.g., 6^{th} level HUBs) across the Forest provides a basis for expectation of ecological condition within those units. Similarly, where drivers are modified by human activity, an altered template creates conditions that favor an altered ecological community. Therefore, identifying the major ecological drivers is an appropriate place to begin an ecosystem-level assessment because of the overwhelming influence of habitat conditions on the distribution and functioning of aquatic, riparian, and wetland resources across a region.

Identification of Ecological Drivers

Identifying the major ecological drivers important for determining aquatic, riparian, and wetland resources within a region forms the basis for the ecosystem assessment protocol described in this document. There is an extensive scientific literature that describes the influence of various abiotic and anthropogenic factors on the structure and function of aquatic, riparian, and wetland ecosystems. From this literature, a team of hydrologists, ecologists, and biologists familiar with the region should be able to identify a set of ecological drivers that determine the spatial distribution and levels of productivity for aquatic, riparian, and wetland ecosystems in the management area of interest.

The drivers identified for the analysis of riparian and aquatic analysis were geology, chemistry, hydroclimatology, and stream gradient characteristics. These drivers influence the riparian communities, fish community distribution and abundance, instream production, and sediment transport dynamics. These influences and resulting clusters can also help understand the sensitivity of management activities to environmental change and the abundance or rarity of ecosystem characteristics.

The drivers identified for the wetland analysis included chemistry, hydroclimatology, and the presence or absence of Pleistocene glaciation, because they are the major factors influencing the distribution and abundance of wetlands.

Ecological Driver Definitions for Aquatic and Riparian Systems

Geology

The geology of the San Juan region is extremely complicated (Bankey, 2004; Day and Bove, 2004). Various rock units record 1.8 billion years of repeated uplift, erosion, sedimentary deposition, and volcanic activity. The oldest rocks are sediments and volcanic units deposited in an island-arc setting similar to present-day Indonesia and subsequently buried, intruded by igneous rocks, metamorphosed and deformed. The Ancestral Rockies formed approximately 300-400 million years ago were subsequently eroded and replaced by both continental and marine depositional sedimentary environments. Renewed uplift beginning circa 60 million years ago was accompanied by extensive volcanism. Rifting facilitated basalt flows and the intrusion of granitic rocks. Several episodes of volcanism between 30 and 22 million years ago formed the highlands of the San Juan Mountains. The period between 28 and 26 million years ago had particularly extensive and often violently explosive eruptions of volcanic materials which created 9 major ash-flow sheets and several collapse calderas that are now deeply eroded (Lipman, 2000). Many of the mineral deposits that form the Colorado Mineral Belt were emplaced during this period. Further uplift between 20 and 5 million years ago exposed the region to erosion, forming a regional erosional surface that dissected earlier surfaces.

Influence on Aquatic and Riparian Systems

Geology is used in this analysis primarily in reference to the relative volume and grain-size of sediment introduced to stream channels through weathering and erosion. Bedrock in the San Juan study area is designated either *Ri* or *Ro*. *Ri* indicates intrusive igneous rocks that, in this study area, produce low to moderate sediment yield to rivers.

Ro indicates all other bedrock types (sedimentary, volcanic, and metamorphic) present in the study area (Figure 2-1), all of which produce moderate to high sediment yields of both fine (clay to fine gravel) and coarse (medium gravel to boulders) sediment. Many aquatic and riparian organisms are sensitive to increased yields of sediment to river channels. Bedrock lithologies that consistently produce larger amounts of fine sediment, in particular, create watersheds that are sensitive to hill slope disturbance in the sense that any natural (eg. wildfire) or anthropogenic (eg. timber harvest) activity that destabilizes hill slopes is likely to produce massive sediment yields to rivers over a period of several years following the disturbance. However, the physical characteristics of these rivers may already reflect high sediment supply (as for example, in a braided river), and the aquatic and riparian species living in these rivers may be those that are more tolerant of periodic disturbance from excess sediment.

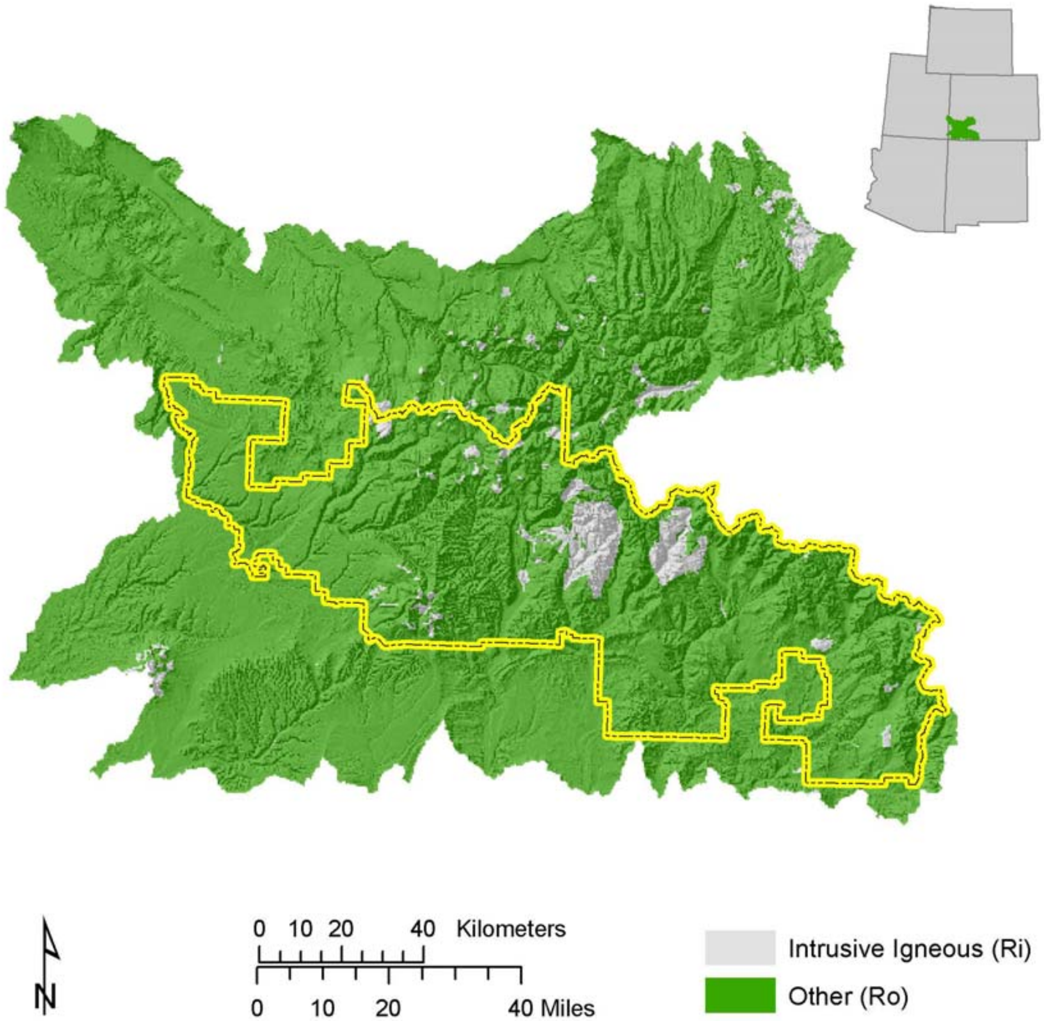

Figure 2-1. Rock types of the San Juan NF Landscape Scale.

Influence on Wetland Systems

Bedrock type influences the rate of mineral sediment flux from hillslopes as well as the geochemistry of surface and ground waters. Many igneous and metamorphic rocks decompose more slowly than sedimentary or volcanic rocks and produce less sediment. An abundance of sediment can fill basins in mountain landscapes reducing the area available for wetlands, and may limit the occurrence of specific wetland types. For example, high mineral sediment fluxes may fill kettle basins, and sediment deposited in wet meadows, floodplains, or fens increases the relative water table depth, limiting the area of wetlands. Fens, with organic soils and exceedingly slow peat accumulation rates (~20 cm /1000 years in many areas (Chimner and Cooper 2003) cannot form or persist where the influx of mineral sediment from slopes exceeds the rate of organic matter accumulation.

Chemistry

The chemical composition of the surficial geology significantly influences aquatic, riparian, and wetland ecology. For the purpose of the San Juan NF ARW assessment, it is important to differentiate between calcareous and non-calcareous lithologies (Figure 2-2).

Calcareous rocks contain calcium carbonate (CaCO3). This includes sedimentary rocks such as dolomite and limestone, as well as metamorphic rocks (e.g., marble) derived from calcareous sedimentary rocks. Non-calcareous rocks do not contain calcium carbonate, and include igneous rocks, sedimentary rocks, such as shales, sandstones, mudstones, and siltstones, as well as metamorphic rocks derived from non-calcareous parent rocks, such as gneiss, schists, and quartzite's.

Weathering processes affect calcareous and non-calcareous rocks differently. Calcareous rocks weather by solution. The weak acids in rainfall, groundwater, and snowmelt react with the calcium carbonate in the rock. As this occurs, minerals are carried away in solution. The solution resulting from this weathering process is introduced into surface and ground water. As a result of the chemical reactions between the calcium carbonate and the acids in the water, the chemistry of the solution differs from that of the rainfall, snowmelt, or groundwater. Runoff or groundwater percolation introduces this solution into stream, riparian, and wetland habitats. This solution consequently interacts with the rainfall, snowmelt, or groundwater to influence aquatic, riparian, and wetland biota.
Non-calcareous rocks weather by mechanical processes, including frost action, crystal growth, and attrition of particles as they are transported by wind, water, ice, or gravity. The physical structure of the rock influences the size of the sediment produced by weathering. Crystalline rocks such as granites, diorites, basalts, and gabbros will produce particles ranging in size from boulders to silts or very fine sands. Sandstones will weather into sand sized particles. Siltstones and shales will produce silt and clay size particles, respectively.

Influence on Aquatic and Riparian Systems

Chemistry is used in this analysis to differentiate calcareous and non-calcareous bedrock lithologies. *Ca* indicates calcareous rocks that contain calcium carbonate ($CaCO_3$). In the San Juan study area, this includes sedimentary rocks (eg. Leadville Limestone, Dyer Dolomite, Rico Formation, Hermosa Formation, Dolores Formation), and volcanic units other than basalts. Calcareous rocks weather by dissolution when weakly acidic precipitation, surface and ground waters react with the calcium carbonate. The resulting dissolved constituents move through surface and ground waters and affect aquatic and riparian biota. The weathering of calcareous rocks has several beneficial effects on aquatic ecosystems that enhance productivity; raising the pH of stream waters and producing carbon dioxide for photosynthesis (Hynes 1970). This change may effect production of benthic macroinvertebrates and fish dramatically. *Cn* in this analysis indicates non-calcareous lithologies that weather by both mechanical and chemical processes, but produce only negligible amounts of dissolved materials.

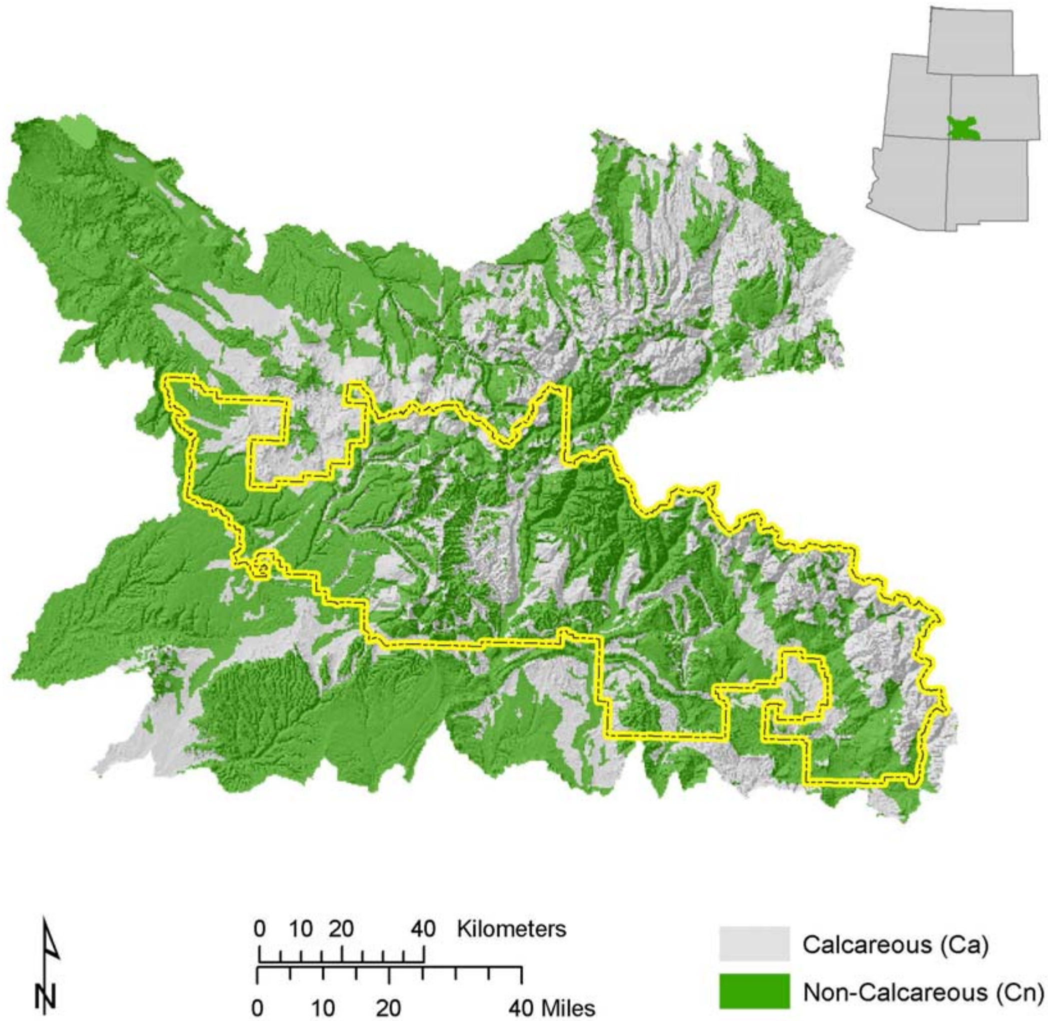

Figure 2-2. Extent of calcareous geology in the San Juan NF ARWA landscape scale.

Influence on Wetland Systems

Bedrock type influences water chemical content, and natural waters in the San Juan National Forest vary from acid in areas with granite and hard metamorphic rocks, to basic in areas with limestone, dolomite, and marine shale. Differences in mineral ion and salt concentrations dissolved in ground water, which supplies fens influences plant species composition forming the mineral rich to mineral poor gradient (Sjors 1950, Cooper and Andrus 1995, Chadde et al. 1998). In addition, salts may accumulate in salt flats, marshes and wet meadows and influence the soil geochemistry and control plant species composition and community production. Because of the solubility of calcareous bedrock, springs are often associated with the porous nature of this rock type, often creating areas of abundant spring habitats.

Hydroclimatology

Three major moisture input patterns resulting from large-scale seasonal atmospheric circulation affect Colorado. During midwinter, most atmospheric moisture originates from the Pacific Ocean and is directed by the polar jet stream into Colorado from the northwest, west, and southwest (Collins et al., 1991). This moisture fuels the mid-latitude cyclones that produce heavy snows at higher elevations, such as the San Juan Mountains. Orographic effects increase the amount of winter precipitation on the windward (usually the western) mountain slopes. Moisture from the Gulf of Mexico primarily affects the eastern half of Colorado during the spring and summer, and is associated with convective storms. The third major moisture source affects primarily the San Juan Mountains. From about mid-June to as late as early October, a monsoon-like circulation affects mainly the southern half, and especially the southwest corner, of Colorado. Subtropical moisture from the Pacific Ocean and the Gulf of California is transported into the southwestern part of the State, producing frequent summer thunderstorms. From late August through October moisture from dissipating tropical storms occasionally enters southwestern Colorado, as well. Severe and widespread flooding has historically resulted from dissipating tropical storms crossing the San Juan Mountains, as in October 1911, August 1951, and September 1970 (Pruess, 1996). Categories for this driver are snowfall (*Ps*), rain and snow (*Prs*), and rainfall (*Pr*) (figure 2.3).

Influence on Aquatic and Riparian Systems

Hydroclimatology is used to characterize the dominant flow regime along a river. *Ps* indicates streams with snowmelt dominated flow regime. In the San Juan study area, this characterizes stream segments above 2400 m elevation (Pruess, 1996). These stream segments typically have less interannual variability in flow than the other hydroclimatic types; have a broader portion of the annual hydrograph above base flow; and have a lower peak and a longer duration than rainfall-dominated streams. These streams generally exhibit lower temperatures and reduced productivity than warmer streams. *Prs* indicates a flow regime with an annual snowmelt peak during late spring or early summer, as well as rainfall from convective storms or from dissipating tropical storms from mid-summer through autumn. Many of these stream segments at least once a decade have a rainfall-generated peak discharge that is greater than the snowmelt peak discharge. In the San Juan study area, these stream segments occur below 2400 m elevation and have perennial flow. Because of the high variability in stream discharge throughout the year, stream productivity and biota population dynamics can also be quite variable. Localized effects of sudden discharge changes can influence populations of algae, benthic macroinvertebrates and fish at locally. However, most biota life-history characteristics are influenced more by the higher magnitude snowmelt runoff events. *Pr* indicates streams with a flow regime dominated by rainfall-generated runoff. These streams have flashy hydrographs with a larger peak and shorter duration than snowmelt streams. In the San Juan study area, these stream segments are likely to be ephemeral, flowing only after rainfall, and to originate below 2128 m in elevation. Biota that inhabit these types of systems have developed strategies to exist in these harsh environments.

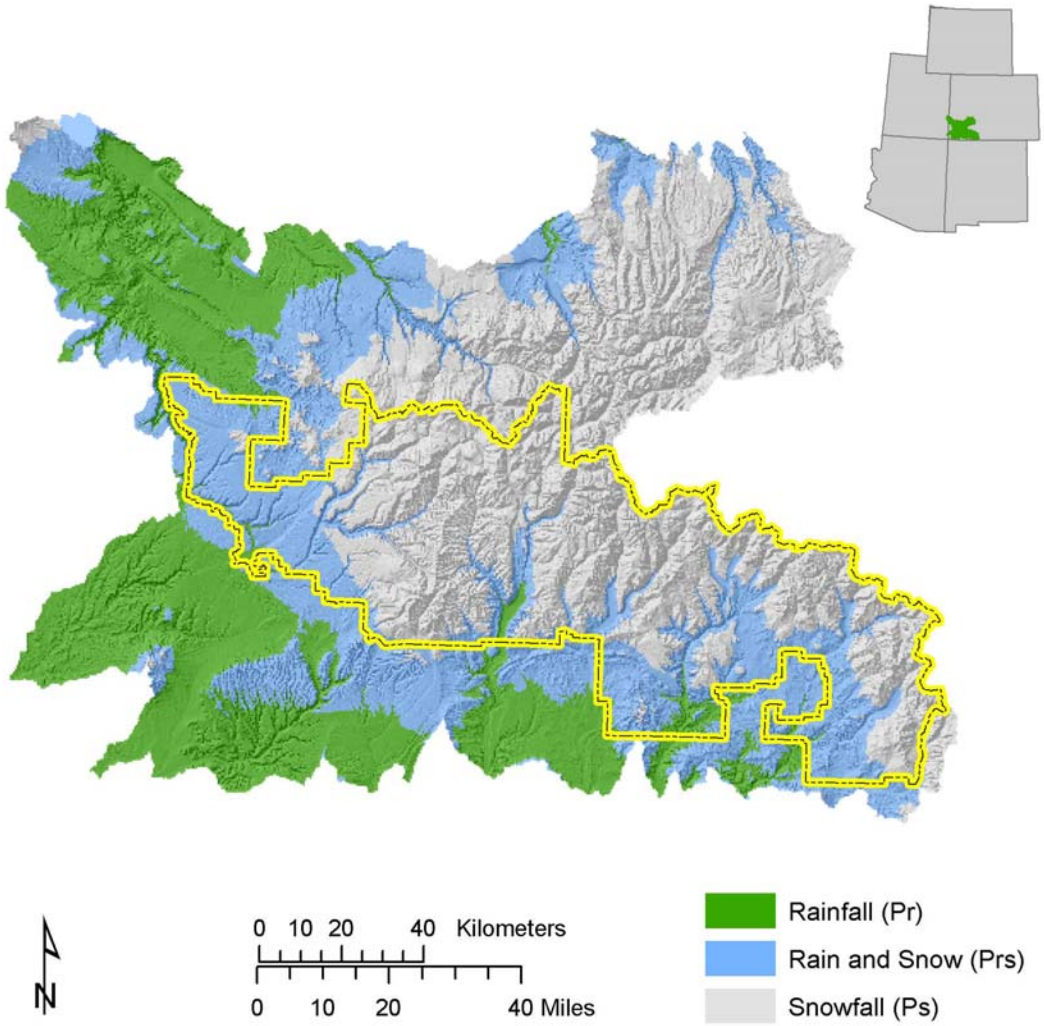

Figure 2-3. Hydroclimatic regimes of the San Juan NF Landscape Scale.

Influence on Wetland Systems

Climate controls the hydrologic regime of streams, influencing riparian ecosystems through the timing and magnitude of peak flows, and the perennial or intermittent nature of streams. Most precipitation in the higher elevation mountains and valleys of the San Juan NF is from snow, and these areas also receive much greater amounts of precipitation than lower elevation areas. The greater input of water via precipitation supports an abundance of wetlands, and greater variation in wetland types, because large ground water-driven wetland complexes are found primarily in association with snowmelt-recharged aquifers. Within the snow dominated precipitation zone, streams have a more predictable annual flow pattern, and experience fewer extreme floods. These streams are influenced by snowmelt recharge of hill slope aquifers, which provides groundwater to support perennial stream flow during the summer. Lower elevation watersheds dominated by rain or rain-and-snow driven hydrologic regimes tend to be flashier, with less predictability in timing and magnitude of the annual peak flow, and potentially higher peak floods relative to the mean annual flow. Many streams with headwaters in areas with rain and rain-and-snow precipitation regimes are intermittent and many lack riparian vegetation because perennial groundwater during the summer is too deep to be reached by the roots of riparian plants.

Gradient

Gradient is used here to designate the average downstream gradient of a segment of channel. Gradient influences stream power, stream erosive capability, and sediment texture in the channel and floodplain. “High” indicates stream segments with a downstream gradient greater than 4%, which usually corresponds to a step-pool morphology that is fairly resistant to high-flow disturbances. These streams typically have bedrock or coarse boulder and cobble channel beds. Floodplains are narrow or may be non-existent, and have coarse-textured soils that drain rapidly and are periodically eroded by high-energy floods or debris flows. Narrow valley bottoms promote high connectivity between hill slope and valley bottom, with debris flows and landslides episodically introducing sediment, wood and nutrients directly to the channel. “Medium” indicates stream gradients with a downstream gradient between 1.5% and 4%, which often corresponds to a channel form transitional between step-pool and pool-riffle morphology. These stream segments are intermediate between high and low gradient streams in terms of valley-bottom width, streambed grain size, and resistance to disturbance. Medium gradient streams have wider valley bottoms in which some of the sediment transported from valley side slopes can be stored before reaching the channel. “Low” indicates stream segments with a gradient less than 1.5%, which usually corresponds to straight or meandering pool-riffle morphology formed in gravel- to sand-size sediments. The pools are particularly sensitive to sediment disturbance and low gradient streams are sometimes designated response reaches (Montgomery and Buffington, 1997) because of their tendency to accumulate excess sediment preferentially in pools. Low gradient streams have wider valley bottoms and greater lateral mobility compared to stream segments in steeper, narrower valley bottoms. Lateral mobility depends on both flow characteristics and bank resistance; bank resistance depends on grain size, stratigraphy and the presence and type of riparian vegetation. Sediment coming from adjacent hill slopes is less likely to reach low-gradient channels directly during mass movements, but is more likely to be stored on the valley bottom for a period of years and then mobilized into the channel during lateral channel migration or overbank flooding.

Influence on Aquatic and Riparian Systems

Stream gradient influences stream power, stream erosive capability, and sediment texture in the channel and floodplain. High gradient streams typically have bedrock or coarse gravel and cobble channel beds. Floodplains also are typically narrow, or may be non-existent. Those that do exist typically have coarse-grained sediments. Floodplains with coarse-textured soils drain rapidly, and are periodically eroded by high-energy floods. These sites support primarily small communities of herbaceous vegetation, or woody plants that can tolerate periodic high-energy floods, and many support clonal plants, such as narrow leaf cottonwood (Populus angustifolia) and red osier dogwood (Cornus stolonifera) that sucker following flood disturbance. Low gradient streams typically have wider floodplains with finer-grained soils, and support diverse plant and animal communities. Low gradient stream reaches with extensive willow communities may also support beavers, ecosystem engineers that distribute water and sediment across the valley, increasing hydrologic and ecological complexity.

Biota such as benthic macroinvertebrates are highly adapted to different substrate sizes. Those that live in steeper stream channels with larger substrate and reduced boundary layers have adaptations that help them cling to the substrate, feed on attached algae, and are
Often dorso-ventrally flattened to avoid the current (Hynes 1970). Others take advantage of the current and build elaborate nets or hold appendages in the current to trap food that floats by. Benthic macroinvertebrates that live in lower gradient reaches with smaller substrate have adapted to these conditions by burrowing into the finer substrate and become more generalist feeders. As a result, there are typically considerable differences in the composition of community structure of benthic macroinvertebrates between high and low gradient stream channels.

Fish also exhibit changes between high and low gradient stream channels, with moderate sloped channels showing some characteristics of both. In high gradient channels, large substrate and "roughness" create adequate habitat. However, high stream velocities reduce this habitat especially during high discharge conditions. Generally, trout and other fish species found in the san Juan mountains exhibit relatively lower population levels in these areas. Low gradient stream reaches that are not impacted by anthropogenic activities typically exhibit much higher habitat conditions and population sizes. Increased stream depths and reduced stream velocities are more conducive habitats than the steeper high velocity areas in high gradient reaches. However, because these low gradient reaches are where sediment tends to deposit from upstream erosion, they are often the most disturbed by anthropogenic activities.

Glaciation

The high areas of the San Juan Mountains were repeatedly glaciated during the Pleistocene epoch (2 million to 10 thousand years ago). The latest major period of glaciation, termed the Pinedale Glaciation, covered large areas of the highlands centered near Silverton, where localized ice caps formed, and extensive valley glaciers flowed to the north down the Uncompahgre, south down the Animas and east down the Rio Grande valleys. In many areas the glaciers extended far from the highland areas where ice accumulated and produced glacial landforms in relatively low elevation landscapes. The Pinedale glacial period ended approximately 14,000 years ago. Glaciers scour cirques and valleys as the ice flows downhill, and pushes debris ahead of it, and off to the side. In addition, the glaciers pluck rock and finer sediments from bedrock along its path, which gets incorporated into the ice. At the glacier's terminus an end moraine is deposited, as if pushed up by a huge bulldozer. In addition, large lateral moraines, along the glacier's margins are produced. Once the glacier stagnates, it melts and the debris within the ice is deposited forming "dead ice deposits", such as kettles and ground moraine. Terminal moraines may have blocked the drainage of entire valleys forming lakes, some of which persist today. Sediments from the melting glacier filled some lakes, and in other cases the filling of lakes by stream transported sediment led to the breaching of terminal moraines and the stream channel eroded through the debris. Where moraines have persisted and the valleys behind them have filled with sediments large relatively level landforms were generated that are conducive to wetland formation. The area covered by ice during the last glacial maximum is well known for the San Juan Mountains from the work of Atwood and Mather (1932). Glaciated and unglaciated regions in the San Juan National Forest are delineated in Figure 2-4. For our analysis glaciated regions are labeled as "Qg", and non-glaciated regions are labeled as "Qn".

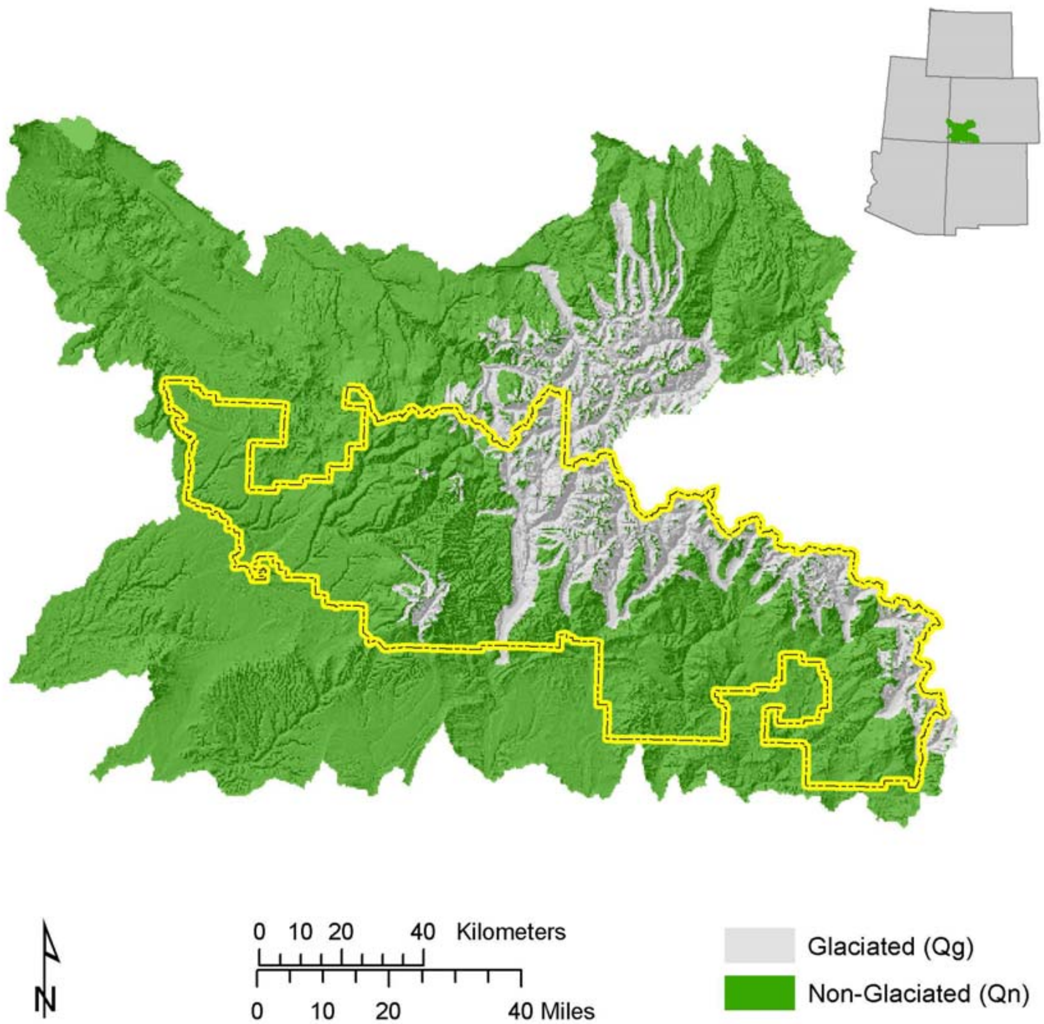

Figure 2-4. Extent of Pleistocene glaciation for the San Juan NF ARWA landscape scale.

Influence on Wetland Systems

Glaciation during the Pleistocene created landforms in high and middle elevation valleys and mesas that are conducive to the formation of wetlands and riparian zones. The broad relatively level valleys created by glaciers support sinuous streams, and broad riparian zones. Cirques and high elevation valleys have been scoured so that they are wider and flatter, and are conducive to wetland formation. Lateral moraines on the sides of valleys are composed of thick masses of unconsolidated sediments, and hold large volumes of snowmelt-recharged ground water, supporting localized flow systems that feed wetland complexes, including fens, wet meadows and marshes at their base. Kettle basins in dead ice moraines are depressions that support lakes, ponds, marshes, and fens. In general the processes of glacial erosion have made landscapes more suitable for wetland and riparian area development by flattening the gradient of these high mountain landscapes and retarding the runoff of water. In addition, the deposition of terminal and lateral moraines near the glaciers terminus and along the sides of glacial valleys have produced the largest unconsolidated deposits in the mountains, which support critical ground water resources that supply water to streams and wetlands. These wetlands provide critical habitat for waterfowl, amphibians, aquatic invertebrates and many plant species.

Ecological Driver Analysis for Riparian Areas Including Sediment Dynamics, Instream Production, and Fisheries

Landscape Scale

Key Findings

- Clusters 2r and 3r are found primarily in the San Juan National Forest boundary and may constitute ecosystems and associated species that are relatively rare outside the Forest boundary and may provide management opportunities
- Clusters 5r, 7r and 8r are found predominately outside the Forest boundary, with potentially limited ability for protection for these type of ecosystems when compared to the surrounding landscape
- Most of the streams at this scale exhibited high stream gradients, especially associated with the Forest. These results would indicate that the mountainous areas associated with the National Forest have a relatively high potential for moving sediment from uplands into stream systems, both naturally and through management activities.
- Calcareous geology is found throughout this scale, with the highest concentrations found in clusters mostly outside of the Forest boundary (e.g. 6r, 7r). Areas of high calcareous geology within the Forest boundary are most likely associated with spring and wetland development as well as higher aquatic productivity
- The limited amount of low gradient stream reaches, calcareous geology and high percentage of snow driven precipitation would indicate that riparian and aquatic productivity is limited and sensitive to management activities. Productivity and populations would be expected to be in watersheds and reaches with low gradient stream channels; calcareous geology and rain on snow precipitation would be expected to increase productivity further.

Introduction

The following sections contain the results of the ecological driver analysis associated with the ARWA landscape scale of the San Juan National Forest. Results at this scale are influenced most directly by conditions and management activities within the National Forest boundary (Winters et al. 2004a). Ecological processes (including species dynamics) are not limited by administrative boundaries but by ecological processes. As a result, entire HUBs are considered wherever possible instead of ending the assessment at the Forest Service boundary.

The cluster analysis of the 314 6th level watersheds comprising the San Juan National Forest management scale produced 8 groups of watersheds (Figure 2-5). In order to explain the importance of and differences between HUBs, we have prepared the following section. These sections will:

1) Provide a description of the cluster analysis methodology
2) Describe the individual clusters
3) Describe the relative importance of the clusters to fisheries
4) Describe the relative importance of the clusters to riparian vegetation
5) Describe the sensitivity of the clusters to alterations of the sediment regime and hydrology from natural and anthropogenic disturbances

Cluster Identification

An agglomerative cluster analysis was used to identify groups of watersheds that have similar ecological driver characteristics. Ecological drivers are defined as environmental factors that exert a major influence on the fitness of individual organisms and their populations, and help constitute the physio-chemical template of an ecosystem. Four ecological drivers were selected for the San Juan National Forest riparian driver analysis: lithologic composition (calcareous or non-calcareous), formative geologic process (igneous or non-igneous), hydroclimatic regime (rainfall, rain and snow, or snowfall), and stream gradient (high, medium and low). The agglomerative cluster analysis is based upon the percent area comprised by the potential ecological driver combinations within each HUB. The numerous combinations are abbreviated into percent of total stream length within each 6th level HUB for summary purposes (Table 2-1). The cluster analysis produces a dendrogram from which the ecological driver clusters are identified (Figure 2-6). Ecological driver clusters are identified by number (1 – 8) and color.

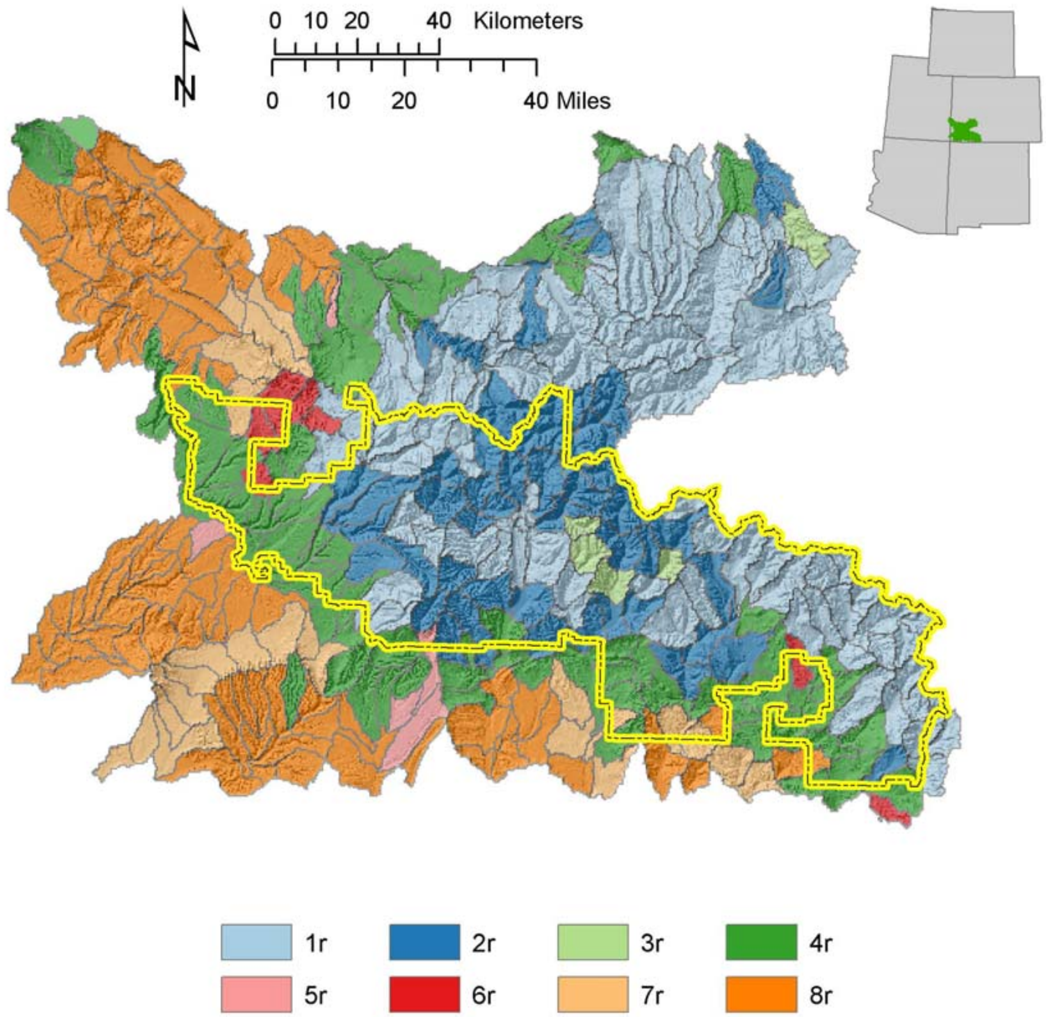

Figure 2-5. Riparian clusters of the San Juan NF Landscape Scale.

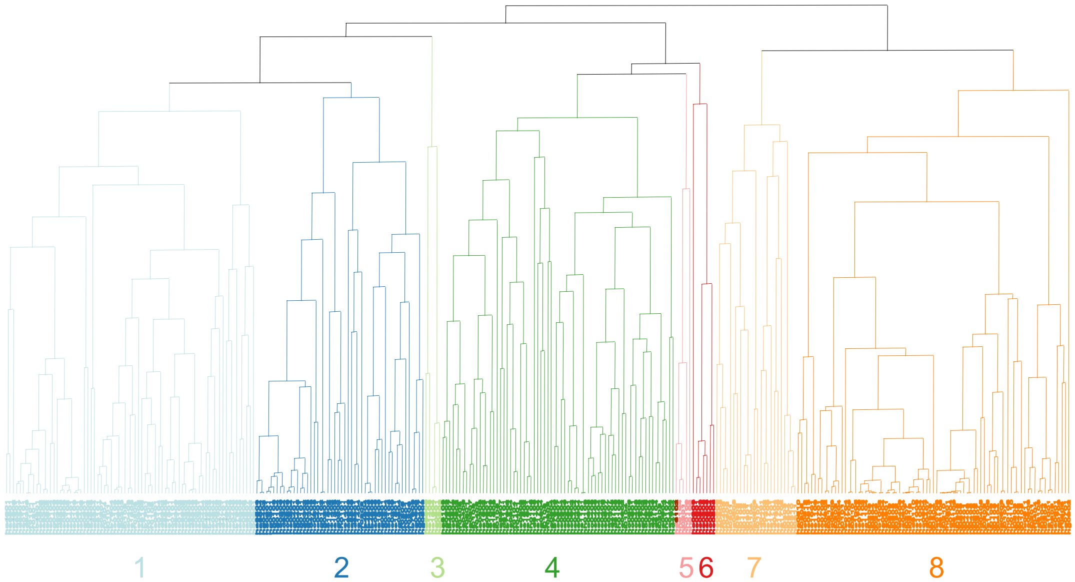

Figure 2-6. Dendrogram used to identify the riparian clusters of the San Juan NF Landscape Scale.

Table 2-1. Mean percentages of each driver in the San Juan NF Landscape Scale riparian clusters.

Clusters	Ca	Cn	Ri	Ro	Pr	Prs	Ps	low	medium	high	% in NF
1r	**60.9**	39.1	4.4	**95.6**	0.1	22.2	**77.7**	4.9	9.7	**85.4**	40.7
2r	24.1	**75.9**	7.5	**92.5**	1.1	25.7	**73.2**	6.8	9.1	**84.1**	73.4
3r	9.9	**90.1**	**73.7**	26.3	0.0	14.6	**85.4**	6.2	5.2	**88.6**	69.1
4r	27.0	**73.0**	0.2	**99.8**	16.3	**76.4**	7.3	12.5	27.6	**59.9**	38.3
5r	5.4	**94.6**	1.2	**98.8**	26.2	**68.5**	5.3	8.9	**71.2**	19.9	6.5
6r	**81.4**	18.6	0.0	**100.0**	7.5	**87.7**	4.8	13.0	29.0	**58.1**	31.3
7r	**73.6**	26.4	0.8	**99.2**	**82.5**	17.3	0.2	21.2	37.2	**41.6**	8.1
8r	6.4	**93.6**	0.2	**99.8**	**89.4**	10.6	0.0	18.3	33.1	**48.6**	1.9

Ca: Calcareous
Cn: Non-Calcareous
Ri: Igneous Rocktype
Ro: Non-Igneous Rocktype

Prs: Rain and Snow Precipitation Regime
Ps: Snowfall Precipitation Regime
Pr: Rainfall Precipitation Regime
Low: Low Gradient (> 2.0)
Medium: Medium Gradient (2.0 - 4.0)
High: High Gradient (> 4.0)

Description of Landscape Scale Riparian Clusters

Cluster 1r

Summary

The 74 HUBs in cluster 1r are characterized as high elevation watersheds in the central and eastern San Juan mountains. They have a snowmelt driven hydrologic regime and high gradient streams. There is a high percentage of calcareous bedrock and sediment loads may be high. This cluster represents the greatest proportion of the landscape scale, with these 25 watersheds constituting nearly 30% of the total area included in the analysis. This cluster also represents the largest proportion of the area administered by the San Juan NF, constituting 35% of the total FS area. 41% of the total area of this cluster is within the San Juan NF.

Hydrology and Sediment Transport

Streams in cluster 1r are systems characterized by moderate to high yields of both coarse and fine sediment. These stream types are expected to be only moderately sensitive to hydrology and sediment disturbances, primarily because of their high gradient. However, these streams have a high potential to "pass disturbances downstream" (i.e., to flush excess sediment downstream) and thus create substantial disturbances in the more sensitive stream segments that lie just beyond the forest boundaries.

Fisheries

Although high sediment yields would be detrimental to fish, the high stream gradients in these watersheds likely move much of the sediment downstream. There is a moderate amount of calcium in the bedrock (moderate Ca) which would enhance stream productivity. Fish assemblages would be dominated by coldwater species but productivity would be moderate due to cold water temperatures. Areas of low stream gradient would be important areas for fish production and could be considered to be very important in maintaining fish populations in this cluster.

Riparian Vegetation

There will be high stream density in this cluster because of the very high elevation and deep snow pack, which will produce numerous small riparian zones dominated by herbaceous plants, but many snowmelt driven streams will be ephemeral. The high sediment loads will produce many small floodplains that are largely rock, and highly disturbed by floods. HUBs will contain alpine tundra, subalpine forest and meadow and upper montane forest areas, and support a wide range of riparian vegetation. Along with the small snowmelt dominated streams and floodplains, broad willow dominated riparian vegetation will occur in the highest elevation snowmelt basins. In canyons tall willows and river birch will be common. Riparian forests of blue spruce and narrow leaf cottonwood may also occur along perennial streams.

Aquatic Productivity and Benthic Macroinvertebrates

Similar to the fishery resources, aquatic productivity would be expected to be moderate to potentially high where water temperatures are warmed by open canopies and calcium carbonate is produced by underlain calcareous geology. Generally, aquatic productivity, including benthic macroinvertebrate populations would be expected to be higher than in clusters at similar elevations without the high percentage of calcareous geology. Stream reaches with low gradients could increase stream temperatures somewhat due to increased solar penetration. These reaches would also be important for production of benthic macroinvertebrates, both directly by increased habitat and indirectly through stream temperature warming.

Cluster 2r

Summary

The 50 watersheds in cluster 2r occupy many of the highest elevation watersheds in the San Juan Mountains. This cluster is dominated by snowmelt driven hydrologic regimes and high gradient streams. This cluster represents 15 % of the total area included in the landscape scale. This cluster also represents the second largest proportion of the area administered by the San Juan NF, constituting 33% of the total FS area. 73% of the total area of this cluster is within the San Juan NF.

Hydrology and Sediment Transport

Streams in cluster 2r are systems characterized by moderate to high yields of both coarse and fine sediment that could be exacerbated by anthropogenic activities. These stream types are expected to be only moderately sensitive to hydrology and sediment disturbances, primarily because of their high gradient. However, these streams have a high potential to "pass disturbances downstream" (i.e., to flush excess sediment downstream) and thus create substantial disturbances in the more sensitive stream segments that lie just beyond the forest boundaries.

Fisheries

The high stream gradients in these watersheds again would likely move much of the sediment downstream. However, Cluster 2r watersheds have relatively little calcareous bedrock and thus would be less productive biologically than streams in Cluster 1r watersheds. Fish assemblages would be dominated by coldwater species, which could be influenced considerably by increased inputs of sediment. However, taxa that have evolved in this type of system, such as Colorado River cutthroat trout would be expected to be self-sustaining in the absence of non-native species and elevated anthropogenic influences. The highest concentrations of fish are expected to be located in low gradient stream reaches.

Riparian Vegetation

In this cluster there will be a large number of streams, because of the high elevation and deep snow pack, and many streams will have relatively stable beds, but the nature of volcanic rocks in some watersheds will produce unstable beds and floodplains. Many snowmelt driven streams will be ephemeral and will not support riparian vegetation, or the vegetation will be largely herbaceous. HUBs will contain alpine tundra, subalpine forest and meadow and upper montane forest areas, and support a wide range of riparian vegetation. At the highest elevations the floodplains will have broad willow dominated riparian vegetation. In canyons tall willows and river birch will be common. Riparian forests of blue spruce and narrow leaf cottonwood may also occur along perennial streams.

Aquatic Productivity and Benthic Macroinvertebrates

Aquatic productivity and benthic macroinvertebrate populations would be expected to be lower in this cluster than cluster 1. Localized areas of low gradient stream channels could warm water temperatures to the point that productivity would increase. However, comparisons of aquatic biota populations between cluster 1r and cluster 2r streams could be misleading due to the large difference in geology alone.

Cluster 3r

Summary

The five watersheds in cluster 3r in this cluster occupy the high elevation granite region in the central San Juan Mountains. These HUBs have a snowmelt driven hydrologic regime and steep yet relatively stable streams. While these watersheds only comprise a small proportion of the total area (1%) and FS area (3%), three of the five watersheds are completely contained by the San Juan NF. 69% of the total area of this cluster is within the San Juan NF. The USDA Forest Service could have a major role in managing unique ecological conditions (including biota) that are restricted to the conditions found within this cluster.

Hydrology and Sediment Transport

Streams in cluster 3, which are rare within the forest boundaries, are relatively insensitive to hydrology and sediment disturbances because of high gradients.

Fisheries

The high stream gradients, low calcium levels, and cold temperatures indicate that streams in these watersheds would have low biological productivity and would be dominated by coldwater fish species with relatively low population numbers.

Riparian Vegetation

Riparian vegetation will be diverse and abundant along small and larger streams, with short willow dominated vegetation at higher elevations, and taller willows, river birch and alder at lower elevations, mixed with narrow leaf cottonwood and blue spruce forests. Snowmelt basins and cirques at high elevation could have extensive willow and herbaceous species vegetation along small streams. Some plants could be unique to this cluster as the characteristics are relatively rare in this landscape

Aquatic Productivity and Benthic Macroinvertebrates

Aquatic productivity, including benthic macroinvertebrates populations would be expected to be limited by cold water temperatures and the scarcity of calcareous geology. Population dynamics would be fairly unique to this cluster and comparisons with other clusters should be made with caution.

Cluster 4r

Summary
The 69 HUBs in this cluster occupy intermediate elevation watersheds of the southern and western San Juan Mountains. These watersheds are typified as having a relatively high percentage of moderate and low gradient streams underlain by calcareous geology of an almost exclusively non-igneous origin. The hydroclimatology is driven by a mix of rainfall and snowfall. This cluster occupies 21% of the landscape scale and 24% of the San Juan NF. 38% of the total area of this cluster is within the San Juan NF.

Hydrology and Sediment Transport
Streams in cluster 4r are systems characterized by moderate to high yields of both coarse and fine sediment. These stream types are expected to be only moderately sensitive to hydrology and sediment disturbances, primarily because of their high gradient. However, these streams have a high potential to "pass disturbances downstream" (i.e., to flush excess sediment downstream) and thus create substantial disturbances in the more sensitive stream segments that lie within and just beyond the National Forest boundary.

Fisheries
Cluster 4r watersheds encompass a transition from high elevation to low elevation stream systems with moderate temperatures. Cold water fish productivity would be high where calcareous geology influences water chemistry within a HUB. Hubs with limited calcareous geology would also be expected to have higher productivity than the clusters at higher elevations and lower percentages of low gradient stream channels. The combination of lower elevation, calcareous input and low to moderate gradient stream channels in Hubs located in this cluster would produce probably the highest potential for salmonid productivity in the San Juan Forest. Anthropogenic influences from upstream could greatly affect the capability to sustain high fish populations.

Riparian Vegetation
The mixed rain and snow melt driven hydrologic regime and erosive parent material indicates that the largely high gradient streams will be dynamic and there will be large gravel bars and a high intensity disturbance regime. Monsoon rains in late summer may produce the highest peak stream flows on intermittent and perennial streams. Narrow leaf cottonwood, blue spruce, tall willows, river birch and alder along perennial rivers, and willows along intermittent streams will dominate riparian vegetation.

Aquatic Productivity and Benthic Macroinvertebrates

Aquatic productivity would be highly variable in this cluster. Localized calcareous geology in relatively stabile watersheds would be expected to have higher productivity levels than in non-calcareous watersheds. In addition, anthropogenic influences from upstream or within these watersheds could influence productivity and population levels considerably.

<u>Cluster 5r</u>

Summary

The five HUBs in cluster 5r are located in intermediate elevation watersheds in the southern and western San Juan Mountains. The predominately moderate gradient streams in this cluster are underlain mostly by non-calcareous lithology of a non-igneous origin. The hydroclimatic regime is driven by a mix of rainfall and snowfall. This cluster occupies 1% of the landscape scale and 0.2% of the San Juan NF. Only 7% of the total area of this cluster is within the San Juan NF.

Hydrology and Sediment Transport

Streams in cluster 5r are rare within the forest boundaries. These streams are more sensitive to both hydrology and sediment disturbances because their moderate gradients facilitate deposition of excess sediment. In addition, rock types present produce more sediment and are more sensitive to ground disturbing activities. Because of their rarity and sensitivity to disturbance, these streams may be particularly important at the landscape scales.

Fisheries

Cluster 5r watersheds have more moderate stream gradients that those in Cluster 4r. Although the more moderate stream gradients would be conducive to improved fish production, streams in Cluster 5r watersheds would still have low biological productivity because of low calcium concentrations. Streams in these clusters would have coldwater fish assemblages, and management by the San Juan National Forest would be limited due to the relatively small amount of land located within its boundary.

Riparian Vegetation

Rains in late summer may produce the highest peak stream flows on intermittent and perennial streams. Because this cluster of HUBs has largely intermediate gradient stream, erosion may be lower than in HUBs in cluster 4, and well-developed riparian vegetation may occur in many stream reaches. Narrow leaf cottonwood, blue spruce, tall willows, river birch and alder along perennial rivers, and willows along intermittent streams will dominate riparian vegetation.

Aquatic Productivity and Benthic Macroinvertebrates

Aquatic productivity and benthic macroinvertebrate populations would be highly variable in this cluster. Because of the high sensitivity to disturbance and low amounts of calcareous geology, it would seem feasible that aquatic productivity would naturally be limited. The addition of sediment from anthropogenic activities within this cluster would lower productivity further.

Cluster 6r

Summary

The seven watersheds in cluster 6r are characterized by high gradient streams underlain by predominately calcareous lithology formed by exclusively non-igneous processes. These streams are driven by a mixed precipitation hydroclimatic regime. This cluster occupies 1.6% of the landscape scale and 2% of the San Juan NF. HUBs in this cluster occupy intermediate elevation watersheds that are scattered in the southern and western San Juan mountains. Thirty one percent of the total area of this cluster is within the San Juan NF. The ecological characteristics within this cluster result in a relatively rare situation within this landscape. Biota and ecosystems that require these characteristics

Hydrology and Sediment Transport

Streams in cluster 6r are rare within the forest boundaries, are relatively insensitive to both hydrology and sediment disturbances because of the high gradients and the low sediment production of calcareous rocks. Because of their rarity, these streams may be particularly important at the landscape scales.

Fisheries

Unlike the mid-elevation watersheds in Clusters 4r and 5r, the bedrock in Cluster 6r watersheds contains high amounts of calcium (high *Ca*). The moderate water temperatures and high calcium concentrations would facilitate high biological productivity and stream fish assemblages should be dominated by coldwater species. Stream gradients are mainly in the medium to high range, hence fine sediments should get moved downstream.

Riparian Vegetation

The rain/snow melt driven hydrologic regime and erosive parent material indicates that the largely high gradient streams will be dynamic and there will be large gravel bars. Monsoon rains in late summer may produce the highest peak flows on intermittent and perennial streams. The influence of calcareous parent material may be to produce higher sediment erosion rates, with sediment rich riparian zones. Riparian vegetation will be dominated by narrow leaf cottonwood, blue spruce, tall willows, river birch and alder along perennial rivers, and willows along intermittent streams.

Aquatic Productivity and Benthic Macroinvertebrates

In the absence of anthropogenic activities, aquatic productivity, including benthic macroinvertebrate populations could be high in this cluster. Because of the relatively high gradient stream channels located here, sediment deposition would only be expected to influence populations of macroinvetebrates in the low gradient reaches.

Cluster 7r

Summary

The 24 watersheds are at low elevation and flow regimes are dominated by rain events. Watersheds in this cluster have a bedrock geology that produces large amounts of fine sediments (high *Ro*). Stream gradient is not a defining characteristic. This cluster occupies 7% of the landscape scale and 2% of the San Juan NF. These low elevation watersheds are found off-forest to the northwest, west, southwest and south of the forest boundary. 8% of the total area of this cluster is within the San Juan NF.

Hydrology and Sediment Transport

Streams in clusters 7r, which largely occur outside the forest boundaries, are expected to be relatively sensitive to hydrology and sediment. Streams in cluster 7r would be the most sensitive to disturbance on the National Forest because of the greater percentages of streams with low and moderate gradients and the potential for high sediment production. These streams would receive sediment from upstream in higher gradient reaches.

Fisheries

Streams span a range of gradient categories, suggesting that accumulation of fine sediments could be a problem in low gradient stream reaches. Cluster 7r watersheds have bedrocks with high calcium concentrations. Fish assemblages would represent a transition from coldwater to warmwater species. Given the moderate stream temperatures and high calcium concentrations, biological productivity should be high.

Riparian Vegetation

Desert lands are common in this cluster, with pinion and juniper and shrub vegetation being dominant, with large areas of exposed soil and rock. The erosive character of these landscapes along with the monsoon rain driven hydrologic regime indicates that small streams will have only scattered patches of riparian vegetation, particularly intermittent streams. The larger streams will have a well-developed riparian community, dominated by Fremont cottonwood, tamarisk and Russian olive. The calcareous bedrock in these HUBs means that surface and riparian ground water will have higher mineral content, and could produce more alkaline and saline soils, which could limit the plant species composition to tamarisk and other salt tolerant species.

Aquatic Productivity and Benthic Macroinvertebrates

Periphyton and benthic macroinvertebrate communities would be expected to be dissimilar to those found at higher elevations. Because of the relatively warm water and rain driven hydrology, aquatic communities would be expected to contain taxa that have evolved in conditions of high flow change and warmer water.

Cluster 8r

Summary

The 81 HUBs in this cluster occupy the southern and western portion of the study area and are at low elevations. This grouping is characterized by streams of all gradients underlain by non-calcareous lithology of nearly exclusive igneous origin. Streamflow is driven by predominately a rainfall hydroclimatic regime. Stream gradient is not a defining characteristic. This cluster occupies 23% of the landscape scale and 1% of the San Juan NF. Only 2% of the total area of this cluster is within the San Juan NF.

Hydrology and Sediment Transport

Streams in clusters 8r, which largely occur outside the National Forest boundary, are expected to be relatively sensitive to hydrology disturbances, and to vary in sensitivity to sediment disturbances, as a function of stream gradient

Fisheries

As in cluster 7r, watersheds have a bedrock geology that produces large amounts of fine sediments (high *Ro*) and streams span a range of gradient categories; suggesting that accumulation of fine sediments could be a problem in low gradient stream reaches. The main difference from Cluster 7r is that Cluster 8r watersheds have bedrocks with little calcium. Thus, biological productivity would be lower than for streams in Cluster 7r watersheds. Again, fish assemblages would represent a transition from coldwater to warmwater species.

Riparian Vegetation

Desert lands are common in this cluster, with pinion and juniper and shrub vegetation being dominant, with large areas of exposed soil and rock. The erosive character of these landscapes along with the monsoon rain driven hydrologic regime indicates that many streams will have only spotty riparian vegetation, particularly intermittent streams. The larger streams will have a well-developed riparian community, dominated by Fremont cottonwood, tamarisk and Russian olive.

Aquatic Productivity and Benthic Macroinvertebrates

Taxa of benthic macroinvertebrates and periphyton would be expected to be similar to those found in cluster 7r. However, because of the lack of calcareous geology, productivity would be expected to be less in streams not influenced by anthropogenic activities.

Management Scale

Key Findings

- Most of the clusters identified at this scale are dominated by non-calcareous, non-igneous HUBs within the snowmelt driven precipitation zone. As a result, areas of high aquatic productivity and riparian abundance are restricted to limited areas in and surrounding the National Forest. These areas may be important for reproduction and dispersal.
- Clusters 1r and 5 r exhibit the highest percentage of calcareous geology, with cluster 5r also being mostly within the rain on snow area. While all the watersheds are important, watersheds within these clusters could potentially have the highest productivity potential.
- Because of the dominance of steep gradient stream channels, non-calcareous geology and snow and rain-on-snow precipitation patterns, the potential for sediment movement is relatively high at this scale throughout most of the analysis area. Sediment produced in higher gradient reaches could be deposited in the low gradient more productive reaches.
- Low gradient stream channels are extremely limited at this scale, but are probably the most important component for production of aquatic organisms and riparian vegetation. Impacts to these habitats could severely limit fish as well as other aquatic productivity
- High gradient stream channels indicate that valleys are mostly narrow with limited riparian production. Activities that influence the valley floor, such as road construction may severely limit the abundance of riparian vegetation and fauna associated with them.

Introduction

This section of the chapter contains the results of the ecological driver analysis associated with the San Juan National Forest. Results at this scale are influenced most directly by conditions and management activities within the National Forest boundary (Winters et al. 2004a). Ecological processes (including species dynamics) are not limited by administrative boundaries but by ecological processes. As a result, entire HUBs are considered wherever possible instead of ending the assessment at the Forest Service boundary.

The cluster analysis of the 197 6^{th} level watersheds comprising the San Juan National Forest management scale produced 8 groups of watersheds (Figure 2-7). It should be noted that the cluster descriptions differ between the landscape and management scale. In order to explain the importance of and differences between HUBs, we have prepared the following sections. These sections will:

1) Provide a description of the cluster analysis methodology
2) Describe the individual clusters
3) Describe the relative importance of the clusters to fisheries
4) Describe the relative importance of the clusters to riparian vegetation
5) Describe the sensitivity of the clusters to alterations of the sediment regime and hydrology from natural and anthropogenic disturbances

Cluster Identification

A dendrogram is used to illustrate the results associated with the clustering technique (Figure 2-8). The numbers and colors identify the resultant cluster number, while the letters within the dendrogram identify the significant breakpoints within the data. This cluster process is further described in detail by Winters et al (2004a). Tabular data identifying the mean percentages of each driver within each break group is represented in **Error! Reference source not found.**. The purpose of the following section is to present and explain the differences in the distribution of ecological drivers and show how the clusters were subdivided into similar groups.

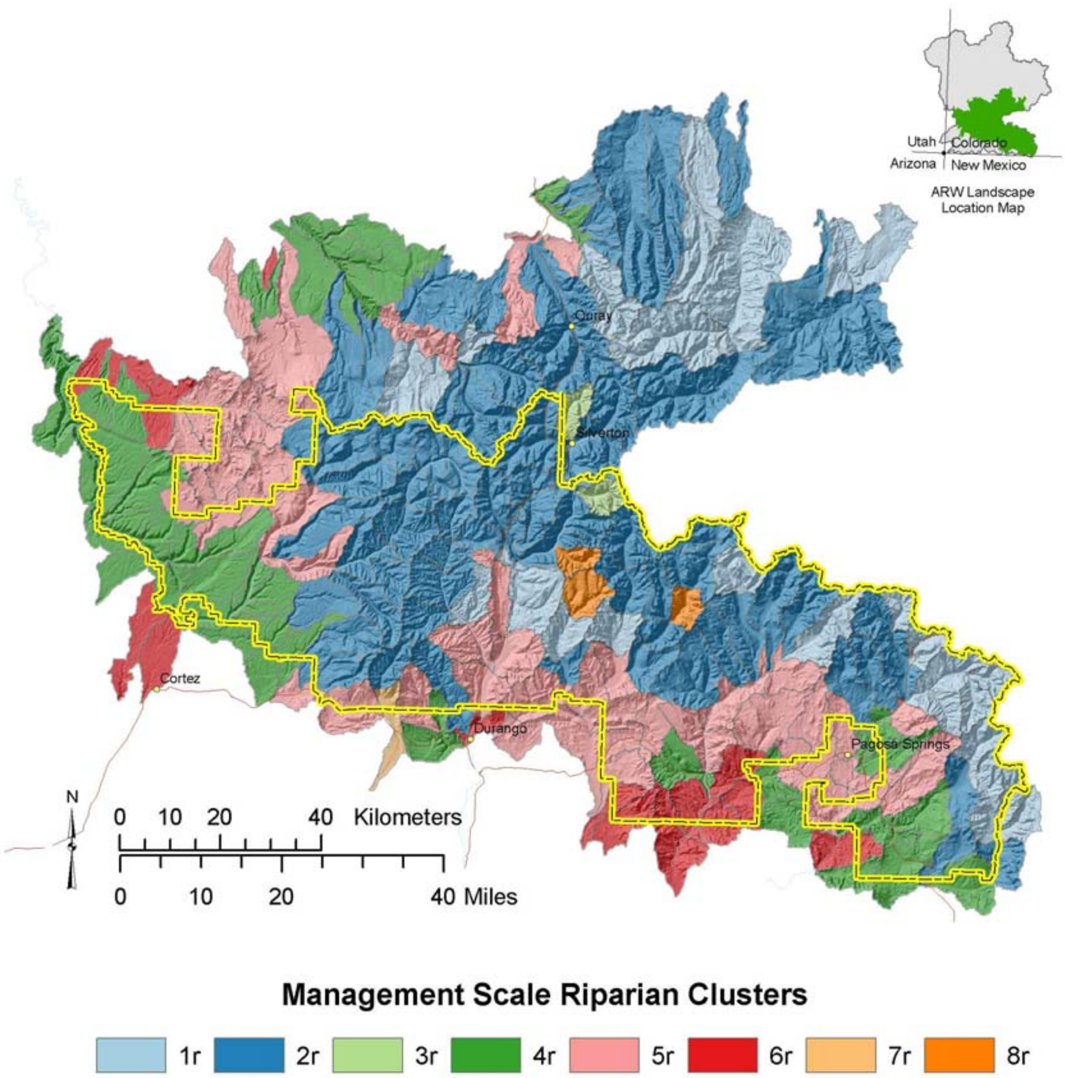

Figure 2-7. Riparian clusters of the San Juan NF Management Scale.

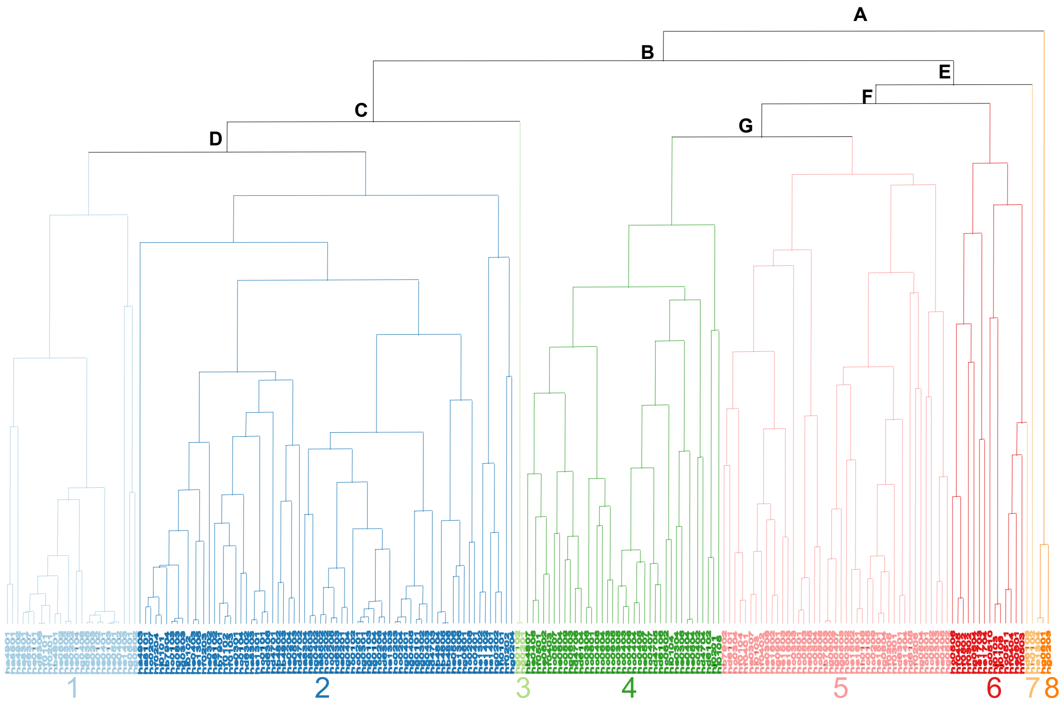

Figure 2-8. Dendrogram used to identify the riparian clusters of the San Juan NF Management Scale.

Description of the Management Scale Riparian Clusters

As discussed for the landscape-scale evaluation of the ecological importance of riparian clusters, it is important to remember that headwater streams are disproportionately important, relative to their spatial extent, in supplying water and sediment to downstream river segments. Using the 10 clusters of driver combinations developed for the management scale in the San Juan study area, streams in clusters 3r, 6r and 7r are relatively rare within the San Juan National Forest (Figure 2-7). Most of the streams on the forest occur in clusters 1r, 2r, 4r, and 5r. Cluster 8r is completely contained within the San Juan National Forest. The mean percentages of each driver within the clusters are tabulated within Table 2-2.

In general, most of the clusters are associated with HUBs underlain by lithology formed by non-igneous processes. Most clusters contain a significant proportion of high gradient streams driven by snowfall or mixed rain and snow hydroclimatic regimes. This information could be valuable when identifying inventory and monitoring programs. While general ecological characteristics may be similar within clusters with similar anthropogenic influences, comparisons across cluster types could provide very different results. While there are some logical distribution patterns within each cluster, there is also enough variability that comparisons between clusters could easily occur (Table 2-2).

Table 2-2. Mean percent area for each ecological driver summarized by cluster.

Riparian Cluster	Ca	Cn	Ri	Ro	Pr	Prs	Ps	Low	Medium	High
Cluster 1r	**76.58**	23.42	6.43	**93.57**	0.02	11.60	**88.38**	3.41	7.34	**89.25**
Cluster 2r	35.67	**64.33**	6.99	**93.01**	0.23	17.15	**82.62**	4.68	9.01	**86.32**
Cluster 3r	1.05	**98.95**	0.98	**99.02**	0.00	0.00	**100.00**	1.64	7.44	**90.92**
Cluster 4r	16.22	**83.78**	0.21	**99.79**	16.25	**78.20**	5.54	12.66	32.17	**55.18**
Cluster 5r	52.85	47.15	0.67	**99.33**	6.85	**71.64**	21.51	12.87	20.16	**66.97**
Cluster 6r	31.61	**68.39**	0.10	**99.90**	**66.58**	31.94	1.48	16.81	22.08	**61.11**
Cluster 7r	13.22	**86.78**	5.94	**94.06**	0.00	**73.38**	26.62	4.52	**68.48**	27.01
Cluster 8r	3.25	**96.75**	**89.65**	10.35	0.00	2.14	**97.86**	4.17	4.13	**91.70**

Ca: Calcareous
Cn: Non-Calcareous
Ri: Igneous Rocktype
Ro: Non-Igneous Rocktype

Prs: Rain and Snow Hydroclimatic regime
Ps: Snowfall Hydroclimatic regime
Pr: Rainfall Hydroclimatic regime
Low: Low Gradient (> 2.0)
Medium: Medium Gradient (2.0 - 4.0)
High: High Gradient (> 4.0)

Cluster 1r

Summary

The 25, 6th level HUBs in cluster 1r are characterized by high elevation, snowfall driven hydroclimatic regimes. The predominately high gradient streams are underlain by calcareous geology formed by non-igneous processes. This cluster occupies 14% of the management scale, with 42% of its area within the San Juan NF.

Hydrology and Sediment Transport

This cluster group is dominated by high-gradient streams with a snowmelt flow regime that are underlain by calcareous bedrock that produces moderate to high yields of both coarse and fine sediment. There is a relatively high risk of sediment movement from management activities in this cluster that could influence ARW resources downstream as well as adjacent low gradient areas. There is a low percentage of low gradient stream channels in this cluster. However, because of the high potential for natural and anthropogenic input of sediment, these areas could be influenced to a large extent from upstream activities. Sediment would be deposited in these areas, resulting in increased erosion and widening of the channel.

Fisheries

Cluster 1 watersheds are at high elevation and are dominated by a snowmelt hydrologic regime. Water removals would reduce fish habitat considerably but would not likely alter thermal regimes. The bedrock weathers to produce a considerable amount of fine sediment that would be detrimental to fish, especially in the relatively few low gradient areas where the highest quality habitat would be expected. However, the high stream gradients that are prevalent throughout these watersheds would move much of the sediment downstream. The relatively high percentage of calcareous geology within this cluster could increase fish production. While the temperatures are cold, the effects of increased nutrient input could result in abundant fishery resources if habitat conditions are adequate (e.g. stream size). Introduction of nonnative trout species would have negative impacts on native trout in higher elevation stream reaches.

Riparian Vegetation

HUBs in this cluster are high elevation, snowmelt driven watersheds. They have primarily calcareous bedrock and high gradient streams, which may produce high sediment loads and unstable streams. Because of the high elevation there will be high stream density, and due the erosive nature of the bedrock, some valleys may be wide with thick alluvial bodies. Many streams will be ephemeral. HUBs with alpine tundra will support small riparian zones dominated by low willows. Within the subalpine forest a wide range of riparian vegetation can occur including broad bands of short stature and tall willow dominated riparian vegetation, and at lower elevations riparian forests of blue spruce and narrow leaf cottonwood.

Aquatic Productivity and Benthic Macroinvertebrates

Cluster 1r is among the most sensitive to changes in the thermal regime. Increased temperatures could result in increased production, yet cause local extinction of cold-adapted, high elevation species. This cluster is relatively unresponsive to changes in sediment regime resulting from the overall dominance of high gradient stream channels and would not have considerable influences on benthic macroinvertebrate populations. Additional sediment will be temporarily stored during low-flow conditions, degrading the local biotic condition, especially in low gradient reaches. This cluster is also highly sensitive to alterations in the hydrologic regime as it is largely dependent upon snowmelt contributions to streamflow. Streams in this grouping are likely not nutrient limited, and may result in increased periphyton and macroinvertebrate populations where temperatures are adequate.

Cluster 2r

Summary

The 71 watersheds in cluster 2r are characterized by a high elevation snowfall driven hydroclimatic regime. The largely high and moderate gradient streams are underlain by rock units derived from mainly non-igneous formative processes. While calcareous bedrock is not dominating in this cluster, it is prevalent to the point that 6^{th} level HUB productivity could be influenced considerably. Cluster 2r is the largest cluster in the management scale, with it comprising 40% of the management scale, with 54% of its area within the San Juan NF.

Hydrology and Sediment Transport

This cluster group is dominated by high-gradient streams with a snowmelt flow regime that are underlain by both calcareous and non-calcareous bedrock that produces moderate to high yields of both coarse and fine sediment. Anthropogenic influences could have large influences on low gradient reaches if excessive sediment were produced. In addition, sediment produced in this cluster could influence stream reaches downstream.

Fisheries

Cluster 2r watersheds are similar to those in Cluster 1r and would have similar sensitivities to anthropogenic alteration related to hydrology, thermal regimes, and sediment inputs. However, watersheds in Cluster 2r somewhat less calcareous bedrock and thus would likely be more sensitive to nutrient additions. Watersheds in this cluster that have higher percentages of calcareous bedrock would be expected to have higher native fishery potential. Because of the relatively high potential for native fish productivity where conditions are favorable, nonnative biota would have considerable negative effects on native trout.

Riparian Vegetation

HUBs in this cluster occupy the majority of the highest elevation watersheds in the San Juan Mts. These HUBs have s largely snowmelt driven hydrologic regime and high gradient streams. High suspended sediment and bed loads in streams may occur due to the volcanic bedrock, which is unstable in many areas. There will be high stream density, because of the very high elevation and deep snow pack of this landscape, which will produce numerous drainage patterns. Some snowmelt driven streams will be ephemeral. HUBs will contain alpine tundra, subalpine forest and meadow and upper montane forest areas, and support a wide range of riparian vegetation. At the highest elevations the floodplains will have broad bands of willow dominated riparian vegetation. In canyons tall willows and river birch will be common. Riparian forests of blue spruce and narrow leaf cottonwood may also occur along perennial streams.

Aquatic Productivity and Benthic Macroinvertebrates

Cluster 2r is among the most sensitive to changes in the thermal regime. Increased temperatures could result in increased production, yet cause local extinction of cold-adapted, high elevation species. Watersheds in this cluster are relatively unresponsive to changes in sediment regime resulting from the overall dominance of high gradient stream channels. Additional sediment will be temporarily stored during low-flow conditions, degrading the local biotic condition. However, low gradient reaches could be influenced significantly as sediment is deposited. This cluster is also highly sensitive to alterations in the hydrologic regime as it is largely dependent upon snowmelt contributions to streamflow. Streams in this grouping are likely nutrient limited, but the lack of calcareous lithology accentuates the influence of additional nutrients supplied to the system.

Cluster 3r

Summary

The 2 watersheds in cluster 3r are entirely within the snowfall driven hydroclimatic regime. The predominately high gradient streams in this cluster are nearly entirely underlain by non-calcareous lithology of a non-igneous origin. This cluster occupies 0.6% of the management scale, with 55.3% of its area within the San Juan NF.

Hydrology and Sediment Transport

This cluster group is dominated by high-gradient streams with a snowmelt flow regime that are underlain by non-calcareous bedrock (cluster 2 also has a moderate percentage of non-calcareous bedrock) that produces moderate to high yields of both coarse and fine sediment.

Fisheries

Cluster 3r watersheds are also similar to those in Cluster 1r except for having virtually no calcareous bedrock. In Cluster 3r watersheds, water removal would reduce fish habitat but would not likely alter thermal regimes. Although the bedrock weathers to produce fine sediment, the high stream gradients would move much of the sediment downstream. The absence of calcareous rocks means that productivity in these watersheds should be low. Fish production should increase following to nutrient additions although cold water temperatures would still be a limiting factor. Introduction of nonnative trout species would have negative impacts on native trout in higher elevation stream reaches. Fish populations would be expected to be less than clusters with more calcareous geology.

Riparian Vegetation

The two HUBs in this cluster occur in the central San Juan Mts. and are distinctive because they are at very high elevations, have snowmelt driven hydrologic regimes, and almost no calcareous rocks. Riparian vegetation will be abundant along small and larger streams, with short willow dominated vegetation at higher elevations, and taller willows, river birch and alder at lower elevations. However, the Silverton Caldera with highly mineralized rock, erodable sediments, and heavy metal pollution influences many watersheds.

Aquatic Productivity and Benthic Macroinvertebrates

Cluster 3r is among the most sensitive to changes in the thermal regime. Increased temperatures could result in increased production, yet cause local extinction of cold-adapted, high elevation species. This cluster is relatively unresponsive to changes in sediment regime resulting from the overall dominance of high gradient stream channels. Additional sediment will be temporarily stored during low-flow conditions, degrading the local biotic condition. This cluster is also highly sensitive to alterations in the hydrologic regime as it is largely dependent upon snowmelt contributions to streamflow. Streams in this grouping are likely nutrient limited, but the lack of calcareous lithology accentuates the influence of additional nutrients supplied to the system.

Cluster 4r

Summary

The 37 watersheds in cluster 4r are driven by a predominately mixed precipitation hydroclimatic regime. The largely high gradient streams in this cluster are typically underlain by non-calcareous lithology of a non-igneous origin. This cluster occupies 16.6% of the management scale, with 48% of its area within the San Juan NF.

Hydrology and Sediment Transport

This cluster group is dominated by high-gradient streams with a mixed snowmelt and rainfall flow regime that are underlain by non-calcareous bedrock that produces moderate to high yields of both coarse and fine sediment. The rain and snow driven conditions here would generate significant amounts of sediment if exposed during periods of increased runoff.

Fisheries

Cluster 4r watersheds are mainly at mid-elevations and thus have hydrologic regimes that are a mixture of snowmelt and rainfall events. A mixture of stream gradients is present. Water removal would reduce summer flows for irrigation and winter flows for snowmaking, especially in years with low summer rainfall and/or snowpack. The resultant loss of habitat and likely warming of stream water temperatures during summer months and reduced habitat in winter would be detrimental to coldwater fishes. The bedrock produces moderate to high sediment yields, thus anthropogenic disturbances that increase sediment production would be detrimental to fish populations. Calcareous rocks are not abundant; hence streams should be sensitive to anthropogenic activities that increase nutrients. Because the streams within this cluster are at moderate elevations, stream size and resultant habitat would be expected to increase from higher elevation streams. Although calcareous geology is limited in this cluster, the areas with higher stream orders would be expected to have increased fish productivity. Introduction of nonnative trout species would have negative impacts on native trout in higher elevation stream reaches.

Riparian Vegetation

HUBs in this cluster are intermediate elevation watersheds of the southern and western San Juan Mts. and will have upland vegetation dominated by Douglas fir, ponderosa pine and Engelmann spruce forests. The rain/snow melt driven hydrologic regime and erosive parent material suggests that the largely high gradient streams will be dynamic and there will be large gravel bars. Monsoon rains in late summer may produce the highest peak flows on intermittent and perennial streams. Narrow leaf cottonwood, blue spruce, tall willows, river birch and alder along perennial rivers, and willows along intermittent streams will dominate riparian vegetation.

Aquatic Productivity and Benthic Macroinvertebrates

Cluster 4r is somewhat sensitive to changes in the thermal regime. Increased temperatures could result in increased production. This cluster is relatively unresponsive to changes in sediment regime resulting from the overall dominance of high gradient stream channels. Additional sediment will be temporarily stored during low-flow conditions, degrading the local biotic condition. This cluster is also highly sensitive to alterations in the hydrologic regime as it is largely dependent upon mixed rainfall and rain and snow contributions to streamflow. Streams in this grouping are likely nutrient limited, but the presence of calcareous lithology minimizes the influence of additional nutrients supplied to the system.

Cluster 5r

Summary

The 43 watersheds in cluster 4r are driven by a predominately mixed precipitation hydroclimatic regime. The largely high gradient streams in this cluster are typically underlain by lithology of a non-igneous origin. Geochemistry is not a defining characteristic of this cluster. This cluster is the second largest of this scale as it occupies 20.9% of the management scale, with 54.7% of its area within the San Juan NF.

Hydrology and Sediment Transport

This cluster group is dominated by high-gradient and mid-gradient streams with a mixed snowmelt and rainfall flow regime that are underlain by calcareous bedrock that produces moderate to high yields of both coarse and fine sediment. Because of the heterogeneity of conditions within this cluster more site specific analysis would be necessary to determine potential for sediment movement from management activities.

Fisheries

Cluster 5r watersheds are similar to those in Cluster 4r in terms of being at mid-elevations, having bedrock that produces moderate to high sediment yields, and having a mixture of stream gradients. Thus streams in both watersheds would respond in a similar manner to water removal and sediment increases. However, Cluster 5r watersheds have more calcareous bedrock and thus would not be as responsive to nutrient inputs as Cluster 4r watersheds. This cluster of watersheds would be one of the most conducive to high fishery and aquatic productivity due to a variety of factors, including a mixture of stream gradients, calcareous geology and somewhat warmer temperatures. Again, introduction of nonnative trout species would be detrimental to native trout in these watersheds.

Riparian Vegetation

HUBs in cluster 5r are intermediate elevation watersheds of the southern and western San Juan Mts. and will have upland vegetation dominated by Douglas fir, ponderosa pine and Engelmann spruce forests. Monsoon rains in late summer may produce the highest peak flows on intermittent and perennial streams. Because this cluster of HUBs has largely intermediate gradient stream, erosion may be limited and better developed riparian vegetation may occur. Narrow leaf cottonwood, blue spruce, tall willows, river birch and alder along perennial rivers, and willows along intermittent streams will dominate riparian vegetation.

Aquatic Productivity and Benthic Macroinvertebrates

Cluster 5r is somewhat sensitive to changes in the thermal regime. Increased temperatures could result in increased production. Additional sediment will be temporarily stored during low-flow conditions, degrading the local biotic condition. This cluster is also highly sensitive to alterations in the hydrologic regime as it is largely dependent upon mixed rainfall and rain and snow contributions to streamflow. Streams in this grouping are likely nutrient limited, but those streams influence presence of calcareous lithology will exhibit a lesser influence of additional nutrients supplied to the system. Diversity of benthic macroinvertebrates would be considered higher in this cluster as the variability of conditions influencing them are also high.

Cluster 6r

Summary

A majority of the area of the 15 watersheds in cluster 6r are driven by a rainfall hydroclimatic regime, with a smaller proportion driven by a mixed regime. A high degree of variability is found within the distribution of stream gradients. The streams in this watershed are underlain by rock units formed by predominately non-igneous processes. A majority of these units are calcareous. This cluster occupies 5.8% of the management scale, with 36.1% of its area within the San Juan NF.

Hydrology and Sediment Transport

This cluster group is dominated by high and moderate gradient streams with a rainfall flow regime that are underlain by non-calcareous bedrock that produces moderate to high yields of both coarse and fine sediment. This cluster of watersheds is influenced dramatically by sediment produced upstream in other watersheds. Sediment deposition could influence stream bank stability and over widen channels where deposition occurs. Braiding of the stream channel could be realized in low gradient channels where deposition occurs from upstream.

Fisheries

Cluster 6r watersheds are at lower elevations than watersheds in the other seven clusters and have a hydrologic regime dominated by rainfall. Streamflows in these watersheds would fluctuate considerably depending on summer rainfall patterns. Water diversions would reduce habitat for fish, possibly to critically low levels in drought years. Thermal regimes would likely be suboptimal for coldwater fishes and would become even warmer with water withdrawals. The bedrock produces moderate to high sediment yields, thus anthropogenic disturbances that increase sediment production would be detrimental to fish populations. Calcareous bedrock is present in only moderate amounts, thus streams in these watersheds should be responsive to nutrient additions, particularly given the warm summer water temperatures. Given the warm water temperatures and naturally high variability in streamflows, stream fish assemblages would be dominated by non-game species adapted to these stressful conditions. Relatively few nonnative fish species would likely be able to survive in these conditions.

Riparian Vegetation

HUBs in cluster 6r are the lowest elevation watersheds in the study area of the southern and pinon pine and juniper, Gambel oak, Douglas fir or ponderosa pine may dominate western San Juan Mts. Upland vegetation. The primarily rain driven hydrologic regime and erosive parent material indicates that the largely high gradient streams will be dynamic and there will be large gravel bars. Monsoon rains in late summer may produce the highest peak flows on intermittent and perennial streams. Many small streams will be intermittent or ephemeral. Narrow leaf cottonwood, blue spruce, tall willows, river birch and alder along perennial rivers, and willows along intermittent streams will dominate riparian vegetation. Tamarisk and Russian olive may also be present on the lowest elevation streams.

Aquatic Productivity and Benthic Macroinvertebrates

Cluster 6r is unique in that it is the grouping that is least likely to be influenced by changes in hydrology. Decreased precipitation could increase the intermittency of the streams in this cluster. This cluster is less sensitive to alterations in the thermal regime. This cluster is relatively unresponsive to changes in sediment regime. Additional sediment will be temporarily stored during low-flow conditions, degrading the local biotic condition. Minor perturbations in the nutrient regime will not likely influence these systems. Benthic macroinvertebrate diversity may be high and some taxa would be tolerant to fluctuating discharge, temperature and sediment.

Cluster 7r

Summary

The single watershed in cluster 7 has a slight majority of its streams in the moderate gradient category. These streams are driven by a largely mixed precipitation type and snowfall driven hydroclimatic regimes. No stream length is within the rainfall driven hydroclimatic regime. Rock units in this watershed are largely non-calcareous, and formed by mainly non-igneous processes. This cluster occupies 0.3% of the management scale, with 33.2% of its area within the San Juan NF.

Hydrology and Sediment Transport

This cluster group is dominated by medium-gradient streams with a mixed snowmelt and rainfall flow regime that are underlain by non-calcareous bedrock that produces moderate to high yields of both coarse and fine sediment.

Fisheries

Cluster 7r consists of two watersheds that similar to those in Cluster 4r. The main difference is that Cluster 7r watersheds are dominated by streams with medium gradients. Cluster 7r watersheds are at mid-elevations and therefore have a combination snowmelt and rainfall hydrology. Water removal would reduce summer flows, especially in years with low summer rainfall. The resultant loss of habitat and likely warming of stream water temperatures would be detrimental to coldwater fishes. The bedrock produces moderate to high sediment yields, thus anthropogenic disturbances that increase sediment production would be detrimental to fish populations. Calcareous rocks are not abundant; hence streams should be sensitive to anthropogenic activities that increase nutrients. Introduction of nonnative trout species would have negative impacts on native trout in higher elevation stream reaches.

Riparian Vegetation

The two HUBs in this cluster occupy the lower elevations of the Hesperus River drainage portion. The area is forested with ponderosa pine and other low elevation tree species. The erosive character of the bedrock in these watersheds, along with the monsoon rain driven hydrologic regimes indicates that many streams will have spotty riparian vegetation, particularly intermittent streams, even though medium gradient streams are most abundant. The larger streams have a well-developed riparian community, dominated by Fremont cottonwood, tamarisk and Russian olive.

Aquatic Productivity and Benthic Macroinvertebrates

Cluster 7r is somewhat sensitive to changes in the thermal regime. Increased temperatures could result in increased production. This cluster is more responsive to changes in sediment regime resulting from a dominance of medium and low gradient stream reaches. Additional sediment will be temporarily stored in these reaches during low-flow conditions, degrading the local biotic condition. This cluster is also highly sensitive to alterations in the hydrologic regime as it is largely dependent upon mixed rainfall and rain and snow contributions to streamflow. Streams in this grouping are likely nutrient limited. The overall dominance of noncalcareous lithology would likely make this the most sensitive cluster to alternations in the nutrient regime.

Cluster 8r

Summary

The three watersheds in cluster 8r are unique in that the streams in these watersheds are underlain by predominately non-calcareous lithology formed by igneous processes. These streams are typically high gradient, and are driven by a snowfall hydroclimatic regime. This cluster occupies 0.9% of the management scale, and is entirely within the San Juan NF.

Hydrology and Sediment Transport

This cluster group is dominated by high-gradient streams with a snowmelt flow regime that are underlain by non-calcareous bedrock that produces low to moderate sediment yields. Because of the steep topography and snowmelt conditions, considerable sediment could be produced if disturbed by management activities and transported downstream, influencing important habitat reaches.

Fisheries

Cluster 8r consists of three high elevation watersheds that are unique in having bedrock that is mostly igneous and thus produces less sediment upon weathering than the bedrock in the other seven clusters. Water removals would reduce fish habitat but would not likely alter thermal regimes. Given the igneous bedrock, streams in these watersheds would be the least susceptible to increases in sediment loads. The low amount of calcareous bedrock would result in low water fertility, but these streams would likely be too cold to show much response in fish production following nutrient additions. Introduction of nonnative trout species would be detrimental to native trout in these watersheds.

Riparian Vegetation

The three HUBs in this cluster occupy the granite rock portion of the central San Juan and are at very high elevation. The rocks are non-calcareous, produce little sediment, and the watersheds are snowmelt driven with high gradient streams. These watersheds will have extensive high elevation riparian zones dominated by short willows near tree line. At lower elevations stable streams, particularly those with perennial flow will support extensive willow stands. Narrow riparian corridors may have an overstory of Engelmann spruce and subalpine firs, with an understory of obligate riparian plants such as *Mertensia ciliata*.

Fisheries and Aquatic Productivity and Benthic Macroinvertebrates

Cluster 8r is among the most sensitive to changes in the thermal regime. Increased temperatures could result in increased production, yet cause local extinction of cold-adapted, high elevation species. This cluster is relatively unresponsive to changes in sediment regime resulting from an overall dominance of high gradient stream reaches. Additional sediment will be temporarily stored during low-flow conditions, degrading the local biotic condition. Streams in this grouping are likely nutrient limited, further limiting production and diversity.

Ecological Importance of Riparian Clusters and Sensitivity to Management

<u>Hydrology and Sediment Transport</u>

This discussion of the relative sensitivity of each cluster to natural or human-induced disturbances focuses only on physical characteristics of rivers. In this context, the *Ca*/*Cn* driver does not apply. The rationale for assigning relative sensitivity is as follows: Hydrologic sensitivity depends primarily on gradient (*H*/*M*/*L*) and flow regime (*Ps*/*Prs*/*Pr*), and to a lesser extent on sediment supply (*Ri*/*Ro*). Sediment sensitivity depends primarily on gradient and sediment supply, and to a lesser extent on flow regime. High-gradient streams are assigned the lowest sensitivity to both water and sediment. The channel bed and banks of these stream segments are composed of very coarse sediment that is less likely to experience a substantial change in mobility as a result of either a decrease or increase in water supply. These so-called transport reaches also usually pass excess sediment downstream fairly efficiently and, if sediment-starved, are less likely to have channel erosion than lower-gradient stream segments. Low-gradient streams are assigned the highest sensitivity to both water and sediment. Sediment forming the channel bed and banks in these stream segments is likely to be the most mobile of all the gradient categories, and thus most likely to be eroded in response to increased flow or reduced sediment load, or deposited in response to reduced flow or increased sediment load.

Streams with a snowmelt flow regime are considered less sensitive to changes in hydrologic regime and sediment supply than are those with mixed snowmelt and rainfall or rainfall flow regimes. The snowmelt streams are more likely to have well-packed and well-sorted bed and bank sediments that have little change in mobility in response to changed flow magnitude or duration.

Streams underlain by rock types that produce moderate to high yields of both fine and coarse sediment (*Ro*) are rated more sensitive to sediment disturbances than those underlain by other rock types (*Ri*) because any natural or human-induced change in sediment supply to the stream is likely to be more substantial in basins underlain by *Ro* units.

Riparian Vegetation

HUBs in clusters 1-3 and 8 occur at the highest elevations in the San Juan Mountains, have high gradient snowmelt driven streams. There will be numerous small streams with willow dominated riparian zones. HUBs in clusters 4-7 occupy the middle and lower elevation region of the western and southern San Juan Mts. in a broad forest belt. These sites will have both snowmelt and rain driven hydrologic regimes, and can support well developed riparian forests and shrub lands where erosion is not severe. The low elevation watersheds in clusters 6 have many ephemeral streams, streams that are regularly disturbed by summer rain driven floods, and many areas with exotic tamarisk and Russian olive dominated riparian vegetation. The larger streams will have broad floodplains supporting the most biologically productive Fremont cottonwood stands.

Fisheries and Aquatic Productivity

The conditions present in the San Juan management scale provide a variety of habitats for fish and benthic macroinvertebrates. Clusters with higher percentages of calcareous geology would be expected to have higher productivity than those with lower percentages. Generally, the Rocky Mountains are considered to be fairly unproductive and have limited diversity of fish and other aquatic organisms. However, springs and other influences that increase temperature, nutrients, and substrate can all influence productivity. The relatively high percentage of non-calcareous geology, snow driven precipitation and high stream gradients would indicate that the areas with higher productivity are rare and should be considered important resources. In addition, habitat loss would result in a far more negative response than if conditions were more diverse and productive. In order to understand the variability within the management scale, clustering of the watersheds begins to show areas with similar characteristics. This information is important in order to design meaningful monitoring sites so variability is reduced.

Ecological Driver Analysis for Wetlands

Landscape Scale

Key Findings

- The most important key finding of this exercise was that the clusters with the highest percentage of glaciated valleys (primarily 7w, 8w, and 9w) were found mostly within the San Juan National Forest boundary. These clusters are expected to have the highest percentage of wetlands, including rare habitats such as fens and springs. Flora and fauna associated with these clusters could be relicts from the last major glaciation period and could be quite rare. Most of the remaining area for these clusters are found on the adjacent GMUG National Forest. While these types of wetlands may appear to be abundant on the Forest, they are relatively less common at the landscape scale, and certainly rare at larger scales. The Forest has a unique opportunity to manage a rare type of environment within its boundaries.
- Clusters 4w and 7w also have high percentages of calcareous geology. Cluster 7w in particular would be expected to have high amounts of springs and associated fens as a result of the abundance of glaciated landscapes as well. However, cluster 4w may also have numerous springs associated with this type of geology.

Introduction

The following sections contain the results of the ecological driver analysis associated with the ARWA landscape scale of the San Juan National Forest. Results at this scale are influenced most directly by conditions and management activities within the National Forest boundary (Winters et al. 2004a). Ecological processes (including species dynamics) are not limited by administrative boundaries but by ecological processes. As a result, entire HUBs are considered wherever possible instead of ending the assessment at the Forest Service boundary.

The cluster analysis of the 314, 6th level watersheds comprising the San Juan National Forest management scale produced 8 groups of watersheds (Figure 2-9). In order to explain the importance of and differences between HUBs, we have prepared the following section. These sections will:

1) Provide a description of the cluster analysis methodology
2) Describe the individual clusters
3) Describe the relative importance of the clusters to wetlands

Cluster Identification

An agglomerative cluster analysis was used to identify groups of watersheds that have similar ecological driver characteristics. Ecological drivers are defined as environmental factors that exert a major influence on the fitness of individual organisms and their populations, and help constitute the physio-chemical template of an ecosystem. Four ecological drivers were selected for the San Juan National Forest riparian driver analysis: lithologic composition (calcareous or non-calcareous), formative geologic process (igneous or non-igneous), hydroclimatic regime (rainfall, rain and snow, or snowfall), and influence of Pleistocene glaciation. The agglomerative cluster analysis is based upon the percent area comprised by the potential ecological driver combinations within each HUB. The numerous combinations are abbreviated into percent of total wetland area within each 6th level HUB for summary purposes (Table 2-3). The cluster analysis produces a dendrogram from which the ecological driver clusters are identified (Figure 2-10). Ecological driver clusters are identified by number (1 – 9) and color.

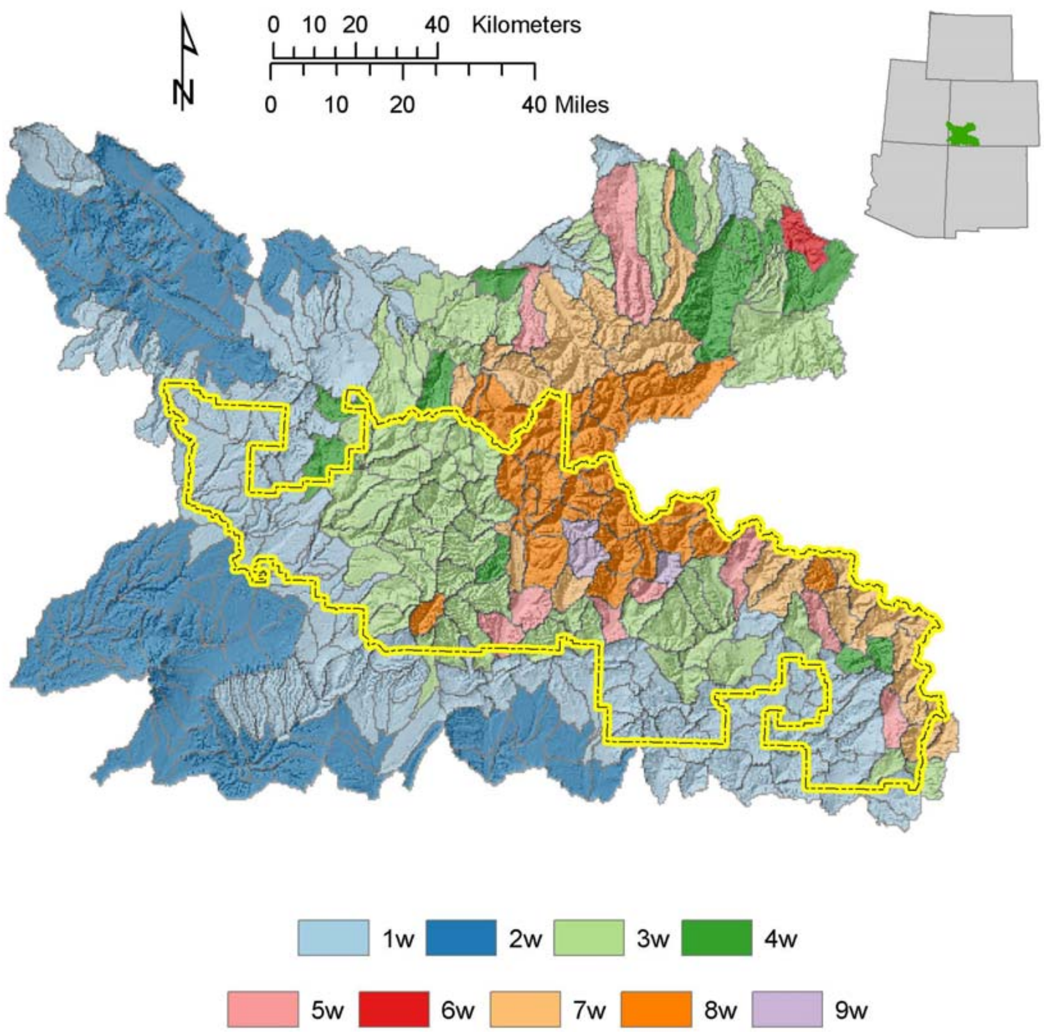

Figure 2-9. Wetland clusters of the ARWA landscape scale of the San Juan NF.

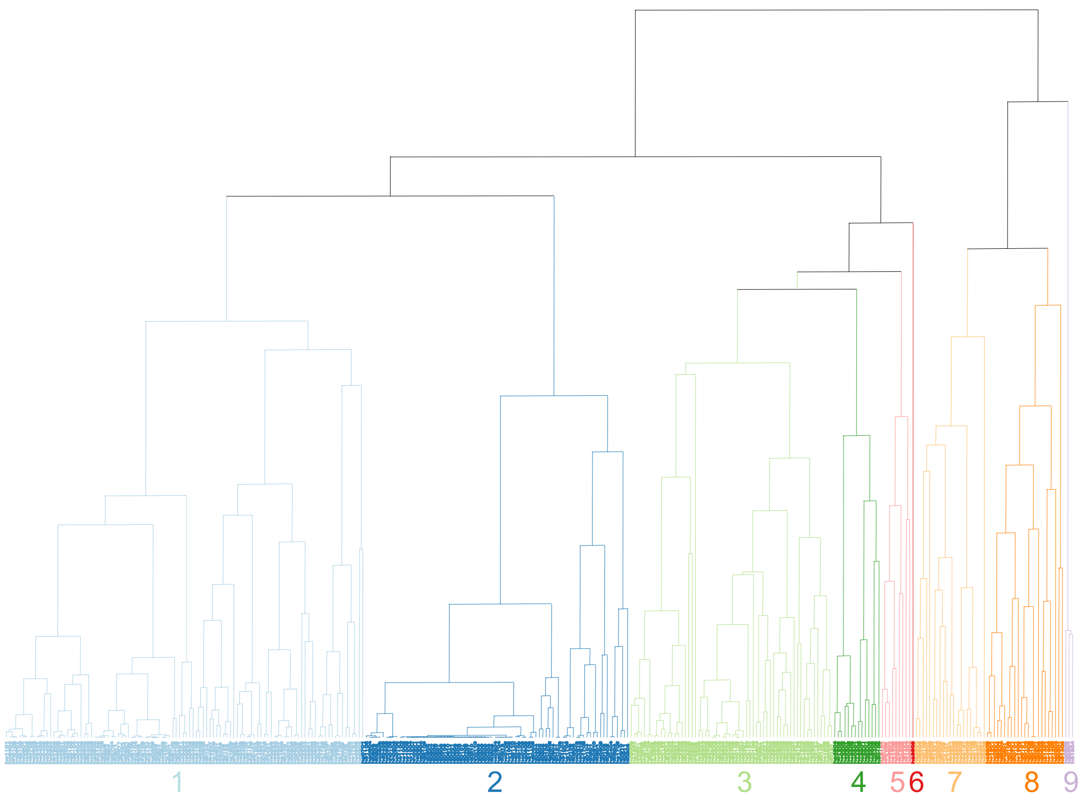

Figure 2-10. Dendrogram used to identify the 9 wetland clusters of the San Juan NF ARWA landscape scale.

Table 2-3. Mean percentages of each driver within the landscape scale wetland clusters.

Cluster	Ca	Cn	Ri	Ro	Pr	Prs	Ps	Qg	Qn	% in NF
1w	30.4	**69.6**	0.3	**99.7**	19.9	**71.9**	8.2	0.3	**99.7**	32.5
2w	16.3	**83.7**	0.7	**99.3**	**92.1**	7.8	0.1	0.0	**100.0**	0.0
3w	34.8	**65.2**	3.4	**96.6**	0.3	21.8	**77.9**	5.9	**94.1**	58.2
4w	**79.8**	20.2	2.8	**97.2**	0.0	24.8	**75.2**	3.1	**96.9**	14.6
5w	46.1	53.9	4.4	**95.6**	4.5	28.4	**67.1**	39.9	**60.1**	53.6
6w	16.3	**83.7**	**53.3**	46.7	0.0	17.7	**82.3**	0.0	**100.0**	0.0
7w	**75.9**	24.1	3.0	**97.0**	0.0	9.6	**90.4**	**64.2**	35.8	43.5
8w	28.6	**71.4**	17.8	**82.2**	0.0	3.2	**96.8**	**81.6**	18.4	64.8
9w	3.8	**96.2**	**88.5**	11.5	0.0	0.9	**99.1**	**87.0**	13.0	100.0

Ca: Calcareous
Cn: Non-Calcareous
Ri: Igneous Rocktype
Ro: Non-Igneous Rocktype

Qg: Pleistocene Glaciation
Qg: Non-Glaciated
Pr: Rainfall Hydroclimatic regime
Prs: Rain and Snow Hydroclimatic regime
Ps: Snowfall Hydroclimatic regime

Description of Landscape Scale Wetland Clusters

Cluster 1w

Summary

The 106 HUBs in this cluster occupy the broad foothills zones of the southern and western San Juan Mts. They have a combined rain and snowmelt driven hydrologic regime. This cluster comprises the greatest proportion of the landscape scale (30.3%) and the second greatest proportion of the San Juan NF (29.3%). 32.5% of this clusters total area lies within the San Juan NF.

Wetlands

Wetlands will occur on benches, at seeps, and toe slopes. The most common type of wetland will be wet meadows dominated by rushes, sedges and grasses. These will have seasonally saturated soils, but be dry in late summer. Marshes will also be common, filling with water during the snowmelt period, and drying by late summer, although they may refill with water during prolonged summer rainy periods. Wetlands may be quite widespread in the higher elevation portions of these HUBS, especially where the topography is relatively level. Project level identification is important to understand the extent and specific locations of these isolated wetlands.

Cluster 2w

Summary

The 78 HUBs in this cluster occupy the lowest elevation watersheds in the region to the south and west of the main mountain mass. This cluster comprises the second highest proportion of the landscape scale (23.6%), but is not found on the San Juan NF.

Wetlands

All wetlands that occur will have rain driven hydrologic regimes, which will fill basins and create marshes. Summer temperatures will be high and most wetlands will be ephemeral. Salt flats will also be common driven by shallow water tables, capillary fringes that reach the surface and high soil evaporation rates that lead to salt accumulation. Many wetlands will be fed by agricultural tail water, and in places wetlands could cover a large portion of the landscape. In some agricultural areas wet meadows are created by flood irrigation. As with cluster 1, these wetlands are fairly isolated and ground reconnaissance is important to locate them.

Cluster 3w

Summary

The 60 HUBs in this cluster occupy the mid elevation forested belt of the western San Juan Mts. with many HUBs in the northeast and southern mountains as well. This cluster comprises 19.8% of the landscape scale, and the greatest proportion (34.2%) of the San Juan NF. 58.2% of the total area of this cluster is within the San Juan NF.

Wetlands

A snowmelt driven hydrologic regime occurs, but monsoon rains will recharge ground water flow systems and produce rising water levels in the late summer in many areas. The most common wetland type will be wet meadows, in relatively level openings in the forest. These wetlands will be surrounded by either conifer forest, or dry grassland, and will occur where ground water reaches the soil surface in the early summer. Fens will be present, but not as common as they are in clusters 7-9. Springs will be common, especially where bedrock discontinuities cause ground water to discharge to the soil surface. In addition, calcareous geology comprises over 38% of the area, resulting in spring activity ion many areas where the correct hydrologic characteristics are present. These springs will support herbaceous plants, and be important for both livestock and wildlife. Most of the prominent springs will probably have been modified for livestock watering, making springs in natural conditions relatively rare.

Cluster 4w

Summary

The 14 HUBs in this cluster occur in the mid elevation forested belt of the San Juan Mts. This cluster comprises 5.2% of the landscape scale and 2.2% of the San Juan NF. 14.6% of the total area of this cluster is located within the San Juan NF.

Wetlands

These HUBs have a prevalence of calcareous parent material, which occurs in scattered outcrops in the study area. Hence, HUBs in this cluster are scattered through the San Juan's. These HUBs have a snowmelt driven hydrologic regime, but monsoon rains will recharge ground water flow systems and produce rising water levels in the late summer in many areas especially in the southern San Juan Mts., while HUBs in the northeast will have little monsoon influence. As a result wetlands will be less abundant in HUBs in the northeastern portion of the study area, than in HUBs in the southern and western area due to the influence of monsoon rains in the later area, which helps maintain a high water table in wet meadows. The most common wetland type will be wet meadows, in openings in the forest. These wetlands will be surrounded by either conifer forest, or dry grassland, and will occur where ground water reaches the soil surface in the early summer. Fens will be present, but not as common as they will be in clusters 7-9. Springs will be common, especially where bedrock discontinuities cause ground water to discharge to the soil surface. These springs will support herbaceous plants, and be important for both livestock and wildlife. The springs in particular may be more common due to the calcareous bedrock, and the ion rich water may support uncommon plant and animal communities. Where fens occur in watersheds with calcareous parent material rich and extreme rich fens may occur, supporting rare plants.

Cluster 5w

Summary

The nine HUBs in this cluster occupy intermediate elevation watersheds around the edges of the San Juan Mts. and include the larger river valleys. Pleistocene glaciers flowing from the high elevation regions of the San Juan Mts. reached their lowest elevations limits in these HUBs and at least one valley glacier had its terminus in each HUB. Thus, these are unusual low elevation landscapes that had their main valleys glaciated. This cluster comprises 3.9% of the landscape scale and 6.2% of the San Juan NF. 53.6% of the total area of this cluster is located within the San Juan NF.

Wetlands

Unusual dead ice moraine landscapes could occur with kettles, as well as terminal and lateral moraine dammed valleys producing low gradient basins, and lateral moraines forming large hillslope aquifers that could hold snowmelt and rain recharged ground water, and support wetlands at their bases. These HUBs will have abundant wet meadows and marshes, similar to lower elevation HUBs, but may also have marshes in kettles, and large valley bottom flats dominated by sedges or willows.

Cluster 6w

Summary

The single HUB in cluster 6 occurs at intermediate elevation in the far northeastern portion of the San Juan Mts. and is the only unglaciated HUB to have igneous bedrock. It is largely snowmelt driven, and will have relatively little summer rain, being on the northeastern side of the mountains, in a rain shadow. This cluster comprises 0.4% of the landscape scale and is not found on the San Juan NF.

Wetlands

Due to the greater aridity and lack of glaciated landforms, wetlands will be less abundant, but wet meadows should be common in areas with relatively level topography.

Cluster 7w

Summary

The 21 HUBs in this cluster occupy the northern and southern portions of the main high mountain region. 43.5% of the total area of this cluster is located within the San Juan NF.

Wetlands

These HUBs all have snow melt driven hydrologic regimes, although monsoon rains will play a key role in recharging hillslope ground water aquifers. These areas also have calcareous bedrock and were glaciated. Wetlands will be abundant at all elevations and all landforms except the steepest slopes. Fens will be common, and in calcareous areas may support rich and extreme rich fens, which are rare in Colorado. Wet meadows will be common in areas with seasonally saturated soils.

Cluster 8w

Summary

The 23 HUBs in this cluster occupy the central volcanic mountain region of the study area. The bedrock is non-calcareous and non-igneous, and the HUBs have snowmelt hydrologic regimes with significant inputs of monsoon rain. Pleistocene glaciers covered large areas of these HUBs. This cluster comprises 8.0% of the landscape scale and 10.3% of the San Juan NF. 64.8% of the total area of this cluster is located within the San Juan NF.

Wetlands

Landforms conducive to wetland formation are present throughout this region, particularly on plateaus at all elevations, at toe slopes and valley bottoms. Ground water will be abundant and fens numerous. Iron fens are present, particularly in the area around the Silverton Caldera.

Cluster 9w

Summary

The three HUBs in this cluster occupy the central igneous rock portion of the study area, which contains the most spectacular mountains in the region. The bedrock is non-calcareous, and the HUBs have snowmelt driven hydrologic regimes with significant inputs of monsoon rain. Pleistocene glaciers covered large areas of these HUBs. This cluster is completely within the San Juan NF, and comprises 0.6% of the landscape scale and 1.8% of the San Juan NF.

Wetlands

Landforms conducive to wetland formation are present throughout these HUBs, particularly nearly flat glacial basins, and toe slopes of moraines, and talus slopes and on valley bottoms. Ground water will be abundant and fens numerous. Fens will be present, particularly in the area and some areas may have a richness of wet meadow and fen complexes.

Management Scale

Key Findings

- Clusters 7w, 8w, and 9w have relatively high percentages of Pleistocene glaciation occurring within them, with cluster 9w being totally located within the Forest boundary. These results would indicate that management focus for large areas of wetlands could be focused on these clusters, with truly unique characteristics found in cluster 9w
- Clusters 2w and 5w also have relatively high percentages of glaciation occurring within them also, and probably also contain numerous wetlands. The remaining clusters are probably more typical of landscapes with "isolated' wetlands.
- The San Juan National Forest is associated with variable amounts of limestone geology. Because this geology is generally porous they are often associated with springs, which may be common in many areas of the Forest, creating unique and stabile environments for rare flora and fauna.

Introduction

This section contains the results of the ecological driver analysis for wetland systems associated with the San Juan National Forest. Results at this scale are influenced most directly by conditions and management activities within the National Forest boundary (Winters et al. 2004a). Ecological processes (including species dynamics) are not limited by administrative boundaries but by ecological processes. As a result, entire HUBs are considered wherever possible instead of ending the assessment at the Forest Service boundary.
The cluster analysis of the 197 6th level watersheds comprising the San Juan National Forest management scale produced 8 groups of watersheds (Figure 2-11). In order to explain the importance of and differences between HUBs, we have prepared the following section. These sections will:

1) Provide a description of the cluster analysis methodology
2) Describe the individual clusters

Cluster Identification

A dendrogram is used to illustrate the results associated with the clustering technique (Figure 2-12). The numbers and colors identify the <u>resultant cluster number</u>, while the letters within the dendrogram identify the significant <u>breakpoints</u> within the data. This cluster process is further described in detail by Winters et al (2004a). The purpose of the following section is to present and explain the differences in the distribution of ecological drivers and show how the clusters were subdivided into similar groups.

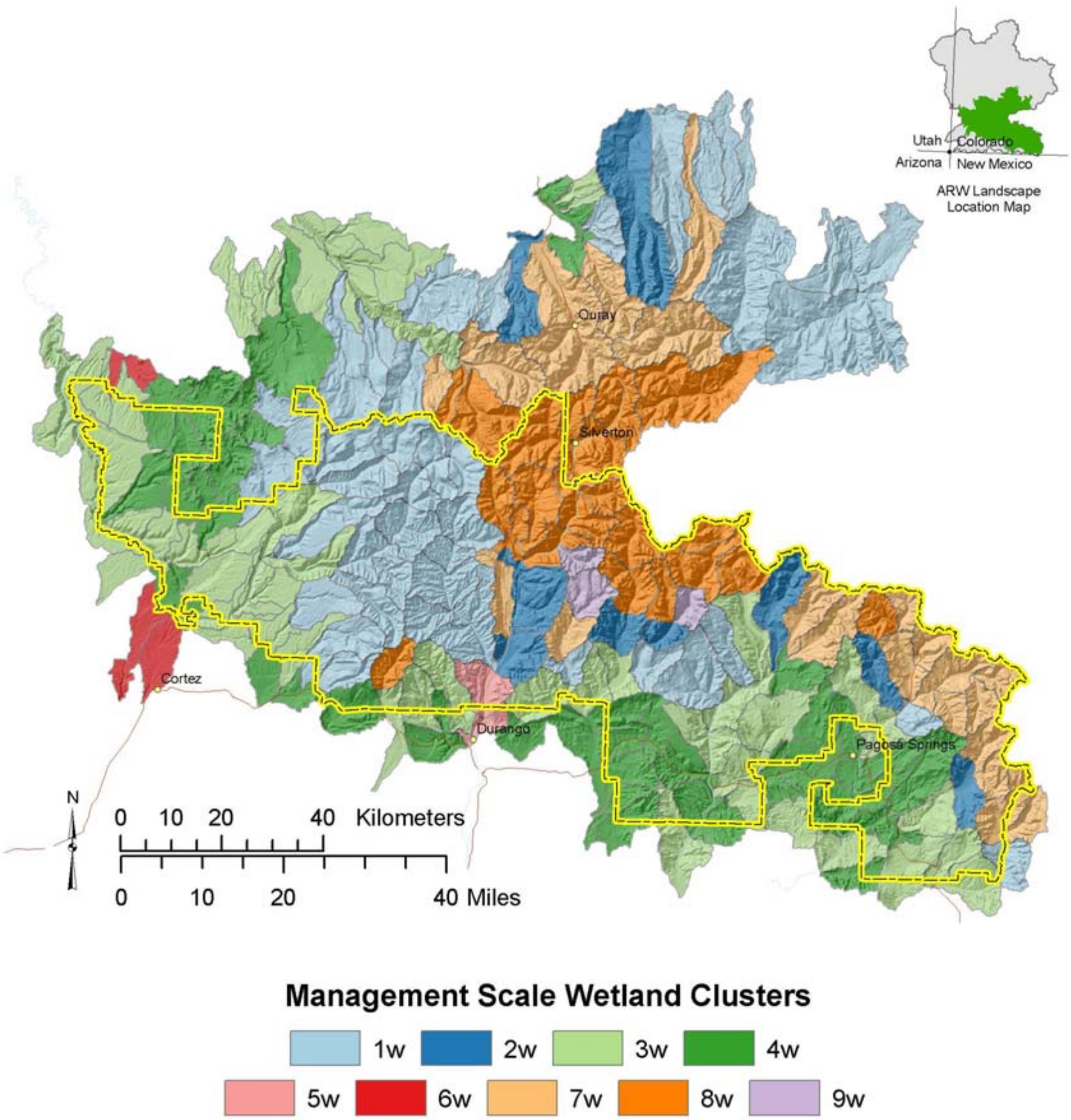

Figure 2-11. Wetland clusters of the San Juan NF Management Scale.

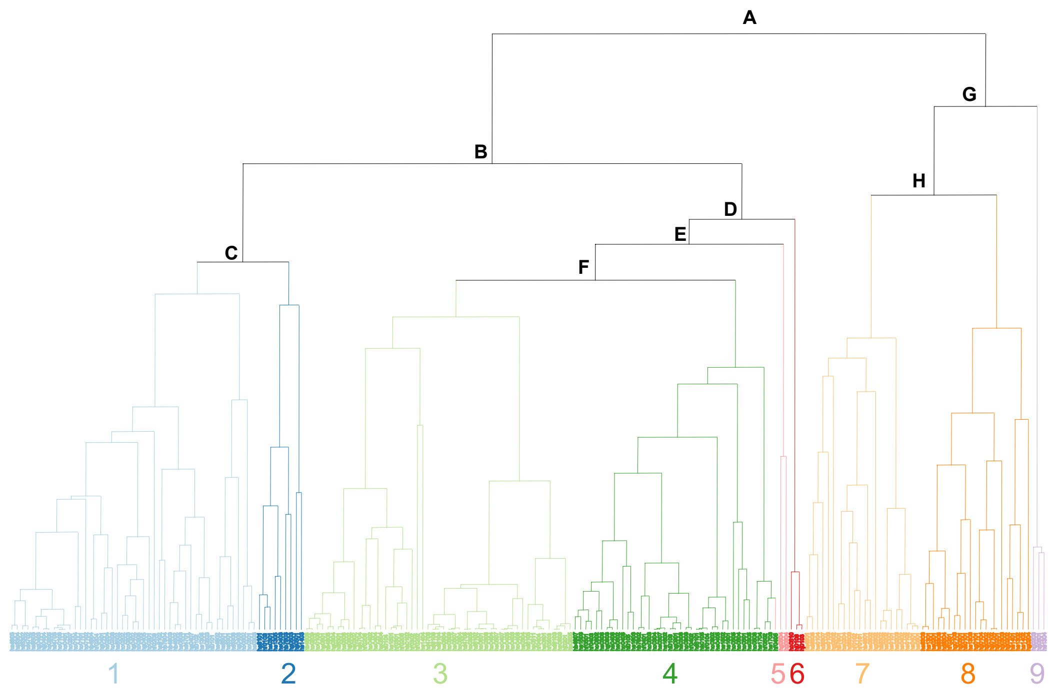

Figure 2-12. Dendrogram of the San Juan NF management scale wetland cluster analysis.

Description of the Management Scale Wetland Clusters

An agglomerative cluster analysis of the spatial distribution of the three ecological drivers identified 9 unique groups of watersheds (Figure 2-11). The mean percentage of each driver within each cluster is tabulated below (

Table 2-4). The following section is intended to give an overview of the composition and location of each cluster, and then provide a description of the expected influence each cluster has upon the nature and distribution of wetland ecosystems at the management scale of the San Juan National Forest Aquatic, Riparian and Wetland Assessment.

Table 2-4. Mean percentage of each driver within the 10 management scale wetland clusters.

Cluster	Ca	Cn	Ri	Ro	Qg	Prs	Ps	Pr	% in NF
1w	46.6	53.4	3.2	96.8	6.8	13.1	86.8	0.1	46.1
2w	44.6	55.4	11.3	88.7	47.3	24.2	73.7	2.1	57.5
3w	14.1	85.9	1.3	98.7	1.7	66.6	23.5	9.8	56.5
4w	52.3	47.7	0.3	99.7	0.2	75.9	11.3	12.8	46.2
5w	26.6	73.4	0.0	100.0	31.9	45.6	18.0	36.3	65.2
6w	26.5	73.5	0.5	99.5	0.0	9.0	0.0	91.0	1.1
7w	77.0	23.0	2.9	97.1	62.5	9.4	90.6	0.0	44.8
8w	26.9	73.1	16.4	83.6	83.2	1.6	98.4	0.0	61.0
9w	3.8	96.2	88.5	11.5	87.0	0.9	99.1	0.0	100.0

Ca: Calcareous
Cn: Non-Calcareous
Ri: Igneous Rocktype
Ro: Non-Igneous Rocktype
Qg: Pleistocene Glaciation
Prs: Rain and Snow Precipitation Regime
Ps: Snowfall Precipitation Regime
Pr: Rainfall Precipitation Regime

Cluster 1w

Summary

The 47 watersheds in cluster 1w are typified by moderate to high elevation, non-glaciated catchments with a fairly even distribution of calcareous and non-calcareous geology formed by predominately non-igneous processes. A snowfall hydroclimatic regime drives the hydrology of this cluster. HUBs in this cluster occupy the broad mid elevation forest zone on the western and northern sides of the San Juan Mts. They have a snowmelt driven hydrologic regime, however monsoon rains add significant water to soils and aquifers in late summer of most years. HUBs have both calcareous and non-calcareous bedrock and were largely unglaciated, although some HUBs, especially near Rico had small valley glaciers in high mountain basins. Wetlands will occur on benches, at seeps, and toe slopes. Cluster 1w constitutes the greatest proportion of the management scale (27%) and the second greatest proportion of the San Juan NF (24%). 46% of the total cluster area is located within the San Juan NF.

Wetlands

The most common type of wetland will be wet meadows dominated by rushes, sedges and grasses. These will have seasonally saturated soils, and may remain wet in late summer. Fens are present in some higher elevation watersheds, especially where bedrock is close to the surface, or where special geological situations produce abundant ground water discharge. Wetlands may be abundant in the higher elevation portions of these HUBS, especially where the topography is relatively level. Due to a relatively high percentage of calcareous geology, spring may be abundant in some areas.

Cluster 2w

Summary

The nine watersheds in cluster 2w are typified by high elevation, glaciated watersheds with a fairly even distribution of calcareous and non-calcareous geology formed by predominately non-igneous processes. This cluster is predominately within the snowfall hydroclimatic regime. Relatively few HUBs are in this cluster, and they occupy watersheds in the mid elevation to foothills zone. Valley glaciers that originated in the snow and ice accumulating higher elevation landscapes reached these HUBs, scouring and depositing till. They have snowmelt driven hydrologic regimes, however monsoon rains add significant water to soils and aquifers in late summer of most years. HUBs have both calcareous and non-calcareous bedrock. As with cluster 1w, the relatively high percentage of calcareous geology may result in springs being abundant in some areas. This cluster comprises 6.3% of the management scale and 7.2% of the San Juan NF. 57.5% of the total cluster area is located within the San Juan NF.

Wetlands

Wetlands will occur on benches, at seeps, and toe slopes. The most common type of wetland will be wet meadows dominated by rushes, sedges and grasses. They will have seasonally saturated soils, and may remain wet in late summer. Fens are common in some higher elevation areas and associated with dead ice moraines, toe slopes of lateral moraines and in level terrain created by end moraines. Wetlands may be abundant in the higher elevation portions of these HUBS, especially where the topography is relatively level.

Cluster 3w

Summary

The 51 watersheds in cluster 3w are typified by moderate elevation, non-glaciated catchments with a low proportion of calcareous geology formed by predominately almost entirely non-igneous processes. A majority of the area of this cluster is within the mixed hydroclimatic regime. HUBs in this cluster occupy low elevation foothills on the southern and western edges of the San Juan Mts. The HUBs have a rain and snowmelt driven hydrologic regime, with monsoon rains providing significant rain in late summer on many years. Cluster 3w constitutes the second greatest proportion of the management scale (23.1%) and the greatest proportion of the San Juan NF (25.7%). 56.5% of the total cluster area is located within the San Juan NF.

Wetlands

The most common wetland type will be wet meadows, in openings in the forest. These wetlands will be surrounded by either conifer forest, or dry grassland, and will occur where ground water reaches the soil surface in the early summer. Fens will be present, but will not be as common as they are in clusters 7-9. Springs will be common, especially where bedrock discontinuities cause ground water to discharge to the soil surface. There are agricultural communities within HUBs of this cluster and there will be water diversions, ditches and drains that have changed the spatial distribution of water and wetlands, and in many areas wetlands will have been created by irrigation.

Cluster 4w

Summary

The 39 watersheds in cluster 4w are typified by low elevation, non-glaciated catchments with fairly equal proportions of calcareous and non-calcareous geology formed by predominately almost entirely non-igneous processes. A majority of the area of this cluster is within the mixed hydroclimatic regime. HUBs in this cluster occupy low elevation foothills on the southern and western edge of the San Juan Mts. The HUBs have a rain and snowmelt driven hydrologic regime, with monsoon rains providing significant rain in late summer on many years. Bedrock in many areas is calcareous, and water will have higher pH and dissolved ion concentrations. This cluster comprises 17.4% of the management scale and 15.8% of the San Juan NF. 46.2% of the total cluster area is located within the San Juan NF.

Wetlands

The most common wetland type will be wet meadows, in openings in the forest. These wetlands will be surrounded by either conifer forest, or dry grassland, and will occur where ground water reaches the soil surface in the early summer. Fens will be present, but will not be as common as they are in clusters 7-9. Wet meadows and fens may be highly calcareous and may support rare plants. Springs will be common, especially where bedrock discontinuities cause ground water to discharge to the soil surface, and where they are calcareous may support many rare plants and animals. There are agricultural communities within HUBs of this cluster and there will be water diversions, ditches and drains that have changed the spatial distribution of water and wetlands, and in many areas wetlands will have been created by irrigation.

Cluster 5w

Summary

The two watersheds in cluster 5w are typified as having equal proportions of calcareous and non-calcareous geology formed by exclusively non-igneous processes. This cluster has a majority of its area uninfluenced by Pleistocene glaciation. Hydroclimatic regime is not an identifying characteristic of these watersheds, as fairly equal proportions of rainfall, snowfall and mixed hydroclimatic regimes are found. HUBs in this cluster occupy intermediate elevation watersheds around the edges of the San Juan Mts. and include the larger river valleys. Pleistocene glaciers flowing from the high San Juan Mts. reached the lower elevations of these HUBs and at least one valley glacier had its terminus in each HUB. Thus, these are unusual lower elevation landscape that had glaciers in their largest valleys. This cluster comprises 0.7% of the management scale and 0.9% of the San Juan NF. 65.2% of the total cluster area is located within the San Juan NF.

Wetlands

Unusual dead ice moraine landscapes could occur with kettles, as well as terminal and lateral moraine dammed valleys with low gradient, and lateral moraines which form large hillslope aquifers that could hold snowmelt and rain recharged ground water. These HUBs will have abundant wet meadows and marshes, similar to lower elevation HUBs, but may also have marshes in kettles, and large valley bottom flats dominated by sedges or willows.

Cluster 6w

Summary

The three watersheds in cluster 6w are typified as having equal proportions of calcareous and non-calcareous geology formed by exclusively non-igneous processes. A small percentage of the cluster area is modified by Pleistocene glaciation. Hydroclimatic regime for this cluster is predominately rainfall or mixed precipitation, although the snowfall regime does constitute a small proportion of the total area. HUBs in this cluster occupy the lowest elevations in the far western portion of the study area. These are the only rain driven HUBs in the study area. Wetlands will be relatively uncommon, and consist of small marshes where rain fills basins, irrigated lands, and small springs. Some salt flats may also occur, where high water tables create a capillary fringe that reaches the soil surface, but salts are infrequently flushed from the soils. This cluster comprises 1.3% of the management scale and 46.1% of the total cluster area is located within the San Juan NF.

Wetlands

Wetlands will be relatively uncommon, and consist of small marshes where rain fills basins, irrigated lands, and small springs. Some salt flats may also occur, where high water tables create a capillary fringe that reaches the soil surface, but salts are infrequently flushed from the soils.

Cluster 7w

Summary

The 22 watersheds in cluster 7w are typified as having a majority of their area underlain by calcareous geology formed by almost exclusively non-igneous processes. This cluster has a slight majority of its area modified by Pleistocene glaciation and typically within the snowfall hydroclimatic regime. HUBs in this cluster occupy the northern and southern portions of the main high mountain region. These HUBs have snow melt driven hydrologic regimes, although monsoon rains will play a key role in recharging hillslope ground water aquifers. These areas also have calcareous bedrock and were glaciated. This cluster comprises 12% of the management scale and 11% of the San Juan NF. 45% of the total cluster area is located within the San Juan NF.

Wetlands

Wetlands will be abundant at all elevations and all landforms except the steepest slopes. Fens will be common, and in calcareous areas may support rich and extreme rich fens, which are rare in Colorado. Wet meadows will be common in areas with seasonally saturated soils.

Cluster 8w

Summary

The 21 watersheds in cluster 8w are typified as having a less majority of their area underlain by calcareous geology formed by mainly non-igneous processes. This cluster has a significant majority of its area modified by Pleistocene glaciation. This cluster is typically within the snowfall hydroclimatic regime. HUBs in this cluster occupy the central volcanic mountain region of the study area. The bedrock is non-calcareous and non-igneous, and the HUBs have snowmelt driven hydrologic regimes with significant inputs of monsoon rain. Pleistocene glaciers covered large areas of these HUBs. This cluster comprises 11.3% of the management scale and 13.5% of the San Juan NF. 61% of the total cluster area is located within the San Juan NF.

Wetlands

Landforms conducive to wetland formation are present throughout this region, particularly on plateaus at all elevations, at toe slopes and valley bottoms. Ground water will be abundant and fens numerous. Iron fens are present, particularly in the area around the Silverton Caldera.

Cluster 9w

Summary

The three watersheds in cluster 9w have a fairly even distribution of calcareous and non-calcareous geology formed by mainly igneous processes. This cluster has a significant majority of its area modified by Pleistocene glaciation, and is typified as being a part of the snowfall-driven hydroclimatic regime. HUBs in this cluster occupy the central igneous rock portion of the study area, which has the most spectacular mountains in the region. The bedrock is non-calcareous, and the HUBs have snowmelt driven hydrologic regimes with significant inputs of monsoon rain. Pleistocene glaciers covered large areas of these HUBs. The watersheds within this unique cluster are completely within the San Juan NF. This cluster comprises 0.9% of the management scale and 1.8% of the San Juan NF.

Wetlands

Landforms conducive to wetland formation are present throughout these HUBs, particularly flat glaciated basins, at toe slopes and valley bottoms. Ground water will be abundant and fens numerous. Fens will be present, particularly in the area and some areas may have a richness of wet meadow and fen complexes.

Ecological Importance of Wetland Clusters and Sensitivity to Management

The area of HUB's that were glaciated, as well as differences in climate driven hydrologic regime, are the major physical drivers separating HUBs in the cluster analysis (

Table 2-4). Clusters 7-9 were largely covered by Pleistocene glaciers and have snowmelt driven hydrologic regimes. Cluster 6 is rain driven, 3-5 rain-and-snow driven, and 1 and 2 are snowmelt driven. HUBs in cluster 6 occupy a small portion of the far western portion of the study area. HUBs in clusters 3-5 occupy the western and southern slopes of the San Juan Mountains, particularly the valley, drier low elevation and middle elevation slopes. HUBs in clusters 1-2 occupy large areas in the western and northern portions of the study area, particularly those occupying mixed conifer forests.

HUBs in clusters 1 and 2 are separated from clusters 7-9, which are also snowmelt driven, because HUBs in clusters 7-9 have a much higher percent area that is snowmelt drive, and because they all have >50% of their area as glaciated. HUBs in cluster 1 have little area that was glaciated, while HUBs in cluster 2 have a large area of glaciated landscape, but occur in the main river valleys on the north and south sides of the mountain range, and received glaciers that flowed from the higher mountains. HUBs in cluster 6 are rain driven, while those in clusters 3-5 are rain-and-snow driven. HUBs in clusters 3 and 5 have largely non-calcareous bedrock, while cluster 4 has large areas of calcareous rock, and HUBs in cluster 5 supported some glaciers.

HUBs in cluster 7-9 all have most of their area with snow driven hydrologic regimes, and large areas with glacial landforms. They are distinguished from each other because cluster 9 has largely igneous bedrock, cluster 8 has non-calcareous but non-igneous bedrock, while cluster 7 has largely calcareous bedrock.

The location of wetland clusters is graphically displayed in Figure 2-11. HUBs in clusters 3-4 occupy the lowlands and foothills of the San Juan Mountains, and will support salt flat and marsh wetlands. In addition, wetlands supported or created by agricultural irrigation will be common in certain areas, as well as in HUBs of clusters 3 and 4. HUBs in clusters 3-6 occupy the middle elevation regions in a broad forest belt. These sites will have both snowmelt and rain driven hydrologic regimes, and can support well developed wet meadows and springs. Cluster 2 HUBs are mid elevation HUBs that were glaciated and unique landforms may produce clusters of wetlands that are not present in other low elevation or middle elevation HUBs. HUBs in clusters 7-9 occur at the highest elevations and were glaciated and have snowmelt driven hydrologic regimes, with very deep snow pack on many years. They will also receive monsoon rains, which can recharge hillslope aquifers. Fens and wet meadows will be the most common wetland types, and there may be clusters of wetlands in areas with suitable topography, landforms, and ground water flow systems.

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