Ecosphere
Environmental Services

District 10 and 4
2012 Vegetation Inventory

Many Farms, Rough Rock, and portions of Black Mesa Communities

Arizona

Prepared for:

Bureau of Indian Affairs
Chinle Agency – Natural Resources

May 2013

Durango, CO
Cortez, CO
Pagosa Springs, CO
Farmington, NM

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ACRONYMS

ADW	Air-Dry Weight
%ADW	percent air dry weight
AUM	animal unit months
BIA	Bureau of Indian Affairs
Ecosphere	Ecosphere Environmental Services
ft^2	square foot
g	grams
GIS	geographic information systems
GPS	Global Positioning System
HCPC	historic climax plant community
lbs	pounds
NNDOA	Navajo Nation Department of Agriculture
NNDWR	Navajo Nation Division of Water Resources
NRCS	Natural Resource Conservation Service
RMU	Range Management Unit
SOW	Statement of Work
SUYL	sheep unit year long
USDA	United States Department of Agriculture

ABSTRACT

Ecosphere Environmental Services was contracted by the Bureau of Indian Affairs to collect and compile vegetation data on portions of Land Management Districts 10 and 4, of the Chinle Agency. Data were collected from 391 transect locations in three communities—Many Farms, Rough Rock, and part of Black Mesa. Data collection occurred during July of 2012. Measurements were taken for biomass production, ground cover, and species composition. The data were analyzed to determine annual production, species frequency, condition class of the range resource and initial stocking rates for each management area. The results include the carrying capacity of the range resource, as well as the similarity to the historic climax plant community.

Data were analyzed by range sites within grazing compartments. Carrying capacities and recommended stocking rates were calculated by compartment using available forage. The data were aggregated by range site and then analyzed according to the acreage within each compartment.

Overall, range sites in the project area are in poor to fair condition when compared to the historic climax community. Carrying capacity is less than the current permitted numbers.

1. INTRODUCTION

Ecosphere Environmental Services (Ecosphere) was contracted by the Bureau of Indian Affairs (BIA) to conduct under-story rangeland vegetation inventories on a portion of Grazing Districts 10 and 4 of the Chinle Agency. Species-specific vegetation data measurements included annual production, cover, and frequency. This data was also used to calculate carrying capacity based on available forage production. Information derived from these calculations can be used to guide management decisions, including stocking rates. This report supplies the results of the vegetation inventory as well as the background, methodology, and discussion necessary for management planning.

1.1 Purpose and Need

Baseline range condition data is critical to establishing quality range management practices. The purpose of the inventory is to provide baseline information regarding the existing range resource so resource managers and permittees are further enabled to improve and/or maintain the condition of the range resource. The results of this inventory will also enable recommendations for adjusted stocking rates and more comprehensive range management plans that are crucial for future range productivity.

1.2 Regulatory Entities

The Navajo Nation Department of Agriculture (NNDOA) manages livestock grazing activities on the Navajo Nation, primarily through District Grazing Committees. Livestock grazing permits are administered by the BIA Natural Resources Program in accordance with the Navajo Grazing Regulations (25 CFR §167). All three parties—the BIA, NNDOA, and the Grazing Committees—coordinate their activities in an effort to utilize and manage the range resources.

1.2.1 BIA Agency Natural Resources Program

All livestock grazing permits are issued by the BIA Natural Resources. Master livestock grazing records are also maintained by the BIA Natural Resources. The BIA is responsible for complying with all federal statutes, orders, and regulations. According to the BIA, their obligation “is to protect and preserve the resources on the land, including the land itself, on behalf of the Indian landowners. Protection and preservation includes conservation, highest and best use, and protection against misuse of the property for illegal purposes. BIA will use the best scientific information available, and reasonable and prudent conservation practices, to manage trust and restricted Indian lands. Conservation practices must reflect local land management goals and objectives. Tribes, individual landowners, and BIA will manage Indian agricultural lands (BIA 2003).” A summary of the BIA range policy (BIA 2003) is outlined below.

BIA Range Policy

- Comply with the American Indian Agricultural Resources Management Act of December 3, 1993, as amended.
- Comply with applicable environmental and cultural resources laws.
- Comply with applicable sections of the Indian Land Consolidation Act, as amended.

- Unless prohibited by federal law, recognize and comply with tribal laws regulating activities on Indian Agricultural land including tribal laws relating to land use, environmental protection, and historic and/or cultural preservation.
- Manage Indian agricultural lands either directly or through contracts, compacts, cooperative agreements, or grants under the Indian Self-Determination and Education Assistance Act, as amended.
- Administer land use as set forth by 25 CFR 162—Leases and Permits and 25 CFR 167-Navajo Grazing Regulations.
- Seek tribal participation in BIA agriculture and rangeland management decision making.
- Integrate environmental considerations into the initial stage of planning for all activities with potential impact on the quality of the land, air, water, or biological resources.

1.2.2 District Grazing Committees

Districts, formally called Land Management Districts, were established in 1936 by the Soil Conservation Service (now called Natural Resource Conservation Service [NRCS]) and adopted by the BIA. The periodic sampling of rangelands allows district grazing committees to evaluate the carrying capacity and resulting stocking rates of rangelands (Goodman 1982).

The Navajo Nation is organized into 110 chapters. Chapters, also called communities, are locally organized entities similar to counties, and are the smallest political unit. District grazing committees consist of elected representatives from each community who are responsible for monitoring livestock grazing within their respective chapters. District grazing committees approve the carrying capacities of their districts.

Individual grazing district committee members are directly accountable to their local chapters and administratively accountable to the Director of the NNDOA. The NNDOA is also responsible for annual livestock tallies to determine if permittees are in compliance with their permit. In addition, the NNDOA and the district grazing committees are responsible for enforcement of range management and resolving grazing disputes. The district grazing committee members are responsible for attending district grazing committee meetings, as well as chapter meetings, and for ensuring that permittees respect applicable laws, regulations, and policies.

1.3 Grazing Overview

Timing of grazing, movement, and dispersal of livestock, and animal numbers are all factors that must be considered when optimizing livestock production. Prior to considering these factors, managers should first recognize animals’ ability to harvest efficiently the nutrients present in their surroundings. This requires an understanding of foraging behavior as influenced by an animal’s environment. Established grazing patterns are dictated by topography, plant distribution, composition, and location of water, shelter, and minerals (Heitschmidt 1991). The total forage production of a given pasture or grazing area does not necessarily reflect the amount of forage available to livestock. It is important, therefore, to recognize specific factors that restrict forage availability such as inaccessibility, long distances to water, steep slopes, or other factors. Once identified, production from these areas can be subtracted from the total or adjustments can be made for inclusion of these areas. An example of this would be to develop additional water sources in areas rarely visited by livestock due to a scarcity of water.

After likely foraging patterns have been determined for a given area, production and forage value data can be used to help determine how many animals should be allowed to graze in the given area. Low stocking rates benefit individual animals, as more resources are available due to lowered competition with other animals. Conversely, high stocking rates can inhibit the individual animal, but the increase in total livestock production allows for greater, short-term gains for the producer. The final stocking-rate decision must take into consideration the ecosystem as a whole. Maintaining long-term viable rangelands provides for the continued health of livestock and long-term financial gains for producers or permittees. Viable rangelands also provide for the continued health of the local air, water, and other ecological resources.

Grazing during the initial growing season and late season grazing at the time of seed development can be very detrimental to plant vigor and root development. This will remain a problem for rangeland managers as long as livestock grazing permits are issued for year-round grazing. However, Holecheck (1999) argues that stocking rate has a much greater impact on range condition than the season of use.

Stocking rates are correlated with the prevention of overgrazing. When livestock, wildlife, and feral horses graze and browse on a site, they each select their own preferred species. If the site is stocked too heavily and for too long a time, the desired forage species will become overgrazed. These preferred species are weakened and their mortality rate increases, resulting in a reduction of their percent composition on the site. If deterioration continues, the less valuable forage species are replaced by invaders and noxious weeds.

In general, managers should be aware that the final products of this inventory are subject to a variety of factors. The application of stocking rates to determine carrying capacity should be used with care and in context to seasonal, topographic, and behavioral factors.

2. RESOURCE DESCRIPTIONS

Knowledge of the resource issues that affect rangeland health and productivity is essential to any management plan. Stocking rates, season of use, annual precipitation, soil types, location of water sources, and topography strongly influence the variety and quality of forage on rangelands. The results of this vegetative inventory quantify the current conditions of the rangelands on Districts 10 and 4—Many Farms, Rough Rock, and portions of Black Mesa communities. This information can be used to document future changes on the rangelands and assist with management decisions.

2.1 Geographic Setting

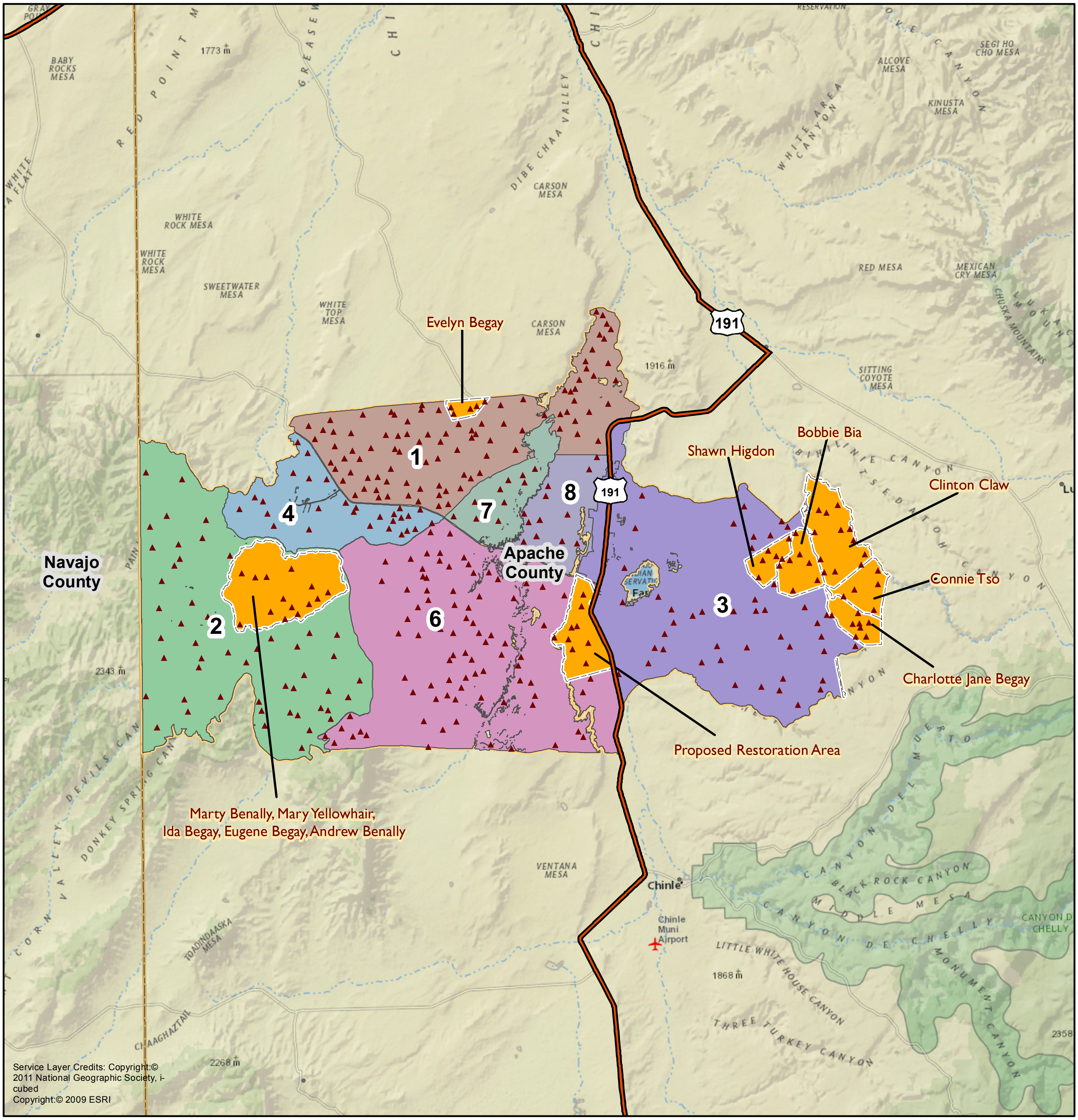
The project area is located within the Colorado Plateau Major Land Resource Area. The study area surveyed is geographically diverse and ranges from the piñon-juniper woodlands on Black Mesa at 7,800 feet in elevation to the Chinle Valley at 5,200 feet. The Black Mesa community contains steep canyons and piñon-juniper woodlands on its western side; the eastern side of Many Farms includes clay and greasewood flats that continue north into Rough Rock community. Both Rough Rock and Many Farms communities have dunes/stabilized sand dunes formed from the decomposition of nearby sandstone mesas. The topography of Rough Rock and Many Farms is rolling and far less drastic than the canyons and steep slopes of Black Mesa.

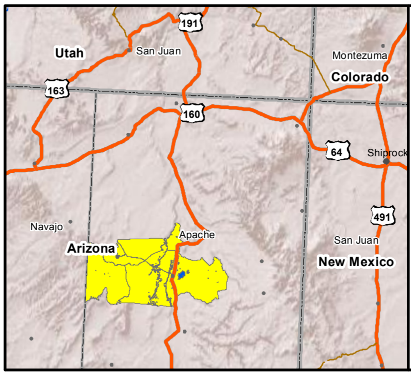
The communities of Rough Rock, Many Farms, and Black Mesa are located in Apache County, Arizona. Many Farms is bordered on its east side by Agua Sal Creek, while the western side abuts the base of Black Mesa. This physical edge of Black Mesa also forms the eastern boundary of Black Mesa Community. This community is bounded on the west by the Apache county line, which runs north to the northern edge of Black Mesa. This point also forms the southern boundary of Rough Rock community. Rough Rock is defined on the north by a fence line that runs east, to the heart of the Chinle Valley and the Many Farms Community.

Acreages for each compartment were extracted from digital shapefiles provided by the BIA, Chinle Agency. According to these shapefiles and the soil survey boundaries, there are a total of 268,789.69 acres within the project area. The majority (202,603.18) is in District 10 and the remaining acreage (66,186.51) extends into the eastern portion of District 4. The area is subdivided into seven compartments. There are also eight Range Management Units (RMUs) representing portions of Compartments 1, 2, 3, and 6. The acreage for each compartment and RMU can be found in Table2-1.

Table 2-1. Acreages of each Compartment and Range Management Unit

Compartment	District	Acreage
1	10	36,687.55
2	4	55,347.12
3	10	55,389.98
4	10	15,700.32
6	10	59,104.21
7	10	5,165.61
8	10	9,793.65
Range Management Unit	**District/Compartment**	**Acreage**
Bobby Bia	10/3	2,909.25
Charlotte Jane Begay	10/3	2,172.18
Clinton Claw	10/3	5,921.34
Connie Tso	10/3	2,690.09
Evelyn Begay	10/1	826.51
Martin Benally, Mary Yellowhair, Ida Begay, Eugene Begay, Andrew Benally	4/2	10,708.22
Proposed Restoration Area	10/6	4,675.10
Shawn Higdon	10/3	1,698.56





▲ D10 Transects
▭ Range Analysis Boundary
🟧 RMUs
▭ Navajo Nation
▭ State
▭ County
〰 US Highway

Compartments

🟫 1
🟩 2
🟪 3
🟦 4
🟪 6
🟩 7
🟪 8

Total Acreage:
268,790

0 1.5 3 6 Miles

1:400,000

Coordinate System: NAD 1983 UTM Zone 12N

BIA Chinle Agency 2012 District 10/4 Range Assessment

Project Overview Map

Navajo Nation, AZ

Date: 6/7/2013

2.2 Precipitation

An accurate precipitation monitoring system is essential to range management programs. Biomass production calculations are directly affected by precipitation measurements when reconstructing the plant community to a normal production year. If precipitation is over-estimated in the reconstruction factor, the total annual production estimate decreases. If precipitation is under-estimated in the reconstruction factor, the total annual production estimate increases. Precipitation gauges are located throughout the Navajo Nation and data are managed by the Navajo Nation Division of Water Resources (NNDWR). The NNDWR provided 11 years of precipitation data from several rain can stations in the Chinle Agency. The precipitation data are provided as Appendix A.

2.3 Soils

Knowledge of the soil properties in a particular area can help predict forage production. Soil properties such as texture, depth, moisture content, and capacity can dictate the type and amount of vegetation that will grow in a particular soil. The application of soil survey information is what enables rangeland managers to provide estimates of forage production in a given area.

“The type and size of map unit delineations, scale of data collection, sampling protocols, and date of the last inventory completed are all factors to consider when using existing soil surveys and rangeland inventories… [S]oil types, plant composition and production yield are representative for an area but may have significant dissimilar inclusions and/or change over time” (BIA 2003).

Most of the inventory project area is located within the boundaries of a soil survey produced by the United States Department of Agriculture, Soil Conservation Service: Chinle Area, Parts of Apache and Navajo Counties, Arizona, and San Juan County, New Mexico (AZ713). However, this soil survey was not complete before the initiation of the study; therefore, AZ713 soil map units were not applied.

The study area soils, however, are wholly mapped by a 1974 soils survey that relied on aerial photo delineation of soil units and field verification of these boundaries. The physical and chemical characteristics of each soil type were also quantified and correlated to the plants that grow on each major soil unit. The 1974 soils survey produced Range Site sheets associated with each major soil type, describing the typical dominant plants and expected biomass production for varying degrees of range condition classes. They are further described in the next section.

3. RANGE SITES

Range sites are areas of land having a unique set of soil, climate, and vegetation characteristics. These characteristics include soil texture, soil depth and permeability, average slope, precipitation, elevation, exposure, temperature, historic plant composition, potential forage production, and tree overstory. Range sites are a traditional component of rangeland inventories and serve as way to classify rangeland for the purposes of study, evaluation, and management. Range site descriptions are based on the concept that plant succession progresses in a linear fashion. A plant community starts from essentially bare ground and, if left undisturbed, will eventually develop into a predictable suite of species that is in equilibrium with climate, soil, and biotic factors associated with a given range site. This final set of plant species is known as the climax community. Rangeland condition scores are assigned to current plant communities based upon plant composition and annual production as compared to the climax community. The corresponding weight or percentage of “allowable” species designates whether a range site is in poor, fair, good, or excellent condition.

The linear mode of succession is a convenient model, but it does not accurately portray the complexity inherent in biological communities. A vegetation community undergoes numerous internal factors, such as inter- and intra-specific competitions that interact and combine with external factors like climate change, fire, and grazing. These interactions are what dictate species composition and abundance at any given time. As a result, rather than a plant community simply moving toward or away from a single climax community, there is potential for the plant community to be pushed down a number of different pathways, each ending up with a unique composition of plant species. The ending points of these differing trajectories are known as steady states. Many steady states may be present that do not necessarily reflect the ultimate end result, as presented in the range site descriptions.

Transects in the study area were located within 17 range sites. Three range site descriptions were not available and were combined with similar range sites for analysis, according to direction from the BIA range staff at Chinle Agency. The replacements are Sandy Saline 2 for Saline 2, Loamy 4 for Sandy 4, and Sandy 4,poor. The Sandy 2 and Thin Breaks 4 range sites account for more than half of the project area, followed by Saline Lowland 2, Loamy 2, and Thin Breaks 2. All other range sites cover less than 10,000 acres each. Approximately 43,000 acres in the study area did not contain any transects either due to a low capacity to produce forage, such as farm lands or rough broken range sites, or because of small acreage, such as the 88 acres of Sand 2. The acreage with no transects includes riverwash areas, rock complexes, badlands, and designated non-usable lands.

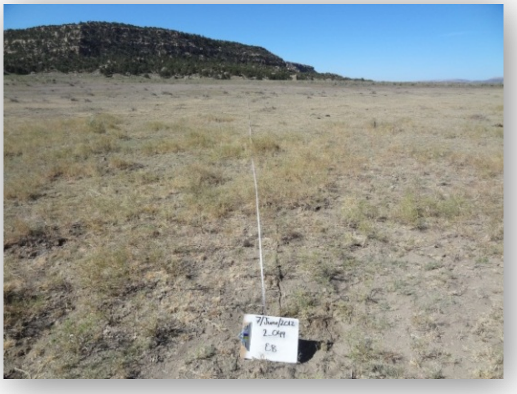
The 17 range sites which contained transects in the District 10/4 study area are listed below (Table 3-1), followed by representative examples of each site in one or two photographs with transect locations identified.

Table 3-1. Transect Range Sites

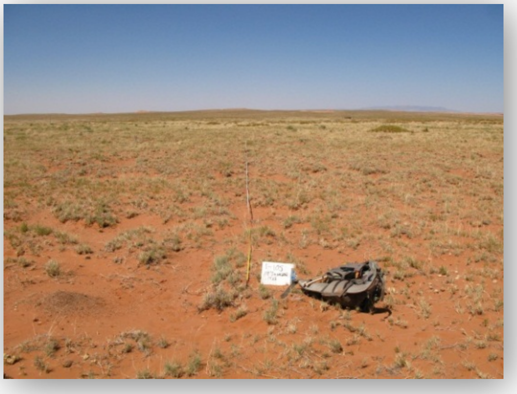
Range Site	# of Transects
Clayey 2	4
Clayey 3	8
Loamy 2	69
Loamy 3	11
Loamy 4	18
Saline Lowland 2	37
Sands 2	9
Sandy 2	144
Sandy 3	2
Sandy Saline 2	13
Shallow 2	18
Shallow 4	5
Thin Breaks 2	9
Thin Breaks 3	3
Thin Breaks 4	35
Very Shallow 2	3
Very Shallow 4	3
TOTAL	391

Clayey 2 (Transects 6-213 and 6-209)

Clayey 3 (Transects 2-049 and 2-045)



Loamy 2 (Transects 1-105 and 3-300)

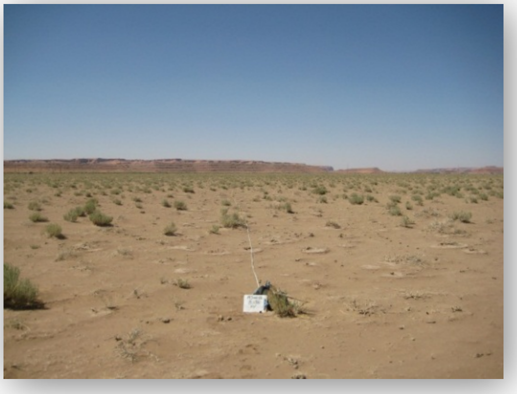


Loamy 3 (Transects 3-271 and 3-273)

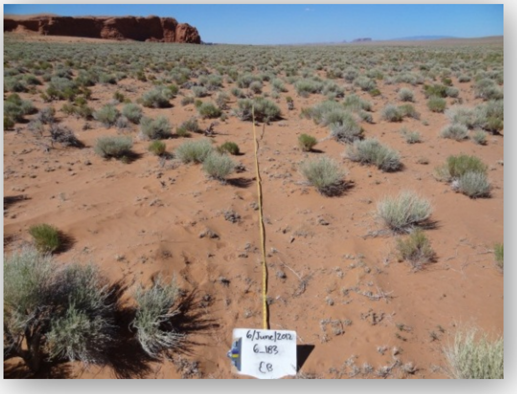
Loamy 4 (Transects 2-060 and 2-039)

Saline 2 (Transects 3-247 and 3-137)

Saline Lowland 2 (Transects 1-125 and 8-136)



Sands 2 (Transects 6-183 and 1-059)



Sandy 2 (Transects 1-066 and 1-109)

Sandy 3 (Transects 2-046 and 3-258)

Sandy Saline 2 (Transects 6-150 and 6-239)

Shallow 2 (Transects 3-324 and 3-309)

Shallow 4 (Transects 6-217 and 6-215)

Thin Breaks 2, 2a, & 2b (Transect 4-026)

Thin Breaks 3 & 3a (Transects 4-022 and 4-027)

Thin Breaks 4a & 4c (Transects 2-022 and 2-008)

Very Shallow 2 & 2a (Transects 3-327 and 3-261)

Very Shallow 4 & 4a (Transects 6-220 and 6-218)

4. METHODOLOGY

The methods used to collect project data included protocols provided by the BIA modified to standards used in federally published Technical References.

The Statement of Work (SOW), provided by the BIA, described the study design and cited specific methodologies for data collection (Coulloudon 1999, Habich 2001, and USDA NRCS 2003).

The field methodology was based on the SOW and the technical references listed above, with modifications approved by the BIA.

4.1 Field Methodology

4.1.1 Transect Establishment

Data collection occurred between June 2 and June 19 of 2012. The BIA provided Ecosphere with predetermined transect locations. The Universal Transverse Mercator coordinates of these transect locations were downloaded into hand held Global Positioning System (GPS) units. The GPS unit was used in combination with topographic maps to navigate by vehicle and foot to the transect locations. Transects were established within ten meters of the GPS coordinates and usually within one meter.

Transects consisted of a 200-foot straight line that was measured with an open-reel tape placed flat and straight along the ground and stretched taut as much as possible. Using field maps and topography as a guide, each transect was placed within a single soil unit and vegetation community. The transect azimuth was randomly determined by selecting a prominent distant landmark, such as a mountain or lone tree. The transect azimuth was read with a compass and recorded. The 200-foot tape was then extended along the transect azimuth. Vegetation attributes were read from ten plots at 20-foot intervals along the open reel tape. The plots were measured with a square 9.6 square foot (ft^2) quadrant frame. The 9.6 ft^2 plot is generally used in areas where vegetation density and production are relatively light (USDA NRCS 2003). Care was taken to avoid bias by establishing each plot using a consistent method; in this case, always laying the frame to the right side of the tape. Point intercept for ground cover was first measured at the four corners of each plot. Aspect, slope, surface soil texture, and notes were recorded in addition to the vegetative attributes.

4.1.2 Production Data Collection

Weight is the most meaningful expression of the productivity of a plant community or an individual species. It has a direct relationship to feed units for grazing animals that other measurements do not have. Production is determined by measuring the weight of annual aboveground growth of vegetation. Some aboveground growth is used by insects and rodents, or it disappears because of weathering before production measurements are made.

For the purposes of this study, production was measured as standing forage crop and reconstructed to peak standing crop. Standing forage crop is the total herbaceous and woody plant biomass present aboveground and available to herbivores, while peak standing crop is the greatest amount of plant biomass aboveground present during a given year (Coulloudon et al. 1999). Production includes the aboveground parts of all plants produced during a single growth year. Excluded are underground growth, production from previous years, and any increase in the stem diameter of shrubs.

Production and composition of the plant communities were determined by a combination of estimating and harvesting (double sampling). Ecosphere followed the double sampling methodology of the United States Department of Agriculture, Natural Resources Conservation Service (USDA NRCS) modified to standards outlined in the SOW, and modifications generated from the pre-work conference. This double sampling method is detailed in the following sections.

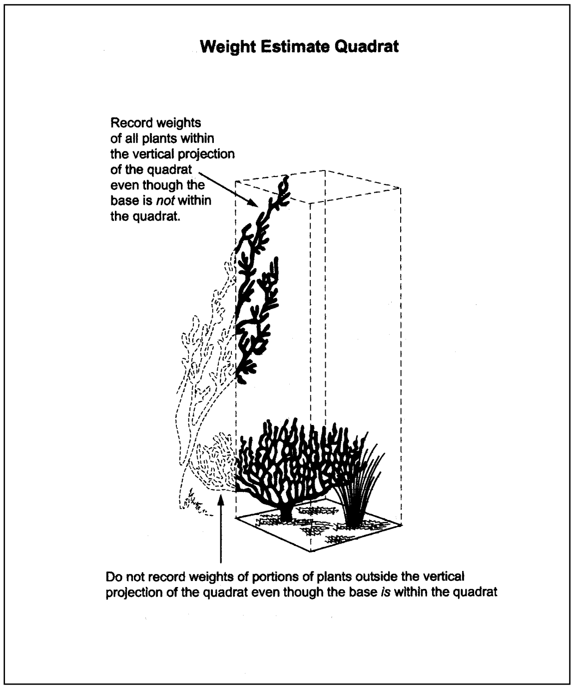
4.1.2.1 Establishing a Weight Unit

A weight unit is a part of a plant, an entire plant, or a group of plants of the same species used for estimation purposes. The weight unit method is an efficient means of estimating production. After weight units are established, field teams can be very accurate in production estimation. A weight unit estimation is created by visually selecting part of a plant, an entire plant, or a group of plants that will most likely equal an estimated weight. For example, a fist-sized clump of healthy, un-grazed *Achnatherum hymenoides* may equal 10 grams (g). This clump of grass is then harvested and weighed with a hand scale to determine actual weight. The process is repeated until 10 g of *Achnatherum hymenoides* can be visually estimated with accuracy. The field team maintained proficiency in estimating by periodically harvesting and weighing to check estimates of production.

4.1.2.2 Double Sampling Methodology (Estimating and Harvesting)

Production (in grams) was estimated by counting the weight units of each species in each plot. All plants and parts of plants inside an imaginary box that was outlined by the actual 9.6 ft^2 frame up to a height of four feet were estimated. Excluded were any plants and parts of plants outside of the box (Figure 4-1). Two plots on each transect were chosen for harvesting. On the harvested plots, all species were estimated *in situ* and then harvested at ground level. In many cases, vegetation was diverse and widespread such that no two plots could effectively represent all species. In an effort to include more species in the harvested material, a weight unit of species that was absent in the two harvested plots, but contributed 10 g or more of estimated production on the transect, was estimated and clipped individually outside of the transect and recorded as plot 11. Clipped biomass was weighed with a hand scale, and both estimated and harvested (green) weights were recorded. All harvested materials were collected and stored in paper bags labeled with tracking information including transect, date, species, and plot number. All of the harvested material was allowed to air-dry for ten days or more before re-weighing to convert from field (green) weight to air-dry weight (ADW). The purpose of the double sampling is to correct any variability between the estimation of production and the actual weighed production. This is accomplished by using an estimation correction factor that is calculated in the post-field methodology.

Figure 4-1. Weight Estimate Box



Source: USDA NRCS 2003

4.1.2.3 Large Shrub Plots

Extended plots were established when the vegetation in the transect consisted of “large” shrubs. Neither the SOW nor the National Range and Pasture Handbook (USDA NRCS 2003) adequately define the large shrub plot methodology; however, the purpose of the large shrub plots is to capture the production of larger shrubs that are too big to be adequately measured within the 9.6 ft^2 frame. After consultation with the NRCS (Peter Lefebvre, personal communication) the following method was used. Two extended plots (0.1 acre) were measured at fixed points along the transect and only the large shrub species inside those plots were estimated. These shrubs were not measured in the ten, 9.6 ft^2 plots because that would be doubling the measurement. Large shrub plots would be expected in areas of tall, thick *Artemisia tridentata*, on flats of *Sarcobatus vermiculatus*, or in mountain shrub communities with *Amalenchier utahensis* and *Cercocarpus montanus*, for example.

4.1.2.4 Ocular Estimates of Utilization

Utilization, or use, is the proportion of annual growth that has been consumed by grazing animals. The purpose of estimating utilization is to include in the vegetation measurements the forage that has been consumed prior to the vegetation inventory. With the Ocular Estimation Method (Coulloudon et al. 1999a), utilization is determined by visual inspection of forage species. This method is reasonably accurate, commonly applied, and suited for use with both grasses and forbs. Field team personnel were thoroughly trained and practiced in making ocular estimates of utilization of plants. An attempt was made to locate un-grazed plants near the transect. These un-grazed plants were assumed to approximately represent the species before grazing occurred and were used as a comparison to estimate grazed plants. Some re-growth may have occurred before the inventory period. However, if grazing patterns are undetectable on the plant, it is impossible to determine what re-growth, if any, may have occurred. The percentage of un-grazed plant remaining was recorded for each species on each transect.

4.1.2.5 Sensitive Plants Protocol

Threatened, endangered, culturally important, or otherwise sensitive plants were never intentionally harvested for the purposes of this inventory. The weight of such plants was estimated, but the plants were not clipped. Cacti and yucca species were not clipped, their annual production was estimated using standard protocols as described in the National Range and Pasture Handbook (USDA NRCS 2003)). Production for yuccas was considered 15 percent of total green weight. Cholla cacti production was considered 15 percent of active tissue, prickly pear 10 percent, and barrel cacti 5 percent. A list of all plant species recorded during the inventory is included as Appendix B. Also in Appendix B is a list of scientific collections made during the data collection, under Ecosphere's valid Navajo Nation permit.

4.1.3 Frequency Data Collection

Frequency describes the abundance and distribution of species. Frequency measurements are an easy and efficient method for monitoring changes in a plant community over time. Frequency is the number of times a species is present in a given number of sampling units, usually expressed as a percentage.

On rangeland, regeneration of desirable plants maintains good range conditions. Grazing by too many animals (livestock and wildlife) or heavy utilization by a few animals results in overuse, loss of vigor, and ultimately disappearance of the preferred and desirable plants. Deterioration of the range vegetation begins when less valuable forage species replace the desirable species. If deterioration continues, the less valuable forage species are replaced by invaders and noxious weeds. The frequency and composition of preferred and desirable species compared to less valuable forage is an indication of the range condition.

4.1.4 Cover Data Collection

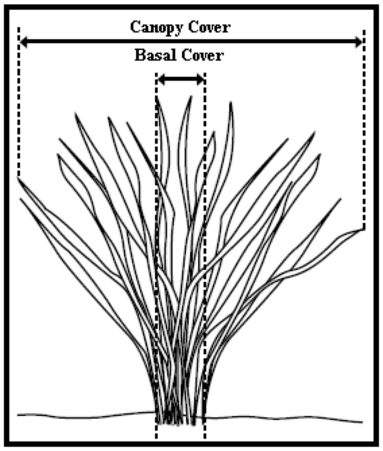
Ground cover measurements are used to quantify the amount of vegetation, organic litter, biological crusts, and exposed soil surface throughout an area. Cover is also important from a hydrologic perspective when examining basal and canopy (foliar) cover of perennial and annual species and litter cover. This study measured understory vegetation; no trees were included in the cover data.

Ground cover data can assist in determining the soil stability and proper hydrologic function of a site, as well as the biotic integrity of a site. Point-Intercept cover measurements are highly repeatable and lead to more precise measurements than cover estimates using quadrants. For trend comparisons in herbaceous plant communities, basal cover is generally considered to be the most stable because it does not vary as much from climatic and seasonal conditions (compared to canopy cover). Canopy cover can vary widely over the course of the growing season, which can make it hard to compare results from different portions of large areas where sampling takes several weeks or a few months. In the future, ground cover monitoring for each ecological site within each grazing unit should replicate the sampling period from this baseline inventory.

The Point-Intercept method employed on this study consisted of a modified pin/point frame. At each plot along a transect a sighting device (pin flag) was placed in each of the four corners of the 9.6 ft^2 quadrant frame. The cover category is determined by the first interception at each of the pin points. A total of 40 measurements, or hits, were recorded from ten frame placements. Only the point of the pin flag was used to record a hit. Emphasis was placed on lowering the pin directly (perpendicular to the ground) in the corners of the quadrant frame as specified in technical reference 1734-4 Sampling Vegetation Attributes (Coulloudon et al.1999). Ground cover hits fell into the following categories: Basal Vegetation, Canopy Vegetation, Litter, Bare Ground, Rock/Gravel, and Biological Crust. A Basal Vegetation cover hit was recorded when the pin flag struck the ground surface occupied by the basal portion of the plant. Canopy Vegetation hits were recorded when the pin flag struck the area covered by the projection of the outermost perimeter of the natural spread of foliage of plants (Figure 3-2). Litter hits were recorded when the pin flag intercepted herbaceous or woody plant debris. Bare Ground was recorded when the pin flag struck bare ground free of litter, vegetation, gravel or stone, or any biological crusts. Rock/Gravel was recorded when the pin flag intercepted gravel or stone free of vegetation. Measuring cover by points is considered one of the least biased and most objective cover measures (Bonham1989).

Measuring cover by points is considered one of the least biased and most objective cover measures (Bonham 1989). Results of the ground cover data analysis are included in Section 5: Results

Figure 4-2. Vegetative Cover



Source: Elzinga, Salzer, and Willoughby 1998)

4.1.5 Soil Surface Texture Test

At each transect the A Horizon (top 0-6 inches) of the soil surface was sampled. The surface was cleared of debris to bare mineral soil. A small sample was analyzed using the USDA Soil Texturing Field Flow Chart (Appendix C). The Flow Chart uses a step-by-step procedure for estimating sand, silt, and clay content. The test also uses the ribbon method to determine the fraction of fine-grained particles within the sample. Field teams assigned a texture class to the sample based on its tested content and ribbon characteristics.

4.2 Post-Field Methodology

After field data collection is complete, the data must be prepared and analyzed. All field data is downloaded into a database. Harvested biomass is air-dried for ten days and then each sample is weighed. Dry weights are then entered individually into the database by each species on each transect. When the initial field dataset is complete, calculations are applied to reconstruct the collected production data to the amount of vegetation that would occur in a "normal" year. These adjustments include utilization, climate, growth curve, and air dry weight corrections.

When the reconstruction factor calculation is complete for every species on every transect, the results are grouped by ecological sites within each community and the data are analyzed. Analysis includes similarity indices, available forage based on forage value and harvest efficiency factors, and stocking rates and carrying capacity.

4.2.1 Reconstructed Annual Production

The translation of a plot that is full of plants to a measure of pounds (lbs) per acre is achieved through a series of calculations. The formula, derived from technical reference 1734-7 Ecological Site Inventory (Habich 2001) and the National Range and Pasture Handbook (USDA NRCS 2003), reconstructs the measured weight of biomass to a "normal" annual air-dry production weight, which accounts for physical, physiological, and climatological factors. First, the green weight of a species that was estimated in the field is multiplied by an estimation correction factor and then by a reconstruction factor. The reconstruction factor is the percent air-dry weight (%ADW) of the species divided by the result of the utilization multiplied by the percent of normal precipitation for the current water year and multiplied by the growth curve for that time of year. This may be more easily understood with the formula below:

$$\text{Corrected Green Weight}\left\{\frac{\%ADW}{(\%\text{Utilization})(\%\text{Normal Precipitation})(\%\text{Growth Curve})}\right\}$$

The result is called the total reconstructed annual production. The details of each of the elements in this equation are explained in the following sections.

4.2.1.1 Corrected Green Weight (Estimation Correction Factor)

The harvested or clipped plots provide the data for correction factors of estimated species weights from the field. Measured (clipped) weights of species were divided by the estimated weights of the same species in the same plots to establish a correction factor. This correction factor was then applied to all estimations of that species for the entire transect. For example, if *Sporobolus airoides* was estimated to weigh 10 g, but the clipped weight was actually 9 g, then all estimates of *S. airoides* for that transect would be multiplied by 0.90. If the total estimated weight for estimates of *S. airoides* on all plots in this transect was 80 g, the resulting corrected weight would be 72 g as illustrated below.

$$\text{Correction Factor} = \frac{\text{Sum of Measured Weights}}{\text{Sum of Estimated Weights}} = \frac{9g}{10g} = 0.90$$

Thus, in the example: (estimated green weight (g) x correction factor) = 80g x 0.90 = 72g, the corrected green weight is 72 g.

4.2.1.2 Biomass ADW Conversion

The air dry weight percentage is part of the Reconstruction Factor and accounts for the amount of water contained in plants. The purpose is to remove the weight of water from the weight of the actual forage of the plant. All biomass from harvested plots was collected in paper bags, with tracking information recorded on the bags (date, transect identification, plot number, and species). Harvested, or green, weights were immediately weighed with a hand scale (which was adjusted for the weight of the bag) and recorded. The paper bags filled with biomass were air-dried for a minimum of ten days. All bags were then weighed again and dry weights were recorded into the dataset. The weights after drying were divided by the green weights to give a %ADW in grams to be used in the Reconstruction Factor. In the example above, the green weight of the harvested biomass was 9 g. If the dry weight in the lab was measured at 8 g, then the %ADW would be 0.888.

For species in a transect that were not harvested, an average %ADW was used, generated from the same species in the same community. In the case of remaining species, the %ADW defaulted to one.

$$\%ADW = \frac{\text{Dry Weight (lab)}}{\text{Green Weight(field)}} = \frac{8g}{9g} = 0.8888$$

This value (0.8888) represents the numerator of the Reconstruction Factor. The three values in the denominator are explained below.

4.2.1.3 Utilization

The utilization estimate is applied to adjust for portions of plants that were not measured due to grazing of the plant prior to the survey. The default is 100 percent un-grazed. Grazed, or utilized, species were measured according to the average amount of plants that remained un-grazed in the vicinity of the transect. As an example, if *S. airoides* was recorded at a utilization factor of 90 percent un-grazed, then the amount of *S. airoides* estimated would represent only 90 percent of the total amount of *S. airoides*.

Utilization = 0.9000

The total weight of the species in the transect is divided by 0.9 to bring the measured weight up to 100 percent.

4.2.1.4 Growth Curves

Growth curves are used to reconstruct the above-ground portion of a plant that has not yet reached its full growth potential for the season. The application of a growth curve accounts for the amount of forage that has not yet grown, and thus was not measured during the vegetation inventory. A measurement taken in June will be much less than a measurement of the same plant taken in September, when the plant is nearing full growth. A growth curve calculates the average growth, by month, of plant species throughout the year within a specific region. For example, if *S. airoides* was measured in a transect during August, that measurement may represent only 88 percent of the full growth of that species.

Each growth curve entry was a pro-rated value according to the day of the month. For example, using the growth curve AZ3521, and a transect that was sampled August 21, the first step would be to total the percentage of growth completed up to that date by adding up the monthly categories: Feb (1 percent), plus Mar (9 percent), plus Apr (20 percent), plus May (27 percent), plus June (14 percent), and plus July (10 percent) for a subtotal of 81 percent of the growth curve completed.

Then, for the month of August, 21 days would need to be pro-rated and added to the total. The value is determined by dividing the percent of growth occurring in August (11 percent) by the 31 days that occur in the month of August. This calculation yields a rate of .35 percent per day. The number of days that have occurred up to that date (21) is multiplied by the daily rate (.35 percent) for 7.45 percent. This is added to the 81 percent that had occurred up to the end of July for 88.45 percent of the growth curve completed.

Growth curves are often provided in an ecological site description. Since ecological site descriptions were not available for the study area, a standard Arizona growth curve from the NRCS was used.

The growth curve used for all sites was:

AZ3511, 35.1, 10-14” precipitation zone all sites.

Growth Curve Description: Growth begins in the spring and continues through the summer, most growth occurs during the summer rainy season. Percent production by month:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	1	5	11	18	25	24	13	3	0	0

Growth Curve = 0.8845

The growth curve for the example equation is 0.8845 percent. The total weight of the species in the transect is divided by 0.8845 to bring the measured weight up to 100 percent of growth for the year.

4.2.1.5 Percent Normal Production

The Percent Normal Production is directly affected by growing conditions. Precipitation amount and timing, as well as temperature and their relationship, have an impact on species production. Production varies each year, depending on the favorability of growing conditions. Biomass production measurements from year to year are not accurate without accounting for percent of normal production influences. For this inventory, the variation in precipitation was used as the value for percent of normal production. The factors of precipitation timing and temperature are extremely difficult factors to quantify and apply to biomass production because the impacts vary by individual species. All weather stations in the Chinle Agency were used to reconstruct percent of normal precipitation, and thus percent of normal production. Percent of normal production for the project in 2012 was 81.7 percent of average.

For this calculation example, the water year was 102 percent of the average.

4.2.1.6 Reconstruction Equation

Using the example carried through the previous sections, Ecosphere began with an estimated green weight (in the field) of 80 g of *S. airoides*, multiplied by the estimation correction factor for a corrected green weight of 72 g. This corrected green weight of 72 g is then multiplied by the reconstruction equation:

$$\text{Reconstruction Equation} = \frac{\underline{0.888}}{(0.900 \times 1.02 \times 0.8845)} = \underline{1.094}$$

The formula for the reconstruction equation, as explained above, is repeated here:

$$\text{Corrected Green Weight}\left\{\frac{\%ADW}{(\%\text{Utilization})(\%\text{Normal Precipitation})(\%\text{Growth Curve})}\right\}$$

When actual values from the *S. airoides* example are inserted into the formula the equation becomes:

$$72g\left\{\frac{0.8888}{0.900 \times 1.02 \times 0.8845}\right\} = 72g \times 1.094 = 78.74g$$

The corrected green weight from the example above (72 g) multiplied by the reconstruction factor (1.094) results in a total reconstructed annual production of 78.74 g. In summary, the original estimate of *S. airoides* in the field, after the estimation correction factor, was 72 g, but when adjustments were made for air-dry weight, utilization of the plant, percent of normal precipitation for that year, and amount of forage expected to grow after the field measurement, the total was bumped up to 78.74 g.

4.2.1.7 Conversion from Grams to Pounds per Acre

The conversion from the working unit of grams (per transect) into the application of lbs per acre is factored into the formula. The plot size, 9.6 ft^2, was repeated ten times in each transect, thereby creating 96 ft^2 of sampling area, which calculates into a 1:1 conversion (Coulloudon et al. 1999). In this case, therefore, the conversion factor equals 1 and so is not explicitly written into the equation. Hence, in the example, there were 78.74 lbs per acre of *S. airoides*. The value 78.74 represents the total reconstructed annual production of the species in lbs per acre.

4.2.2 Calculating Ground Cover

Forty ground cover point intercepts were measured in each transect.Ground cover categories were calculated by a percentage of the total. For example, if 30 hits were recorded for bare ground, the percent of bare ground on that transect would be 75 percent (see equation below). Ground cover calculation categories were canopy vegetation, basal vegetation, litter, rocks or gravel, biological soil crust, and bare ground. It is important to note that bare ground refers to situations where soil was the only substrate present. A lack of foliar or basal cover in conjunction with duff, litter, rock, or bedrock is not considered bare ground. This is because true bare soil has less soil stability than duff, litter, rock, or bedrock. Cover data was averaged by compartment or RMU.

30 "bare ground" hits/40 total hits = 75% bare ground

4.2.3 Calculating Frequency

Species frequency was measured when weights were estimated for all species in each production plot. For example, if *S. airoides* occurred in six of the ten plots on a given transect, the frequency would be 75 percent. Frequency of species on each transect is included in the spreadsheet production data with this report (Appendix D). Frequency of the five most common species to appear on transects within each community is presented in Section 5: Results.

4.2.4 Calculating Condition Class

Range site descriptions use condition classes (poor, fair, good, and excellent) to indicate the present vegetation production as compared to the potential climax vegetation community. The climax community in a range site is similar to the Historic Climax Plant Community in ecological site descriptions.

In the District 10/4 study, the comparison began by looking at each species that occurred on a given transect. The total reconstructed weights of each species were compared against their corresponding allowable percentages on the range site description. On the more updated versions of the range site descriptions (ecological site descriptions) the reconstructed weight would then be multiplied by the percent allowable. For instance, if a Clayey site allowed 15 percent of *Bouteloua gracilis* and there were 40 lbs per acre on the transect, then only 6 lbs per acre would be allowed toward determining the condition of the site. In areas where ecological site descriptions have yet to be developed (this includes the project area), it is necessary to rely on the older range site descriptions. However, even though they also have percent allowable, range conservationists with the Natural Resource Conservation Service have recommended treating the percentages as actual weights (lbs per acre) and using the smaller of the two numbers when comparing the reconstructed weight to the allowable weight. So, in the aforementioned example, the 15 percent becomes 15 lbs per acre and, as this weight is less than 40 lbs per acre, it is the one used toward determining a condition class. In the data for this project (Appendix D) the allowable weights are located in the Reference Weight column and the results of the comparisons are recorded in the Total Allowable Weight column.

Most range site descriptions contain a production table showing the expected lbs per acre of annual air dry forage in both favorable and unfavorable years. The production table is further subdivided into the condition classes of Poor, Fair, Good, and Excellent. These numbers represent the amount of forage per acre that a range site would produce in a given condition. To illustrate, the Loamy4a range site with an excellent condition class should produce 460 lbs of forage in a favorable year and 305 lbs in an unfavorable year. Averaged together, production becomes 382.50 lbs per acre. The favorable and unfavorable figures were averaged because the reconstruction factor in the species calculations has already factored in the percent of normal precipitation and growth. In the data for this project (Appendix D) the averaged weights appear in the column labeled, *Total Production in Reference State*.

The "Allowable Percent" represents the percent composition of each species that would be expected within an Excellent condition class. All production for decreaser species is included and no production from invader species is included. Increaser species are given a percentage allowable to be included in the total forage. For example, if on a Loamy4a range site the reconstructed weight of *Pleuraphis jamesii* was 200 lbs, it would comprise 52 percent of the plant community (200 divided by 382.5). However, *P. jamesii* should not exceed 20 percent of the total or 76.5 lbs per acre (382.5 multiplied by 20 percent). The resulting 76.5 lbs per acre is the "pounds allowable." No more than 76.5 lbs per acre is included in the total lbs allowable.

The sum of lbs allowable for each species resulted in a total lbs allowable of forage. The amount of this forage determines the condition class. In Loamy 4a, a Poor condition class was assigned to transects with allowable forage production from 0 to 75 lbs per acre, a Fair condition class was assigned to transects with allowable forage production greater than 76 and up to 150 lbs per acre. For Good condition class the allowable forage was greater than 150 and up to 382.5 lbs per acre. Transects with more than 382.5 lbs per acre of allowable forage were assigned an "Excellent" condition class.

4.2.5 Calculating Available Forage

The forage value of a species is defined by a particular type of livestock in terms of palatability and the availability of the species. Only the values for common species are listed in the ecological site descriptions. However, a comprehensive list of species from the Colorado Plateau area was developed by the Utah NRCS. This list was used to assign forage values to all species recorded in the data collection. The list is included with the data in Appendix D. Species are grouped into five categories and each category is weighted accordingly. The five groups recognized by the National Range and Pasture Handbook (USDA NRCS 2003) are as follows:

- **Preferred plants**—These plants are abundant and furnish useful forage for a reasonably long grazing period. They are preferred by grazing animals. Preferred plants are generally more sensitive to grazing misuse than other plants and they decline under continued heavy grazing.
- **Desirable plants**—These plants are useful forage plants, although not highly preferred by grazing animals. They either provide forage for a relatively short period or they are not generally

abundant in the stand. Some of these plants increase, at least in percentage, if the more highly preferred plants decline.

- **Emergency (or Undesirable) plants**—These plants are relatively unpalatable to grazing animals or they are available for only a very short period. They generally occur in insignificant amounts, but may become abundant if more highly preferred species are removed.
- **Non-consumed plants**—These plants are unpalatable to grazing animals or they are unavailable for use because of structural or chemical adaptations. They may become abundant if more highly preferred species are removed.
- **Toxic plants—**These plants are poisonous to grazing animals. They have various palatability ratings and may or may not be consumed. Toxic plants may become abundant if unpalatable and if the more highly preferred species are removed.

Species that can be injurious to livestock, regardless of their palatability, were also noted with the forage value.

In many cases, a species has more than one forage value according to the season of use. For example, *Poa fendleriana* is considered preferred in the spring, but desirable during the remainder of the year. Year-round grazing currently occurs across the project area, so a single forage value is needed. Sheep preference was chosen for forage value, using the value of a plant during the least palatable season of the year. Choosing the lowest value provides a conservative estimate of the forage available for year-round grazing and lessens the chance of overgrazing during times of the year when forage resources are limited.

Each category of plants is assigned a harvest efficiency factor. The harvest efficiency factor accounts for production actually consumed by grazers and generally averages 25 percent on rangelands with continuous grazing (NRCS 2003). Not all annual production is available for livestock consumption due to trampling, loafing, and other non-livestock factors such as loss to disease, insects, or utilization by wildlife. Using NRCS guidelines, the harvest efficiency factors applied for this project were 35 percent for preferred plants, 25 percent for desirable, and 15 percent for undesirable/emergency plants. Non-consumed and toxic species were excluded from the calculations. The harvest efficiency factor is applied to the amount of production within a management area and its purpose is to ensure watershed protection and sustainability of the range resource by limiting allocation of the available forage.

The available forage was calculated from the amount of production provided by preferred, desirable, and undesirable/emergency plants, with harvest efficiency applied. Initial stocking rates were calculated from the available forage.

4.2.6 Acreage Reductions

The amount of actual land available for grazing was quantified using geographic information systems (GIS) files from the BIA. Homesites, farmland, and roads were buffered and removed from the total acreage available for livestock grazing. Other non-range areas were excluded from the analysis. Slopes that are greater than 60 percent are generally inaccessible to livestock and were not included in the grazing area. Moderately steep slopes may had reduced stocking rate (Table 4-1).

Livestock will rarely range more than 2 miles from a water source Holechek (1988). Areas further than 2 miles from a water source can be considered un-grazeable and that acreage should be removed from stocking rate calculations. Permitting in areas beyond 2 miles will lead to overgrazing and deterioration. However, if permittees are hauling water to their stock, this should be considered when determining stocking rates.

Based on livestock behavior, stocking rates were adjusted in the geodatabase for this study to account for distance to water and the steepness of slopes. Distance to water and slope percent were adjusted incrementally. BIA recommendations include 100 percent stocking rates between 0 and 1 mile from a water source, 50 percent stocking rate between 1 and 2 miles from the water source, and no grazing more than 2 miles from the water source (Table 4-1).

Water sources included windmill and artesian well data supplied by the BIA and wetland data created by Ecosphere for the Navajo Nation Wetland Mapping Project. Monitoring of the condition, addition, or loss of water sources should be updated in the geodatabase and resulting stocking rates.

Table 4-1. Distance to Water Reduction and Slope/Reductions

Distance to Water/ Reduction	Slope/Reduction
0-1 Mile/0%	0-10%/0%
1-2 Miles/50%	11-30%/30%
>2 Miles/100%	31-60%/60%
	>60%/100%

4.2.7 Initial Stocking Rates and Carrying Capacity

Stocking rate is the number of kinds and classes of animals grazing a specific area of land for a specific period. Carrying capacity for rangeland management purposes defines the number of grazing animals (maximum stocking rate) that a specified area is able to support without depleting the forage resources of that area. Carrying capacity incorporates both domestic and wild grazing animals, and the capacity may vary annually in response to forage production. Carrying capacity is largely determined by climate, topography, and soils. Stocking rates are set by managers in an attempt to achieve a balance between livestock performance, profitability, and rangeland health.

Maximum stocking rates were derived from the preferred, desirable, and emergency production with an application of harvest efficiency factors. The lbs of preferred, desirable, and emergency forage were incorporated into animal unit months (AUMs) or 790 lbs of forage per month. This standard figure was approved by BIA rangeland managers instead of a more conservative figure. For comparison, stocking rates were also calculated using an AUM of 912.5 lbs per month. Carrying capacities were calculated using the available forage, coupled with the acreage of each range site in a compartment.

5. RESULTS

Data were collected from 391 transects on the District 10/4 study area, which includes the communities of Many Farms, Rough Rock, and a portion of Black Mesa. The attributes collected at each transect included ground cover, biomass, and species composition. These data were used to calculate annual production, species frequency, condition class, and initial stocking rates for each compartment and RMU. Carrying capacity was calculated using GIS analysis and adjusted to reflect those portions of the project area currently not utilized by livestock due to excessive distance from a water source or inaccessible topography. At the recommendation of Chinle range staff, three range sites with missing range site descriptions were combined with similar range sites for analysis. Saline 2 range site was combined with Sandy Saline 2, while Sandy 4 and Sandy 4, poor were combined with Loamy 4. The study area included almost 270,000 acres that were analyzed by range site. Additional acreage was removed from the analysis due to unsuitability for grazing including 21,611 acres of badlands, rough broken range sites and rock complex. Another 6,238 acres was non usable range land including river wash and Many Farms Lake. Further, 18,706 acres of grazeable range sites within compartments or RMUs had no transect data to analyze and were not assigned any carrying capacity.

Overall, the majority of transects in each compartment was found to be in either fair or poor condition. Findings were better across the RMUs, but these are much smaller units and do not represent the project area as a whole. The following tables and charts show the summarized results for condition class, species composition, available forage, stocking rates, carrying capacity, and ground cover. A brief discussion of the results accompanies each table. A more thorough exploration of observed patterns and trends can be found in Section 6: Discussion.

5.1 Condition Class by Compartment

The summarized data for each compartment (Table 5-1) shows the area for most transects to be in fair to poor condition. Transects in good to excellent condition comprise only a little over 10 percent of the total, while those in poor and fair condition make up 55 percent and 32 percent respectively. Compartment 3 is in the best overall condition with 20 percent of the transect areas in excellent condition, 8 percent in good condition, and 27 percent in fair condition. The different sizes and composition of range sites makes comparing compartments impractical. It is possible, however, to observe some patterns and commonalities. For example, the most prevalent range site across the project area is Sandy 2; it occurs in all compartments except for Compartment 2 (Table 5-2) and nearly 40 percent of all transects fall within this range site. Five transects are in excellent condition, nine are in good condition, 63 are in fair condition, and the remaining 67 are in poor condition. The species producing the most biomass are *Pleuraphis jamesii*, *Salsola tragus*, *Gutierrezia sarothrae*, *Ericameria nauseosa*, and *Achnatherum hymenoides*. *Bouteloua gracilis*, *Hesperostipa comata*, *Krascheninnikovia lanata*, *Atriplex* spp., and *S. airoides* are also abundant. The majority of the 28 transects falling within the Loamy 2 range site are in poor condition. The Loamy 2 range site occurs in all compartments except for Compartments 2 and 7. Common plants found on transects within this range site include *Artemisia tridentata*, *P. jamesii*, *G. sarothrae*, *Atriplex canescens*, *Bromus tectorum,* and *Chrysothamnus greenei*.

A. hymenoides, *Atriplex confertifolia*, *H. comata*, *S. airoides,* and *Elymus elymoides* are also fairly common, but contribute less biomass. A final range site that is fairly ubiquitous across the project area is Saline Lowland 2. Fifteen transects were placed within this site, 13 are in poor condition and 2 are in excellent condition. This range site is currently dominated by *Sarcobatus vermiculatus*, *Atriplex obovata, A. confertifolia, S. tragus, P. jamesii,* and *S. airoides.* A discussion of condition across range sites in each compartment is presented below.

Table 5-1. Condition Class by Compartment

Compartment	Condition Class				Transect Total
	Excellent	Good	Fair	Poor	
Compartment 1	0	2	35	62	99
Compartment 2	2	10	21	31	64
Compartment 3	17	7	22	37	83
Compartment 4	0	0	9	19	28
Compartment 6	4	6	35	46	94
Compartment 7	0	0	3	7	10
Compartment 8	0	0	0	13	13
Condition Class Total	**23**	**25**	**125**	**215**	**391**

Table 5-2. Range Sites by Compartment

Compartment	Range Site	# Transects
1	Badlands 2	0
1	Loamy 2	22
1	Riverwash 2	0
1	Rockland Complex 2	0
1	Rough Broken 2	0
1	Saline Lowland 2	4
1	Sands 2	6
1	Sandy 2	62
1	Sandy Saline 2	0
1	Thin Breaks 2, 2a, & 2b	5
1	Very Shallow 2	0
2	Clayey 3	8
2	Loamy 3	0
2	Loamy 4	16
2	Loamy 4, Poor	0
2	Rough Broken	0
2	Rough Broken 3	0
2	Rough Broken 3a	0
2	Rough Broken 4	0
2	Sandy 3	2
2	Sandy 4	0
2	Sandy 4, Poor	0
2	Shallow 4	3

Compartment	Range Site	# Transects
2	Thin Breaks 4a & 4c	35
2	Very Shallow 4	0
3	Badlands 2	0
3	Loamy 2	20
3	Loamy 3	10
3	Many Farms Lake	0
3	Non-Usable 2	0
3	Riverwash 2	0
3	Rock Complex 2	0
3	Rockland Complex 2	0
3	Rough Broken 2	0
3	Rough Broken 3	0
3	Saline 2	0
3	Saline Lowland 2	7
3	Sand 2	0
3	Sands	0
3	Sands 2	0
3	Sandy-Shallow 2	0
3	Sandy 2	23
3	Sandy Saline 2	3
3	Shallow 2	17
3	Thin Breaks	0
3	Thin Breaks 2	0
3	Very Shallow 2 & 2a	3
4	Loamy 2	4
4	Loamy 3	1
4	Rough Broken 3a	0
4	Saline Lowland 2	0
4	Sandy 2	18
4	Thin Breaks 2, 2a, & 2b	2
4	Thin Breaks 3 & 3a	3
4	Thin Breaks 4 & 4a	0
4	Very Shallow 2	0
6	Badlands 2	0
6	Clayey 2	4
6	Clayey 3	0
6	Loamy 2	22
6	Loamy 4	2
6	Non-Usable 2	0
6	Rough Broken 2	0
6	Rough Broken 3a	0
6	Saline Lowland 2	17
6	Sands 2	3
6	Sandy 2	28
6	Sandy 3	0
6	Sandy Saline 2	10
6	Shallow 2	1
6	Shallow 4	2

Compartment	Range Site	# Transects
6	Thin Breaks	0
6	Thin Breaks 2, 2a, & 2b	2
6	Thin Breaks 3 & 3a	0
6	Thin Breaks 4	0
6	Very Shallow 4 & 4a	3
7	Loamy 2	0
7	Rockland Complex 2	0
7	Sandy 2	10
8	Loamy 2	1
8	Non-Usable 2	0
8	Rockland Complex 2	0
8	Rough Broken 2	0
8	Saline Lowland 2	9
8	Sands 2	0
8	Sandy 2	3
8	Sandy Saline 2	0

5.1.1 Compartment 1

The majority of transects in Compartment 1 are in poor condition. All but a few of these transects are associated with either the Loamy 2 or Sandy 2 range sites. The target or historic climax community for the Loamy 2 range site should include a mix of *Pascopyrum smithii*, *Bouteloua curtipendula*, *Bouteloua eriopoda*, *A. hymenoides*, *E. elymoides*, *H. comata*, and *Achnatherum nelsonii*. As these plants decrease, they are generally replaced by *Aristida* spp., *B. gracilis, P. jamesii, Sporobolus* spp., *Ephedra* spp., and various perennial forbs. As conditions worsen due to heavy grazing, drought, or other factors, species like *G. sarothrae*, *Chrysothamnus* spp., *Opuntia* spp., and *S. tragus* will begin to encroach and often times come to dominate the site. The species currently contributing the most biomass within this range site are *P. jamesii, S. tragus, A. obovata,* and *G. sarothrae.* As explained in Section 3: Range Sites, condition classes are established based upon the percentage of allowable weights of each species present as listed in the range site description. Of the above listed species, *P. jamesii* is the only one allowed any weight toward establishing condition. In particular, it is only allowed 20 lbs per acre per transect. Transects that contribute less than 52.5 lbs per acre of allowable forage are considered to be in poor condition for this range site. The general lack of allowable forage in the Loamy 2 range site description helps explain why so many transects in this range site are rated as being in poor condition. More favorable species like *A. hymenoides* and *E. elymoides* are present, but do not contribute significant biomass.

The Sandy 2 range site's historic climax community is very similar to the Loamy 2 range site community. However, more weight is allowed from shrub species like *A. tridentata*, *Artemisia nova*, *Artemisia filifolia*, and *Purshia tridentata*. *S. tragus* and *G. sarothrae* make a substantial contribution to biomass within this range site, but more desirable plants like *A. hymenoides*, *P. jamesii*, and *B. gracilis* furnish much of the overall weight as well. This mix of species is reflected in a nearly even split between transects in poor condition and those in fair condition. The remaining range sites in Compartment 1 are Saline Lowland 2, Sands 2, and Thin Breaks 2, 2a, & 2b. The primary species present in the Saline

Lowland areas are *A. obovata*, *S. tragus*, *and S. vermiculatus*. Virtually no grass species were encountered on these transects and all transects are in poor condition. Although this range site is characterized by saline soils and salt-loving *Atriplex* species, it does have the potential to support large amounts of forage species when in good condition. Some of these species include *S. airoides*, *A. hymenoides*, *P. jamesii,* and *K. lanata*. Transects placed in the Sands 2 range site are dominated by *P. jamesii*. Other common species are *S. tragus*, *Cryptantha* spp., and *A. hymenoides*. Half of these transects are in fair condition and half are in poor condition. Typically, this site will have more perennial grass species, but the ones encountered are beneficial to livestock and work to stabilize the sandy soil. Transects in the Thin Breaks range site are also in poor to fair condition. This site is characterized by fairly steep slopes, shallow soil, and exposed bedrock. Productivity is fairly low and to be considered to be in good condition species like *B. eriopoda*, *P. smithii*, *A. hymenoides, B. gracilis*, and *P. jamesii* should be abundant. Some of these species were recorded on the transects, but the species most abundant by weight were *S. vermiculatus*, *S. tragus* and *E. nauseosa*.

5.1.2 Compartment 2

The main range sites in Compartment 2 are Thin Breaks 4a & 4c and Loamy 4. Thin Breaks 4a & 4c sites are characterized by a moderate to dense overstory of pinyon and juniper with a diverse understory of native grasses, forbs, and shrubs. Approximately 50 percent of the species found during the survey were comprised of *A. tridentata*, *Opuntia* spp., *A. canescens*, and *Purshia stansburiana*. All of these species, except for *Opuntia* spp., should be present in this site's potential or climax community. *P. fendleriana*, *E. elymoides*, and *P. smithii* were also encountered during the survey, but in smaller quantities than would be growing on land in good to excellent condition. Historically, Loamy 4 range sites produce high yields of quality forage consisting of *P. smithii*, *A. hymenoides*, *Hesperostipa* spp., *P. fendleriana*, and *K. lanata*. Currently, the site is dominated by *A. canescens* which, should only make up five percent of the climax community. *A. tridentata*, *B. gracilis*, *B. tectorum*, *C. greenei*, and *G. sarothrae* make up the bulk of the remaining species. The remaining range sites in this compartment consist of Clayey 3, Sandy3, and Shallow 4. The Clayey 3 site currently has a high proportion of *Opuntia* spp., but also has a good proportion of desirable grasses. Only two transects fell within the Sandy 3 site, but the results show the area to be dominated by *A. canescens* with an understory of annual forbs and grasses including *B. tectorum*. The Shallow 4 range site has an abundance of *Opuntia* spp., but also has high amounts of desirable grasses like *P. fendleriana* and *E. elymoides*. The recorded data also show that the vegetation community has the recommended proportion of perennial forbs and *A. tridentata*.

5.1.3 Compartment 3

This compartment is comprised primarily of Sandy 2, Loamy 2, Shallow 2, and Loamy 3 range sites. Conditions range from poor to excellent in the Sandy 2 site. Transects in good to excellent condition are located in areas supporting healthy populations of *H. comata* and *A. hymenoides*. Overall, moderate forage species such as *P. jamesii* and *Sporobolus* spp. make up the appropriate percentage of the community when compared to the historic climax community. Transects in poor to fair condition have a high percentage of shrub species and *S. tragus*. The Loamy 2 site also has a mix of conditions ranging from poor to excellent. Once again, *H. comata* and *A. hymenoides* are the main species driving condition in the areas rated as excellent. All of areas in poor condition are characterized by *G. sarothrae*, *C. greenei*, and annual plants. *A. tridentata* was also found on some locations. Although not an entirely undesirable species, this plant is not considered a part of the climax community. The Shallow 2 site is one of the few range sites in this project area that consider *P. jamesii* and *S. airoides* to be a significant part of the climax community. All of the production associated with these plants can be counted toward allowable weight when determining condition. As a result, 50 percent of the transects in this range site are in excellent condition and only one is in poor condition. *S. tragus* was found on many transects, but in much smaller amounts than in other regions of the project area.

Poor conditions were uniformly reported throughout transects located in the Loamy 3 range site. Aside from a small shrub component, this site should be dominated by perennial grass species. However, this survey found the most common plants to be *Opuntia* spp., *G. sarothrae*, *C. greenei*, and a mix of annual forbs and grasses. Prevalent among the annual species was *B. tectorum*. The other range sites in Compartment 3 are Saline Lowland 2, Sandy Saline 2, and Very Shallow 2 & 2a. Vegetation in the Saline Lowland 2 site was comprised mostly of *S. vermiculatus*, *Atriplex* spp., *P. jamesii*, and *C. greenei*. In general, the species composition is similar to what would be found in the climax community, but the shrub to grass ratio is much higher than it should be. There is also a moderate presence of invasive species including *S. tragus* and *B. tectorum*. Only three transects are located in the Sandy Saline 2 range site and all are in poor condition. The vegetation community at this site should be made up mostly of *P. jamesii*, *Sporobolus* spp., and *A. canescens*. Data collected at the transects revealed the area to be dominated by *A. obovata* and *S. tragus*. The three transects located in the Very Shallow 2 & 2a range site are in fair to good condition A fair amount of perennial grass species like *P. jamesii*, *Sporobolus cryptandrus*, and *A. hymenoides* occur across the transects. Conditions are lower than they could be due to the prevalence of shrub species. The current plant community is made up of about 80 percent shrubs whereas the climax community should only have about 30 percent.

5.1.4 Compartment 4

Approximately two thirds of the transects in this compartment are in the Sandy 2 range site and are in poor to fair condition. Similar to the Sandy 2 range sites in other compartments, *G. sarothrae*, *S. tragus*, and *P. jamesii* are the main contributors to biomass. *E. nauseosa*, *A. canescens*, *A. hymenoides*, and *B. gracilis* make a smaller portion of the community. Poor conditions predominate in the other range sites within this compartment. The Loamy 2 and Loamy 3 range sites have a similar vegetation component as listed above in the Sandy 2 range site, although *Opuntia* spp. And *A. confertifolia* are more predominant on transects within the Loamy 3 site. The two Thin Breaks sites both have a moderate canopy of pinyon and juniper. Ideally, the open spaces would be producing mostly perennial grass species with about a 10 percent shrub cover. As of now, many of the grass species are missing and the openings are dominated by shrub species. The majority of the shrub species are also ones not associated with the climax community.

5.1.5 Compartment 6

This compartment is broken up into 11 different range sites. Most transects fall within the Loamy 2, Sandy 2, Saline Lowland 2, and Sandy Saline 2 range sites. This compartment has the greatest species diversity with over 50 species recorded on transects in the Loamy 2 site alone. Most transects within the Loamy 2 site are in poor condition and a few are in fair condition. *A. canescens*, *G. sarothrae, P. jamesii*, and *A. confertifolia* are the primary species contributing production at this site. The range site description allows for 5 percent shrub species. *A. canescens* and *S. vermiculatus* make up over 20 percent of the community. *G. sarothrae* and *A. confertifolia* are not considered acceptable shrub species in this range site. The percentage of *P. jamesii* is a little high, but still fairly close to 10 percent that would be present if the community was at its climax. *S. tragus* was recorded at many of the transects, but favorable forage species like *S. airoides* and *A. hymenoides* were fairly common as well. The majority of transects within the Sandy 2 range site are in fair condition with a few being in poor and good condition. Dominant species include *P. jamesii*, *Ephedra viridis*, *C. greenei*, *A. hymenoides*, and *G. sarothrae*. One species that is continually missing from all compartments with the Sandy 2 range site is *B. curtipendula*. This is a highly palatable and nutritious species readily consumed by livestock of all classes. It is a key indicator of rangeland health in many parts of the project area, but now is generally only found in rocky, sheltered areas that are inaccessible to livestock.

Vegetation communities across the Saline Lowland 2 range site are composed chiefly of *S. vermiculatus, S. tragus, A. confertifolia, S. airoides, A. obovata,* and *Sphaeralcea spp.* Half of the production for *S. airoides* took place in a single transect. This transect is in excellent condition, while the other transects are all in poor to fair condition. *S. tragus* is wide spread while climax community species such as *E. elymoides*, *P. jamesii*, and *A. hymenoides* make up only a small portion of the species sampled. The density of acceptable shrub species is also higher than it should be for this range site. Most transects in the Sandy Saline 2 range site are in poor condition and a few are in fair condition. *S. airoides* and *P. jamesii* make up a substantial portion of the climax community for this site. Both of these species are fairly well represented in the current vegetation communities, but *S. tragus* and *A. obovata* have an even greater presence; therefore, overall condition is low across all transects. The other seven range sites in this compartment contain between one and four transects. Transects in the Loamy 4, Sands 2, Shallow 2 and Thin Breaks 2, 2a & 2b sites are generally all in fair condition. The four transects in the Clayey 2 site are mostly in poor condition. This is due to a prevalence of *S. tragus* and annual forbs. Conversely, the two transects in the Shallow 4 range site are in good and excellent condition. The limit of 10 percent *A. tridentata* in the climax community is well exceeded, but desired species like *E. elymoides* and *P. fendleriana* are abundant. This portion of the project area stands out as having the highest proportion of *E. elymoides* in the plant community.

5.1.6 Compartment 7

This is a small compartment and only contains the Sandy 2 range site. There are ten transects, most in poor condition and some in fair condition. As with most compartments, *S. tragus* is a problem across this range site. However, conditions on transects in this compartment are mostly poor due more to the large amounts of *G. sarothrae* and *E. nauseosa*. Neither of these species should be in the climax community, but they currently contribute over 40 percent of the total production for this site. Nonetheless, *P. jamesii* and *A. hymenoides* are also present and are supplying a fair amount of the production as well.

5.1.7 Compartment 8

Saline Lowland 2 is the dominate range site for this compartment and contains nine of the 13 transects. All transects are in poor condition due primarily to a lack of production. *A. obovata* contributes about 65 percent of the total production and the remaining production is provided primarily by annual and perennial forbs. Only one grass was recorded on any of the transects (*A. hymenoides*) and it makes up only a tiny fraction of total production. The Sandy 2 range site contains three transects, which are also all in poor condition. In this case, condition was driven down by the prevalence of shrub species like *E. nauseosa* and *C. greenei* and large populations of *S. tragus*. The final range site is Loamy 2. The single transect in this range site is in poor condition. *E. nauseosa* provides most of the biomass produced at this location. More desirable species like *A. hymenoides*, *B. gracilis*, *P. jamesii*, and *K. lanata* are also in the associated community, but are not very abundant.

5.2 Species Composition by Compartment

The most common species recorded on transects are presented here. Table 5-3 contains the species that occurred most frequently. Table 5-4 shows the most frequently occurring species as a factor of biomass rather than abundance. Typically, only the three most frequently occurring species are included. However, several species occurred with the same frequency and therefore more than three species are listed. Individual species frequency data within each transect can be found in the data calculations (Appendix D).

Available forage in each compartment is located in Table 5-3, which shows data pertaining to species with forage value ratings of Preferred, Desirable, and Emergency. Forage value ratings were assigned based upon the least desirable season for sheep to present a more conservative estimate of available forage. All other forage is not considered available to livestock and is not used when calculating stocking rates.

Table 5-3. Most Frequently Occurring Species by Compartment

Species	Compartment(s)	Forage Value*	Nativity*	Toxic?	Notes/Seasons
Achnatherum hymenoides	1,6,7,8	D	N	No	
Astragalus spp.	7	T	N	Yes	Astragalus species are generally unpalatable to livestock, but can cause mortality if consumed.
Atriplex obovata	8	Emergency	N	No	Although the specific forage value is unknown, this plant is palatable to livestock.

Species	Compartment(s)	Forage Value*	Nativity*	Toxic?	Notes/Seasons
Bouteloua gracilis	2,4	E	N	No	
Chaetopappa ericoides	7	NC	N	No	
Cryptantha spp.	7,8	NC	N	No	
Descurainia sophia	8	NC	I	No	Palatable in the spring.
Elymus elymoides	2	P	N	No	
Ericameria nauseosa	8	NC	N	No	Important forage plant for wildlife, especially during the winter.
Gutierrezia sarothrae	2,3,4,7	INJ	N	Yes	Can be toxic to livestock if large quantities are consumed.
Lappula occidentalis	3	NC	N	No	
Pleuraphis jamesii	1,3,4,6,7	E	N	No	
Salsola tragus	1,4,6,8	INJ	I	No	Injurious in all seasons except spring.
Sphaeralcea ambigua	8	NC	N	No	Preferred plant in the spring, but not used in the winter.

*P= Preferred, D=Desirable, E=Emergency, INJ= Injurious, NC=Not Consumed, I=Introduced, N=Native

Only two species, *A. hymenoides,* and *E. elymoides,* are considered desirable or preferred by sheep in the winter. Other species are more desirable during different seasons. *B. gracilis* is considered desirable during the spring and summer, and *P. jamesii* is desirable during the spring, summer, and fall. *Sphaeralcea ambigua* is a preferred species during the spring, desirable in the summer and considered emergency forage during the fall. The relative abundance of *S. tragus* in most compartments is regrettable as the spines on this plant can cause injuries to herbivores. It is also highly competitive and can quickly replace more desirable species.

However, the frequency in which plant species occur across a given area does not tell the whole story. It is also important to assess how much biomass a species is contributing, as this number is used when calculating range condition and stocking rates. For example, *E. elymoides* occurs frequently in Compartment 2, but its total reconstructed weight only accounts for 2 percent of the total weight of all species sampled. The following table displays the top three species in terms of total reconstructed weight for each compartment. The relatively low percentages of each species' total weight reflect the diversity of species present in the project area.

Table 5-4. Frequently Occurring Species by Weight (Compartment)

Compartment	Species	Total Reconstructed Weight (lbs/acre)	Percentage of Total Weight by Compartment	Life Form
1	*Salsola tragus*	10,768	24	Forb
1	*Pleuraphis jamesii*	8,553	19	Grass
1	*Ericameria nauseosa*	2,747	6	Shrub
2	*Atriplex canescens*	17,555	32	Shrub
2	*Artemisia tridentata*	7,459	14	Shrub
2	*Opuntia polyacantha*	4,995	9	Cactus
3	*Pleuraphis jamesii*	15,908	18	Grass
3	*Artemisia tridentata*	12,938	15	Shrub
3	*Gutierrezia sarothrae*	6,271	7	Shrub
4	*Gutierrezia sarothrae*	1,846	12	Shrub
4	*Pleuraphis jamesii*	1,731	12	Grass
4	*Ericameria nauseosa*	1,517	10	Shrub
6	*Artemisia tridentata*	18,867	30	Shrub
6	*Pleuraphis jamesii*	6,139	10	Grass
6	*Salsola tragus*	3,986	6	Forb
7	*Gutierrezia sarothrae*	1,051	28	Shrub
7	*Ericameria nauseosa*	562	15	Shrub
7	*Ephedra torreyana*	332	9	Shrub
8	*Atriplex obovata*	654	27	Shrub
8	*Ericameria nauseosa*	641	26	Shrub
8	*Chrysothamnus greenei*	236	10	Shrub

A quick look at the table above shows that shrub species contribute a substantial portion of the biomass in all compartments. This makes sense, given that shrubs tend to grow much larger than grass and forb species. Shrubs are also a key component of the landscape and provide shelter and food for livestock and wildlife, especially during the winter. However, much of the area surveyed should have a high forage production potential when in good condition. The abundance of shrub species indicates the need to identify areas of high brush density that would benefit from a thinning program to increase production of perennial grass species. There is also a need to implement control measures for *S. tragus*. This species prefers sandy soils and does particularly well in areas that have been disturbed by grazing or environmental factors. Sandy soils are prevalent in all compartments; especially in Compartments 1, 3, 4, and 7. The prevalence of *P. jamesii* is encouraging. Although this plant loses much of its nutritive quality in the winter and is not especially palatable to livestock when it has dried out, it is a reliable source of food when actively growing. This grass is also rhizomatous and, during favorable conditions, it forms a sod that helps protect the soil and exclude less desirable species (West 1972; Dittberner and Olson 1983).

The weight and abundance of plant species provide useful information for determining the condition of the land. More detail is needed to manage grazing activities properly. Grazing animals are selective and prefer to consume certain species of plants over others; therefore, it is useful to know forage values of commonly occurring range plants. The palatability of plants, coupled with the amounts available to livestock, allows managers to calculate appropriate stocking rates. Forage values and the calculation of available forage are discussed in detail in Section 4.2.5. Table 5-5 shows the breakdown by weight and percentage of available forage for each compartment.

Table 5-5. Available Forage by Compartment

Compartment	Preferred Forage (lbs/acre)	%*	Desirable Forage (lbs/acre)	%*	Emergency Forage (lbs/acre)	%*
1	444.1	1.3	4,518.6	13.1	11,970.5	34.6
2	1,229.8	2.8	22,973	52.0	11,552.0	26.2
3	3,025.8	4.6	3,835.9	5.8	34,554.0	52.5
4	17.2	0.2	1,359.9	13.7	3,825.7	38.6
6	866.4	1.7	7,208.5	13.8	29,539.2	56.5
7	22.0	0.8	561.9	21.5	290.4	11.1
8	0.5	0.0	44.3	3.0	357.7	24.4

*Percentages are based on all forage types including toxic and non-consumed.

The bulk of available forage for all compartments, except for Compartment 2, comes from emergency forage. *P. jamesii* is the most common emergency forage, followed by *B. gracilis* and, in Compartments 3 and 6, *S. airoides*. In Compartment 2, the high percentage of desirable forage comes from *P. fendleriana*, *P. smithii*, *A. hymenoides*, and to a lesser extent, *Amelanchier utahensis,* and *A. canescens*. In all other compartments, *A. hymenoides* is the primary contributor to desirable forage, followed by *Ephedra* spp. Although generally not common, preferred forage species consisted of *E. elymoides*, *H. comata*, and *K. lanata*.

5.3 Initial Stocking Rates and Carrying Capacity

The results of the GIS analysis indicate that the carrying capacity of the project area has been exceeded. The existing 284 permits allow for 10,544 sheep units year long (SUYL). The current rangeland resources can only support 431.54 SUYL. This number drops significantly after limiting factors, such as inaccessible terrain, have been applied.

The total initial carrying capacity for the project area was calculated using a 790 pound AUM and again using a 912.5 pound AUM in order to compare with previous studies. The carrying capacity was then adjusted for slope and distance to water. The results provided here represent initial maximum stocking rates for the project area under normal precipitation patterns and should be further adjusted according to local and seasonal conditions. The total carrying capacity at 790 AUM was 431.54 sheep units year long (SUYL), at 912.5 AUM this decreased to 373.61 SUYL. Adjustments for slope and distance to water at 790 AUM resulted in a 189.65 SUYL and decreased to 41.05 using a 912.5 AUM. Although slope is a fixed factor, the addition or location of water sources could improve the adjusted carrying capacities.

Tables 5-6 and 5-7 show carrying capacities for each compartment and RMU. Table 5-8 lists stocking rates by range site for each compartment and RMU.

Table 5-6. Carrying Capacity by Compartment

Compartment	Carrying Capacity (SUYL)		Adjusted Carrying Capacity (SUYL)	
	790 AUM	**912.5 AUM**	**790 AUM**	**912.5 AUM**
Compartment 1	46.44	40.21	28.08	6.08
Compartment 2	169.12	146.42	49.59	10.73
Compartment 3	67.18	58.17	37.81	8.18
Compartment 4	22.55	19.52	11.79	2.55
Compartment 6	121.15	104.89	59.65	12.91
Compartment 7	3.07	2.65	1.62	0.35
Compartment 8	2.03	1.76	1.11	0.24
Carrying Capacity Total	**431.54**	**373.61**	**189.65**	**41.05**

Table 5-7. Carrying Capacity by RMU

Compartment	Carrying Capacity (SUYL)		Adjusted Carrying Capacity (SUYL)	
	790 AUM	**912.5 AUM**	**790 AUM**	**912.5 AUM**
Bobbie Bia	13.42	11.61	8.03	1.74
Charlotte Jane Begay	7.17	6.20	5.09	1.10
Clinton Claw	21.76	18.84	9.23	2.00
Connie Tso	4.28	3.70	2.80	0.61
Evelyn Begay (Chinle part)	1.49	1.29	0.86	0.19
Marty Benally, Mary Yellowhair, Ida Begay, Eugene Begay, Andrew Benally	34.47	29.84	7.54	1.63
Proposed Restoration Area	3.54	3.07	2.60	0.56
Shawn Higdon	2.58	2.23	1.41	0.31
Carrying Capacity Total	**88.69**	**76.78**	**37.57**	**8.13**

Table 5-8. Stocking Rates

Compartment or RMU and Range Site	Acres	Initial Stocking Rate (acres/790 AUM)	Initial Stocking Rate (acres/912.5 AUM)
1			
Badlands 2	651.36	N/A	N/A
Loamy 2	7505.65	481.81	556.53
Non range	9.30	N/A	N/A
Riverwash 2	575.59	N/A	N/A
Rockland Complex 2	226.35	N/A	N/A
Rough Broken 2	371.97	N/A	N/A
Saline Lowland 2	2705.43	0.00	0.00
Sands 2	1251.28	575.69	664.95
Sandy 2	18685.51	734.97	848.93
Sandy Saline 2	225.61	N/A	N/A
Thin Breaks 2	4417.9	1352.97	1562.76
Very Shallow 2	61.65	N/A	N/A
2			
Clayey 3	5421.29	490.90	567.02
Loamy 3	28.97	N/A	N/A
Loamy 4	3113.35	102.15	117.99
Loamy 4, Poor	2787.43	N/A	N/A
Rough Broken	41.50	N/A	N/A
Rough Broken 3	118.44	N/A	N/A
Rough Broken 3a	752.34	N/A	N/A
Rough Broken 4	66.72	N/A	N/A
Sandy 3	1128.46	110.10	127.18
Sandy 4	697.31	N/A	N/A
Sandy 4, Poor	727.91	N/A	N/A
Shallow 4	3695.93	566.00	653.77
Thin Breaks 4	36737.29	331.50	382.91
Very Shallow 4	30.19	N/A	N/A
3			
Badlands 2	7657.23	N/A	N/A
Loamy 2	951.93	186.81	215.77
Loamy 3	3796.18	767.25	886.22
Many Farms Lake	4.59	N/A	N/A
Non-Usable 2	3141.06	N/A	N/A
Riverwash 2	1594.39	N/A	N/A
Rock Complex 2	315.54	N/A	N/A
Rockland Complex 2	220.46	N/A	N/A
Rough Broken 2	268.74	N/A	N/A
Rough Broken 3	232.27	N/A	N/A

Compartment or RMU and Range Site	Acres	Initial Stocking Rate (acres/790 AUM)	Initial Stocking Rate (acres/912.5 AUM)
Saline 2	1826.23	N/A	N/A
Saline Lowland 2	2825.13	790.19	912.72
Sands	466.74	N/A	N/A
Sands 2	1431.92	N/A	N/A
Sandy 2	13564.22	331.72	383.15
Sandy Saline 2	4480.22	0.00	0.00
Sandy-Shallow 2	979.21	N/A	N/A
Shallow 2	5642.86	628.01	725.39
Very Shallow 2	3587.31	972.27	1123.03
Thin Breaks	636.89	N/A	N/A
Thin Breaks 2	1766.86	N/A	N/A
4			
Loamy 2	1967.16	492.38	568.73
Loamy 3	521.24	6647.85	7678.69
Rough Broken 3a	1400.57	N/A	N/A
Saline Lowland 2	26.69	N/A	N/A
Sandy 2	5124.26	872.28	1007.53
Thin Breaks 2	3227.56	382.42	441.72
Thin Breaks 3	3404.87	818.85	945.82
Thin Breaks 4	26.53	N/A	N/A
Very Shallow 2	1.44	N/A	N/A
6			
Badlands 2	200.50	N/A	N/A
Clayey 2	1287.21	738.23	852.70
Clayey 3	57.82	N/A	N/A
Loamy 2	8854.23	477.27	551.28
Loamy 4	354.74	43.21	49.91
Non-Usable	912.81	N/A	N/A
Rough Broken 2	1015.21	N/A	N/A
Rough Broken 3a	7450.54	N/A	N/A
Saline Lowland 2	11303.53	1317.91	1522.27
Sands 2	1473.84	1317.02	1521.25
Sandy 2	14001.73	459.02	530.19
Sandy 3	17.43	N/A	N/A
Sandy Saline 2	2085.11	785.10	906.84
Shallow 2	2067.03	485.79	561.12
Shallow 4	684.82	18.31	21.15
Thin Breaks	1149.15	N/A	N/A
Thin Breaks 2	5295.28	1268.89	1465.64
Thin Breaks 3	62.96	N/A	N/A
Thin Breaks 4	383.82	N/A	N/A

Compartment or RMU and Range Site	Acres	Initial Stocking Rate (acres/790 AUM)	Initial Stocking Rate (acres/912.5 AUM)
Very Shallow 4	446.44	112.49	129.93
7			
Loamy 2	314.41	N/A	N/A
Rockland Complex 2	6.73	N/A	N/A
Sandy 2	4844.48	1580.00	1825.00
8			
Loamy 2	1229.48	3627.73	4190.26
Non-Usable 2	0.11	N/A	N/A
Rockland Complex 2	6.73	N/A	N/A
Rough Broken 2	641.50	N/A	N/A
Saline Lowland 2	4550.31	210603.89	243260.82
Sands 2	20.70	N/A	N/A
Sandy 2	2243.23	1345.97	1554.68
Sandy Saline 2	1134.84	N/A	N/A
Bobbie Bia			
Loamy 2	1041.07	240.35	277.62
Sandy 2	1308.95	144.09	166.44
Shallow 2	324.02	N/A	N/A
Very Shallow 2	235.20	N/A	N/A
Charlottee Jane Begay			
Loamy 2	1175.51	171.32	197.88
Loamy 3	132.38	436.15	503.78
Rough Broken 2	391.94	N/A	N/A
Rough Broken 3	14.29	N/A	N/A
Sandy 2	433.88	N/A	N/A
Very Shallow 2	24.18	N/A	N/A
Clinton Claw			
Loamy 2	849.26	378.77	437.50
Sandy 2	3512.10	207.72	239.93
Shallow 2	787.82	302.12	348.97
Very Shallow 2	772.16	N/A	N/A
Connie Tso			
Loamy 2	990.51	655.45	757.09
Sandy 2	64.68	N/A	N/A
Shallow 2	1007.78	364.56	421.09
Very Shallow 2	627.11	N/A	N/A
Evelyn Begay			
Loamy 2	95.84	1337.99	1545.47
Sands 2	701.15	493.57	570.10
Sandy 2	29.52	N/A	N/A

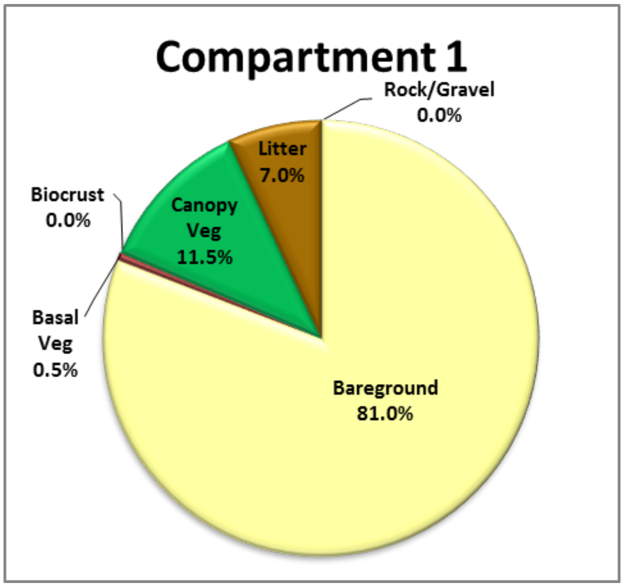
Compartment or RMU and Range Site	Acres	Initial Stocking Rate (acres/790 AUM)	Initial Stocking Rate (acres/912.5 AUM)
Marty Benally, Mary Yellowhair, Ida Begay, Eugene Begay, Andrew Benally			
Loamy 4	882.72	533.23	615.92
Rough Broken 3a	22.64	N/A	N/A
Shallow 4	702.05	N/A	N/A
Thin Breaks 4	9100.81	277.37	320.38
Proposed Restoration			
Loamy 2	11.67	N/A	N/A
Rough Broken 2	330.90	N/A	N/A
Saline Lowland 2	325.56	282.37	326.16
Sandy Saline 2	3990.48	1671.25	1930.40
Shallow 2	16.50	N/A	N/A
Shawn Higdon			
Loamy 2	95.37	467.50	539.99
Saline Lowland 2	327.07	448.57	518.13
Sandy 2	302.91	525.66	607.17
Shallow 2	962.69	902.33	1042.24
Very Shallow	10.50	N/A	N/A

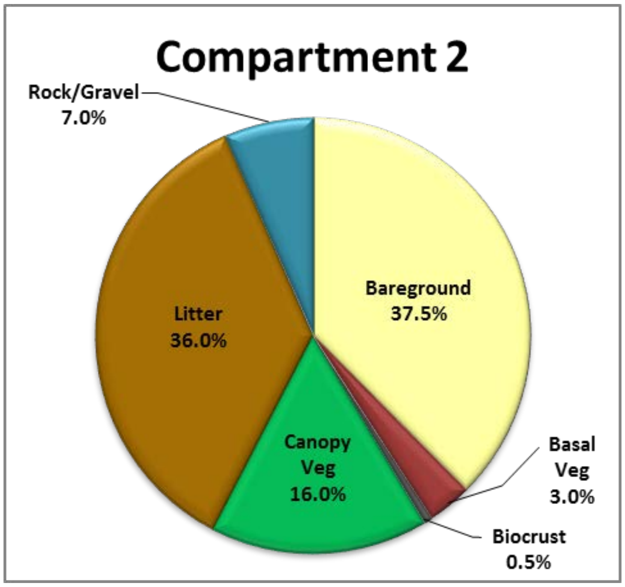
5.4 Ground Cover by Compartment

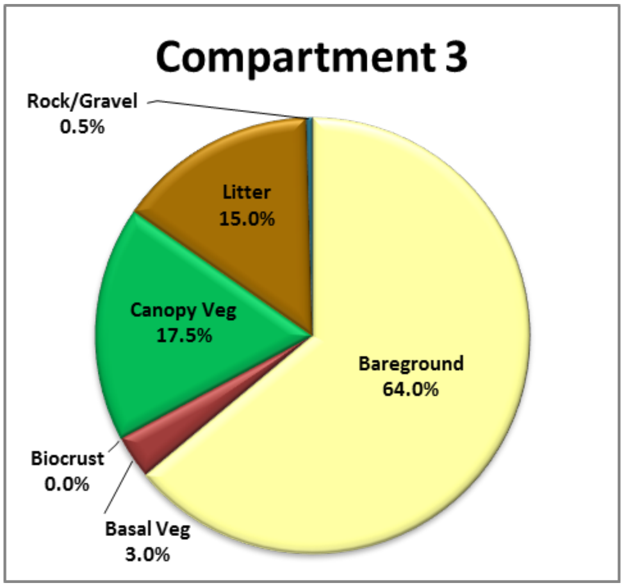
Ground cover by compartment is summarized in Table 5-8. The same results are also presented in a pie chart format after the table. Ground cover information was not provided in the range site descriptions, so direct comparisons cannot be made. However, these results can be used as baseline data for monitoring changes in the amount and composition of ground cover. With the exception of Compartment 2, bare ground constitutes the main ground cover category followed by canopy vegetation and litter. Rock/gravel, basal vegetation, and biocrust are either absent or only make up a small fraction of ground cover. This information reinforces the picture presented by the vegetation data of a landscape largely dominated by shrub species, with a mix of litter and sparse vegetation in the interspaces. Areas within Compartments 1, 7, and 8 are largely devoid of vegetation, which greatly contributes to the amount of bare ground encountered as well. Compartment 2 is unique not only in the composition of ground cover, but it is also the highest elevation compartment within the project area. This compartment encompasses the eastern end of Black Mesa and has a lot of exposed bedrock and pinyon-juniper woodland. Although trees species were not inventoried, it is evident that litter from the pinyon and juniper trees greatly contributed to the litter counts. Rock counts are higher due to the amount of exposed bedrock. Steep slopes limit the amount of grazing by livestock, which helps facilitate the growth and maintenance of biocrust. Canopy cover is similar to that found in the other compartments, but the vegetation data shows that most of the vegetation consists of desirable species rather than *S. tragus* or undesirable shrub species. The current state of ground cover and vegetation across the project area is not ideal. A higher ratio of bare ground to vegetation is common on semi-arid/arid rangelands due to the structure of vegetation, climate, and soils. However, the extremely high measure of bare ground found in most compartments greatly enhances wind and water erosion, and lowers the ability of the soil to capture and retain moisture.

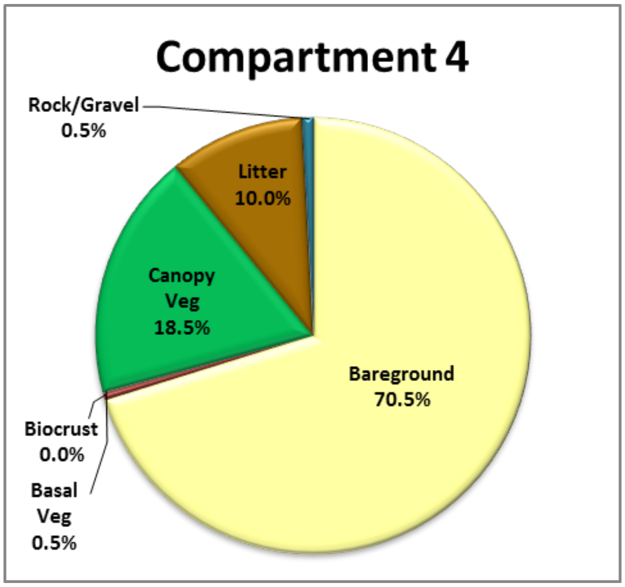
Table 5-9. Ground Cover by Compartment

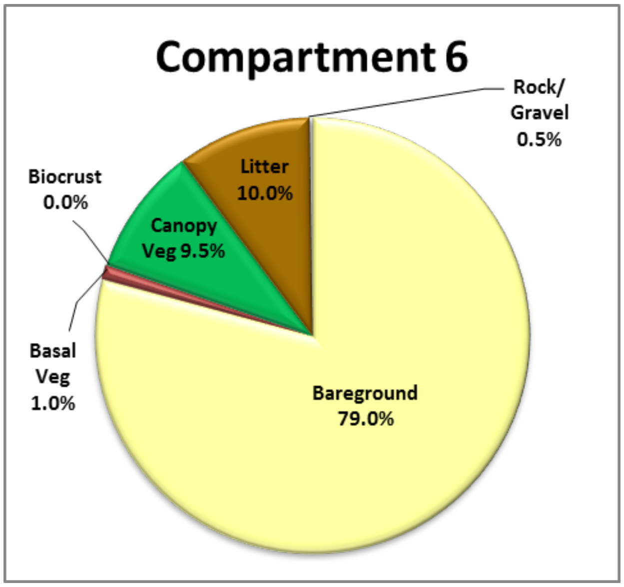
Compartment	% Bare Ground	% Rock/Gravel	% Litter	% Basal Veg	% Biocrust	% Canopy Veg
Compartment 1	81.0	0.0	7.0	0.5	0.0	11.5
Compartment 2	37.5	7.0	36.0	3.0	0.5	16.0
Compartment 3	64.0	0.5	15.0	3.0	0.0	17.5
Compartment 4	70.5	0.5	10.0	0.5	0.0	18.5
Compartment 6	79.0	0.5	10.0	1.0	0.0	9.5
Compartment 7	79.0	1.0	9.0	1.0	0.0	10.0
Compartment 8	90.5	0.0	5.0	0.5	0.0	4.0

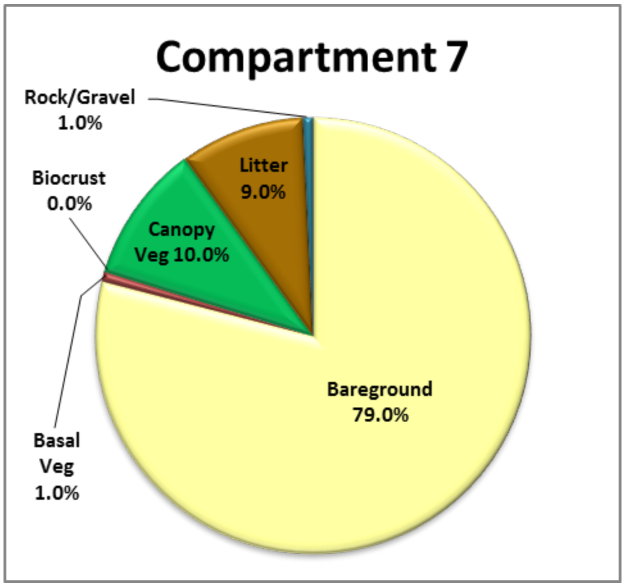


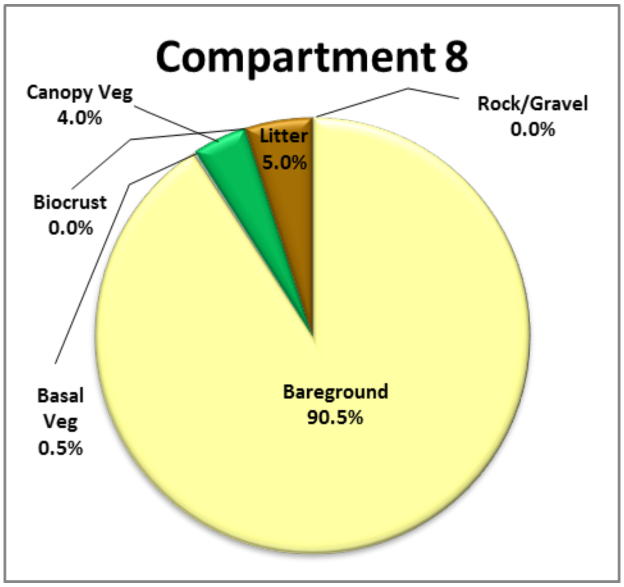



Compartment 3
Rock/Gravel 0.5%
Litter 15.0%
Canopy Veg 17.5%
Bareground 64.0%
Biocrust 0.0%
Basal Veg 3.0%


Compartment 4
Rock/Gravel 0.5%
Litter 10.0%
Canopy Veg 18.5%
Bareground 70.5%
Biocrust 0.0%
Basal Veg 0.5%


Compartment 6
Rock/ Gravel 0.5%
Biocrust 0.0%
Litter 10.0%
Canopy Veg 9.5%
Basal Veg 1.0%
Bareground 79.0%


Compartment 7
Rock/Gravel 1.0%
Biocrust 0.0%
Litter 9.0%
Canopy Veg 10.0%
Bareground 79.0%
Basal Veg 1.0%



5.5 Condition Class by RMU

This study was designed to gather sufficient data based upon range sites and compartments (Table 5-10 and Table 5-11). As a result, only a few transects ended up within the RMUs. The limited data for RMUs means that the analysis cannot be considered especially rigorous. However, some general patterns did emerge. As with the compartments, the majority of transects are in poor to fair condition. Transects rated as good to excellent condition are almost all located in RMUs contained within Compartment 3. Not surprisingly, this compartment had the highest proportion of transects in excellent condition and a high number of transects in good condition as compared to the other compartments. The RMUs in Compartment 3 have transects located primarily in Loamy 2 and Sandy 2 range sites. The Bobby Bia RMU has seven transects, four of which fall in the Sandy 2 range site and three that are in Loamy 2. One transect in the Sandy 2 site is in fair condition; the rest are in excellent condition. *H. comata* and *A. hymenoides* are the primary species driving condition on transects. *P. jamesii*, *G. sarothrae*, and *Sphaeralcea coccinea* are also prevalent in the community. Transects in the Loamy 2 range site are in poor to fair condition. This is to be expected as the primary contributors to total production are a mix of favorable and unfavorable species including *P. jamesii*, *C. greenei*, *S. cryptandrus*, and annual forbs. The Charlotte Jane Begay RMU has eight transects, seven in the Loamy 2 range site and one in the Loamy 3 range site. Transects in the Loamy 2 range site are in poor, fair, and good condition. The vegetation is predominantly *A. tridentata* shrub land with *B. tectorum*, *P. jamesii*, *E. elymoides*, *Aristida purpurea*, and *Erodium cicutarium* growing in the interspaces. The single transect in the Loamy 3 site is in fair condition. Cover consists mostly of *P. jamesii*, *B. tectorum*, *A. hymenoides*, and *S. tragus*.

The Connie Tso RMU consists of Loamy 2 and Shallow range sites. Transects in the Loamy 2 site are in poor to fair condition. Common plants are *P. jamesii*, *B. tectorum*, *G. sarothrae*, and a mixture of annual grasses and forbs. The two transects in the Shallow 2 site are both in excellent condition. The most common plant is a species of *Calochortus*. These species are palatable to livestock, but are not considered particularly important forage and are usually not overly abundant. It is unclear as to why it is so prevalent in this area. The second most common plant is *P. jamesii*. The total production for this species is allowed when calculating condition within this range site, which is the main reason why the transects are in excellent condition. *C. greenei*, *Chaetopappa ericoides*, and *S. coccinea* also contribute a substantial amount to total production. *C. greenei*, although not an allowable shrub in the climax community, is considered emergency forage, while *S. coccinea* and *C. ericoides* are not consumed during the winter months. Transects in the Clinton Claw RMU are located within Loamy 2, Sandy 2, and Shallow 2 range sites. Only two transects are in poor condition, while the rest are in good or excellent condition. *P. jamesii* is the main contributor to production across all range sites. Quality forage species like *H. comata* and *A. hymenoides* are also common in the Loamy 2 and Shallow 2 sites, while *Ephedra cutleri* contributes a lot of production in the Sandy 2 site. Less desirable species like *S. tragus* and *C. greenei* are common in the Sandy 2 site as well. The final RMU in Compartment 3 is Shawn Higdon. Four transects are in excellent condition, one is in good condition, and one is in fair condition. These transects fall within Loamy 2, Saline Lowland 2, Sandy 2, and Shallow 2 range sites. Similar to the Clinton Claw RMU, *P. jamesii* supplies a large amount to total production in all range sites. *A. confertifolia* also produces a lot of the biomass in the Saline Lowland 2 and Shallow 2 sites. In addition to *P. jamesii, A. hymenoides* and *H. comata* are abundant in the Loamy 2 range site. *A. hymenoides* is also a common species in the Saline Lowland 2 site. The invasive grass, *B. tectorum* is prevalent in the Sandy 2 site, while the invasive forb *S. tragus* occurs frequently in the Shallow 2 site.

The Evelyn Begay RMU is located in Compartment 1 and is comprised of Loamy 2 and Sands 2 range sites. All but one transect are in the Sands 2 site and conditions range from poor to fair. The most abundant species include *P. jamesii*, *S. tragus*, *A. hymenoides*, and a variety of annual forbs. The transect in the Loamy 2 site is in poor condition. Very few species were encountered at this location and the dominant plant was *S. tragus*. The Marty Benally, Mary Yellowhair, Ida Begay, Eugene Begay, and Andrew Benally RMU resides within Compartment 2. Range sites include Loamy 4 and Thin Breaks 4a & 4c and the accompanying transects are in poor, good, fair, and excellent condition. All transects in the Loamy 4 site are in poor condition as evidenced by the lack of allowable forage. Two of the main species are forage species (*B. gracilis* and *A. canescens*), but the overall usable production for this site is quite low. A diverse suite of species was found at transects located in the Thin Breaks 4a & 4c range site. This RMU is located at higher elevation than the other RMUs and the vegetation community reflects this. Common species range from *G. sarothrae*, *P. fendleriana*, and *B. gracilis* to *Yucca baccata, Quercus gambelii*, and *Penstemon linarioides*. The last RMU is the Proposed Restoration Area and is located within Compartment 6. There are nine transects—one in the Saline Lowland 2 range site and eight in the Sandy Saline 2 range site. The transect in the Saline Lowland 2 site is in excellent condition due to a preponderance of *S. airoides* and to a lesser extent, *P. jamesii*. However, *S. tragus* was recorded as the species contributing the most biomass to total production. All but two transects are in poor condition in the Sandy Saline 2 range site due once again to the large presence of *S. tragus* as well as numerous annual forb species. More desirable species include *S. airoides* and *A. obovata*.

Table 5-10. Condition Class by Range Management Unit

Range Management Unit	Condition Class				Transect Total	Compartment
	Excellent	Good	Fair	Poor		
Bobbie Bia	3	0	3	1	7	3
Charlottee Jane Begay	0	2	4	2	8	3
Clinton Claw	6	3	0	3	12	3
Connie Tso	2	0	1	2	5	3
Evelyn Begay	0	0	2	3	5	1
Marty Benally, Mary Yellowhair, Ida Begay, Eugene Begay, Andrew Benally	1	1	4	8	14	2
Proposed Restoration Area – Not Officially Withdrawn	1	0	2	6	9	6
Shawn Higdon	4	1	1	0	6	3
Condition Class Total	**17**	**7**	**17**	**25**	**66**	

Table 5-11. Range Sites by RMU

RMU	Compartment	Range Site	# Transects
Bobby Bia	3	Loamy 2	3
Bobby Bia	3	Sandy 2	4
Bobby Bia	3	Shallow 2	0
Bobby Bia	3	Very Shallow 2	0
Charlotte Jane Begay	3	Loamy2	7
Charlotte Jane Begay	3	Loamy 3	1
Charlotte Jane Begay	3	Rough Broken 2	0
Charlotte Jane Begay	3	Rough Broken 3	0
Charlotte Jane Begay	3	Sandy 2	0
Charlotte Jane Begay	3	Very Shallow 2	0
Clinton Claw	3	Loamy 2	4
Clinton Claw	3	Sandy 2	5
Clinton Claw	3	Shallow 2	3
Clinton Claw	3	Very Shallow 2	0
Connie Tso	3	Loamy 2	3
Connie Tso	3	Sandy 2	0
Connie Tso	3	Shallow 2	2
Connie Tso	3	Very Shallow 2	0
Evelyn Begay	1	Loamy 2	1
Evelyn Begay	1	Sands 2	4
Evelyn Begay	1	Sandy 2	0
Marty Benally, et al.	2	Loamy 4	3
Marty Benally, et al.	2	Rough Broken 3a	0
Marty Benally, et al.	2	Shallow 4	0
Marty Benally, et al.	2	Thin Breaks 4a & 4c	11
Proposed Restoration Area	6	Loamy 2	0

RMU	Compartment	Range Site	# Transects
Proposed Restoration Area	6	Rough Broken 2	0
Proposed Restoration Area	6	Saline Lowland 2	1
Proposed Restoration Area	6	Sandy Saline 2	8
Proposed Restoration Area	6	Shallow 2	0
Shawn Higdon	3	Loamy 2	1
Shawn Higdon	3	Saline Lowland 2	1
Shawn Higdon	3	Sandy 2	1
Shawn Higdon	3	Shallow 2	3
Shawn Higdon	3	Very Shallow 2	0

5.6 Species Composition by RMU

The most common species recorded on transects are presented here. Table 5-12 contains the species that occurred most frequently. Table 5-13 lists the species contributing the most biomass. Typically, only the three most frequently occurring species are included. However, several species occurred with the same frequency and therefore more than three species are listed. Individual species frequency data within each transect can be found in the calculation data (Appendix D).

Available forage in each compartment is located in Table 5-14. Table 5-15 displays ground cover by RMU. These tables only show data pertaining to species with forage value ratings of Preferred, Desirable, and Emergency. All other forage is not considered available to livestock and is not used when calculating stocking rates. The same table results are also presented in a pie chart format after the table.

Table 5-12. Most Frequently Occurring Species by RMU

Species	RMU(s)*	Forage Value**	Nativity**	Toxic?	Notes/Seasons
Achnatherum hymenoides	BB,CC,EB,SH	D	N	No	
Arabis perennans	MB et al.	NC	N	No	
Aristida purpurea	CT	NC	N	No	Palatable in the spring.
Astragalus sp.	SH	T	N	Yes	Astragalus species are generally unpalatable to livestock, but can cause mortality if consumed.
Atriplex obovata	PRA	Unknown	N	No	Although the specific forage value is unknown, this plant is palatable to livestock.
Bouteloua gracilis	EB, MB et al.	E	N	No	
Bromus tectorum	CJB,CC,CT,SH	INJ	I	No	Palatable in the spring.
Calochortus sp.	CT	Unknown	N	No	
Chaetopappa ericoides	CJB,CC,CT	NC	N	No	
Chrysothamnus greenei	CC,SH	E	N	No	
Cryptantha sp.	BB,EB,SH	NC	N	No	
Descurainia sp.	BB,CC,CT,EB,SH	Unknown	N	No	
Elymus elymoides	CJB,CT	P	N	No	

Species	RMU(s)*	Forage Value**	Nativity**	Toxic?	Notes/Seasons
Ephedra viridis	CT,EB	D	N	No	
Erodium cicutarium	CJB	NC	I	No	
Gutierrezia sarothrae	BB,CJB,CT,EB, MB et al., SH	INJ	N	Yes	Can be toxic to livestock if large quantities are consumed.
Lappula occidentalis	CJB,CT,SH	NC	N	No	
Plantago patagonica	SH	NC	N	No	
Pleuraphis jamesii	BB,CJB,CC,CT,EB, PRA,SH	E	N	No	
Salsola tragus	EB,PRA,SH	INJ	I	No	Injurious in all seasons except spring.
Sphaeralcea coccinea	BB,CT	NC	N	No	Palatable in the spring, summer, and fall.
Sporobolus cryptandrus	SH	NC	N	No	Palatable in the spring and summer.
Townsendia sp.	EB	NC	N	No	
Vulpia ocotoflora	CJB,CT,SH	NC	N	No	

*RMUs: BB = Bobby Bia; CJB = Charlotte Jane Begay; CC = Clinton Claw; CT = Connie Tso; EB = Evelyn Begay;
MB et al. = Mary Benally, Mary Yellowhair, Ida Begay, Eugene Begay, & Andrew Benally;
PRA = Proposed Restoration Area; SH = Shawn Higdon

**P= Preferred, D=Desirable, E=Emergency, INJ= Injurious, NC=Not Consumed, I=Introduced, N=Native

Table 5-13. Frequently Occurring Species by Weight (RMU)

RMU*	Species	Total Reconstructed Weight (lbs/acre)	Percentage of Total Weight by RMU	Life Form
BB	*Pleuraphis jamesii*	2,856.4	41.1	Grass
BB	*Hesperostipa comata*	1,246.7	17.9	Grass
BB	*Achnatherum hymenoides*	494.7	7.1	Grass
CJB	*Artemisia tridentata*	5,434..1	45.2	Shrub
CJB	*Bromus tectorum*	2,283.4	19.0	Grass
CJB	*Pleuraphis jamesii*	1,827.8	15.2	Grass
CC	*Pleuraphis jamesii*	3,275.6	25.3	Grass
CC	*Chaetopappa ericoides*	1,064.2	8.2	Forb
CC	*Ephedra cutleri*	975.4	7.5	Shrub
CT	*Calochortus sp.*	3,192.4	39.6	Forb
CT	*Pleuraphis jamesii*	1,609.6	20.0	Grass
CT	*Bromus tectorum*	505.8	6.3	Grass
EB	*Salsola tragus*	635.1	32.5	Forb
EB	*Pleuraphis jamesii*	622.0	31.8	Grass
EB	*Cryptantha sp.*	250.1	12.8	Forb

RMU*	Species	Total Reconstructed Weight (lbs/acre)	Percentage of Total Weight by RMU	Life Form
MB et al.	*Bouteloua gracilis*	744.9	25.3	Grass
MB et al.	*Gutierrezia sarothrae*	260.6	8.8	Shrub
MB et al.	*Yucca baccata*	218.6	7.4	Cactus
PRA	*Salsola tragus*	1552.1	47.3	Forb
PRA	*Sporobolus airoides*	668.3	20.4	Grass
PRA	*Atriplex obovata*	506.3	15.4	Shrub
SH	*Pleuraphis jamesii*	1674.6	30.7	Grass
SH	*Atriplex confertifolia*	1109.2	20.4	Shrub
SH	*Salsola tragus*	337.1	6.2	Forb

* RMUs: BB = Bobby Bia; CJB = Charlotte Jane Begay; CC = Clinton Claw; CT = Connie Tso; EB = Evelyn Begay; MB et al. = Mary Benally, Mary Yellowhair, Ida Begay, Eugene Begay, & Andrew Benally; PRA = Proposed Restoration Area; SH = Shawn Higdon.

Table 5-14. Available Forage by RMU

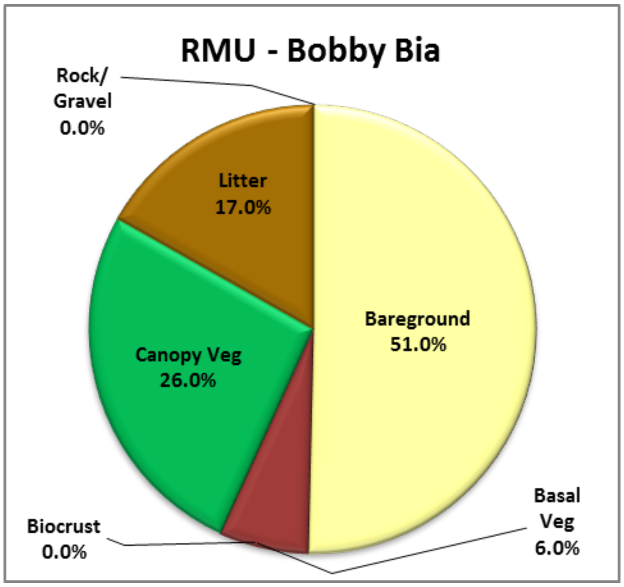
RMU*	Preferred Forage (lbs/acre)	%**	Desirable Forage (lbs/acre)	%**	Emergency Forage (lbs/acre)	%**
BB	1,328.3	19.1	706.2	10.2	3,208.9	46.2
CJB	393.3	3.3	166.5	1.4	7,350.2	61.1
CC	1,011.6	7.8	1,694.5	13.1	4,417.0	34.1
CT	103.9	1.3	42.5	0.5	1,968.4	24.4
EB	0.0	0.0	186.2	9.5	669.4	34.3
MB et al.	116.1	3.9	419.2	14.2	755.9	25.6
PRA	0.0	0	0.0	0	778.2	23.7
SH	68.2	1.3	377.0	6.9	2,024.8	37.2

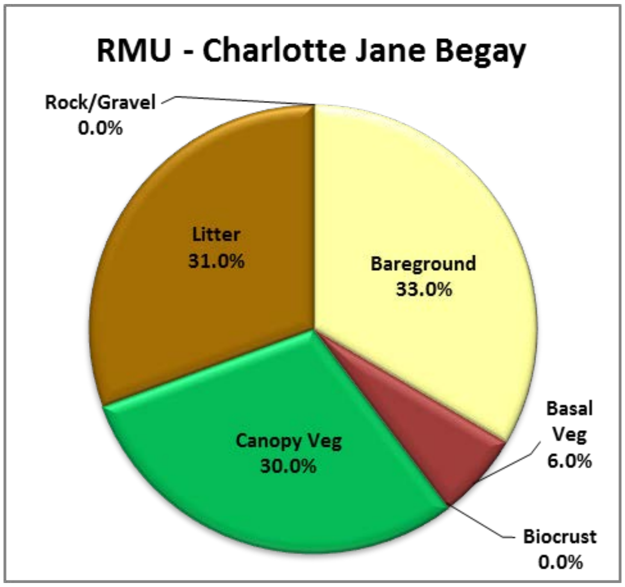
*Percentages are based on all forage types, including toxic and non-consumed.

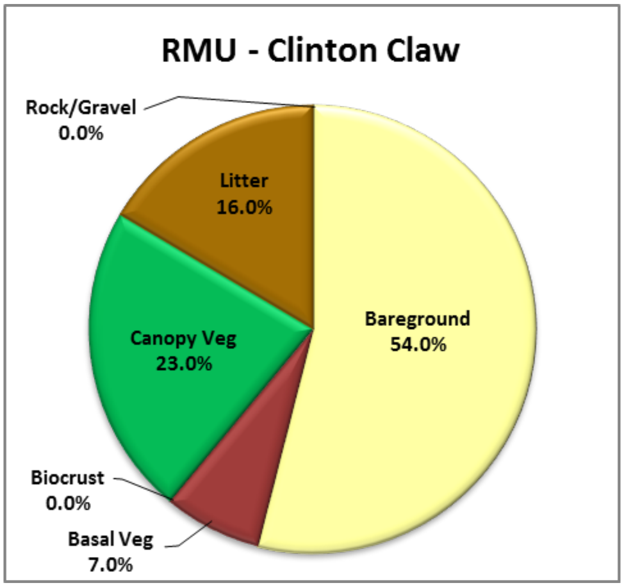
** RMUs: BB = Bobby Bia; CJB = Charlotte Jane Begay; CC = Clinton Claw; CT = Connie Tso; EB = Evelyn Begay; MB et al. = Mary Benally, Mary Yellowhair, Ida Begay, Eugene Begay, & Andrew Benally; PRA = Proposed Restoration Area; SH = Shawn Higdon

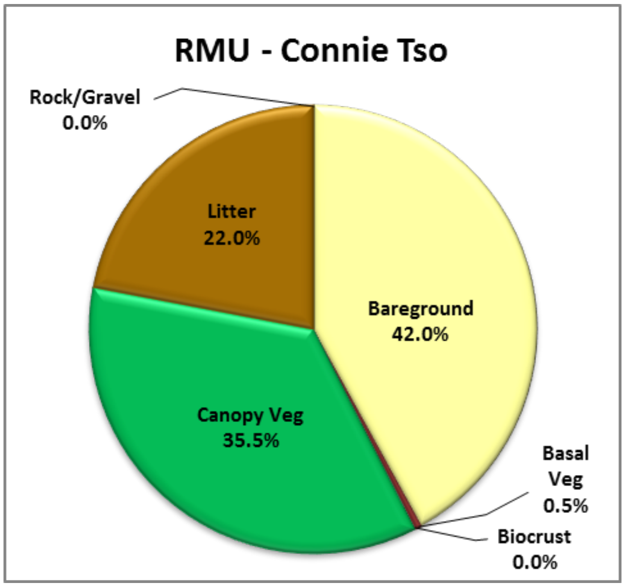
Table 5-15. Ground Cover by Range Management Unit

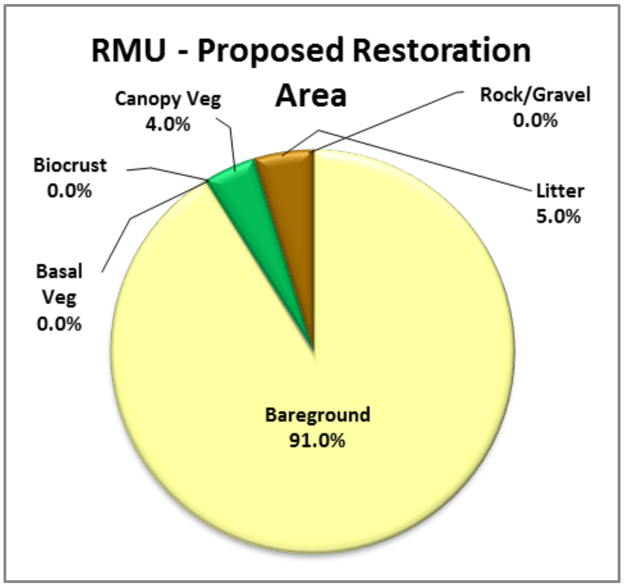
Range Management Unit	% Bare Ground	% Rock/Gravel	% Litter	% Basal Veg	% Biocrust	% Canopy Veg
Bobby Bia	51.0	0.0	17.0	6.0	0.0	26.0
Charlotte Jane Begay	33.0	0.0	31.0	6.0	0.0	30.0
Clinton Claw	54.0	0.0	16.0	7.0	0.0	23.0
Connie Tso	42.0	0.0	22.0	0.5	0.0	35.5
Evelyn Begay	77.0	0.0	14.5	0.5	0.0	8.0
Marty Benally, et al.	33.0	2.5	39.0	3.5	2.0	20.0
Proposed Restoration Area	91.0	0.0	5.0	5.0	0.0	4.0
Shawn Higdon	67.0	0.0	12.0	2.0	0.0	19.0

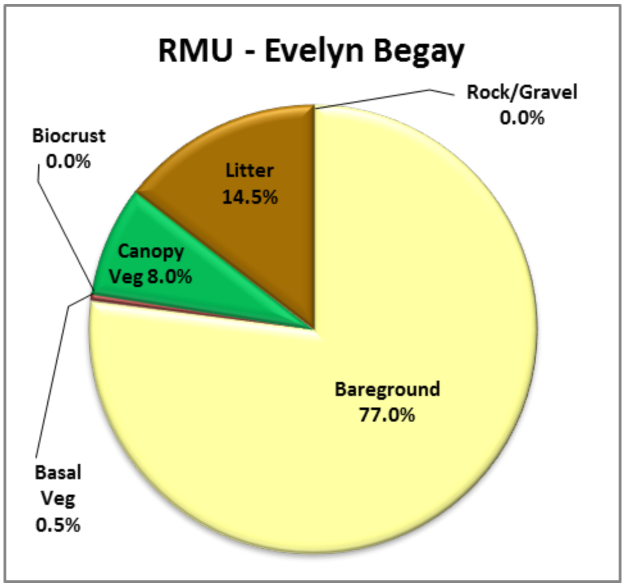

RMU - Bobby Bia
Rock/ Gravel 0.0%
Litter 17.0%
Canopy Veg 26.0%
Bareground 51.0%
Biocrust 0.0%
Basal Veg 6.0%

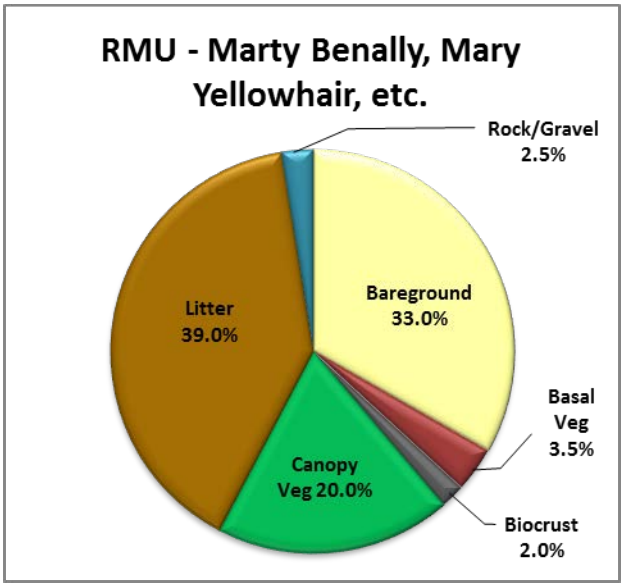

RMU - Charlotte Jane Begay
Rock/Gravel 0.0%
Litter 31.0%
Bareground 33.0%
Basal Veg 6.0%
Canopy Veg 30.0%
Biocrust 0.0%

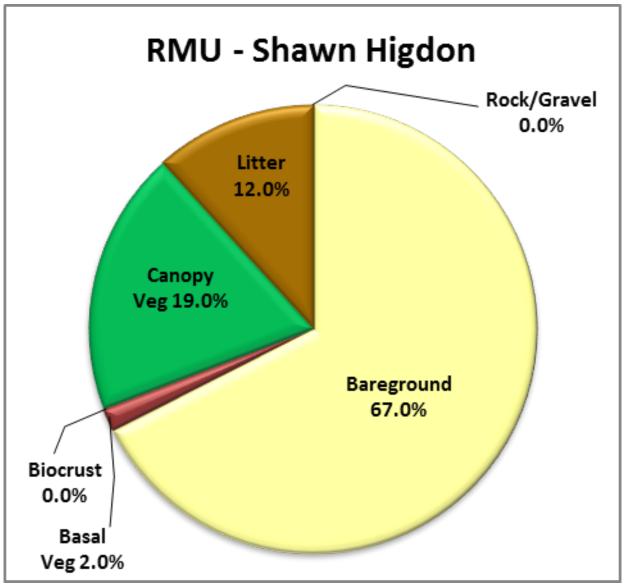

RMU - Clinton Claw
Rock/Gravel 0.0%
Litter 16.0%
Canopy Veg 23.0%
Bareground 54.0%
Biocrust 0.0%
Basal Veg 7.0%


RMU - Connie Tso
Rock/Gravel 0.0%
Litter 22.0%
Bareground 42.0%
Canopy Veg 35.5%
Basal Veg 0.5%
Biocrust 0.0%


RMU - Proposed Restoration Area
Canopy Veg 4.0%
Rock/Gravel 0.0%
Biocrust 0.0%
Litter 5.0%
Basal Veg 0.0%
Bareground 91.0%


RMU - Evelyn Begay
Rock/Gravel 0.0%
Biocrust 0.0%
Litter 14.5%
Canopy Veg 8.0%
Bareground 77.0%
Basal Veg 0.5%


RMU - Marty Benally, Mary Yellowhair, etc.
Rock/Gravel 2.5%
Bareground 33.0%
Litter 39.0%
Basal Veg 3.5%
Canopy Veg 20.0%
Biocrust 2.0%


RMU - Shawn Higdon
Rock/Gravel 0.0%
Litter 12.0%
Canopy Veg 19.0%
Bareground 67.0%
Biocrust 0.0%
Basal Veg 2.0%

6. DISCUSSION

The results from this survey provide a picture of range condition across the project area and supply a starting point from which to develop land management goals and implement rangeland improvement projects. It is important, though, to assess each category thoroughly in the results section before making decisions. To begin with, ecological site descriptions have not been developed for this area that necessitated the use of the older range site descriptions for determining range condition. The goal, in which the range site descriptions were written, is to maintain or restore all range sites to excellent condition. This approach is useful, as it provides managers with a way to establish a baseline condition quickly for a given area. Subsequent monitoring reveals whether a site is staying the same, moving away from, or moving toward the climax community. The problem with this approach is it has limited application and doesn't necessarily accommodate individual management strategies.

It is more important to assess the current state of the plant community as it applies to a desired steady state, rather than a single climax community. An excellent condition score may not always be the most suitable outcome, depending upon management goals. With this in mind, let's examine the range site description for a Loamy 2 range site. The climax community should mostly be comprised of perennial grasses like *Pascopyrum smithii, Bouteloua curtipendula, Achnatherum hymenoides, Elymus elymoides*, and *Hesperostipa comata*. Other grasses that are allowed in a limited capacity are *Bouteloua gracilis*, *Pleuraphis jamesii*, *Aristida* spp., and *Sporobolus* spp. Perennial forbs should only make up 5 percent of the community and various shrubs that are allowed, such as *Atriplex canescens* and *Sarcobatus vermiculatus*, should only be at 5 percent as well. Annual species and shrubs like *Gutierrezia sarothrae* and *Chrysothamnus* spp. should not be present in the community. In general, managing for the above community makes sense, as it favors native forage grasses and minimizes the shrub and annual species component. What it does not account for, though, is the dietary preferences of different animals. If the goal is to provide adequate forage for sheep, goats, and wildlife such as mule deer, it makes more sense to manage for a community with a more even mix of grasses, forbs, and shrubs. In the context of the range site description, the desired end result would likely rate as being in fair or good condition rather than excellent. In addition, there are several species occurring in the project area that provide good forage or browse for livestock, but are not listed in the given site description and therefore, could not be included in the condition calculation. Examples of these are *Atriplex obovata* and *Artemisia bigelovii*. Other species are listed, but are listed as plants that should not occur in the climax community. It stands to reason that invasive species should be excluded, but certain shrubs like *Chrysothamnus greenei* and *Ericameria nauseosa* are native shrubs that function as soil stabilizers and provide food and habitat for wildlife species. It may not be good to have a large component of a community made up of these shrubs, but their presence alone is not necessarily undesirable. Understanding the limitations of range site descriptions allows one to utilize them in a more efficient manner.

6.1 Planning for Drought

The measure of forage production based upon a normal year allows managers to establish a "ceiling" or carrying capacity for their land. These measures should not be used to generate stocking rates when precipitation is below normal, especially during drought conditions. A conservative initial stocking rate is appropriate under drought conditions. If there is very little precipitation during the winter and early spring, stock numbers should not be permitted at the rate of a normal years' precipitation. The same is true when an area endures several years of precipitation below normal levels. In a continuous grazing system, it is difficult to prepare for times of scarce moisture. Successful plans often implement a standard of light to moderate livestock numbers and adjust upwards as precipitation increases.

Range managers need to have the ability to increase stock numbers and reduce stock numbers based on current resource conditions. Ideally, permits would require an estimate of the current climate and production of the range resource at periodic intervals. Expected precipitation generally falls during late summer and winter, which would be good times to assess the rangelands. For example, if precipitation was below average during the winter, expected production in the spring and early summer will also be below average. The stock numbers should be adjusted promptly and accordingly. Further, the 2003 Navajo Nation Drought Contingency Plan (2003) clearly states that the reduction of animal numbers and improved range management is more likely to prevent overgrazing than providing supplemental feed and water.

Drought is one of the biggest variables in Southwestern U.S. rangelands. Livestock operators must plan for drought as a normal part of the range-livestock business. Failure to prepare and manage before, during, and after drought conditions is probably one of the biggest reasons why range areas are in deteriorating or irreversible states.

6.2 Patterns and Recommendations

In this report, we assessed range condition and then analyzed the data to determine what factors were driving the results. Several main patterns emerged that apply to the majority of the project area. The first is the predominance of shrub species.

6.2.1 Shrub Composition

Shrubs play a valuable role in maintaining healthy, functioning rangelands, but the ratio of shrubs to forb and grass species is higher than it should be in many parts of the study area. Compartment 2 and the upper reaches of Compartments 3 and 6 are largely dominated by *A. tridentata* and *A. canescens*. The other regions are dominated by *G. sarothrae*, *E. nauseosa*, *C. greenei* and various *Atriplex* spp. In some cases, proper grazing management may be sufficient to encourage the reestablishment of native forbs and grasses. As the herbaceous component begins to flourish, woody species will cease to dominate and a more balanced plant community will develop. In other cases, it may be necessary to reduce shrub populations either by mechanical or chemical means. A number of mechanical methods have been used to control shrubs on rangelands including roller chopping, root-plowing, shredding, chaining, and bulldozing. These practices require relatively gentle terrain to implement and the cost of operating the equipment can be expensive, which limits their practicality in this area. There is also the danger of encouraging the spread of invasive species by removing large swaths of vegetation at one time (DiTomaso 2000).

Chemical control is cheaper than mechanical methods and can be more effective at thinning brush stands rather than eradicating them entirely. This is generally the more desirable route to take, as it leaves cover and browse for livestock and wildlife. Soil exposure is also much reduced, which decreases opportunities for exotic plants to invade the site (Olsen et al. 1994; DiTomaso 2000).The use of the herbicide tebuthiuron, which works to inhibit photosynthetic activity, has been quite successful in thinning dense stands of *A. tridentata*. Low rates of this chemical effectively thin the stand, while still leaving adequate cover and browse for wildlife species. Application rates ranging from 0.3 to 0.5 lbs of active ingredient per acre have proven to be both cost effective and suitable for creating a mix of shrubs, grasses, and forbs (Hooley 1991; Olsen et al. 1994). Tebuthiuron and Picloram have proven to be effective in controlling *G. sarothrae* as well. However, most studies have found that at least 90 percent of the plants need to be killed to see significant increases in perennial forage species (Schmutz and Little 1970; Gesink et al. 1973; Sosebee et al. 1979; McDaniel and Duncan 1987). A common shrub species growing with *G. sarothrae* is *C. greenei*. Aerial applications of Picloram are often successfully used to control *C. greenei* and mixing Picloram with 2,4-dichlorophenoxyacetic acid (2, 4-D) can effectively reduce brush stands containing both *C. greenei* and *A. tridentata* (Cook et al. 1965; Tueller and Evans 1969; Evans and Young 1974).

The lower saline valley portion of the project area is considered part of the Great Basin Salt Desert Shrublands ecosystem. This system is more fragile than *A. tridentata* shrublands due to harsh environmental conditions, including extremely dry conditions and salty soils. *A. canescens* was found to be a major contributor on transects located within this region. Typically this species does not form dense stands, but it does do well on disturbed land that can lead to the exclusion of other species. It is also an early seral species, which prepares the way for later succession plants if disturbance factors are mitigated (Booth 1985; Aldon et al. 1995). This suggests that it may be better not to control this species, as it serves a valuable role in plant community development in this sensitive system. Restricting livestock grazing in the spring will encourage the development of native, herbaceous species, which should cause a natural reduction of *A. canescens* over several years (Kitchen and Hall 1996). In addition, *A. canescens* provides habitat for numerous wildlife species as well as forage for livestock (Humphrey 1953; Mozingo 1987). Consultation with experts is recommended prior to implementing shrub control measures to determine the best rates and timing for herbicide applications and to explore alternate control methods.

6.2.2 Salsola Tragus

The second pattern that emerged from the analyzed data was the abundance of the invasive *S. tragus*. This is a drought tolerant, disturbance-loving species that does well in sandy soils (Whitson et al. 2002). The largest populations were found in the flatlands associated with the Chinle Valley. These areas are comprised mostly of sandy soils, and being closer to the main highway corridor and population centers, disturbance is high. Although this plant is an invasive species, it does provide forage for sheep and cattle in its immature form and when softened by snow or rain (United States Department of Agriculture 1937). Consumption of large quantities of this plant has been known to cause diarrhea, especially in lambs, which can compromise the heath of animals already in a weakened condition (Cook et al. 1954). This can be an issue in areas where little else is growing and consumption is likely to be high.

S. tragus can also accelerate revegetation of disturbed areas by supporting the growth of soil mycorrhiza. Soil mycorrhiza are fungi that form associations with many native plant species. The fungi help the plants absorb more soil water and nutrients and, in return, receive carbohydrates from the roots of the plants. Certain mycorrhiza will invade the roots of *S. tragus* and they do not form an association with this plant, but rather kill the infected roots and then move on to the roots of neighboring plants. In this manner, the fungi population increases while *S. tragus* populations begin to die (Allen and Allen 1988; Allen et al. 1989). The dead plants provide cover for seedlings of other species that are capable of forming associations with the newly established mycorrhiza colonies (Allen and Allen 1988; Grilz et al. 1988). Typically, *S. tragus* will persist on a site for about two years and then will be replaced by annual and biennial mustards like *Sisymbrium altissimum* and various species of *Descurainia* (Chapman et al. 1969). *Descurainia* spp. and to some extent *Sisymbrium altissimum* are very common across all compartments in the project area, especially where populations of *S. tragus* frequently occur. The mustard species continue to build up the soil substrate by maintaining soil mycorrhiza populations and adding organic matter to the soil as the plants die.

S. tragus also helps prepare a site by releasing oxalates into the soil. These chemicals work to change inorganic phosphorous into a soluble form that can be taken up by plants (Cannon et al. 1995). Phosphorus is often a limiting nutrient in the soil and by increasing its availability, favorable forage plants can become established at faster rates. *S. tragus* can be controlled or even eradicated through various mechanical and chemical treatments (Young and Whitesides 1987; Burrill et al. 1989). However, this process is time consuming and expensive. Given the potential benefits of the plant, it is generally better to leave it and focus on encouraging the establishment of desirable, perennial species through proper grazing management and seeding treatments.

6.2.3 Soil Exposure and Loss

The third pattern observed when analyzing vegetation communities was that many areas had either very low production or much of the production was in the form of annual plants. These situations raise the concern that the soils may be unstable and possibly devoid of ground cover. This concern was verified when analysis of ground cover data revealed that the majority of transects were in areas containing a high percentage of bare ground. The greatest obstacle facing restoration efforts in the project area is the lack of topsoil. As soil is lost to erosion, the economic and ecological foundations on which production and conservation are built begin to crumble as well. Reestablishing native perennial species and controlling grazing practices are important steps that need to be taken, but all rehabilitation efforts hinge upon having soils that are capable of supporting healthy plant communities. Thus, it is clear that the first steps that need to be taken are those that prevent further erosion and rebuild soils where they have been lost. Deeply eroded gullies and arroyos are the most difficult and cost prohibitive features to restore. In their immature form, the sides of the channels are usually very steep or even vertical, which makes it difficult for stabilizing vegetation to establish. An effective technique for decreasing slope gradient is to use earthmoving equipment to reshape or terrace the banks, thus creating substrates suitable for plant colonization. This method is particularly effective in arid regions where work can be completed prior to seasonal flows. Unfortunately, the cost and logistics involved with getting equipment into more remote locations can make this option prohibitive (Valentin et al. 2005).

Another option is to focus efforts upstream from deeply eroded channels. In areas where channels are just beginning to develop and the rate and volume of surface runoff is fairly low, effective countermeasures to erosion are simple, hand constructed rock check dams. In addition to capturing soil and preventing further loss, they also serve to redistribute water, especially during the monsoon season. Spreading runoff across the landscape and retaining water for longer periods leads to more plant growth and plant cover, which increases infiltration and soil moisture (Nichols et al. 2012). Seeding programs that utilize fast-growing, native pioneer species tend to produce better and quicker results when working to stabilize channel walls (Valentin et al. 2005).

Regions of the project area that are located on fairly steep slopes and have a dense pinyon-juniper canopy cover may benefit from thinning projects. Spreading out branches and stems from thinned trees helps prevent surface water runoff, thus increasing infiltration rates and soil moisture that promotes regeneration of herbaceous species in the understory. The increased sunlight and air movement also contribute to greater understory production (Allen 2001; Hastings et al. 2003). It can be rather time-consuming and potentially expensive to thin trees and spread out the slash. The United States Forest Service typically utilizes fire crews to help defray expenses. A great resource for technical and financial assistance with natural resource improvements is the NRCS. Tribal entities are considered underserved and may be eligible for higher payments when implementing conservation practices. For more information, visit the Arizona NRCS programs webpage (http://www.az.nrcs.usda.gov/programs/) or contact the NRCS Chinle Field Office (i.e., Lyndon Chee [District Conservationist] and Wilson Halwood, Jr. [Soil Conservation Technician]).

Rebuilding soils requires a combination of erosion control, revegetation, and periodic disturbance of the soil surface. Revegetation may require reseeding programs in some parts. However, a final observation is that much of the native plant community is still present within the vast majority of the project area, despite issues with dense brush cover, invasive species, and bare ground. Production from native species may be low in many areas, but the components are still in place. Especially visible are perennial grass species like *A. hymenoides, E. elymoides*, *P. jamesii*, *B. gracilis*, and *Sporobolus* spp. as well as important forb and shrub species such as *Sphaeralcea* spp., *Atriplex* spp., and *K. lanata*. This indicates that with careful and proactive management, native species production and frequency should increase naturally without a lot of intervention. Areas with dense shrubs or trees will need to be thinned to release the native herbaceous component. Although shrub production is high throughout the study area, shrub populations are not always dense. In many cases, shrub growth stands out simply because there are few other species present in the community. The lack of native herbaceous production is due, in large part, to contemporary grazing practices.

In this report, there is little discussion pertaining to carrying capacity and the fact that it has been exceeded. This is already a known fact and reducing livestock numbers to match the current capacity is not an acceptable solution. The drastic reductions that would be necessary to achieve an adequate carrying capacity would have an enormous negative impact on livestock producers and the Navajo culture in general. Simply removing livestock will have virtually no effect on improving range condition. Marginal improvements would probably be seen initially, but brushy areas would still be brushy, invasive plants would continue to flourish and the cessation of surface disturbance would inhibit revegetation of bare ground. A much more appropriate solution is to implement range improvements and actively manage the movements of livestock and timing of grazing. Some livestock reductions may be necessary initially, but more effort should be made toward improving condition and actively managing grazing.

The final part of rebuilding soil is to make sure that it undergoes periodic disturbance. This is where livestock play a very important role. The trampling effect of livestock works to incorporate manure and litter into the soil, which increases aeration and organic matter content. Hoof indentations also create microsites that encourage seedling growth and moisture retention. However, controlling the timing and duration of grazing is the key to reaping these benefits. Fences are an important component in managing grazing, as they greatly facilitate pasture deferment, rest, and rotation. A critical part of grazing management is allowing the forage to grow before being grazed and allowing it to recoup following grazing. The current grazing scheme of continuous, year-round grazing makes it difficult for plants to become established and keeps forage yields low. In turn, reduced forage leads to increases in shrubs, invasive plants, and erosion. Fence construction, however, is not a straight forward process. On the Navajo Reservation, rangeland is considered a common property resource. The original idea behind holding land in common was that it would help maintain tribal sovereignty and authority. Unfortunately, a whole host of administrative miss-steps, dating clear back to the 1930s, have fostered a general mistrust of government intervention by Navajo tribal members, weak enforcement of grazing regulations, and a pattern of numerous small herds that are generally not sufficient to support a family's livelihood. As a result, the action of dividing grazing lands into individual, fenced units comes up against a virtual wall of political, social, and regulatory issues. It is well beyond the scope and presumptions of this report to try and unravel this situation, but it is clear that a way needs to be found that allows for the incorporation of more range improvements and that fully utilize the inherent ability of livestock to enhance range land health.

7. CONCLUSIONS

This study found that current livestock numbers exceed the overall carrying capacity of the project area. This report recommends improving rangeland conditions not only by adjusted stocking rates but, more importantly, by restoring biotic, hydrologic, and soil stability components of the landscape.

Rangeland deteriorates in a cyclic fashion. Key species begin to disappear, causing less desirable plants to increase. Under continued pressure, these less desirable species begin to decline and allow for the encroachment of shrubs, invasive exotics, and annual species. Bare ground becomes more frequent, leading to accelerated erosion that reduces the supportive capability of the soil and leads back to even more decreases in desired vegetation. This same pattern can be seen in reverse when steps are taken to halt the degradation process. Controlling erosion with check dams and other methods prevents further soil loss and allows for the spreading and retention of water across the landscape. Increased soil moisture enhances the reestablishment of perennial herbaceous species, which further stabilize and increase the water-holding capacity of soils. The most encouraging result produced in this study was that a substantial portion of the perennial, native plant community is still present throughout the project area. In many cases, the prevalence of less desirable species simply indicates that plant succession has been set back, but these changes are not irreversible. Many of the these species (i.e., *S. tragus* and *A. canescens*) are actually improving soil conditions, which serves to pave the way for a natural increase in other, more preferable species. However, this cannot happen if the current disturbance regime does not change. Erosion control and active grazing management are vastly important steps that need to take place to begin the restoration process.

Analysis of the data revealed several patterns including high shrub density, numerous areas devoid of vegetative cover, and other areas that are maintaining good populations of key grass species like *A. hymenoides* and *H. comata*. The next step is to use this data to identify specific locations that would benefit most from improvement measures and organize field visits to gain an “on-the-ground” perspective. Groups of transects that yielded low production and high counts of bare ground may be in severely eroded areas and great effort would be necessary to improve these sites. On the other hand, these groups of transects may just have a high potential for erosion and simple improvements could greatly enhance the soil and plant community. Using the data to pinpoint areas with the highest densities of shrubs would serve as a starting point for assessing whether chemical control measures are necessary. In some cases, it may be better to focus on grazing strategies and let natural succession run its course. Identifying places with high forage production can be helpful for implementing rotational grazing schemes. These areas would be able to withstand higher grazing pressures, while more fragile areas were being rested. Visits to these areas would allow managers to determine the feasibility of adding water sources if none are currently present. If the data from certain transects showed that native forage species were not present, it may be necessary to implement reseeding programs. Agriculture extension offices and the NRCS are good resources to use for help in determining appropriate seed mixes and finding seed sources. Using local, drought tolerant species that can germinate early, like *S. coccinea* and *S. cryptandrus*, will speed up revegetation and increase the likelihood of success. Once principal restoration areas have been determined and some initial assessments have been made, it would be ideal to get people living in these areas involved. A common sentiment encountered while performing the vegetation surveys was that people want to improve the land, but they aren't receiving help or don't know where to ask for help. Approaching permittees with specific, proactive improvement plans and the support for carrying out the plans would greatly help build the momentum necessary for enacting large-scale, long-term changes. NRCS programs like the Environmental Quality Incentives Program can aid in providing the technical and financial support needed for this to happen.

Grazing programs should make use of available tools. When it is possible to erect fences, they should be designed to ease the movement and exclusion of livestock, as dictated by the condition of the vegetation. In keeping with this, water sources and salt blocks can be situated to move animals out of some areas or to encourage them to use underutilized locations. In addition, the provided initial stocking rates and carrying capacities in this report should be used as a guide to be adjusted appropriately with consideration of forage value, the seasonal palatability of forage, and the variability of precipitation. For example, a conservative initial stocking rate is appropriate under drought conditions. If there is very little precipitation during the winter and early spring, stock numbers should not be permitted at the rate of a normal year production. The same is true when an area endures several years of precipitation below normal levels. However, the placement of the previously discussed check dams and other water catchment systems like ponding dikes can greatly offset the negative impacts associated with drought and lessen the need to cut livestock numbers. Positive results from water retention projects have been achieved in arid regions around the world (Tromble 1982; Rango and Havstad 2011).

After restoration efforts have begun, it is important to establish monitoring programs. Because all production measurements are affected by annual precipitation, it is crucial that accurate precipitation data is applied to the production measurements. It would provide more accuracy to the annual production (and resulting stocking rates) if a more comprehensive record was available for multiple locations throughout the project area. Now that the initial baseline data has been collected, it is not necessary to sample vegetation at each transect. Instead, a smaller number of permanent transects and photo monitoring points can be set up at locations targeted for restoration and in representative areas for each range site. In addition to monitoring species composition and production, it would also be valuable to assess soil stability and hydrologic function. There are numerous references that can be utilized to develop monitoring programs and help interpret the results, such as the Monitoring Manuel for Grassland, Shrubland, and Savanna Ecosystems put out by the Arid Lands Research Program (Herrick et al. 2005) and the BLM's Technical Reference 1734-6: Interpreting Indicators of Rangeland Health (Pellant et al. 2005).

Because current livestock numbers exceed the overall carrying capacity of the project area, this report provides focused recommendations for improving rangeland conditions not simply by adjusting stocking rates but, more importantly, by restoring biotic, hydrologic, and soil stability components of the landscape.

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Appendix A— Precipitation Data

Monthly Averages (inches) For All Rain Cans in Chinle Agency

Water Year	October	November	December	January	February	March	April	May	June	July	August	September	Water Year Monthly Avg.
2000	0.05	0.12	0.41	1.60	0.67	2.19	0.62	0.22	0.39	0.84	1.77	0.74	0.80
2001	3.24	0.68	0.83	1.76	1.38	1.35	1.42	1.54	0.79	1.61	2.62	0.37	1.47
2002	0.32	0.66	1.07	0.37	0.30	0.49	0.47	0.11	0.03	1.27	0.79	3.03	0.74
2003	1.02	0.96	1.08	0.33	1.85	2.25	0.58	0.30	0.21	1.11	2.36	1.55	1.13
2004	1.15	1.12	0.93	0.95	1.35	0.73	1.87	0.12	0.20	1.49	1.15	2.96	1.17
2005	1.40	1.71	1.17	2.76	3.49	1.44	1.79	0.36	0.39	0.96	3.03	0.92	1.62
2006	1.29	0.07	0.21	0.71	0.07	1.47	0.59	0.16	0.39	1.52	2.45	1.71	0.89
2007	2.64	0.31	0.96	0.65	1.41	1.39	1.49	1.19	0.22	2.04	2.18	1.72	1.35
2008	0.16	0.03	2.76	2.36	1.75	0.03	0.28	0.74	0.43	1.58	1.95	0.75	1.07
2009	0.58	0.87	2.67	0.53	1.16	0.42	1.20	1.07	0.35	0.79	0.44	0.96	0.92
2010	0.43	0.59	1.55	2.80	1.68	1.19	1.06	0.13	0.15	2.53	2.07	1.34	1.29
2011	1.15	0.83	1.20	0.39	0.77	0.69	1.04	0.93	0.01	2.05	1.60	1.72	1.03
2012	1.59	1.67	0.74	0.58	1.13	0.56	0.41	0.09					**0.85**

Summary Data

Average	1.12	0.66	1.24	1.27	1.32	1.14	1.03	0.57					**1.04**
Minimum	0.05	0.03	0.21	0.33	0.07	0.03	0.28	0.09					
Maximum	3.24	1.71	2.76	2.80	3.49	2.25	1.87	1.54					

Data was collected during only the first half of June 2012. Therefore, the average precipitation for the water year up through May was used for determining Percent of Normal precipitation. This number was obtained by dividing the average through May 2012 by the average through May from 2000 up through 2011(0.85/1.04 = 0.817*100 = 81.7%)

Appendix B— Plant List and Collection

Symbol	**Species**	**Life Form**	**Sheep Forage Value (Most Limiting Season of Use)**
ABRON	*Abronia sp.*	Forb	Unknown
ABEL	*Abronia elliptica*	Forb	Unknown
ABFR2	*Abronia fragrans*	Forb	Not Consumed
ACHY	*Achnatherum hymenoides*	Graminoid	Desirable
ALLIU	*Allium sp.*	Forb	Not Consumed
AMARA	*Amaranthus sp.*	Forb	Desirable
AMAC2	*Ambrosia ancanthicarpa*	Forb	Unknown
AMBRO	*Ambrosia sp.*	Forb	Unknown
AMUT	*Amelanchier utahensis*	Shrub	Desirable
ANBR4	*Androstephium breviflorum*	Forb	Unknown
ARPE2	*Arabis perennans*	Forb	Not Consumed
ARPU9	*Aristida purpurea*	Graminoid	Not Consumed
ARBI3	*Artemisia bigelovii*	Shrub	Desirable
ARFR4	*Artemisia frigida*	Shrub	Desirable
ARTEM	*Artemisia sp.*	Shrub	Desirable
ARTR2	*Artemisia tridentata*	Shrub	Emergency
ASIN14	*Asclepias involucrata*	Forb	Unknown
ASCA9	*Astragalus calycosus*	Forb	Not Consumed
ASCE	*Astragalus ceramicus*	Forb	Unknown
ASFU2	*Astragalus fucatus*	Forb	Unknown
ASMOT	*Astragalus mollissimus* var. *thompsoniae*	Forb	Toxic
ASTRA	*Astragalus sp.*	Forb	Toxic
ASZI	*Astragalus zionis*	Forb	Unknown
ATCA2	*Atriplex canescens*	Shrub	Desirable
ATCO	*Atriplex confertifolia*	Shrub	Not Consumed
ATOB	*Atriplex obovata*	Subshrub/Shrub	Unknown
ATPO2	*Atriplex powellii*	Forb	Unknown
ATRIP	*Atriplex sp.*	Shrub	Unknown
BASC5	*Bassia scoparia*	Forb	Injurious
BOER4	*Bouteloua eriopoda*	Graminoid	Unknown
BOGR2	*Bouteloua gracilis*	Graminoid	Emergency
BRTE	*Bromus tectorum*	Graminoid	Injurious
CALOC	*Calochortus sp.*	Forb	Unknown
CAREX	*Carex sp.*	Graminoid	Desirable
CALI4	*Castilleja linariifolia*	Forb	Not Consumed
CEMO2	*Cercocarpus montanus*	Shrub	Desirable
CHST	*Chaenactis stevioides*	Forb	Unknown
CHER2	*Chaetopappa ericoides*	Forb	Not Consumed
CHCO2	*Chamaesaracha coronopus*	Subshrub	Unknown
CHAMA15	*Chamaesyce sp.*	Forb	Unknown
CHAL7	*Chenopodium album*	Forb	Not Consumed
CHGR2	*Chenopodium graveolens*	Forb	Unknown
CHENO	*Chenopodium sp.*	Forb	Unknown
CHDE2	*Chrysothamnus depressus*	Subshrub	Emergency

CHGR6	*Chrysothamnus greenei*	Shrub	Emergency
CHRYS9	*Chrysothamnus sp.*	Shrub	Unknown
CHVI8	*Chrysothamnus viscidiflorus*	Shrub	Emergency
CLLU2	*Cleome lutea*	Forb	Not Consumed
CORA	*Coleogyne ramosissima*	Shrub	Unknown
COUM	*Commandra umbellata*	Subshrub	Not Consumed
CORDY	*Cordylanthus sp.*	Forb	Unknown
CROTO	*Croton sp.*	Forb	Unknown
CRTE4	*Croton texensis*	Forb	Unknown
CRCI3	*Cryptantha cinerea*	Forb	Unknown
CRCR3	*Cryptantha crassisepala*	Forb	Not Consumed
CRYPT	*Cryptantha sp.*	Forb/Subshrub	Not Consumed
CYLIND	*Cylindropuntia sp.*	Cactus	Not Consumed
CYMOP2	*Cymopterus sp.*	Forb	Toxic
DESC	*Delphinium scaposum*	Forb	Injurious
DEPI	*Descurainia pinnata*	Forb	Not Consumed
DESO2	*Descurainia sophia*	Forb	Not Consumed
DESCU	*Descurainia sp.*	Forb	Unknown
DIWI2	*Dimorphocarpa wislizeni*	Forb	Unknown
DRCU	*Draba cuneifolia*	Forb	Unknown
DRPA2	*Dracocephalum parviflorum*	Forb	Unknown
ECHIN3	*Echinocereus sp.*	Cactus	Not Consumed
ELEL5	*Elymus elymoides*	Graminoid	Preferred
EPCU	*Ephedra cutleri*	Shrub	Desirable
EPHED	*Ephedra sp.*	Shrub	Desirable
EPTO	*Ephedra torreyana*	Shrub	Desirable
EPVI	*Ephedra viridis*	Shrub	Desirable
ERTR13	*Eremopyrum triticeum*	Graminoid	Unknown
ERDI2	*Eriastrum diffusum*	Forb	Unknown
ERNA10	*Ericameria nauseosa*	Shrub	Not Consumed
ERFL	*Erigeron flagellaris*	Forb	Unknown
ERIGE2	*Erigeron sp.*	Forb	Not Consumed
ERAL4	*Eriogonum alatum*	Forb/Subshrub	Not Consumed
ERCE2	*Eriogonum cernuum*	Forb	Emergency
ERLE9	*Eriogonum leptocladon*	Subshrub	Unknown
ERLE10	*Eriogonum leptophyllum*	Subshrub	Unknown
ERIOG	*Eriogonum sp.*	Forb	Not Consumed
ERCI6	*Erodium cicutarium*	Forb	Not Consumed
ERYSI	*Erysimum sp.*	Forb	Not Consumed
FRAN2	*Fraxinus anomala*	Shrub/Tree	Unknown
GIOP	*Gilia ophthalmoides*	Forb	Unknown
GISI	*Gilia sinuata*	Forb	Unknown
GILIA	*Gilia sp.*	Forb	Unknown
GUMI	*Gutierrezia microcephala*	Subshrub	Unknown
GUSA2	*Gutierrezia sarothrae*	Shrub	Injurious
HAGL	*Halogeton glomeratus*	Forb	Toxic
HEMU3	*Heliomeris multiflora*	Forb	Unknown

HECO26	*Hesperostipa comata*	Graminoid	Preferred
HENE5	*Hesperostipa neomexicana*	Graminoid	Unknown
HEVI4	*Heterotheca villosa*	Subshrub/Shrub	Not Consumed
HYFI	*Hymenopappus filifolius*	Forb	Not Consumed
HYFIP	*Hymenopappus filifolius* var. *pauciflorus*	Forb	Not Consumed
HYMEN4	*Hymenopappus sp.*	Forb	Desirable
HYRI	*Hymenoxys richardsonii*	Forb	Unknown
IPAG	*Ipomopsis aggregata*	Forb	Not Consumed
IPGU	*Ipomopsis gunnisonii*	Forb	Unknown
IPLO2	*Ipomopsis longiflora*	Forb	Unknown
IPPU4	*Ipomopsis pumila*	Forb	Not Consumed
IPOMO	*Ipomopsis sp.*	Forb	Unknown
KRLA2	*Krascheninnikovia lanata*	Subshrub	Preferred
LAOC3	*Lappula occidentalis*	Forb	Not Consumed
LAGL5	*Layia glandulosa*	Forb	Unknown
LEFR2	*Lepidium fremontii*	Subshrub/Shrub	Unknown
LEPU	*Leptodactylon pungens*	Subshrub	Not Consumed
LESQU	*Lesquerella sp.*	Forb	Not Consumed
LIAR3	*Linum aristatum*	Forb	Unknown
LIPU4	*Linum puberulum*	Forb	Not Consumed
LINUM	*Linum sp.*	Forb	Unknown
LITHO	*Lithocarpus sp.*	Forb	Unknown
LOTUS	*Lotus sp.*	Forb	Unknown
LUAR3	*Lupinus argenteus*	Forb	Toxic
LUPU	*Lupinus pusillus*	Forb	Toxic
LYPA	*Lycium pallidum*	Forb	Unknown
MACA2	*Machaeranthera canescens*	Forb	Not Consumed
MACHA	*Machaeranthera sp.*	Forb	Unknown
MATA2	*Machaeranthera tanacetifolia*	Forb	Not Consumed
MASO	*Malacothrix sonchoides*	Forb	Unknown
MEAL6	*Mentzelia albicaulis*	Forb	Not Consumed
MEMUI	*Mentzelia multiflora*	Forb	Unknown
MEMUL2	*Mentzelia multiflora* var. *longiloba*	Forb	Unknown
MEPU3	*Mentzelia pumila*	Forb	Unknown
MENTZ	*Mentzelia sp.*	Forb	Unknown
MUHLE	*Muhlenbergia sp.*	Graminoid	Unknown
MUTO2	*Muhlenbergia torreyi*	Graminoid	Unknown
MUPU2	*Muhlengergia pungens*	Graminoid	Unknown
OEAL	*Oenothera albicaulis*	Forb	Unknown
OEPA	*Oenothera pallida*	Forb	Unknown
OENOT	*Oenothera sp.*	Forb	Unknown
OPFR	*Opuntia fragilis*	Shrub	Not Consumed
OPMA2	*Opuntia macrorhiza*	Cactus	Not Consumed
OPPO	*Opuntia polyacantha*	Cactus	Not Consumed
OPUNT	*Opuntia sp.*	Cactus	Not Consumed
OPWH	*Opuntia whipplei*	Cactus	Not Consumed
OROBA	*Orobanche sp.*	Forb	Unknown

PAMU11	*Packera multilobata*	Forb	Not Consumed
PASM	*Pascopyrum smithii*	Graminoid	Desirable
PECE	*Pedicularis centranthera*	Forb	Unknown
PEBA2	*Penstemon barbatus*	Forb	Not Consumed
PELI2	*Penstemon linarioides*	Forb	Not Consumed
PENST	*Penstemon sp.*	Forb	Not Consumed
PEPU7	*Petradoria pumila*	Forb	Unknown
PEPUG	*Petradoria pumila* ssp. *graminea*	Forb	Unknown
PHCR	*Phacelia crenulata*	Forb	Unknown
PHACE	*Phacelia sp.*	Forb	Unknown
PHLOX	*Phlox sp.*	Forb	Unknown
PHYSA2	*Physaria sp.*	Forb	Unknown
PLOV	*Plantago ovata*	Forb	Unknown
PLPA2	*Plantago patagonica*	Forb	Not Consumed
PLJA	*Pleuraphis jamesii*	Graminoid	Emergency
POFE	*Poa fendleriana*	Graminoid	Desirable
POSE	*Poa secunda*	Graminoid	Emergency
PUST	*Purshia stansburiana*	Shrub	Desirable
QUGA	*Quercus gambelii*	Shrub	Not Consumed
SATR12	*Salsola tragus*	Forb	Injurious
SAVE4	*Sarcobatus vermiculatus*	Shrub	Not Consumed
SCLER10	*Sclerocactus sp.*	Cactus	Not Consumed
SENEC	*Senecio sp.*	Forb	Unknown
SIAL2	*Sisymbrium altissimum*	Forb	Not Consumed
SOEL	*Solanum elaeagnifolium*	Forb	Unknown
SPLE	*Sphaeralcea leptophylla*	Forb	Unknown
SPAM2	*Sphaeralcea ambigua*	Forb	Not Consumed
SPCO	*Sphaeralcea coccinea*	Forb	Not Consumed
SPCOC	*Sphaeralcea coccinea* ssp. *coccinea*	Forb	Not Consumed
SPFE	*Sphaeralcea fendleri*	Forb	Unknown
SPGR2	*Sphaeralcea grossulariifolia*	Forb	Not Consumed
SPPA2	*Sphaeralcea parvifolia*	Forb	Unknown
SPHAE	*Sphaeralcea sp.*	Forb	Unknown
SPAI	*Sporobolus airoides*	Graminoid	Emergency
SPCR	*Sporobolus cryptandrus*	Graminoid	Not Consumed
SPGI	*Sporobolus giganteus*	Graminoid	Unknown
SPORO	*Sporobolus sp.*	Graminoid	Unknown
STEX	*Stephanomeria exigua*	Forb	Unknown
STLO4	*Streptanthella longirostris*	Forb	Unknown
STCO6	*Streptanthus cordatus*	Forb	Unknown
TEAC	*Tetraneuris acaulis*	Forb	Not Consumed
THME	*Thelesperma megapotamicum*	Forb	Unknown
TOAN	*Townsendia annua*	Forb	Unknown
TOIN	*Townsendia incana*	Forb	Unknown
TOWNS	*Townsendia sp.*	Forb	Not Consumed
TRIFO	*Trifolium sp.*	Forb	Not Consumed
TRCAW2	*Tripterocalyx carneus* var. *wootoni*	Forb	Unknown

UNK	*Unknown spp*	Unknown	Unknown
VEBR	*Verbena bracteata*	Forb	Unknown
VUOC	*Vulpia octoflora*	Graminoid	Not Consumed
YUAN2	*Yucca angustissima*	Subshrub/Shrub	Injurious
YUBA	*Yucca baccata*	Subshrub/Shrub	Injurious

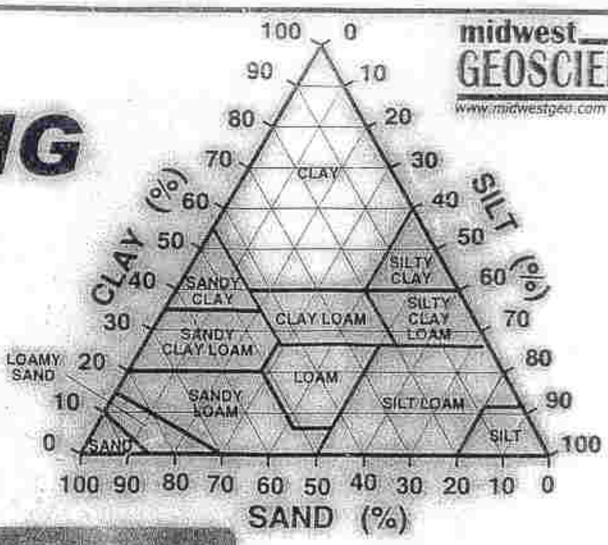
recordNumber	institutionCode	family	scientificName	scientificNameAuthor	recordedBy	eventDate	associatedTaxa
11280	ASC	Brassicaceae	Stanleya albescens	M.E. Jones	G. Rink	6/3/2012	Sarcobatus vermiculatus
11283	ASC	Polygonaceae	Eriogonum divaricatum	Hook.	G. Rink	6/5/2012	Atriplex confertifolia, Kochia americana
11284	ASC	Fabaceae	Astragalus scopulorum	Porter	G. Rink	6/7/2012	Pinus edulis, Purshia stansburiana, Amelanchier utahensis
11286	ASC	Nyctaginaceae	Tripterocalyx wootonii	Standl.	G. Rink	6/8/2012	Atriplex canescens, Salsola tragus, Lappula occidentalis

stateProvince	county	locality	decimalLatitude	decimalLongitude	verbatimCoordinates	minimumElevationIn	verbatimElevation
AZ	Apache	about eight miles southwest of Many Farms	36.278188	-109.775221	12s 610000E 4015500N	1780	5850ft
AZ	Apache	a few miles northeast of Chinle	36.384977	-109.487267	12S 635678E 4027712N	1750	5750ft
AZ	Apache	East side of Black Mesaabove Aspen Wash	36.266045	-109.842181	12s 604002E 4014079N	2190	7200ft
AZ	Apache	Spring Canyon, East side of Black Mesa	36.287364	-109.843971	12S 603813E 4016442N	2000	6550ft

Appendix C— USDA Soil Texture Flow Chart

USDA SOIL TEXTURING FIELD FLOW CHART

midwest GEOSCIENCES group
www.midwestgeo.com



Remove any material larger than 2 mm in size and start with approximately 25g of sediment in palm. Add water dropwise and knead the soil to break down all aggregates. Stop adding water when soil is plastic and moldable.

Add dry sediment

Does soil hold together when squeezed? NO → **Is soil too dry?** (YES → back to start) NO → **Is sediment too wet?** (YES → Add dry sediment) NO → **SAND**

YES

Place ball of soil between thumb and forefinger gently pushing the soil with the thumb, squeezing it upward into a ribbon. Form the ribbon with uniform thickness and width. Allow the ribbon to extend over the forefinger, breaking from its own weight.

YES

Does the soil form a ribbon? NO → **LOAMY SAND**

YES

Is the ribbon less than 2.5cm long before breaking? >2.5 CM? → **Is the ribbon from 2.5 to 5.0cm long before breaking?** >5.0 CM? → **Is the ribbon greater than 5.0cm long before breaking?**

YES YES YES

Excessively wet a small pinch of soil in palm and rub with forefinger

Is soil very sandy? YES → **SANDY LOAM**
NO
Is soil moderately sandy? YES → **LOAM**
NO
Does sample have little or no sand? YES → **SILT LOAM**

Does soil feel very gritty? YES → **SANDY CLAY LOAM**
NO
Does soil feel slightly gritty? YES → **SILTY CLAY LOAM**
NO
Does soil feel smooth? YES → **CLAY LOAM**

Does soil feel very gritty? YES → **SANDY CLAY**
NO
Does soil feel slightly gritty? YES → **SILTY CLAY**
NO
Does soil feel smooth? YES → **CLAY**

TEXTURE MODIFIERS
Fragment Content % by Volume

<15%	No modifier
15% to <35%	Add modifer
36% to <60%	Add "very" with modifier
60% to 90%	Add "extremely" with modifier
>90%	No modifer; use Size Class only

ROCK FRAGMENT MODIFIERS
Size Class & Quantity

Gravelly	>15% but <35% gravel
Fine Gravelly	>15% but <35% fine gravel
Medium Gravelly	>15% but <35% med. gravel
Large Gravelly	>15% but <35% large gravel
Very Gravelly	<35% but <60% gravel
Extremely Gravelly	>60% but <90% gravel
Cobbly	>15% but <35% cobbles
Very Cobbly	<35% but <60% cobbles
Extremely Cobbly	>60% but <90% cobbles
Stony	>15% but <35% stones
Very Stony	<35% but <60% stones
Extremely Stony	>60% but <90% stones
Bouldery	>15% but <35% boulders
Very Bouldery	<35% but <60% boulders
Extremely Bouldery	>60% but <90% boulders

COMPOSITIONAL TEXTURE MODIFIERS
Organic Class

Grassy	> 15% grassy fibers
Herbaceous	> 15% herbaceous fibers
Mossy	>15% moss fibers
Mucky	Minerals >10% but <17% fibers
Peaty	Minerals >10% but >17% fibers
Woody	>15% wood fragments or fiber