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Classification and Map of Vegetation at Yucca and Little Skull Mountains, Nevada

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This report accompanies a map that was produced by the TRW Technical Database Management Division. Audrey Rager led the effort to fuse the latest technology in remote sensing and GIS (Geographical Information Systems) with our field samples, pencilled drawings, and last minute rushes. We are in debt to her, and to the following staff members: Matt Knop, Pam Pratt, Nanda Srinivasan, and Dan Steen.

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DISCLAIMER

EXECUTIVE SUMMARY

This report describes the vegetation associations of Yucca and Little Skull Mountains, Nevada, and explains how vegetation was sampled and classified. The cover of perennial plants was measured on 358 Ecological Landform Units using plotless sampling methods. Cluster analysis was used to group samples into nine vegetation associations. The distribution of vegetation associations is shown on map YMP-98-153.0, which accompanies this report. A GIS coverage was created to facilitate user-friendly, interactive access to floristic and environmental data from user-specified map locations. The map is an improvement over previous Yucca Mountain vegetation maps because it is based on a hierarchical quantitative classification, includes all major vegetation associations, and covers all areas previously used for plant ecology research.

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1. INTRODUCTION

The Nuclear Waste Policy Act of 1982 and the Nuclear Waste Policy Amendments Act of 1987 directed the U.S. Department of Energy (DOE) to characterize Yucca Mountain, Nevada, for potential development of the first monitored geologic repository for spent nuclear fuel and high-level radioactive waste. In response, DOE developed and is implementing the *Site Characterization Plan* (DOE 1988), which consists of a series of multi-disciplinary, scientific investigations designed to provide detailed information necessary to assess the suitability of the Yucca Mountain site as a repository. This vegetation map and report contribute to site characterization by describing the distribution and floristics of vegetation associations at Yucca Mountain. In addition, the map includes Little Skull Mountain, where vegetation was monitored from 1995 to 1997.

During past research at the Nevada Test Site and Yucca Mountain, four vegetation maps have been made, although none represent comprehensive site references. The first vegetation map (Beatley 1976) showed the major vegetation types of the Nevada Test Site, including Yucca Mountain, but provided little mapping detail. O'Farrell and Collins (1984) made a preliminary vegetation map of the portion of Yucca Mountain targeted for site characterization. Environmental Science Associates, under contract to the State of Nevada Nuclear Waste Project Office (ESA 1990), produced a map of dominant species. During 1994 and 1995, approximately 42 ha of Yucca Mountain was mapped by EG&G/EM (1995). The classification scheme for that map was based on Beatley's (1976) vegetation associations, which has also been adopted in Yucca Mountain reclamation and plant ecology research (Angerer, et al. 1994, CRWMS M&O 1996a-c). This preliminary map was inadequate as a site reference because of the small area covered.

The four previous maps were supported by vegetation descriptions based qualitatively on the presence of a few dominant or visually prominent species that may be poor indicators of the entire plant community (Tueller, et al. 1991). Previous research in the Mojave and Great Basin Deserts suggests that quantitative classification avoids the bias created by mapping visually prominent species and successfully delineates groups of species that tend to grow in similar habitats (El-Ghonemey et al. 1980a-b, Tueller, et al. 1991, CRWMS M&O 1996a).

The overall objective of this project was to expand and improve previous mapping efforts by sampling and quantitatively classifying Yucca and Little Skull Mountain vegetation.

2. METHODS

The vegetation map covers two areas: Yucca Mountain and Little Skull Mountain. Approximately 173 km^2 (17,300 ha or 42,750 acres) of Yucca Mountain was mapped, from Windy Wash on the west, to Fortymile Wash on the east; and from the Yucca Wash drainage on the north to Yucca Pass Road on the south. This area was chosen because it includes the major landforms associated with Yucca Mountain and the areas where ecological research was conducted during site characterization. The vegetation map also covers approximately 50 km^2 (5,000 ha or 12,350 acres) of Little Skull Mountain. Little Skull Mountain was mapped because parts of Little Skull Mountain have been used as "far-field" controls for environmental impact assessment at Yucca Mountain.

Elevations within the mapped area range from 975 m in Fortymile Wash to 1,780 m along the crest of Yucca Mountain. Yucca Mountain is a series of north-south ridges of volcanic bedrock separated by alluvial valleys. Along the east side of Yucca Mountain, pluvial dissection has created flanking east-west ridges with associated north- and south-facing hillsides. Little Skull Mountain is a single, east-west oriented ridge of volcanic bedrock with a maximum elevation of 1420 m.

Vegetation sampling units, referred to as Ecological Landform Units (ELUs), were 8 to 100 ha areas with homogeneous geologic, soil, and topographic characteristics. Homogeneous topographic features within ELUs generally result in similarly homogeneous vegetation. ELUs were delineated based on topographic maps, aerial photographs, the Yucca Mountain Site Atlas surficial geology map (CRWMS M&O/TDM 1997), and satellite images. A total of 259 ELUs at Yucca Mountain were identified and sampled between March 4 and July 1, 1997. Fifty-five additional ELUs were identified in the Yucca Mountain area but were not sampled. These ELUs were assigned to vegetation associations based on their topographic similarity to ELUs that had been sampled. An additional group of 99 ELUs at Little Skull Mountain were delineated and sampled between April 1 and June 1, 1998.

The percent cover of each perennial species was estimated within ELUs using a Bitterlich stick (a plotless sampling method) at 8 regularly spaced points along a 200 m transect (Cooper, 1956). Percent cover was transformed to relative cover (Bonham 1989) so that classification would emphasize the dominance relations among species and minimize the importance of ground cover, which fluctuates yearly (CRWMS M&O 1996a). Additional information about the physical environment within each ELU was collected at the middle of each transect and included slope, aspect, soil texture, general soil chemistry, landform description, ground cover of annual plants, rocks, litter, and bare ground, UTM coordinates, and one or two photographs. Soil samples from a subsample of 194 ELUs were analyzed in the laboratory (Inter-Mountain Laboratories, Inc., College Station, Texas) for general soil chemistry and texture. Each ELU was also field-classified into one of the four vegetation associations used in previous site characterization research (CRWMS M&O 1996a), or with a short description when the vegetation did not match the previously used associations. Transects were intentionally located in topography characteristic of the landform, and placed so that they included major topographic features by bisecting washes or diagonally ascending hillsides. Human disturbance was avoided.

The vegetation classification system proposed by the Federal Geographic Data Committee, in conjunction with the Vegetation Classification Panel of the Ecological Society of America, was used to establish the structure and nomenclature of vegetation types (Table 1). The upper levels of the hierarchy are determined by the functional properties of the vegetation, such as physiological attributes or physical structure, whereas the two lowest levels of the hierarchy are determined by floristics (species composition). Therefore, classification at the level of formation or higher requires judgement about whether vegetation types differ functionally or structurally.

Cluster analysis (Gauch 1982, Pielou 1984) was used to classify ELU samples into groups with similar species composition using PC-ORD software (McCune and Mefford 1995). Euclidian distance was used as a measure of dissimilarity and Ward's method was used to agglomerate clusters because it reduced chaining (McCune and Mefford 1995). Because the order of data entry is known to affect cluster analysis (Lesperance 1990), data entry was randomized before analysis. Changing the order of data entry produced minor variation and did not affect classification at the association level. The formation, alliance, and association levels of classification were chosen to correspond with previously used vegetation types (Beatley 1976, O'Farrell and Collins 1984, EG&G/EM 1995, CRWMS M&O 1996b) and ELU field descriptions.

Vegetation classification focused on the Yucca Mountain area, and was not intended to create a regional classification of vegetation types. Vegetation samples from Little Skull Mountain were not included in the classification because they could have blurred the distinction among vegetation types at Yucca Mountain. In addition, nine ELUs were withdrawn from the classification analyses because they represented early successional communities created by relatively recent mechanical or wildfire disturbance. Five ELUs in Fortymile Wash were also withdrawn because quantitative analysis would have overlooked the importance of several species that prefer washes. To reduce possible bias from incidental species, 25 rare species were not used in the analyses (Gauch 1982). Each of the remaining 44 species used for classification analyses was present in at least 13 ELUs, and formed at least 0.1% of the relative cover at Yucca Mountain. Species names follow the National Plants Database (USDA NRCS 1997).

Discriminant function analysis (SAS 1995) was used to develop a mathematical equation for classifying vegetation from sample data into the vegetation associations established with cluster analysis. The discriminant function was used to classify vegetation from 99 ELUs at Little Skull Mountain and 9 ELUs from burned or disturbed ELUs at Yucca Mountain.

A GIS (Geographic Information System) coverage was created to link photographs, environmental data, and plant species composition data with ELU locations and vegetation association distributions. An interactive, user-friendly interface to the GIS coverage was created to enable information retrieval from user-specified locations. The interface will be maintained on the M&O intranet, and can be accessed projectwide. The interface description, location and function can be found on the Geographic Information (GI) subdirectory of the Technical Data Management System (TechData) of the M&O homepage. The printed map that accompanies this report (YMP-98-153.0) is an overlay in the GIS and can be viewed using the interface.

Table 1. Proposed National Vegetation Classification System.

Level	Criteria	Explanation	Example
Division	Substrate	Earth's surface as it might appear from a satellite.	bare soil, marine, terrestrial vegetation
Order	Life Form	Fundamental characters in anatomy and life history, such as presence of secondary tissue or perennial growth.	grassland, forest, desert
Class **Subclass** **Group** **Formation**	Physiognomy and Ecosystem Function	Morphology of species, physical structure of communities, and physiological function.	Deserts with succulents, mixed scrub desert, Mojave Desert
Alliance	Floristics	Groups of associations that share one or more diagnostic or dominant species.	*Ambrosia dumosa - Larrea tridentata*
Association		Groups of stands with consistent floristic composition.	*Ambrosia dumosa*

3. CLASSIFICATION AND DESCRIPTION OF VEGETATION

3.1 CLASSIFICATION

Quantitative classification grouped ELUs into nine associations (Figure 1, Sheets 1 and 2) that fell into five alliances and two formations (Table 2). Alliances and associations were named after the dominant (greatest relative cover) species. Two primary plant groups were identified: Mojave and Great Basin Desert species. Previous research in southern Nevada (Beatley 1976, ESA 1990, Lei and Walker 1997) supports the idea that Great Basin Desert species predominate at higher elevations, and that Mojave Desert species predominate at lower elevations. Vegetation from the two deserts was placed in separate formations (Table 2) because of structural differences between the two floras. Shreve (1942) described the Great Basin Desert as having a single vegetative stratum of small, flexible stemmed shrubs, and the Mojave Desert as more structurally complex due to the presence of larger stemmed, overstory shrubs such as *Larrea tridentata* and *Prosopis glandulosa*. The Mojave Desert also has a group of low growing, prostrate shrubs such as *Krameria erecta* and *Menodora spinescens*.

Using discriminant function analysis, vegetation at Little Skull Mountain was classified primarily within the Mojave Desert Formation. Of 99 ELUS at Little Skull Mountain, only two were classified in the Great Basin Desert Formation. One of these ELUs was classified as *Eriogonum fasciculatum - Ericameria teretifolia* association, and one ELU was classified as the *Coleogyne ramosissima* association.

Nine ELUs at Yucca Mountain contained evidence of fire, although the severity of damage was variable, as was the total area within each ELU that had been burned. In five of the burned ELUs, vegetation from the *Eriogonum fasciculatum - Ericameria teretifolia* association had apparently replaced the *Coleogyne ramosissima* vegetation that existed before the fire.

3.2 DESCRIPTION OF VEGETATION ASSOCIATIONS

Species composition, topography and differentiating characteristics of the nine vegetation associations are described below. Additional, detailed information on species composition, soil chemistry, and the topography of each vegetation association is available in Appendices A - C.

1. *Ambrosia dumosa - Larrea tridentata.* (AL) Previous code at Yucca Mountain: Arroyo (Beatley 1976). Primary associated species: *Hymenoclea salsola, Ericameria nauseosa, Atriplex polycarpa, Ephedra nevadensis, Coleogyne ramosissma, Krameria erecta, Menodora spinescens*, and *Lycium pallidum*. Topography: broad, incised stream channels with braided flood plains and remnant terraces. Found only in Fortymile Wash. Surface soil: sand to loamy sand. Slope: < 1%. Differentiating characteristics: This association is found within the flood plain of large washes or arroyos (Beatley 1976), and harbors wash-preferring species (*Atriplex polycarpa, Ericameria paniculata,* and *Ambrosia eriocentra*). The channels and terraces in the wash create a mosaic of wash species interspersed with vegetation from the AMDU and LE association.

Table 2. Classification of Vegetation at Yucca and Little Skull Mountains. Subdominant species are listed in order of decreasing relative cover. Code names used previously during ecological research at Yucca Mountain are described in Beatley (1976).

Association	Association Code	Previous Code	Association Subdominants
I. Mojave Desert Formation			
A. *Ambrosia dumosa- Larrea tridentata* Alliance			
1. *Ambrosia dumosa - Larrea tridentata*	AL	Arroyo	*Hymenoclea salsola* *Ericameria nauseosa*
2. *Ambrosia dumosa*	AMDU	LA	*Ephedra nevadensis* *Lycium pallidum* *Krameria erecta*
3. *Larrea tridentata - Ephedra nevadensis*	LE	LLG	*Ambrosia dumosa* *Krameria erecta*
B. *Ephedra nevadensis - Ambrosia dumosa* Alliance			
1. *Ambrosia dumosa - Atriplex confertifolia*	AA	ATCO	*Ericameria teretifolia* *Eriogonum fasciculatum*
2. *Ephedra nevadensis - Ambrosia dumosa*	EA	LG	*Krameria erecta* *Larrea tridentata*
4. *Menodora spinescens*	MESP	not recognized	*Ambrosia dumosa* *Ephedra nevadensis* *Krameria erecta*
II. Great Basin Desert Formation			
A. *Eriogonum fasciculatum - Ericameria teretifolia* Alliance			
1. *Eriogonum fasciculatum- Ericameria teretifolia*	EE	LG	*Ephedra nevadensis* *Gutierrezia sarothrae*
B. *Artemisia* Alliance			
1. *Artemisia tridentata*	ARTR	LG	*Ephedra nevadensis* *Ericameria teretifolia*
C. *Coleogyne ramosissima* Alliance			
1. *Coleogyne ramosissima*	CORA	COL	*Ephedra nevadensis* *Ericameria teretifolia*

2. *Ambrosia dumosa.* (AMDU) Previous code at Yucca Mountain: LA (CRWMS M&O 1996a). Primary associated species: *Larrea tridentata, Lycium pallidum, Krameria erecta, Ephedra nevadensis, Atriplex confertifolia, Coleogyne ramosissma, Menodora spinescens,* and *Grayia spinosa.* Topography: piedmonts, toe slopes, and fans extending from ridges. Surface soil: Sand to sandy clay loam and sandy clay on the west drainage of Yucca Mountain. Slope: $\bar{x}$ = 14% (1% - 40%). Differentiating characteristics: This is the common association on flat or gently sloping (2% - 5%) terrain, and extends to moderate slopes (5% - 25%) near the distal end of ridges. The subdominant species appear to favor level to moderately sloping terrain *(e.g., Acamptopappus shockleyi, Larrea tridentata, Lycium pallidum, Oryzopsis hymenoides, and Psorothamnus freemontii). Coleogyne ramosissma* may be present but does not dominate. Annual cover is low to moderate: $\bar{x}$ = 4%.

3. *Larrea tridentata - Ephedra nevadensis.* (LE) Previous code at Yucca Mountain: LLG (CRWMS M&O 1996a) or *Larrea - Ambrosia - Hymenoclea* (EG&G/EM 1995). Primary associated species: *Ephedra nevadensis, Ambrosia dumosa, Krameria erecta, Hymenoclea salsola, Salazaria mexicana, Menodora spinescens, Lycium andersonii, Ericameria cooperi,* and *Lycium pallidum.* Topography: intramountain valleys and alluvial floors of bedrock canyons. Surface soil: Sand to sandy clay with a characteristic layer of subsurface cobbles. Slope: 4% - 10%. Differentiating characteristics: The LE association is dominated by large, uniformly spaced *Larrea tridentata* with abundant growth of annuals between shrubs. The cover of annuals is the greatest of all vegetation associations, $\bar{x}$ = 10.6 %.

4. *Menodora spinescens.* (MESP) Previously unrecognized, often classified as LA (CRWMS M&O 1996a) or *Psorothamnus - Hymenoclea* (EG&G/EM 1995). Primary associated species: *Ambrosia dumosa, Ephedra nevadensis, Krameria erecta, Larrea tridentata, Ericameria cooperi, Lycium pallidum, Lycium andersonii, Atriplex confertifolia,* and *Grayia spinosa.* Topography: Piedmonts and fans. Surface soil: Variable, but often either sand or clay. Slope: 2% - 5%. Differentiating characteristics: *Menodora spinescens* is ubiquitous at Yucca Mountain, but in this vegetation association it becomes dominant. On some ELUs, this association was associated with harsh soil conditions, either very sandy or very clayey. On other ELUs, this association was associated with disturbance, either human activity, wildfire, or naturally occurring aeolian sand deposition. Cover of annuals is relatively low, $\bar{x}$ = 2.3%.

5. *Ambrosia dumosa - Atriplex confertifolia.* (AA) Previous code at Yucca Mountain: *Ambrosia-Ephedra-Atriplex* (EG&G/EM 1995). Primary associated species: *Ericameria teretifolia, Eriogonum fasciculatum, Larrea tridentata, Stipa speciosa, Ephedra nevadensis, Lycium pallidum, Gutierrezia sarothrae,* and *Stephanomeria pauciflora.* Topography: Steep mid slopes and toe slopes that do not face north. Surface soil: gravelly sandy loam. On hill slopes greater than 60% slope, soil may be absent or interspersed with rock. Slope: 25% - 75% ($\bar{x}$ = 47%). Differentiating characteristics: *Atriplex confertifolia* is prevalent but not dominant, forming at least 15% of the relative cover. *Atriplex confertifolia* occurs in all associations, but this is the only association where it forms more than 5% of the relative cover. Cover of annuals is relatively low, $\bar{x}$ = 3.4%, and perennial cover is lower than the other eight associations ($\bar{x}$ = 14%).

6. *Ephedra nevadensis - Ambrosia dumosa.* (EA) Previous code at Yucca Mountain: *Ambrosia-Ephedra-Atriplex* (EG&G/EM 1995). Primary associated species: *Krameria erecta*, *Larrea tridentata*, *Lycium pallidum*, *Grayia spinosa*, and *Coleogyne ramosissma*. Topography: moderate to steep toe slopes and mid slopes that do not face north. Surface soil: gravelly sandy loam. On hillsides greater than 60% slope, soil may be absent or interspersed with rock. Slope: 12% - 75% ($\bar{x}$ = 20%). Differentiating characteristics: This is the common association of southeast- to southwest-facing, moderate to steep hillsides at lower elevations. The EA association is characterized by its subdominant species, which appear to favor moderate to steep slopes. Subdominants include *Amphipappus fremontii*, *Atriplex confertifolia*, *Encelia virginensis*, *Ericameria cooperi*, *Ericameria teretifolia*, *Eriogonum fasciculatum*, *Gutierrezia sarothrae*, *Krasheninnikovia lanata*, *Lycium andersonii*, *Stephanomeria pauciflora*, *Stipa speciosa*, and *Xylorhiza tortifolia*. Annuals are common (5% - 10% relative cover) and most of the ground not covered by rocks is covered by vegetation.

7.) *Eriogonum fasciculatum - Ericameria teretifolia.* (EE) Previous code at Yucca Mountain: LG (CRWMS M&O 1996a), or *Happlopappus, Grayia, Eriogonum* (EG&G/EM 1995). Primary associated species: *Ephedra nevadensis*, *Gutierrezia sarothrae*, *Ephedra viridis*, *Grayia spinosa*, *Stipa speciosa*, *Chrysothamnus viscidiflorus*, *Lycium andersonii*, and *Ambrosia dumosa*. Topography: Steep to moderately steep mid slopes and up slopes that do not face south. Surface soil: Sandy loam to loam. On hill slopes greater than 60% slope, soil may be absent or interspersed with rock. Slope: 25% - 75%. Differentiating characteristics: This is the common association of moderate to steep hillsides at higher elevations, and north-facing hillsides at lower elevations. The EE association is distinguished by subdominants that rarely grow below approximately 1280 m (*e.g.*, *Chrysothamnus viscidiflorus*, *Ephedra viridis*, *Gutierrezia sarothrae*, *Ericameria nauseosa*, *Elymus elymoides*, *Poa secunda*, and *Tetradymia axillaris)*. The ground surface is very rocky. Annual cover is limited.

8.) *Artemisia tridentata.* (ARTR) Previous code at Yucca Mountain: LG (CRWMS M&O 1996a), or *Artemisia* (EG&G/EM 1995). Primary associated species: *Ephedra viridis Ericameria teretifolia*, *Eriogonum fasciculatum*, *Ericameria linearifolia*, *Atriplex canescens*, *Stipa speciosa*, *Ericameria nauseosa*, and *Coleogyne ramosissma*. Topography: Steep to moderately steep hill slopes facing northeast to northwest. Surface soil: Sandy loam. On hillsides greater than 60% slope, soil may be absent or interspersed with rock. Slope: 25% - 75%. Differentiating characteristics: This association is dominated by *Artemisia tridentata*. The ARTR association covers large areas of the Great Basin to the north and east of Yucca Mountain. Cover of annuals is low.

9.) *Coleogyne ramosissma.* (CORA) Previous code at Yucca Mountain: COL (CRWMS M&O 1996a), or *Coleogyne* (EG&G/EM 1995). Primary associated species: *Ephedra nevadensis*, *Ericameria teretifolia*, *Grayia spinosa*, *Eriogonum fasciculatum*, *Ephedra viridis*, *Hymenoclea salsola*, *Artemisia tridentata*, *Menodora spinescens*, and *Larrea tridentata*. Topography: mildly sloping ridge crests, often extending to fans and terraces in alluvial valleys above approximately 1,160 m. Surface soil: Loam to sandy loam. Slope: 5% - 25%. Differentiating characteristics: This association is dominated by *Coleogyne ramosissma*.

4. CONCLUSIONS

- Yucca Mountain vegetation was classified into nine associations forming five alliances and two formations.

- This classification is an improvment over previous efforts to classify Yucca Mountain vegetation because it (1) was determined with quantitative analysis, (2) included 358 vegetation samples from all landform types, and (3) was hierarchical, complying with standards being developed by the Federal Geographic Data Commission.

- The distribution of the nine associations at Yucca and Little Skull Mountains was mapped (YMP-98-153.0). This map displays all major Yucca and Little Skull Mountain vegetation associations, and all areas used to monitor vegetation during the Yucca Mountain Project Site Characterization Effects Program (Environmental Study Plots).

- A GIS coverage was created that (1) displays the map in a graphical environment and (2) facilitates access to floristic and environmental data from user-specified map locations through an interactive, user-friendly interface.

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APPENDIX A

PHYSICAL ENVIRONMENT

APPENDIX A

Physical environment for nine vegetation associations at Yucca and Little Skull Mountains, Nevada. Values are averages of all sampled ELUs in the association. Soil composition values are averages of a subsample of 176 ELUs determined by a commercial laboratory. A key to association names and variables follows APPENDIX B.

	Vegetation Association								
Measurement	**AA**	**AL**	**AMDU**	**ARTR**	**CORA**	**EA**	**EE**	**LE**	**MESP**
Elevation	1305.29	1036.00	1093.04	1648.91	1518.87	1188.79	1268.57	1122.57	1204.07
% Slope	47.29	1.00	13.23	48.00	16.52	19.66	41.95	15.29	5.08
Mean Aspect (Zar 1996)	166.87	176.21	168.21	99.96	151.38	57.35	92.12	95.81	171.36
Variation of Aspect (S_0, Zar 1996)	150.42	5.05	137.56	212.60	86.14	218.41	163.65	90.85	77.67
Annual Cover (%)	4.71	4.20	6.99	2.27	6.47	13.24	6.23	13.39	2.25
Litter Cover (%)	4.14	3.20	3.22	3.45	5.19	4.32	3.91	4.27	4.33
Bare (%, see Key)	16.67	85.60	20.88	14.53	14.36	17.64	11.83	21.74	14.13
Pavement (%, see Key)	82.14	14.40	75.91	84.64	78.75	78.46	84.41	69.55	81.17
Soil Composition									
% Clay	9.77	12.20	12.14	14.57	19.68	13.10	14.59	12.00	20.71
% Silt	21.62	6.60	16.32	26.43	21.82	22.43	24.16	21.00	26.57
% Sand	68.62	81.20	71.54	59.00	58.50	64.48	61.25	67.00	52.71
% Coarse Fragments	28.52	12.44	17.25	28.84	19.19	21.16	25.39	24.28	11.00
Electrical Conductivity (µmhos/cm)	0.51	0.40	0.56	0.37	0.34	0.43	0.45	0.36	0.37
pH	8.15	7.64	7.96	7.37	7.23	7.78	7.55	7.72	7.97
Nitrate (ppm)	4.75	2.00	4.67	2.86	2.86	3.56	2.97	2.46	2.14
Phosphorus (ppm)	5.69	3.00	4.59	14.14	5.90	6.69	6.28	6.00	3.29
Potassium (ppm)	683.69	732.00	574.05	439.71	458.95	572.43	631.88	590.14	685.57
Neutralization Potential (t/kt)	21.81	5.52	24.51	5.57	6.15	20.33	11.91	13.82	21.70

APPENDIX B

FLORISTIC COMPOSTION

APPENDIX B

Floristic composition for nine vegetation associations at Yucca and Little Skull Mountains, Nevada. All values are percents and are averages of all ELUs in the association. A key to association names and variables follows the table. Plant species measurements are percent relative cover.

	Vegetation Association								
SPECIES	**AA**	**AL**	**AMDU**	**ARTR**	**CORA**	**EA**	**EE**	**LE**	**MESP**
Acamptopappus shockleyi	0.11	0.00	1.04	0.00	0.01	0.04	0.00	0.16	0.65
Achnatherum hymenoides	0.25	0.35	0.22	0.00	0.01	0.12	0.00	0.14	0.03
Achnatherum speciosum	6.30	0.00	0.37	3.60	0.94	1.27	3.96	0.67	0.35
Ambrosia dumosa	24.43	29.87	34.74	0.00	1.25	14.78	3.12	10.77	23.59
Ambrosia eriocentra	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Amphipappus fremontii	0.72	0.00	0.31	0.00	0.00	0.52	0.00	0.11	0.02
Arenaria macradenia	0.00	0.00	0.00	0.00	0.04	0.00	0.01	0.00	0.00
Aristida purpurea	0.00	0.00	0.00	0.00	0.03	0.01	0.01	0.00	0.00
Artemisia ludoviciana	0.00	0.00	0.00	0.02	0.01	0.01	0.02	0.00	0.00
Artemisia spinescens	0.00	0.00	0.00	0.00	0.01	0.01	0.07	0.00	0.00
Artemisia tridentata	0.00	0.00	0.00	36.80	2.14	0.08	1.06	0.00	0.00
Atriplex canescens	0.07	0.09	0.00	5.05	0.92	0.27	2.13	0.80	0.15
Atriplex confertifolia	20.86	0.00	3.95	0.08	0.59	2.75	2.44	0.53	2.61
Atriplex hymenelytra	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00
Atriplex polycarpa	0.07	6.50	0.01	0.00	0.00	0.06	0.12	0.00	0.00

APPENDIX B (continued)

SPECIES	Vegetation Association								
	AA	AL	AMDU	ARTR	CORA	EA	EE	LE	MESP
Brickellia arguta	0.00	0.00	0.02	0.00	0.00	0.01	0.04	0.03	0.00
Brickellia microphylla	0.09	0.00	0.00	0.18	0.00	0.00	0.37	0.02	0.00
Castilleja angustifolia	0.09	0.00	0.00	0.16	0.04	0.00	0.00	0.01	0.00
Chrysothamnus viscidiflorus	0.00	0.00	0.01	2.39	0.53	0.13	3.54	0.02	0.14
Coleogyne ramosissima	1.10	0.09	2.16	2.86	54.33	3.49	0.67	0.53	1.09
Cryptantha confertifolia	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
Cryptantha virginensis	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00
Echinocactus polycephalus	0.00	0.00	0.11	0.00	0.01	0.23	0.12	0.02	0.00
Echinocereus engelmannii	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00
Elymus elymoides	0.28	0.00	0.00	0.16	0.10	0.00	0.72	0.00	0.00
Encelia virginensis	1.63	0.00	0.25	0.00	0.13	0.88	4.41	3.12	0.25
Ephedra nevadensis	4.24	5.41	8.53	2.03	9.71	20.08	9.62	8.03	11.12
Ephedra viridis	0.51	0.00	0.00	12.98	2.50	0.05	5.27	0.43	0.00
Ericameria cooperi	0.00	0.00	0.17	0.41	1.19	0.83	2.55	1.25	5.62
Ericameria linearifolia	0.03	0.00	0.10	5.66	0.78	0.07	2.33	0.02	0.00
Ericameria nauseosa	0.00	8.99	0.00	3.04	0.95	0.10	1.85	0.00	0.00
Ericameria paniculata	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ericameria teretifolia	9.62	0.00	0.13	9.69	4.90	1.10	9.48	0.31	0.29
Eriogonum fasciculatum	5.43	0.00	0.49	7.47	2.64	3.37	21.81	0.74	1.38

APPENDIX B (continued)

SPECIES	Vegetation Association								
	AA	AL	AMDU	ARTR	CORA	EA	EE	LE	MESP
Eriogonum inflatum	0.06	0.00	0.58	0.00	0.04	1.00	0.04	0.40	0.03
Eriogonum microthecum	0.00	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00
Galium stellatum	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00
Grayia spinosa	0.43	0.09	1.37	1.17	2.75	3.11	4.31	1.02	1.59
Gutierrezia sarothrae	3.32	0.00	0.13	0.66	0.39	0.50	5.51	0.16	0.19
Hymenoclea salsola	0.44	9.00	0.41	0.00	2.25	1.63	1.60	3.53	1.02
Hymenoclea salsola x Ambrosia dumosa (hybrid)	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Juniperus osteosperma	0.00	0.00	0.00	0.99	0.44	0.00	0.00	0.00	0.00
Krameria erecta	0.34	3.64	8.94	0.00	0.85	12.14	1.02	7.19	9.06
Krascheninnikovia lanata	0.74	0.00	0.75	0.13	0.49	2.62	1.79	0.76	0.81
Larrea tridentata	6.88	30.14	17.42	0.00	1.64	11.59	0.56	45.17	6.03
Lepidium fremontii	2.75	0.00	0.04	0.00	0.00	0.05	0.01	0.20	0.00
Leptodactylon pungens	0.00	0.00	0.01	0.33	0.03	0.05	0.38	0.00	0.00
Lycium andersonii	1.44	0.00	1.77	0.20	1.65	3.98	3.20	2.32	2.84
Lycium pallidum	2.25	1.21	12.33	0.00	0.72	6.74	0.17	3.68	5.26
Menodora spinescens	0.00	3.15	0.97	0.05	1.66	0.76	0.03	1.43	23.72
Mirabilis bigelovii	0.43	0.00	0.03	0.00	0.02	0.12	0.15	0.52	0.00
Nicotiana obtusifolia	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00

APPENDIX B (continued)

SPECIES	Vegetation Association								
	AA	AL	AMDU	ARTR	CORA	EA	EE	LE	MESP
Opuntia basilaris	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Opuntia echinocarpa	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00
Pleuraphis jamesii	0.30	0.00	0.00	1.45	0.09	0.00	0.38	0.00	0.05
Poa secunda	0.00	0.00	0.00	0.21	0.12	0.00	0.47	0.02	0.00
Polygala heterorhyncha	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00
Psorothamnus fremontii	0.00	0.46	1.02	0.00	0.00	1.62	0.00	0.84	1.05
Psorothamnus polydenius	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.15
Purshia glandulosa	0.00	0.00	0.00	0.17	0.28	0.06	0.03	0.17	0.00
Rhus trilobata	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00
Salazaria mexicana	0.00	0.49	0.32	0.34	1.03	1.20	2.33	3.41	0.50
Salvia dorrii	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00
Sphaeralcea ambigua	1.62	0.00	0.27	0.06	0.03	0.87	0.19	0.62	0.03
Stephanomeria pauciflora	1.73	0.07	0.51	0.06	0.01	0.90	0.83	0.30	0.17
Symphoricarpos longiflorus	0.32	0.00	0.00	0.57	0.00	0.02	0.27	0.00	0.00
Tetradymia axillaris	0.22	0.00	0.00	0.00	0.17	0.14	0.74	0.10	0.00
Tetradymia glabrata	0.21	0.00	0.00	0.00	0.02	0.00	0.03	0.00	0.00
Thamnosma montana	0.42	0.00	0.03	0.00	0.03	0.23	0.01	0.37	0.00
Xylorhiza tortifolia	0.29	0.00	0.20	0.00	0.02	0.35	0.13	0.08	0.03
Yucca brevifolia	0.00	0.00	0.00	0.40	1.16	0.01	0.07	0.00	0.14

KEY TO TABLE CODES

Code	Explanation
ARTR	*Artemesia tridentata* association
AA	*Ambrosia dumosa - Atriplex confertifolia* association
CORA	*Coleogyne ramosissima* association
EA	*Ephedra nevadensis - Ambrosia dumosa* association
EE	*Eriogonum fasciculatum - Ericameria teretifolia* association
AMDU	*Ambrosia dumosa* association
LE	*Larrea tridentata - Ephedra nevadensis* association
MESP	*Menodora spinescens* association
AL	*Ambrosia dumosa - Larrea tridentata* association
% Slope	Percent slope, averaged between upward and downward directions.
Annual Cover	Percent of ground covered by annuals, determined by visual estimate.
Litter Cover	Percent of ground covered by litter, determined by visual estimate.
Bare	Percent of ground, **not covered by plants**, that is covered by bare ground, determined by visual estimate.
Pavement	Percent of ground, **not covered by plants**, that is covered by cobble or rocks (stones > 5 cm diameter), determined by visual estimate.
Mean Aspect	Average aspect, calculated using Zar's (1996) method.
S_0	A measure of the variability of the mean aspect (Zar 1996).

APPENDIX C

FAMILY, COMMON NAME, AND LIFE FORM OF PLANTS.

APPENDIX C

Family, common name, and life form of species recorded during vegetation mapping of Yucca and Little Skull Mountains, Nevada. All species are perennial or biennial. Life form codes T, S, SS, C, H, B, or G, indicate tree, shrub, subshrub, cactus, herb, biennial herb, or grass, respectively. Nomeclature follows USDA NRCS 1997.

Scientific Name	Family	Common Name	Life Form
Acamptopappus shockleyi	Asteraceae	Shockley's goldenhead	S
Achnatherum hymenoides	Poaceae	Indian ricegrass	G
Achnatherum speciosum	Poaceae	desert needlegrass	G
Ambrosia dumosa	Asteraceae	bur-sage	S
Amphipappus fremontii	Asteraceae	Fremont's chaffbush	S
Arenaria macradenia	Caryophyllaceae	Mojave sandwort	H
Aristida purpurea	Poaceae	purple threeawn	G
Artemisia spinescens	Asteraceae	bud sagebrush	S
Artemisia tridentata	Asteraceae	big sagebrush	S
Atriplex canescens	Chenopodiaceae	fourwing saltbush	S
Atriplex confertifolia	Chenopodiaceae	shadscale saltbush	S
Atriplex hymenelytra	Chenopodiaceae	desert holly	S
Atriplex polycarpa	Chenopodiaceae	cattle saltbush	S
Brickellia arguta	Asteraceae	brickellia	S
Brickellia microphylla	Asteraceae	littleleaf brickellbush	SS
Castilleja angustifolia	Scrophulariaceae	northwestern Indian paintbrush	H
Chrysothamnus viscidiflorus	Asteraceae	green rabbitbrush	S
Coleogyne ramosissima	Rosaceae	blackbrush	S
Cryptantha confertiflora	Boraginaceae	basin yellow catseye	H
Cryptantha virginensis	Boraginaceae	Virgin River catseye	H
Echinocactus polycephalus	Cactaceae	cottontop cactus	C
Echinocereus engelmannii	Cactaceae	saints cactus	C
Elymus elymoides	Poaceae	bottlebrush squirreltail	G
Encelia virginensis	Asteraceae	Virgin River brittlebush	S
Ephedra nevadensis	Ephedraceae	Nevada jointfir	S
Ephedra viridis	Ephedraceae	mormon tea	S

Scientific Name	Family	Common Name	Life Form
Ericameria cooperi	Asteraceae	Cooper's heathgoldenrod	S
Ericameria linearifolia	Asteraceae	narrowleaf heathgoldenrod	S
Ericameria nauseosa	Asteraceae	heathgoldenrod	S
Ericameria paniculata	Asteraceae	heathgoldenrod	S
Ericameria teretifolia	Asteraceae	heathgoldenrod	S
Eriogonum fasciculatum	Polygonaceae	Eastern Mojave buckwheat	S
Eriogonum inflatum	Polygonaceae	Native American pipeweed	B
Eriogonum microthecum	Polygonaceae	slender buckwheat	S
Grayia spinosa	Chenopodiaceae	spiny hopsage	S
Gutierrezia sarothrae	Asteraceae	broom snakeweed	SS
Hymenoclea salsola	Asteraceae	white burrobush	S
Juniperus osteosperma	Cupressaceae	Utah juniper	T
Krameria erecta	Krameriaceae	littleleaf ratany	S
Krascheninnikovia lanata	Chenopodiaceae	winterfat	S
Larrea tridentata	Zygophyllaceae	creosotebush	S
Lepidium fremontii	Brassicaceae	desert pepperweed	SS
Leptodactylon pungens	Polemoniaceae	granite pricklygilia	S
Lycium andersonii	Solanaceae	Anderson's wolfberry	S
Lycium pallidum	Solanaceae	pale wolfberry	S
Menodora spinescens	Oleaceae	spiny menodora	S
Mirabilis bigelovii	Nyctaginaceae	neakstem four o'clock	H
Nicotiana obtusifolia	Solanaceae	tobacco	H
Opuntia echinocarpa	Cactaceae	staghorn cholla	C
Pleuraphis jamesii	Poaceae	galleta grass	G
Poa secunda	Poaceae	Sandberg bluegrass	G
Psorothamnus fremontii	Fabaceae	Fremont's dalea	S
Psorothamnus polydenius	Fabaceae	Nevada smokebush	S
Purshia glandulosa	Rosaceae	desert bitterbrush	S
Rhus trilobata	Anacardiaceae	skunkbush sumac	S
Salazaria mexicana	Lamiaceae	Mexican bladdersage	S

Scientific Name	Family	Common Name	Life Form
Salvia dorrii	Lamiaceae	grayball sage	S
Sphaeralcea ambigua	Malvaceae	desert globemallow	H
Stephanomeria pauciflora	Asteraceae	brownplume wirelettuce	SS
Symphoricarpos longiflorus	Caprifoliaceae	desert snowberry	S
Tetradymia axillaris	Asteraceae	longspine horsebrush	S
Tetradymia glabrata	Asteraceae	littleleaf horsebrush	S
Thamnosma montana	Rutaceae	turpentinebroom	S
Xylorhiza tortifolia	Asteraceae	Mojave aster	SS
Yucca brevifolia	Agavaceae	Joshua tree	T