A Vegetation Map

for

Holloman Air Force Base, New Mexico

Final Report

Submitted to:

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Introduction

A map of current vegetation of Holloman Air Force Base (HAFB) was produced for use in the Integrated Natural Resource Management Plan (INRMP), sensitive species management and National Environmental Policy Act (NEPA) compliance for the installation. The New Mexico Natural Heritage Program (NMNHP) in association with the Earth Data Analysis Center (EDAC) at the University of New Mexico (UNM) developed the map using computer analysis of high resolution digital ortho-photography provided by HAFB along with previously acquired Thematic Mapper (TM) satellite imagery, and various available Geographical Information System (GIS) data layers.

Ground survey vegetation data gathered by NMNHP provided the basis for the development of ecologically meaningful map units appropriate for use at a 1:24,000 scale. The mapping methodology is described in detail below along with brief descriptions of each map unit. Since the map was developed in the context of GIS technology, it exists in both digital and hard copy paper forms. Hard copies of the map with an annotated legend have been provided. The map is also provided in a digital form with its associated legend, spatial/spectral statistics and biological database, which can then be integrated into the installation GIS and used as a powerful and dynamic tool in natural resource management applications.

Study Area

Location & Landscape

Located west of the city of Alamogordo in south central New Mexico, the study area encompasses approximately 21,281 ha. (52,588 acres) of Holloman Air Force Base and an additional 641 ha. (1,584 acres) of the Boles Wells Water System Annex[1]. It lies between the Sacramento and San Andres Mountains within the Tularosa Basin, a down faulted inter-mountain basin with a minimum elevation of 1,175 m (3855 ft). The landscape is characterized by alluvial piedmonts and plains, and basin flats which are drained by wide draws. The area is notable for its extensive alkaline flats, gypsum lake deposits and shifting dune fields.

Climate

The basin is characterized as an arid high desert and generally receives less than 25 cm (10 in) of precipitation per year. Anderson and Taylor (1983) summarized the climatic data for two local weather stations. They reported that the majority (64%) of this precipitation comes during the summer in the form of intense late-summer thunderstorms of short duration. Mean monthly temperatures in the basin range from minimums of -6°

[1] Calculations are based on GIS layers. The main base map includes easements to the east and west. The Boles Wells Water System Annex includes only the northern extent referred to as the 'Boles Wells Well Field'.

to 1° C (21-34 ° F) in January to maximums of 33° C to 34° C (92-93° F) in July. Extremes have been recorded at -26 and 41 degrees C (-16°-107° F), along with diurnal fluxes of over 25° C (50° F). The average frost free season is long (180 to 250 days), and generally lasts from May through November.

Materials & Methods

Data Sources

Satellite Imagery

Landsat Thematic Mapper (TM) satellite imagery was one of the data sets used for mapping the natural vegetation cover for the study area. The TM scene used for the project was acquired over the area on September 19, 1993 by the Landsat 5 platform. It was imported into ERDAS Imagine (Version 8.2) where all raster processing and analysis was done. The TM scene was of good quality with no clouds, cirrus or scan line defects.

The satellite imagery, with its stable sensor platform, is relatively easy to geometrically correct to known coordinates of a base map. The height of the sensor above the earth (705 km. for Landsat) negates most parallax problems commonly found in aerial photography (parallax is the apparent change in positions of stationary objects affected by the viewing angle – creating greater distortions at greater distances from the center of an aerial photo). Also, satellite data do not have the radiometric problems of air photos, such as hot spots, dark edges, or different contrasts for each photo due to sun-angle changes during the overflight.

The quantitative spectral and spatial aspects of TM imagery add particularly important dimensions to the mapping process. Multi-spectral satellite imagery records the variable reflection of natural radiation of surface materials such as rocks, plants, soils, and water, differently. Variations in plant reflection and absorption due to biochemical composition will register distinct spectral "signatures" (Wickland 1991, Lillesand and Kiefer 1987). These signatures provide a quantitative measure of reflectance of specific wavelengths which can then be statistically analyzed to develop a vegetation map of spectrally similar plant communities.

Landsat TM has the highest spectral discrimination, with six spectral bands and one thermal band, among commercially available space-based sensors. Each band represents a specific range of light wavelength (Table 1). For vegetation mapping, bands 2, 3, 4, and 5 are particularly useful. TM bands 3, 5, and 7 are useful for detecting variations in surface geology. Surface geology and soil discrimination are important in developing mapping units of the vegetation communities in sparsely vegetated areas that commonly occur on HAFB.

TM integrates the spectral characteristics of each band over the Instantaneous Field of View (IFOV) of an area 28.5 m. x 28.5 m.; this is the smallest area resolvable by the sensor and is represented on the computer screen by individual "pixels" (picture elements). Individual occurrences of plants are not resolved by the sensor; therefore, TM is particularly suited for evaluating and quantitatively identifying more generalized vegetation "community" occurrence patterns and their associated surface substrate characteristics.

Table 1. Landsat Thematic Mapper bands, their spectral ranges, and principal remote sensing applications for earth research (derived from Lillesand and Kiefer 1987).

Band	Wavelength (microns)	Spectral Location
1	0.45-0.52	Blue
2	0.52-0.60	Green
3	0.63-0.69	Red
4	0.76-0.90	Near-infrared
5	1.55-1.75	Mid-infrared
6	10.4-12.5	Thermal Infrared
7	2.08-2.35	Mid-infrared

Aerial Photography

Color infrared aerial photographs were taken by Koogle & Poole over HAFB and the northern wellfield (Boles Wells Well Field) in October, 1995 and acquired for this project through Geomarine. The photographs had been ortho-rectified, a process which uses a terrain model to take out distortion such as parallax and correct the photos to a planimetric grid, in this case a Universal Transverse Mercator (UTM) projection, Zone 13, using the 1983 North American Datum and the 1980 Geodetic Reference Spheroid. Color infrared photographs are similar to the spectral wavelengths of TM bands 4, 3, and 2. This portion of the electromagnetic spectrum is important as it includes the near infra-red, seen on the photos as red, is sensitive to vigorous vegetation reflection. Soils and rocks usually occur as gray to cyan with these wavelengths. These photographs were digitized to a 0.75 meter pixel and put on CD-ROM in a TIF format by Geomarine. The images were then imported into the ERDAS Imagine .IMG format. The 22 photos over HAFB were mosaicked together into one file; there was only one photo over the northern wellfield.

The original resolution of 0.75 meters was considered too high to effectively evaluate vegetation pattern at the 1:24,000 scale, both in terms of meaningful pattern and also data load. It was found upon viewing the photos that there was little discernible difference between the original 0.75 meters and a two-meter pixel resolution with respect to the pattern of vegetation communities, but the two-meter image was approximately one quarter the file size as the original photo, which made it significantly easier to process and display. Therefore, both the HAFB and northern wellfield Wells photos were resampled to a two- meter pixel.

Ancillary Map Coverages

In addition to the above data sources, two vector files in ARC/INFO (7.03) format were used. One coverage representing the road edges was later buffered to four meters to create road disturbance polygons which were added on the final classification as part of the Development/Ground Disturbance class. The other coverage representing building polygons was also added to the same class. Both of these files had been originally digitized by Radian from the aerial photographs.

Image Processing

Geometric Correction

The TM scene was rectified to a map-based coordinate system using a nearest-neighbor interpolation. This process makes the image planimetric so that area, direction, and distance measurements can be performed. The image-to-map rectification process involves selecting a point on the map with its coordinate and the same point on the image with its x and y coordinate. The root mean square error (RMS_{error}) is computed to determine how well the map and image coordinates fit in a least-squares regression equation. The RMS_{error} for these images was 0.98 pixel error (or approximately 28 m). The images were projected into UTM, Zone 13, using the 1983 North American Datum and the Geodetic Reference Spheroid 1980.

Radiometric Correction

A radiometric correction was performed on all TM bands to account for the systematic signal distortion of the sensor. One major source of distortion that occurs is the sensor offset, the residual "black noise" that is recorded by the sensor when there is no input signal (Lillesand and Kiefer, 1987). The other major distortion is from the channel gain, which is the slope transfer relation between the signal received and the sensor's response. Differential offsets and gains between bands will cause problems when comparing their responses to a certain feature, so it is necessary to calibrate all the bands to each other. Gain and offset coefficients for each band are provided for by EOSAT for Landsat TM5 in the original header. The effect of these deviations on the original data can be modeled as:

$$L \quad (DN * Gain) + Offset \quad (Eq.$$

where **L** is the radiometrically corrected signal and **DN** is the input digital number value. The gains and offsets found in Table 2 were used to transform the image DN values.

Table 2. Gains and offsets used to radiometrically calibrate the image data.

	TM1	TM2	TM3	TM4	TM5	TM7
OFFSET	-0.15	-0.280487	-0.119403	-0.15	-0.014999	-0.014999
GAIN	0.0602436	0.1175036	0.0805971	0.0815399	0.0108074	0.0056984

Normalized Difference Vegetation Index

The Normalized Difference Vegetation Index (NDVI) was created using Equation 2 and added to the file.

$$NDVI = (TM4 - TM3) / (TM4 + TM3) \quad \text{(Eq. 2)}$$

Where **TM4** is the near infrared TM band and **TM3** is the visible red TM band.

The NDVI enhances vigorous vegetation over other major surface features. It is believed that this enhancement helps to emphasize vegetation response patterns in the classification over soil responses. The NDVI also allows quick assessment of class signatures: for example, riparian areas should have a higher NDVI response than senescent grasslands.

Variance Filter

The aerial photographs had a variance filter applied to them using the below equation:

$$V = \Sigma(DN - \mu)^2 / 9 \quad \text{(Eq. 3)}$$

where **V** is the resulting variance, **DN** is the image value, and μ is the average value for the 3 x 3 filter kernel. There were several reasons for filtering these images. It was expected that different vegetation types would have different spatial patterns; for example a fourwing saltbush shrubland might have a lot of spatial variation due to changes in image response representing the shrub, grass and barren components of this landscape whereas a pickleweed shrubland which is nearly barren may have only have a small variation in response. The results were also hoped to negate some of the problems found with the original data as the variation pattern would be the same despite changes in photo contrast. The filtered image showed both of these results with different variance response on different landscapes and with little discernable evidence of the photograph frame boundaries.

Software and Hardware Used

ERDAS Imagine, version 8.2, was the principal software used throughout the mapping process. All digital imagery and GIS coverages were either processed, manipulated, or used as overlays for analysis within the Imagine environment. The ERDAS Imagine software was loaded on a SUN workstation using a SUNOS Unix operating system.

Arc/Info, version 7.03, was used to create, import, and manipulate vector coverages and Microsoft Access database ASCII files.

PC based Microsoft Access, version 2.0, was used to store and manipulate all field data as well as to integrate ancillary data from other software sources.

Trimble's Pfinder, version 2.0, PC software was used to differentially correct GPS data collected in the field to account for position errors due to Selective Availability (SA).

Mapping Strategy

Initial Image Analysis

This project had the advantage of having both satellite images and digitized aerial photographs to work with. The question was how to combine the spectral capabilities of TM data with the fine spatial detail of the aerial photographs. Several strategies were tested to find out which best mapped the vegetation patterns over the range of landscapes. The test location was where Hay Draw meets the dunes; this location was considered a good test site because in just 16 square kilometers there are shrubland, grassland, drainage, vegetated/barren duneland, and disturbance/development environments. Additionally, it included four aerial photographs mosaicked together with very different contrasts.

The TM bands and NDVI were sampled down to the same pixel size as the aerial photographs. Representative, statistical samples ("seeds") were taken for each of the environments from the TM bands, NDVI, and filtered and unfiltered aerial photographs (the method for the gathering of samples is covered in detail under Image Classification). Once these seeds were collected, eight different test classifications were performed using the following image band combinations:

1) All TM bands including the thermal and NDVI;
2) Non-thermal TM bands and NDVI;
3) Aerial photographs;
4) Aerial photographs with all TM bands and NDVI;
5) Aerial photographs with the non-thermal TM bands and NDVI;
6) Variance filtered photographs;
7) Variance filtered photographs with all TM bands and NDVI;
8) Variance filtered photographs with the non-thermal TM bands and NDVI;

The TM image classifications gave more generalized vegetation patterns, which was expected; the thermal band was tested, despite having an actual IFOV of 120 meters, because it displayed good spectral discrimination between all of these environments on the screen, but its inclusion only softened the classification detail. The aerial photographs with or without the TM bands created an exceptionally heterogeneous classification with different classes mixed with others and with definite contact lines along the picture frame boundaries; this heterogeneity was due to the lack of significant spectral detail in the photos. The classification of the variance filtered photographs alone was the worst; it was even more heterogeneous than their unfiltered counterparts. But, in combination with the TM -- especially without the thermal band -- the image classification closely matched the environments identifiable in the raw image on the screen. There was detailed pattern without the boundary lines or speckle. This last strategy, a classification using the non-thermal TM bands, the NDVI and the variance filtered aerial photographs, was adopted for mapping the entire project area.

Ground Survey Data

The mapping process used here is dependent on a ground vegetation survey data to develop the map. A set of 110 geo-referenced vegetation plots was collected from the study area from April to May of 1997. To ensure a wide coverage of the study area for mapping purposes, potential field plot locations were initially determined using aerial photography interpretation and an unsupervised image classification (see Image Classification below) of the range of patch types. Sampling was directed towards large polygons of uniform spectral characteristics distributed throughout the study area. To complement the ground data, additional "photoplots" in more remote areas were established by aerial photo interpretation based on the ground survey. In addition, 120 validation plots were collected in a random, but systematic process for later testing of the map accuracy (see Map Validation section).

Plot data was gathered following NMNHP guidelines and includes a floristic inventory with percent cover by species within a 400^2 meter area, community type classification and site characteristics (landform, soil surface characteristics, aspect, slope, and elevation along with a brief word description of the site). Plots were placed in the center of stands of more or less uniform vegetation representing the dominant vegetation type of the selected polygon (stands were a minimum of 1 ha in size, with the exception of stands that are limited in size by geomorphological characteristics such as stream channels). This data resides in the NMNHP Biological and Conservation Database on the Microsoft Access platform and was exported to image processing software as needed.

A Global Positioning System (GPS) was used to record the highly accurate plot locations necessary for use in the image analysis. GPS positions were collected using Trimble Geoexplorers, and were differentially post-processed to ± 10 m accuracy using base station data. The data was corrected with base station files from the NPS Southwest Geographic Information Center in Albuquerque, NM.

Image Classification

Supervised Strategy and Seeding

The image classification procedure synthesizes satellite image data with field plot data and ancillary data derived principally from Geographic Information System (GIS) coverages. A supervised classification strategy was adopted to create the vegetation map based on vegetation community types of HAFB. This strategy develops spectral classes based on precise ground locations with known characteristics such as vegetation composition, rock type, and landscape context.

In a supervised classification strategy, the field data is applied to the image data through an interactive process called "seeding." In the seeding process, a pixel at the field plot location was selected in the imagery and its spectral characteristics were used to gather other similar contiguous pixels to create a statistical model or "seed" of the field plot. The seeding algorithm searches around that point within user-defined parameters which contain a seed within: 1) a certain distance, 2) a certain area, and 3) a certain spectral distance defined as:

$$SD = \sqrt{\Sigma(\mu - X)^2}$$

where **SD** is the spectral distance between a new pixel and the mean of the current seed group pixels across all bands, μ is the mean of the seed pixel group for each image band, and X is the spectral value of the new pixel for each band.

In an iterative process, the best seed models were constructed by adjusting the parameters and comparing the resulting pixel distributions against the terrain models and the original imagery. A seed was developed for each field plot using the plot GPS location and associated field information. The seed's maximum area was initially defined by the size of the vegetation community occurrence as determined in the field. The actual seed was then defined by increasing the spectral distance iteratively until the spectral signature collected within the seed generated a covariance matrix which could be inverted, a requirement for the maximum likelihood decision rule used later in the actual classification.

The seed shape and location was checked against field notes and maps, and by direct interpretation of the seed in the image on the screen in conjunction with the terrain models. Each seed is saved in a signature file with its field plot number, mean values for each image band, variance, number of pixels that were used to create the seed, and minimum and maximum values.

Supervised Classification

A supervised classification was performed using the statistics gathered in the seeding process, and is based on a maximum likelihood decision rule. The maximum likelihood decision rule also contains a Bayesian classifier which used probabilities to weight the classification towards particular classes. In this study the probabilities were unknown, so the maximum likelihood equation for each of the classes is given as:

$$D = [0.5\ln(cov_c)]-[0.5(X-M_c)^T * (cov_c^{-1})*(X-M_c)]$$

where **D** is the weighted distance, $\mathbf{cov_c}$ is the covariance matrix for a particular class, X is the measurement vector of the pixel, M_c is the mean vector of the class and ^{T} is the matrix transpose function (ERDAS,1994). Each pixel is then assigned to the class with the lowest weighted distance. This technique assumes the statistical signatures have a normal distribution.

This decision rule is considered the most accurate, because it not only uses a spectral distance (as the minimum distance decision rule), but it also takes into account the variance of each of the signatures. The variance is important when comparing a pixel to a signature representing, for example, a Chihuahuan scrub community which might be fairly heterogeneous, to a water class, which is more homogeneous.

To locate problems, informal accuracy checking was used based on independent field data, air photos, personal knowledge of a site and other ancillary data. If a distribution problem with a seed was detected, the seed was rechecked to insure it was properly modeling the vegetation type and landscape.

Map Unit Development

A preliminary map was created with as many map classes as seeds used to develop it. The seed map classes were then aggregated into a limited number of Mapping Units (MU's) for the final map. These are based on floristic composition, landscape position, spatial contiguity and spectral similarity, e.g. floristically similar seed classes which had similar landscape positions and were spatially near each other, were grouped into a mapping unit. This was an iterative process based on informal accuracy checking that was continued until all seed classes were grouped into the most consistent and accurate mapping units

RESULTS

Map Units

Twenty-five map units were defined, 22 are found on HAFB proper (Table 3), and seven in the northern well field (Table 4). There are five predominantly grassland units where shrubs are few and scattered. These grasslands can cover large areas, particularly in drainages and low-lying places in the landscape. There are ten units where shrubs dominate, particularly fourwing saltbush (*Atriplex canescens*); undergrowths range from very sparse to very grassy. There is also a woodland type dominated by exotic salt cedar (*Tamrix ramosissima*). The remainder of the units represent various miscellaneous land cover type such as rock or airfield, etc. Detailed descriptions of each map unit are provided in Appendix A.

Final Vegetation Map

To create the final map, a filtering process was applied to create a minimum map unit polygon size of 40 square meters (0.004 ha.). The procedure eliminates the "speckle" created by spatially solitary mapping units which have less than six contiguous pixels. The eliminated areas are then filled in by the majority of surrounding pixels using a 3-pixel x 3- pixel majority filter (a majority filter replaces the middle pixel of a 3 x 3 kernel with the class which is the majority within that kernel). The filtered file was substituted into the map wherever there were clusters of pixels of a particular class which covered less than 40 square meters.

No attempt was made to classify general disturbance due to the heterogeneity of reflecting surfaces (buildings, pavement, concrete, lawns, and etc.). A few seeded classes did map disturbance features very well and were used. Roads and buildings GIS coverages in vector format were placed directly onto the map as the ground disturbance class. Likewise, the airfield was placed on the map as its own class. The golf course class was from an actual seed. The trees and lawns of the main cantonment area and Boles Wells were not seeded for, but were created where the saltcedar or golf course seeded classes, the two classes representing the highest NDVI values, occurred in these areas.

In addition, a wetlands map developed independently by Geomarine was integrated into the final vegetation map to reflect the jurisdictional wetlands.

Map Validation

The accuracy of the final vegetation map was tested using an independent set of ground survey plots that were collected in a random-systematic sampling design. Plots were collected at 1-km intervals along roads and at a distance of 100 m from the road edge on alternating sides. A total of validation set of 120 plots were collected representing the range of all vegetation types found in the study area except for the small cottonwood stands of the dunelands (see Appendix B).

The map is highly accurate with over 90.0% (108/120 plots) of the validation points falling within correct map units. In addition, most of the incorrect points (8 of the 12 or 7%) were located within 25 meters of the correct unit; this is within the potential error margin of the GPS location. and/or adjacent to the correct unit. And finally, the remaining four (3%) incorrect plots were in closely related map units i.e. they were only missing a particular shrub or grass component, but the rest of the vegetation elements were correct. Some map units were not well-represented in the validation sample set particularly the various miscellaneous types such as urban vegetation, development etc., but we still feel confident these map units are accurate based on aerial photo interpretation, ground reconnaissance and other ancillary data (particularly from an earlier wetlands mapping project).

Table 3. Holloman Air Force Base, New Mexico vegetation map units.

No.	Vegetation	Hectares
	Grasslands	
2	Gyp Grama Interdune Grassland	913
6	Gyp Dropseed Grassland	2576
8	Semi-Riparian Alkali Sacaton Grassland	1001
9	Alkali Sacaton Grassland	1313
	Shrublands	
1	Rosemarymint Dune Shrubland	2475
4	Pickleweed Shrubland	849
5	Sparse Fourwing Saltbush Shrubland	1494
7	Fourwing Saltbush Shrubland with Honey Mesquite	936
12	Fourwing Saltbush / Gyp Dropseed Shrubland	2395
13	Semi-riparian Honey Mesquite Shrubland	68
19	Creosotebush Shrubland	147
21	Fourwing Saltbush / Alkali Sacaton Shrubland	3147
	Woodlands	
3	Saltcedar Woodland	131
	Miscellaneous	
10	Barren Duneland	1001
11	Rock Outcrop	18
14	Wetland	51
16	Barren Alkaline Playa	161
17	Golf Course	18
18	Surface Water	90
22	Development / Ground Disturbance	2221
26	Airfield	231
28	Urban Vegetation	44

Table 4. Boles Wells area map units.

No.	Vegetation	Hectares
	Shrublands	
19	Creosotebush Shrubland	60
23	Honey Mesquite Shrubland	491
24	Honey Mesquite / Feather Fingergrass Shrubland	48
	Woodlands	
3	Saltcedar Woodland	3
	Miscellaneous	
14	Wetland	0.2
18	Surface Water	2
22	Development / Ground Disturbance	34
28	Urban Vegetation	2

Discussion

The map presented here is the most accurate and detailed map developed to date for the vegetation of Holloman Airforce Base. The intended scale for use of the map is 1:24,000 (7.5' USGS quadrangle size). The map units were designed to both accurately reflect the vegetation composition of the area, but also to be optimally useful for natural resources management at that scale. Use of the map at finer scales is not recommended without review (additional ground truthing). Future refinement of map unit categories and the scale of use might be possible, but not necessarily appropriate for most natural resources management applications. The map has been made available both in hard copy form and in a digital format suitable for integration into the installation GIS. Barring large changes in landuse at the base, the map should prove a useful tool for Holloman Airforce Base well into the future.

Appendix A

Holloman Vegetation Map

Map Units Descriptions

Map Unit No. 1 **(Hectares: 2475-- Acres: 6116)**

Rosemarymint Dune Shrubland

This sparse shrubland occurs on the slopes and summits of shifting gypsum dunes that occur along the western boundary of HAFB. The shrubs are scattered and dominated by hoary rosemarymint (*Poliomintha incana)* with occasional soaptree yucca (*Yucca elata)*, Torrey's jointfir (*Ephedra torreyana)* and skunkbush sumac (*Rhus trilobata)*. The grass cover is sparse with scattered clumps of sandhill muhly (*Muhlenbergia pungens),* mesa dropseed (*Sporobilus flexulosus)*, and near duneland edges, giant dropseed (*Sporobolus giganteus)*. The Hoary Rosemarymint/Sandhill Muhly Community Type (CT) is the major component of this unit, however, the Hoary Rosemarymint/Mesa Dropseed CT is also present, but is generally limited to the duneland periphery.

Major Community Types

Hoary Rosemarymint/Sandhill Muhly	***Poliomintha incanum/Muhlenbergia pungens***
Hoary Rosemarymint/Mesa Dropseed	***Poliomintha inconum/Sporobolus flexuosus***

Map Unit No. 2

(Hectares: 913 Acres: 2256)

Gyp Grama Interdune Grassland

This moderate cover grassland occurs within interdune swales of the gypsum duneland found along the western boundary of HAFB. Gyp grama (*Bouteloua brevista)* and New Mexico bluestem (*Schizachyrium neomexicanum*) dominate the duneland interior, but gyp dropseed (*Sporobolus nealleyi*) becomes more prevalent along duneland edge. The major components are the Gyp Grama-New Mexico Bluestem and the Gyp Grama/Hairy Coldenia grassland CTs. However, inclusions of the Gyp Dropseed/Hairy Coldenia CT are found along the eastern duneland periphery.

Major Community Types

Gyp Grama-New Mexico Bluestem	***Bouteloua breviseta-Schizachyrium neomexicanum***
Gyp Grama/Hairy Coldenia	***Bouteloua breviseta/Tiquilia hispidissima***

Inclusions

Gyp Dropseed/Hairy Coldenia	***Sporobolus nealleyi/Tiquilia hispidissima***

Map Unit No. 3

(Hectares: 134 Acres: 331)

Saltcedar Woodland

A sparse to dense woodland is associated with riparian habitats throughout HAFB (considered a tall shrubland by some). The overstory is clearly dominated by saltcedar (*Tamarix ramosissima*), while the understory can be sparse or may support grasses such as alkali sacaton (*Sporobolus airoides*) and saltgrass (*Distichlis spicata)*. Shrub diversity is low, but fourwing saltbush (*Atriplex canescens*) and Mojave seablite (*Sueda moquinii*) can occur in low amounts.

Major Community Types

Saltcedar/Sparse	***Tamarix ramosissima/Sparse***
Saltcedar/Alkali Sacaton	***Tamarix ramosissima/Sporobolus airoides***

Map Unit No. 4

(Hectares: 849 -- Acres: 2098)

Pickleweed Shrubland

A sparse shrubland of alkaline soils within drainages and swales, and on alluvial flats throughout HAFB. Scattered individuals of pickleweed (*Allenrolfea occidentalis*) are characteristic along with occasional fourwing saltbush (*Atriplex canescens*). The understory is commonly barren alkaline crust, but occasionally alkali sacaton (*Sporobolus airoides*) or Mojave seablite (*Sueda moquinii*) are well represented.

Major Community Types

Pickleweed/Sparse — ***Allenrolfea occidentalis/Sparse***

Inclusions

Pickleweed-Mojave Seablite — ***Allenrolfea occidentalis-Suaeda moquinii***

Pickleweed/Alkali Sacaton — ***Allenrolfea occidentalis/Sporobolus airoides***

Map Unit No. 5

(Hectares: 1494 -- Acres: 3692)

Sparse Fourwing Saltbush Shrubland

An open desert shrubland dominated by fourwing saltbush (*Atriplex canescens*) that occurs within drainages, swales and alluvial flats throughout HAFB. The understory is typically sparse or barren (annual forbs may be present). Pickleweed shrublands and Saltbush/Gyp Dropseed CTs are closely related units that can occur on adjacent on basin flats.

Major Community Types

Fourwing Saltbush/Sparse — ***Atriplex canescens/Sparse***

Map Unit No. 6

(Hectares: 2576 -- Acres: 6365)

Gyp Dropseed Grassland

A sparse grassland that occurs in linear bands along the edges of valley drainages and on gypsum mounds (outcrops) on basin flats throughout HAFB. The grass cover is low and dominated by scattered bunches of gyp dropseed (*Sporobolus nealleyi*). The sub-shrub hairy coldenia (*Tiquilia hispidissima*) is usually a co-dominant. Alkali sacaton (*Sporobolus airoides*) may also be present. Small inclusions of the Fourwing Saltbush/Gyp Dropseed CT can occur.

Major Community Types

Gyp Dropseed/Hairy Coldenia	***Sporobolus nealleyi/Tiquilia hispidissima***
Gyp Dropseed-Alkali Sacaton	***Sporobolus nealleyi-Sporobolus airoides***

Inclusions

Fourwing Saltbush/Gyp Dropseed	***Atriplex canescens/Sporobolus nealleyi***

Map Unit No. 7

(Hectares: 936 -- Acres: 2313)

Fourwing Saltbush Shrubland with Honey Mesquite

This open shrubland is dominated by fourwing saltbush (*Atriplex canescens*) along with scattered honey mesquite (*Prosopis glandulosa*). It is primarily found along the southeastern side of HAFB on alluvial flats. The understory is dominated by alkali sacaton (*Sporobolus airoides*) and/or scattered burrograss (*Scleropogon brevifolius*). There are also inclusions of the Honey Mesquite/Alkali Sacaton CT which lacks a significant fourwing saltbush component, and nearly pure stands of alkali sacaton with a few scattered honey mesquite (north of Malone Draw and west of Dillard Draw).

Major Community Types

Fourwing Saltbush/Alkali Sacaton	***Atriplex canescens/Sporobolus airoides***

Inclusions

Honey Mesquite/Alkali Sacaton	***Prosopis glandulosa/Sporobolus airoides***
Alkali Sacaton/Monotypic	***Sporobolus airoides/Monotypic***

Map Unit No. 8

(Hectares: 1001 -- Acres: 2473)

Semi-riparian Alkali Sacaton Grassland

This open to dense grassland occurs within drainage floodplains and alkaline swales throughout HAFB. Alkali sacaton (*Sporobolus airoides*) cover is generally very high, but becomes less abundant at the duneland edge. Hence, the Alkali Sacaton/James' Seaheath CT becomes more prevalent near the duneland periphery.

Major Community Types

Alkali Sacaton/Monotypic	***Sporobolus airoides/Monotypic***
Alkali Sacaton/James' Seaheath	***Sporobolus airoides/Frankenia jamesii***

Map Unit No. 9

(Hectares: 1313 -- Acres: 3244)

Alkali Sacaton Grassland

This open to moderately dense grassland occurs on basin bottom flats and is predominantly limited to the southwest sector of HAFB. The grassland is dominated by alkali sacaton (*Sporobolus airoides*) but may include scattered fourwing saltbush (*Atriplex canescens*). It is characterized by scattered bunch grasses with bare soil patches in between.

Major Community Types

Alkali Sacaton/Monotypic	***Sporobolus airoides/monotypic***

Map Unit No. 10

(Hectares: 1001 Acres: 2473)

Barren Duneland

Shifting, non-vegetated gypsum dunes found within the interior regions of the duneland along the western boundary of HAFB. There are inclusions of the Hoary Rosemarymint/Sandhill Muhly CT, but these are generally very sparse and small occurrences.

Inclusions

Hoary Rosemarymint/Sandhill Muhly	***Poliomintha incanum/Muhlenbergia pungens***

Map Unit No. 11

(Hectares: 18 -- Acres: 44)

Rock Outcrop

Rock outcrops of limestone found on the slopes of Tularosa Peak that are generally non-vegetated.

Map Unit No. 12

(Hectares: 2395 -- Acres: 5918)

Fourwing Saltbush/Gyp Dropseed Shrubland

An open shrubland predominantly found on gypsum soils east of the HAFB duneland and across the basin bottom flats. Fourwing saltbush clearly dominates the shrub layer with Christmas cactus (*Opuntia leptocaulis*), kingcup cactus (*Echinocerus triglochidiatus*) and Berlandier's wolfberry (*Lycium berlandieri*) as common associates. The understory is dominated by gyp dropseed (*Sporobolus nealleyi)*, but alkali sacaton (*Sporobolus airoides*) may occasionally co-dominate. There may be small inclusions of the Gyp Dropseed-Alkali Sacaton and Gyp Dropseed/Hairy Coldenia CTs grasslands.

Major Community Types

Fourwing Saltbush/Gyp Dropseed	***Atriplex canescens/Sporobolus nealleyi***

Inclusions

Gyp Dropseed/Hairy Coldenia	***Sporobolus nealleyi/Tiquilia hispidissima***
Gyp Dropseed-Alkali Sacaton	***Sporobolus nealleyi-Sporobolus airoides***

Map Unit No. 13

(Hectares: 68 Acres: 168)

Semi-riparian Honey Mesquite Shrubland

This dense shrubland is found within the drainage floodplains of the northern section of HAFB. The shrubland is dominated by a moderately open to closed canopy of honey mesquite (*Prosopis glandulosa*) with dense alkali sacaton (*Sporobolus airoides*) in the understory.

Major Community Types

Honey Mesquite/Alkali Sacaton	***Prosopis glandulosa/Sporobolus airoides***

Map Unit No. 14

(Hectares: 51 -- Acres: 126)

Wetland (Saltgrass Grassland)

This unit is found along the shores of the Holloman Lakes and follows the Lost River Drainage into the duneland on the western side of HAFB and covers lowland playas within the constructed wetland area. The unit is characterized by nearly pure stands of inland saltgrass (*Distichlis spicata*) with occasional, but scattered alkali sacaton (*Sporobolus airoides*). Also includes areas with seep willow, smooth seepweed, pickleweed, and sea-lavender. Sites are periodically inundated, particularly during the summer rainy season.

Major Community Types

Inland Saltgrass/Monotypic	***Distichlis spicata/Monotypic***

Map Unit No. 16

(Hectares: 161 -- Acres: 398)

Barren Alkaline Playa

Playas and alkaline flats of HAFB that are periodically inundated. The largest continuous occurrence is found where the Lost River drainage enters the dunefield, but occurrences are also distributed throughout the Holloman Lakes area.

Map Unit No. 17 (Hectares: 18 -- Acres: 44)

Golf course

The HAFB golf course.

Map Unit No. 18 (Hectares: 92 -- Acres: 227)

Surface Water

Surface water detected on the date of the satellite imagery was acquired. The largest continuous occurrences are located at Lake Holloman and in the Lagoon "G" area.

Map Unit No. 19 (Hectares: 207 -- Acres: 511)

Creosotebush Shrubland

An open to moderately closed shrubland that generally occurs on piedmont surfaces throughout HAFB. Creosotebush (*Larrea tridentata*) is the characteristic dominant with and understory that is either sparse or dominated by alkali sacaton (*Sporobolus airoides*). Fourwing saltbush, hairy coldenia and snakeweed can also be present, but not dominant. The largest continuous occurrence surrounds Tularosa Peak, but other stands are found in the Boles Wells area and in the northeast sector of HAFB

Major Community Types

Creosotebush/Alkali Sacaton	***Larrea tridentata/Sporobolus airoides***
Creosotebush/Sparse	***Larrea tridentata/Sparse***

Map Unit No. 21

(Hectares: 3147 -- Acres: 7776)

Fourwing Saltbush/Alkali Sacaton Shrubland

An open shrubland that predominantly occurs in the central regions of HAFB. It is characterized by an open canopy of fourwing saltbush (*Atriplex canescens*) with a well developed grassy understory dominated by alkali sacaton (*Sporobolus airoides*). Tulip and purple pricklypear (*Opuntia phaecantha* and *O. Macrantha*), crucifix thorn (*Koeberlinia spinosa*) are common associates. Scattered inclusions of the Alkali Sacaton Grassland can occur.

Major Community Types

Fourwing Saltbush/Alkali Sacaton	***Atriplex canescens/Sporobolus airoides***

Inclusions

Alkali Sacaton/Monotypic	*Sporobolus airoides/Monotypic*

Map Unit No. 22

(Hectares: 2255 -- Acres: 5572)

Development/Ground Disturbance

Military facilities, roadside disturbance, range camps, the main base and other extensive development.

Map Unit No. 23

(Hectares: 491 Acres: 1213)

Honey Mesquite Shrubland

This open to moderately closed shrubland occurs on alluvial flats within the northern wellfield (Boles Wells) of HAFB. The landscape is characterized by low slopes with barren surfaces that are dissected by small braided gullies. The shrubland is dominated by honey mesquite (*Prosopis glandulosa*) and generally also includes some fourwing saltbush (*Atriplex canescens*), tarbush (*Flourensia cernua*) and lotebush (*Ziziphus obtusifolia*), which may occasionally co-dominate. Grasses are generally absent or very scattered.

Major Community Types

Honey Mesquite-Fourwing Saltbush	***Prosopis glandulosa-Atriplex canescens***

Map Unit No. 24 (Hectares: 48 Acres: 119)

Honey Mesquite/Feather Fingergrass Shrubland

This open shrubland occurs in shallow swales and drainages within the northern wellfield (Boles Wells) of HAFB. The shrubland is dominated by honey mesquite (*Prosopis glandulosa*), although fourwing saltbush (*Atriplex canescens*) and tarbush (*Flourensia cernua*) are generally present. The understory is clearly dominated by feather fingergrass (*Chloris virgata*) with occasional scattered clumps of alkali sacaton (*Sporobolus airoides*).

Major Community Types

Honey Mesquite-Fourwing Saltbush — ***Prosopis glandulosa-Atriplex***

Inclusions

Fourwing Saltbush/Sparse — *Atriplex canescens/Sparse*

Map Unit No. 26 (Hectares: 231 -- Acres: 571)

Airfield

Runways and associated development. African rue may also occur over disturbed areas within the unit.

Map Unit No. 28 (Hectares: 46 -- Acres: 114)

Urban Vegetation

Trees and lawns associated with office and residential development on HAFB and in the northern wellfield (Boles Wells).