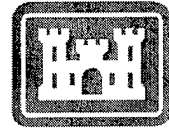


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Ecosystem Classification and Relationships For Pleistocene Lake Thompson Bed, Mojave Desert, California

Robert Lichvar, Steve Sprecher, David Charlton,
Gregory Gustina, Michael Ericsson, and Jonathon Campbell

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Prepared for EDWARDS AIR FORCE BASE, CALIFORNIA

ABSTRACT

A four-year study was undertaken in 1997 to understand ecosystem relationships between vegetation and edaphic features at Edwards Air Force Base, California (Edwards AFB). This report presents the comprehensive analysis and discussion for the entire Lake Thompson Bed contained within Edwards AFB. This study used the ecological land classification (ELC) method for developing ecosystem maps. The concept of an ELC is to integrate ecosystems and landforms into one coherent system with functionally related parts. The study area for the ecosystem map is the boundary of the Pleistocene Lake Thompson Bed within Edwards AFB. The ELC maps are secondary products developed from primary field data. Two mapping teams independently mapped the vegetation communities and the landforms of the study area. The characteristics of the landform and vegetation map units were used to create and describe map units for ELC maps. Samples were collected around Pleistocene Lake Thompson Bed to characterize soil chemistry, vegetation, geomorphic, and other descriptive environmental features. Analyses of the data attempted to test the interaction between geomorphic features, vegetative communities, and sampled environmental parameters. Overall, it appears that soil texture plays an important role in the development and relationships with geomorphology, soil chemistry, and vegetation. Geologically the playa surface was less heterogeneous initially, in terms of geomorphic units. As Lake Thompson Bed began to dry out in response to climate changes, dunes and alluvial fans began to form. The result was a landscape with a higher degree of soil texture variability than had existed on the initial lakebed surface. Soil texture sorting across the landscape, along with climate changes, drove the current distribution pattern of vegetation.

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PREFACE

This report was prepared by Robert Lichvar, Ecologist, Remote Sensing/Geographical Information Systems and Water Resources Branch (RS/GIS), Cold Regions Research and Engineering Laboratory (CRREL), U.S. Army Engineer Research and Development Center (ERDC), Hanover, New Hampshire; Steven Sprecher, Soil Scientist, U.S. Army Corps of Engineers Detroit District, South Bend Field Office, South Bend, Indiana; David Charlton, Botanist, Charis Corporation, Barstow, California; Gregory Gustina, Biologist, Bureau of Land Management, Taos, New Mexico; Michael Ericsson, Geologist, RS/GIS, CRREL, Hanover, New Hampshire; and Jonathon Campbell, Ecologist, University of California at Los Angeles (UCLA), Los Angeles, California.

The efforts of many people from multiple disciplines were involved in developing the landscape ecosystem maps and relationships within Pleistocene Lake Thompson Bed. The efforts of Dr. Anthony Orme, UCLA, Los Angeles, California, to map and decipher the landform patterns located at Lake Thompson Bed were paramount in our overall efforts to understand the relationship between landforms, vegetation, and soil chemistry. Other people besides the authors assisted with many aspects of field and GIS support: Dale Yocum, U.S. Fish and Wildlife Service, Vicksburg, Mississippi; Robert Busch, State of Wisconsin, Madison, Wisconsin; Russell Pringle, Natural Resources Conservation Service, Fort Worth, Texas; and Charles Racine, CRREL, Hanover, New Hampshire. We deeply appreciate the guidance and logistical support provided by Mark Hagan and Wanda Deal of Edwards Air Force Base, California.

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The Commander and Executive Director of the Engineering Research and Development Center is COL James R. Rowan, EN. The Director is Dr. James R. Houston.

ECOSYSTEM CLASSIFICATION AND RELATIONSHIPS FOR PLEISTOCENE LAKE THOMPSON BED, MOJAVE DESERT, CALIFORNIA

ROBERT LICHVAR, STEVE SPRECHER, DAVID CHARLTON, GREGORY
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1 INTRODUCTION

A study was undertaken in 1997 and continued through 2000 to develop ecosystem maps at Edwards Air Force Base (Edwards AFB). This study presents the comprehensive analysis and discussion for the entire Lake Thompson Bed contained within Edwards AFB. This study was designed to collect data, identify and map ecological land classes of the area formerly occupied by Pleistocene Lake Thompson, and develop discussions to explain plant distribution patterns within the lake bed system.

During the mapping of ecosystem and land classes units of Pleistocene Lake Thompson Bed area, a series of environmental variables were measured to help explain plant distribution patterns within the ecosystem. During the field sampling part of the study, the environmental variables were chosen because they would be useful for testing the hypothesis that vegetation communities are distributed across the landscape based on soil texture variables and that these distributions are driven by differences in soil chemistry among soil textures. Data to support these analyses were obtained from the samples taken from within the vegetation units.

This study used the ecological land classification (ELC) method for developing the ecosystem maps. The concept of an ELC is to integrate ecosystems and landforms into one coherent system with functionally related parts (Rowe 1961, Bailey 1980, 1996, Wilken and Ironside 1977, Driscoll et al. 1984) rather than as unrelated aggregations of separate biological and earth sciences classification units. The goal of an ELC is to provide a consistent conceptual framework for modeling, analyzing, interpreting, and applying ecological knowledge. The development of an ELC involves (1) a field inventory of ecosystem units, (2) a field inventory of landforms, (3) an analysis of correspondences between ecosystems and landforms, and (4) the development of a classification system inte-

grating the two. The classification should be hierarchal to allow for use at different map scales (Wilken 1981, O'Neil et al. 1986, Bailey 1996, Klijn and Udo de Haes 1994). This linking and aggregating of components into ecosystem units with co-varying climate, terrain, surface forms, hydrology, and biota provide a spatial stratification that conveys a broad range of information for ecosystem management.

The mapping of ecosystem units used in this report follows the system described by Klijn and Udo de Haes (1994), which combines elements from both the Canadian (Wilken and Ironside 1977) and the United States systems (ECOMAP 1983) for classifying ecosystems (Table 1). This system involves several spatial scales for mapping ecosystems and identifying various ecosystem components for differentiating successive levels of hierarchic organization. At Edwards AFB, we have evaluated and developed two levels of ecosystem organization: the ecosite (1:24,000 scale) and the ecoseries (1:50,000). Ecosites are delineated areas based on mapping of the geomorphology subunits and vegetation at the plant association level. We used these two landscape features because they are generally considered to be the integrators of geologic and weathering processes and they express the development of soil and plant relationships that give rise to the nature of various habitats. Ecoseries are a higher-level division of the geomorphic (hereafter referred to as landform) units and vegetation at the plant community scales.

Table 1. Differentiation of ecosystems at various scales.

Level	Scale		Term (Klijn and Udo De Haes 1994)	Differentiating characteristics
	Sublevel	Typical map scale		
Macro- scale	Continent	1:20,000,000	Ecozone	Continents with related climates
	Macro-region	1:5,000,000	Ecoregion	Climate mixed with geographic landscape mosaics (e.g. Mojave Desert)
Meso- scale	Meso-region	1:1,000,000	Ecodistrict	Major landforms or physiographic units within a climate region (e.g. Antelope Valley)
	Micro-region	1:100,000	Ecosection	Geomorphic units with homogeneous lithology, mode of deposition, depth, texture, and water properties; similar concepts include catena, topo- sequence, and soil associations (e.g. Lake Thompson Bed, Bissell Hills, etc.)
Micro- scale	Macro-site	1:25,000–50,000	Ecoseries	Division of geomorphic units that have similar topoclimate based on elevations, slope, slope position, and soils; also the division of vegetation into plant communities
	Micro-site	1:1,000–25,000	Ecosites	Subdivision of geomorphic units into specific subunits and plant communities into associations.

2 LOCATION

Edwards AFB is located in parts of Kern, Los Angeles, and San Bernardino Counties, CA, in the northern part of Antelope Valley, which is in the far western Mojave Desert. The installation is about 100 km (60 miles) north-northeast of Los Angeles, CA. Edwards AFB is approximately 121,792 ha (300,723 acres) in size (Fig. 1).

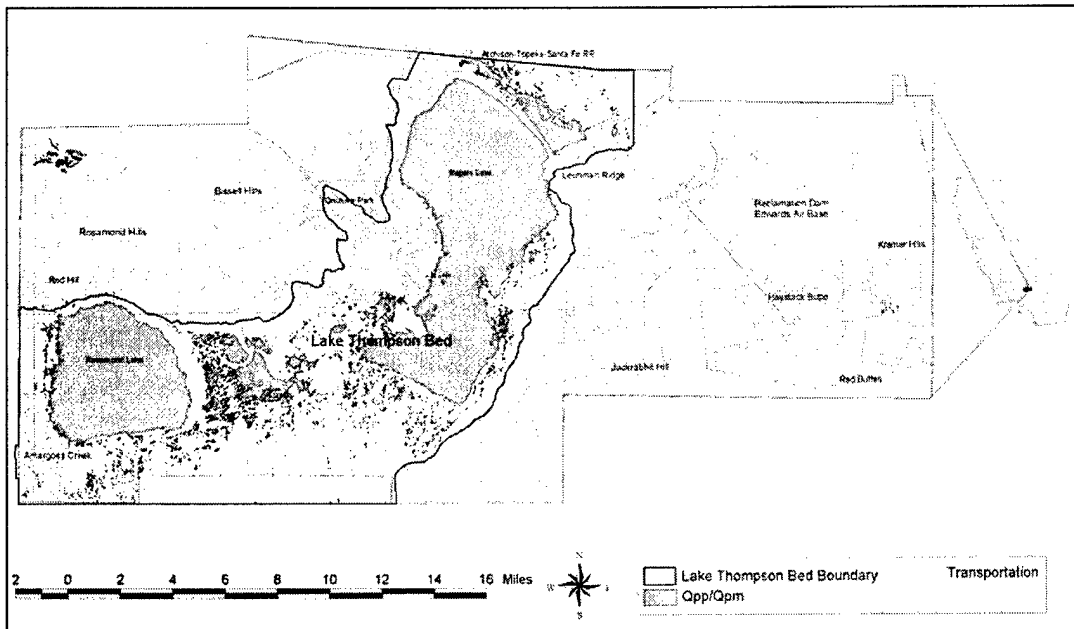


Figure 1. Boundaries of Edwards AFB and Pleistocene Lake Thompson Bed.

The topography of Edwards AFB is dominated by several large playa lake beds, an extensive area of smaller clay pans scattered between the playa lake beds, and a series of small mountains and associated alluvial fans along the north, east, and south sides. The three largest playa lakes at Edwards AFB are Rogers, Rosamond, and Buckhorn. Elevational relief at Edwards AFB is about 327 m (1,080 ft). The lowest point is located at Rogers Dry Lake at 692 m (2,270 ft), and the highest is on Haystack Butte at 1,021 m (3,350 ft).

The study area for the ecosystem map is the boundary of the Pleistocene Lake Thompson Bed within Edwards AFB. The lake is named after David Thompson, who completed several water supply studies in the Mojave Desert, including one for Rosamond Lake (Miller 1946). This historic lakebed filled most of Antelope Valley to elevations of approximately 710 m (2,275–2,350 ft).

Within Edwards AFB the boundary of the historic lakebed is typically defined on the landscape at the lower reaches of the creosote [*Larrea tridentata* (DC.) Cov.] plant community boundary located at the base of the alluvial fans. One of the most prominent features of its boundary is the shoreline cliff located just north of Rosamond Lake. There is also a major break from alkali to non-alkali soils from within Lake Thompson Bed to the adjacent upland foothills and mountains. The bed of Lake Thompson itself is covered in part by shifting aeolian sediments in either dunes or a discontinuous sand sheet. The majority of the vegetation located on the Pleistocene lakebed is composed of members of the Chenopodiaceae, with several phases of saltbush (*Atriplex* spp.) plant communities. An estimated 50,586 ha (125,000 acres) of the lowlands at Edwards AFB are part of this Pleistocene lakebed system.

3 METHODOLOGY

The ELC map is a secondary product developed from primary field data. The ELC map was compiled by combining a map of the landforms with a map of the vegetative communities of the study area. The map units of the vegetation and landform maps had to be characterized and interpreted before they could be combined into one single ELC map.

Two mapping teams independently mapped the vegetation communities and the landforms of the study area. The resulting map units were characterized by collecting information at sample plots distributed across the study area. The characteristics of the landform and vegetation map units were used to create and describe map units for the ELC map. The mapping and sampling protocols are described below.

Mapping Protocols

Orme (2004) mapped the landforms of the study area through an iterative process of field investigations and photo interpretation of stereo pairs of true color, 1:15,840-scale (4 in. = 1 mile) aerial photography taken on 26 April 1992 and 8 August 1992. The map delineations drawn in the photo-interpretation laboratory were checked and revised by field verification over the entire study area.

Vegetation communities of the study area were mapped using the same iterative process of field investigation and air photo interpretation used in developing the landform map. Whenever possible, the vegetation mapping effort used the landform maps as they were developed, in order to enhance the later map-overlay process needed to combine the two sets of maps into one common ELC map. When a vegetation boundary differed from the landform unit boundary, a separate vegetation boundary was delineated.

Both maps were transferred from aerial photographs to the geographic information system (GIS) using ARC/INFO software (ESRI, version 8.0.1). The areas delineated on the aerial photographs were located on the baseline map by using common ground control points. These locations were geo-referenced and digitized into the GIS map file. Appropriate map unit symbols based on the independent classifications for geomorphology and vegetation were assigned to each map layer. Once each map was independently developed, the two layers were digitally overlaid to develop the ELC map. This map has a dual set of codes to indicate the landform and vegetation units.

Sampling Protocols

Map units of the vegetation and landform maps were sampled for ecological, pedologic, and hydrologic characterization. Two sampling schemes were employed. First, 20 transects perpendicular to the lakebeds of Rosamond, Buckhorn, and Rogers were established to cross the range of landform and vegetation types in the study area. Sampling plots were located within each map unit traversed. Second, additional sampling plots were located elsewhere in the study area to collect data from map units not transected and to replicate sample plots in the various map units. The different map units were sampled with sufficient replication to ensure that the vegetative cover was adequately sampled ($p > 0.80$).

Except for linear landforms such as sand dunes and washes, each sample plot was a 50- × 50-m quadrat oriented parallel to the transect line. Sample plots on linear dunes and washes were adjusted to have an area of 2500 m² entirely within the mapped feature. At each sample point, basic data were collected for hydrology, soil chemistry, soil texture, landform, species composition and cover, and an additional 23 environmental variables (Table C1 in Appendix C). Each sample point was photographed.

The major landform units transected included the modern playa, former lake plains, aeolian sand sheets and dunes, alluvial channels, alluvial fans, and talus slope and colluvial surfaces. The major vegetation communities transected included Chenopod Scrub (members of the family Chenopodiaceae), Shadscale Scrub [*Atriplex confertifolia* (Torr. & Frem.) S. Wats.], Spinescale Scrub [*Atriplex spinifera* J.F. Macbr.], Allscale Scrub [*Atriplex polycarpa* (Torrey) S. Watson], Four-Wing Saltbush [*Atriplex canescens* (Pursh) Nutt.], and Mojave Wash Scrub (*Coleogyne ramosissima* Torrey).

Topographic profiles were obtained by measuring relative elevations at topographic breaks along the length of the transect. Measurements were made with an autolevel and rod. Later, elevation points were located at the end of each transect to establish actual elevations.

In every sample plot, bulk soil samples were taken for later chemical analysis in the laboratory. The depth of sampling was the surface horizon of root growth (usually 0 to 10 or 15 cm when vegetated, or the surface 5 cm of hard crust in unvegetated, indurated pans). Chemical analyses were performed on the bulk soil samples at the University of California, Division of Agricultural and Natural Resources Analytical Laboratory (DANR) in Davis, California. In sample plots along transects, shallow stratigraphy was characterized by recording color using a Munsell color book and soil texture to a depth of 180 cm; on some sand dunes augering was stopped at shallower depths because the soil auger would not withdraw loose sand from these depths.

Neither elevation nor soil profile data were collected at sample points off the transects because these sites were isolated from each other and did not contribute to geomorphic profiles of the playa bed and associated lake plain features. Otherwise, sample points on and off the transects were sampled in the same manner.

Vegetation Classification

A vegetation classification was developed following typical framework styles set forth in other California and regional classifications (Holland 1986, Sawyer and Keeler-Wolf 1995). In these classifications, vegetation is organized in groups by series or plant community units. Plant communities are stands of similar overstory species. These units are further subdivided into what are referred to as phases or plant associations (Table 2). A single species or a mixture of species can dominate the stand. These communities are described based on the most dominant species, using either visual observations or plot data. Each of these larger units typically has one or more co-dominant species, representing fine changes in edaphic features. These subgroups defined by the co-dominant level are referred to as plant associations. This approach provides a classification with two levels. The larger-scale level—plant communities—keys in on the major dominant species, and the smaller-scale level—plant association—recognizes the variation in co-dominant species. Nomenclature for plant names provided in Appendix A follows Hickman (1993).

At Edwards AFB, we developed an initial classification that would allow for both field use and stereoscopic interpretation. In most cases, changes of vegetation within the Lake Thompson Bed were so subtle that we were limited in our ability to extrapolate many photographic signatures within the study area. Based on initial reconnaissance work, we classified 65 plant associations within six plant communities. Based on further field sampling data, we reduced the number of plant associations to 58 (Appendix B).

Geomorphic Classification

The geomorphic classification of Pleistocene Lake Thompson Bed follows the standard geomorphic practice of classifying landscape features by age, structure, and process of formation (Orme 2004). The highest level of the classification distinguishes between land surfaces deposited or formed before the Quaternary (e.g., bedrock uplands), during the Quaternary (the age of recent glaciations to the present), and by people in the present time (e.g., agricultural disturbance). The pre-Quaternary bedrock units were divided into six units based on dominant lithology and degree of weathering. The Quaternary age class is divided into the five structural units found in the study area: modern playas, former lake systems,

Table 2. Geomorphic and vegetation units for Lake Thompson Bed.

a. Geomorphic Units		
Modern Playa		
Qp	Qpm	Main playa
	Qpp	Minor pan
Former Lake System		
	Qlp	Exposed lake plain
	Qlpx	Exposed, undissected, flat, or gently inclined lake beds
	Qlpxd	Exposed, dissected, hummocky, or irregular lake beds
	Qlpv	Beds veneered with aeolian sand <2m deep
	Qlpvd	Beds dissected and veneered with aeolian sand <2m deep
Ql	(d)	Degraded exposed or veneered lake beds
	Qlb _n	Beach ridge and nearshore ramp
	Qlbn	Exposed ridge or ramp
	Qlbv	Ridge veneered with aeolian sand <2m deep
	[Qle]	Estuary: abandoned to active or inactive fluvial washes
	Qll	Back-barrier lagoon
	Qllv	Back-barrier lagoon veneered with aeolian or alluvial deposits
Aeolian Sand Sheet and Dune		
	Qea	Active sand sheet or dune
	Qeat	Active transverse/barchanoid
	Qeab	Active barchan
Qe	Qeap	Active parabolic
	Qes	Stable sand sheet or dune
	Qest	Stable transverse/barchanoid
	Qesb	Stable barchan
	Qesp	Stable parabolic
	Qesd	Degraded aeolian sand sheet
Alluvial Channels and Fans		
	Qaa	Active wash or floodplain
	Qai	Abandoned or inactive wash
	Qaw	Wetland (little channel flow)
Qa	Qaf	Alluvial fan (rarely active)
	Qafv	Alluvial fan with aeolian veneer
	Qaf(H)	Holocene alluvial fan
	Qaf(P)	Pleistocene alluvial fan
	Qaf _n	Relative ages of alluvial fan deposits where locally evident
Talus Slopes and Colluvial Surfaces		
Qc	Qct	Talus slopes (present only against old cliffs)
Bedrock Uplands		
	Bc	Sedimentary (conglomeratic) terrain
	Bh	Hypabyssal terrain
B	Bv	Volcanic terrain
	Bp	Plutonic terrain
	Bpg	Grus terrain
	Bpgv	Aeolian veneer on grus

Table 2 (cont.). Geomorphic and vegetation units for Lake Thompson Bed.

b. Vegetation Units		
Chenopod Scrub		
Vch	Vch1	<i>Kochia</i> –Parry saltbush
	Vch2	<i>Allenrolfea</i> – <i>Frankenia</i>
	Vch3a	<i>Suaeda</i> –Parry saltbush–shadscale
	Vch3b	<i>Suaeda</i> –shadscale– <i>Kochia</i>
Shadscale Scrub		
Vsh	Vsh1	Shadscale–rabbitbrush/NM saltbush/Parish sagebrush with <i>Suaeda</i>
	Vsh2	Shadscale–saltgrass
	Vsh3	Shadscale– <i>Suaeda</i> –spinescale
	Vsh4a	Shadscale–mixed four-wing, winterfat–Joshua Tree
	Vsh4b	Shadscale–winterfat
	Vsh4c	Shadscale–four-wing–New Mexico
	Vsh4d	Shadscale–four-wing–spinescale–mesquite
	Vsh5	Shadscale–spinescale
	Vsh6	Shadscale–dropseed/ <i>Distichlis</i> / <i>Kochia</i>
	Vsh7	Shadscale–greasewood
	Vsh8	Shadscale–alyssum/matchweed/ budsage–Joshua tree
	Vsh9	Shadscale–allscale
	Vsh10	Shadscale–desert olive–alyssum
	Vsh11	Shadscale–Parry saltbush
Vsh12	Shadscale–alkali goldenbush–Parry saltbush	
Vsh13	Shadscale–Coopers goldenbush	
Vsh14	Shadscale–burrowbush	
Spinescale Scrub		
Vsp	Vsp1	Spinescale–boxthorn
	Vsp2	Spinescale–budsage/alyssum/dropseed
	Vsp3	Spinescale
	Vsp4	Spinescale–cheesebush
	Vsp5	Spinescale– <i>Suaeda</i> /shadscale
	Vsp6	Spinescale–Allscale
	Vsp7	Spinescale–rabbitbrush–burrowbush
	Vsp8	Spinescale–shadscale
	Vsp9	Spinescale mixed (Joshua tree–budsage–shadscale)
Allscale Scrub		
Val	Val1	Allscale–rabbitbrush
	Val2	Allscale–cheesebush
	Val3	Allscale/allscale–spinescale/Mormon tea
	Val4a	Allscale–goldenheads–Coopers GB–matchweed
	Val4b	Allscale–Coopers GB–cheesebush
	Val5	Allscale–burrowbush
	Val6	Allscale–boxthorn
Val7	Allscale–shadscale	

Table 2 (cont.). Geomorphic and vegetation units for Lake Thompson Bed.

Four-Wing Saltbush		
Vfo	Vfo1a	Four-wing-Joshua tree-shadscale-alyssum
	Vfo1b	Four-wing-Joshua tree-wolfberry
	Vfo2	Four-wing-allscale
	Vfo3	Four-wing-cheesebush
	Vfo4	Four-wing-rabbitbrush
Mojave Desert Scrub		
Vmo	Vmo1	NM saltbush-sagebrush or rabbitbrush
	Vmo2	NM Saltbush-Alkali Goldenbush-Mesquite
	Vmo3	Rabbitbrush-dropseed
	Vmo4	Cheesebush-Joshua tree
Vun	Unvegetated	
A	Human Disturbed	
Creosote Bush		
Vcb	Vcb1	Creosote-burrowbush
	Vcb2	Creosote-allscale
	Vcb3a	Creosote-mixed
	Vcb3b	Creosote-mixed Joshua tree
	Vcb4	Creosote
Burrowbush		
Vg	Vg1	Burrowbush-spinescale
	Vg2	Burrowbush-mixed saltbush (allscale and spinescale)
Vme	Mesquite Bosque	
Vtu	Tule Rush	

aeolian deposits, alluvial deposits, and talus slopes. These are further divided into sub-units defined by stratigraphy, degree of erosion, landscape stability, etc.

This hierarchic classification allows for distinctions between classes and between hierarchic levels. For example, a distinction between classes might be active versus stable sand dunes; a distinction between levels of the hierarchy might be sand fields in general versus the type of dune formation, such as bar-chan or longitudinal.

The geomorphic classification is a classification of surface features applied to a depth of 2 m. It is not a geologic map of deeper subsurface features. Stratigraphy within the surface 2 m is important in that the shallowness of units bears on and reflects surface processes, such as wind erosion, sand deposition, formation of lake beaches, etc.

Map Verification

The accuracy and verification of all maps developed during this study relied on the quality of the initial geomorphic map. The geomorphic mapping team

(Orme 2004) made stereoscopic interpretations on acetate mylar overlays that were later refined in the field. During the refinement phase they visited over 80 percent of the geomorphic map units. The geomorphic unit map relied heavily on photographic signatures that were breaks in vegetation unit boundaries. The subsequent vegetation mapping then identified the vegetation units that occurred in each geomorphic unit. The vegetation map was developed based on the geomorphic map base, incorporating changes in polygon boundaries as vegetation field-work dictated. Labelling the vegetation map required the use of species cover data from both the transects and the sampling points, as well as field visits to the remaining areas. This entailed visiting over 70% of all vegetation units. The maps were subsequently verified for accuracy of their polygon shape and labeling as part of the mapmaking process.

ELC Hierarchical Classification

The ELC classification is a process of integrating map units from the vegetation and geomorphic map layers into combined ecological units. These combined units, or ecosites, represent groups of plant associations and geomorphic sub-units. Over 368 ecosite combinations are possible when combining the current two classifications (Table 2). Only in very specific instances is this level of ecosite knowledge useful for either further analysis or planning purposes (Fig. 2). To make the data more useable we aggregated ecosites into ecoseries by combining to the next hierarchical level up in both classifications. By using a contingency table we reduced the number of 368 potential ecosites to 84 ecoseries combinations (Table 3).

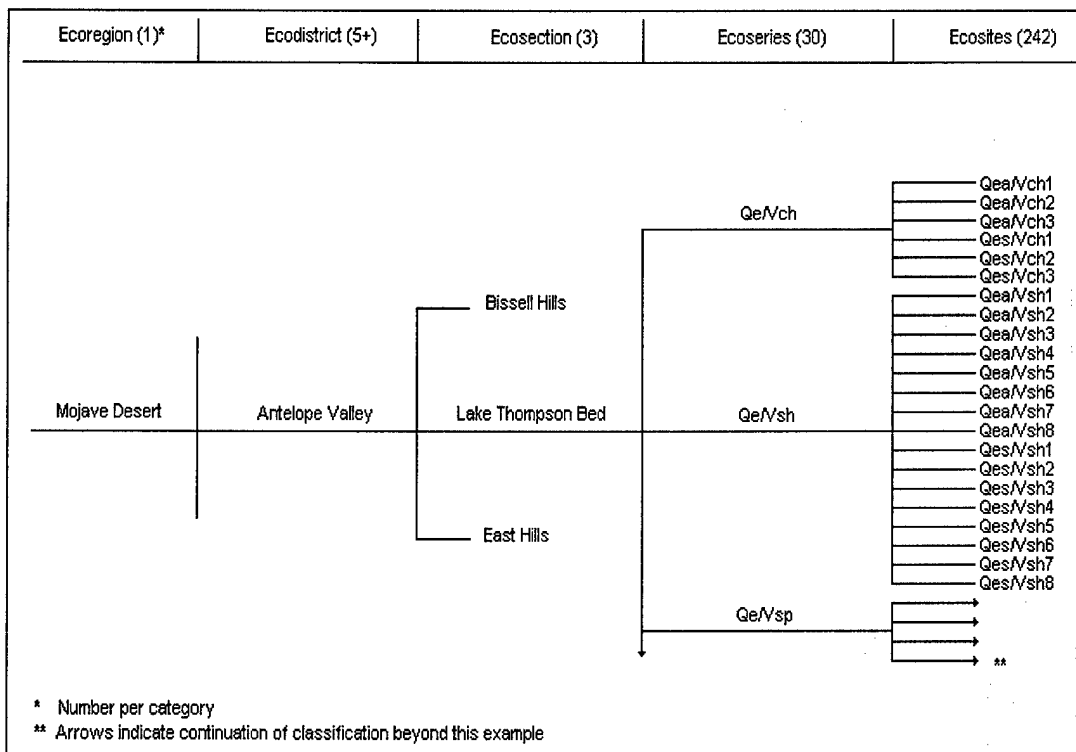


Figure 2. Ecological Land Classification: partial example of hierarchical scale.

Table 3. Number of sample points per ecoseries unit.

Geo Unit / Veg Unit	A	B	Qa	Qe	Qc	Ql	Qp	Total
A	1	0	0	0	0	0	0	1
Val	0	1	5	4	0	12	0	22
Vg	0	0	0	1	0	0	0	1
Vcb	0	4	1	0	0	2	0	23
Vch	0	0	1	0	0	5	0	6
Vfo	0	0	2	6	0	6	0	14
Vme	0	0	0	0	0	0	0	0
Vmo	0	0	1	0	0	0	0	1
Vsh	0	0	1	49	0	47	2	99
Vsp	0	0	0	15	0	16	2	100
Vtu	0	0	0	0	0	0	0	0
Vun	0	0	0	0	0	0	17	17
Total	1	5	11	75	0	88	21	201

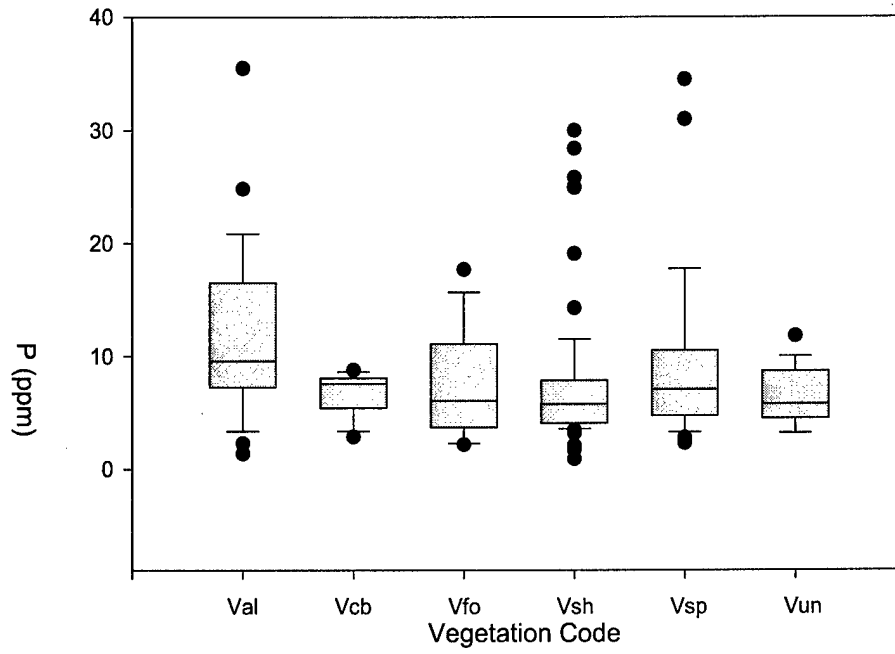


Figure 7. Concentration of P plotted by vegetation unit.

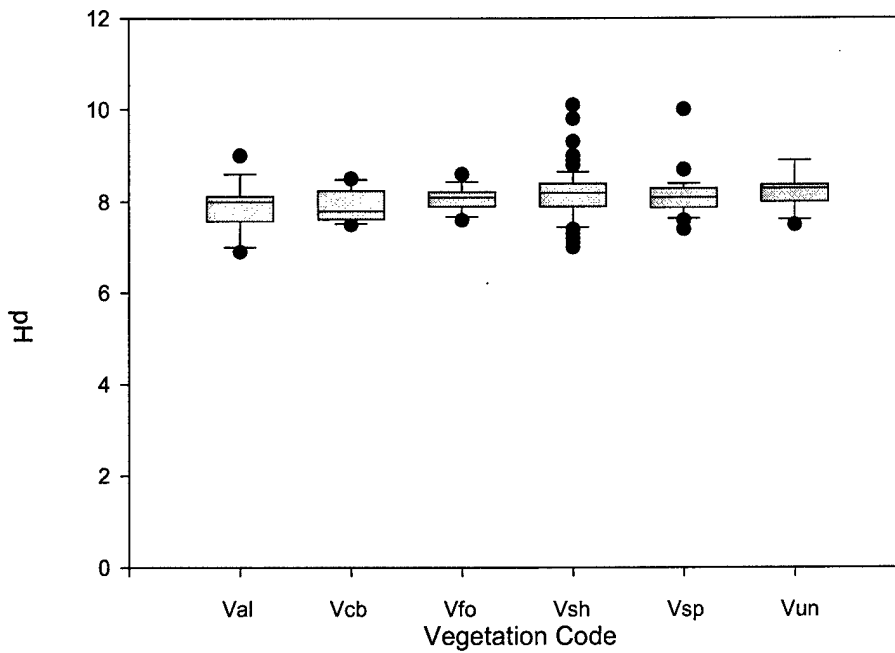


Figure 8. pH plotted by vegetation unit.

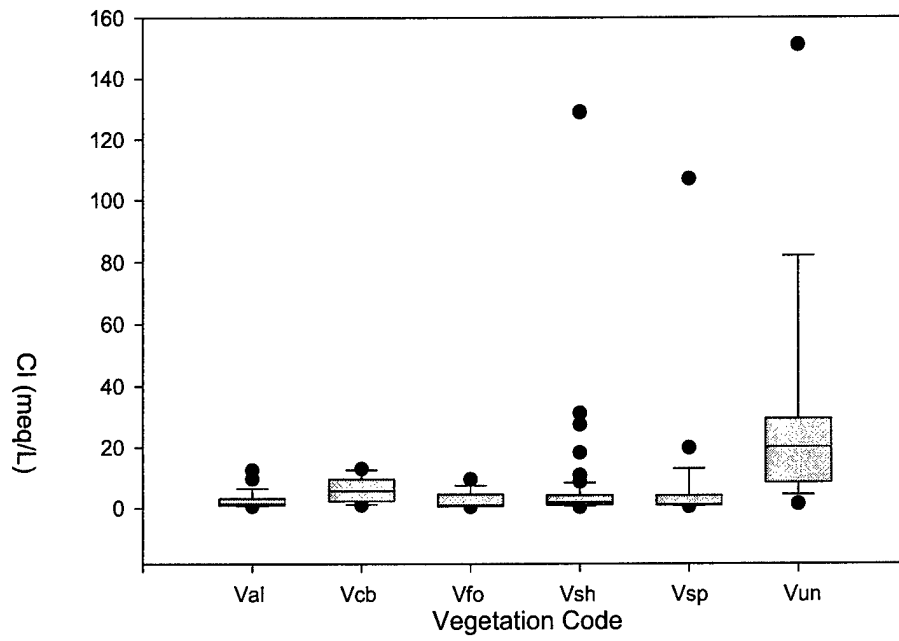


Figure 9. Concentration of Cl plotted by vegetation unit.

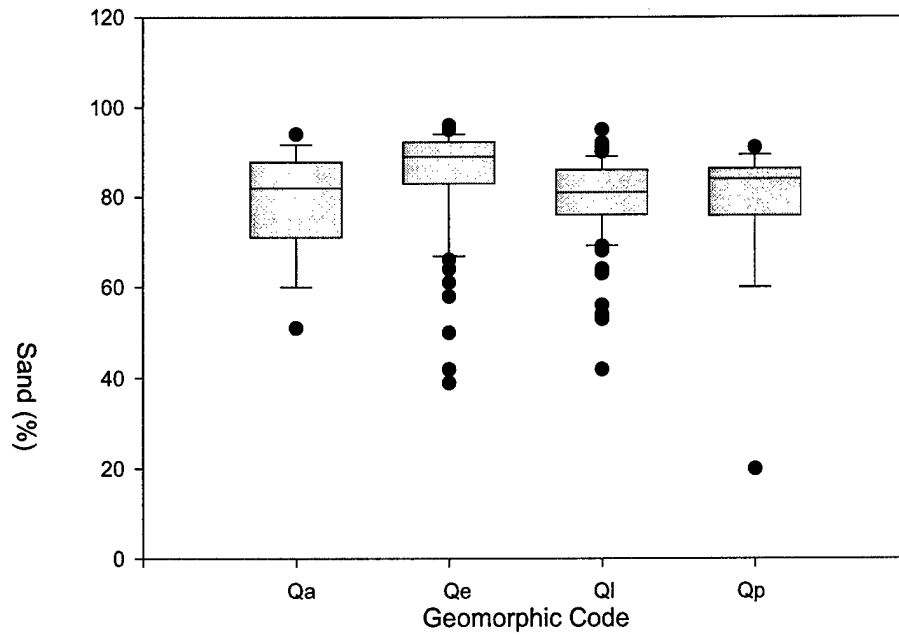


Figure 10. Percent sand plotted by geomorphic unit.

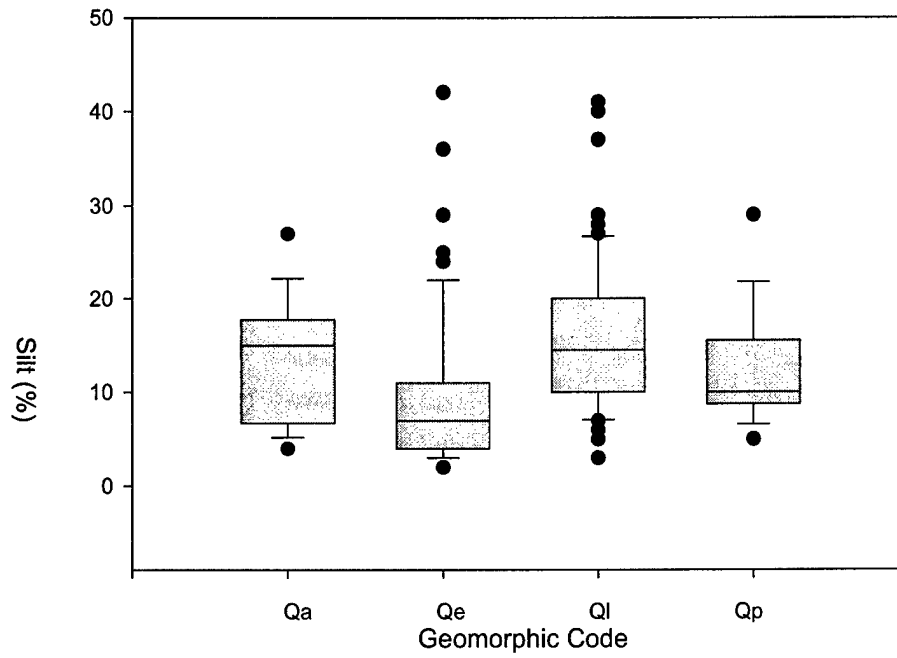


Figure 11. Percent silt plotted by geomorphic unit.

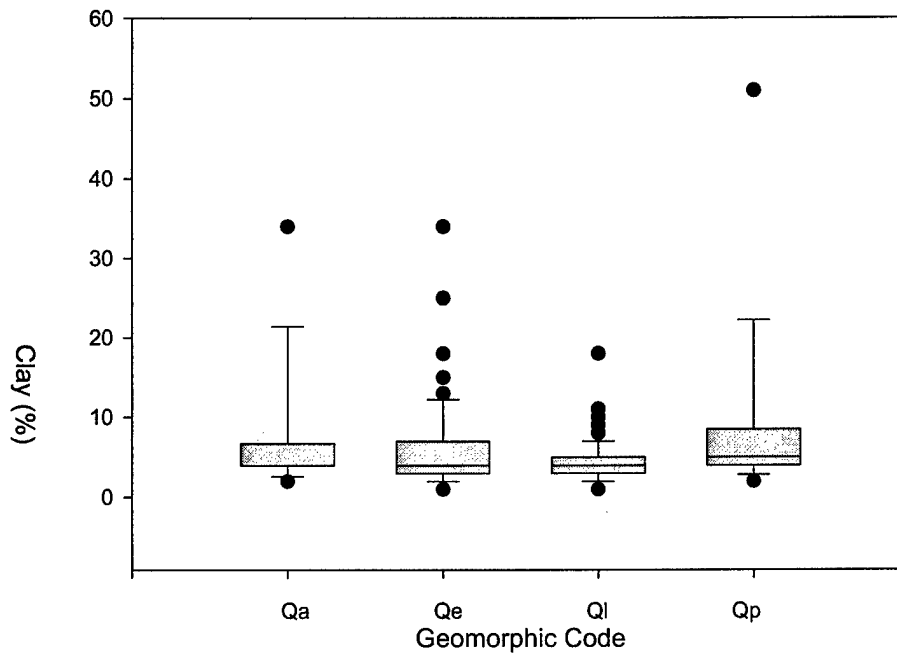


Figure 12. Percent clay plotted by geomorphic unit.

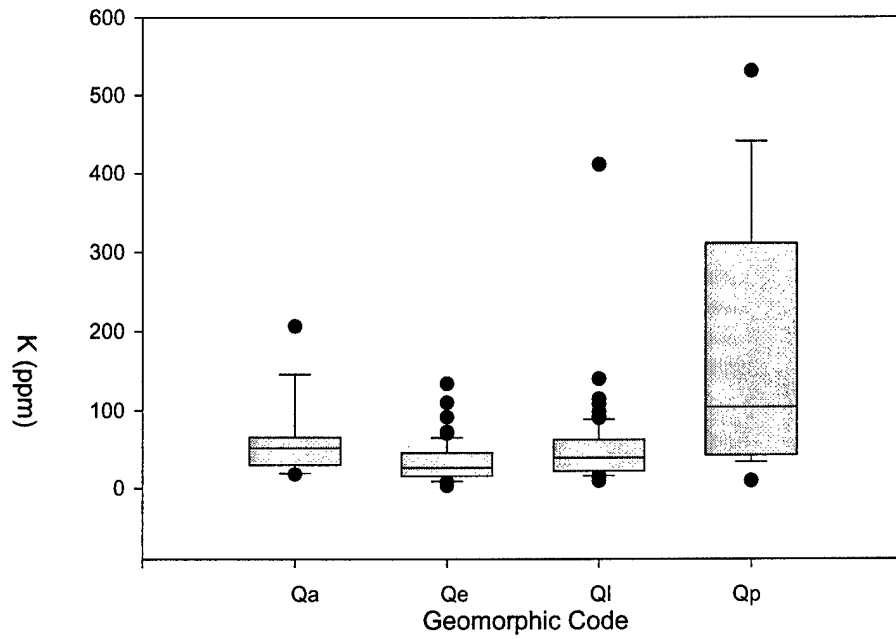


Figure 13. Concentration of K plotted by geomorphic unit.

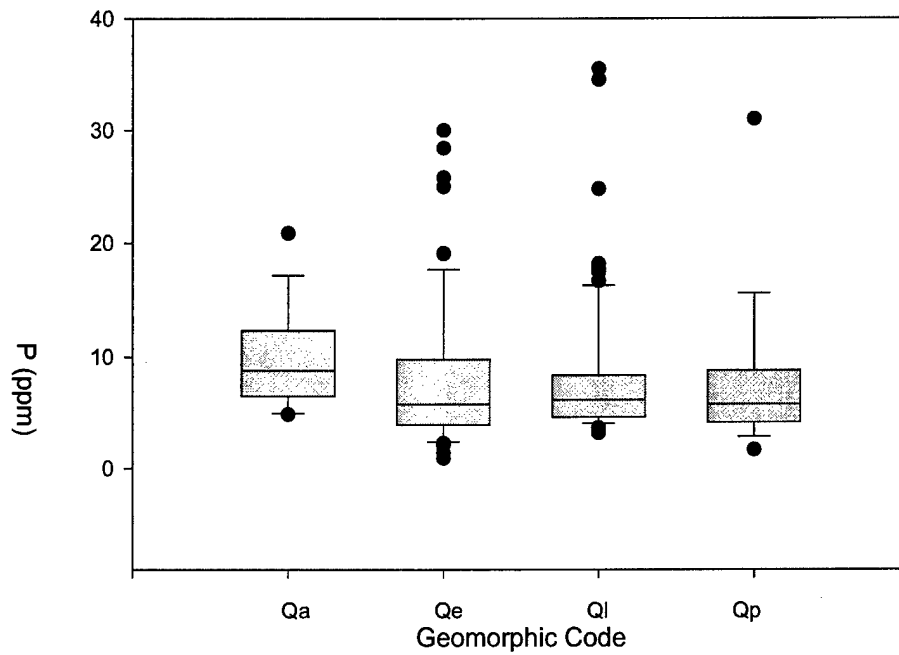


Figure 14. Concentration of P plotted by geomorphic unit.

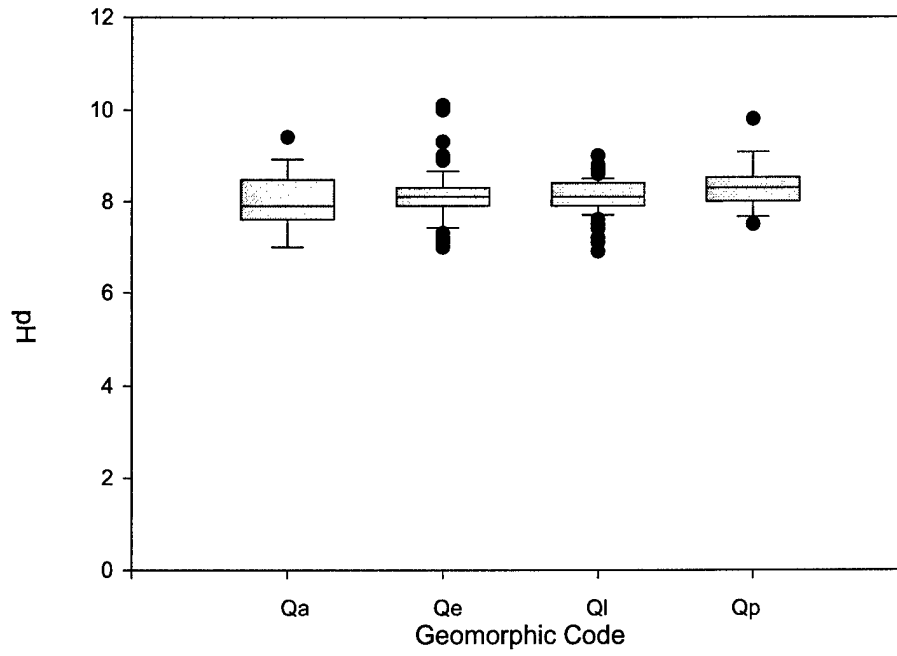


Figure 15. pH plotted by geomorphic unit.

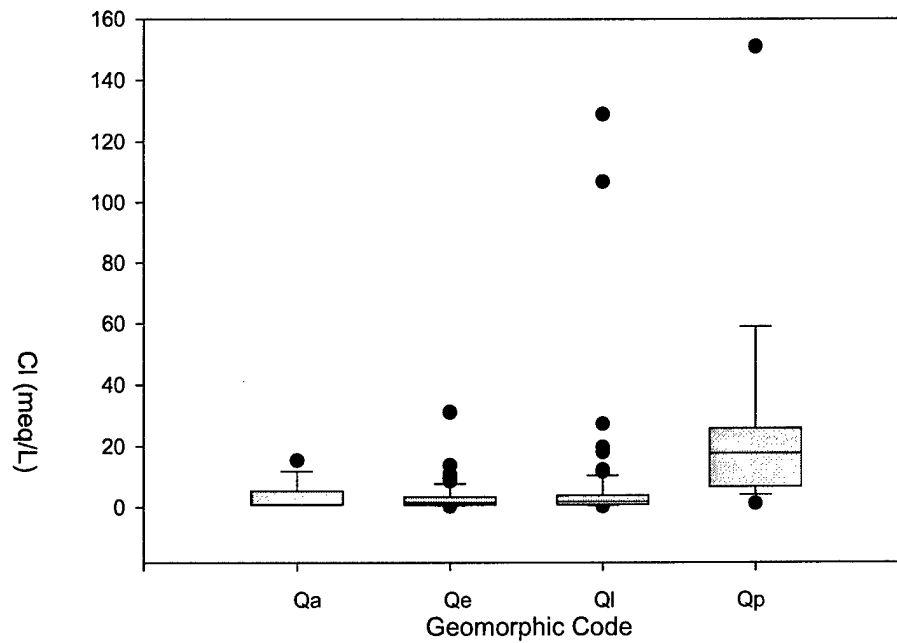


Figure 16. Concentration of Cl plotted by geomorphic unit.

A Reciprocal Average (RA) ordination of species data from sample points around the entire Lake Thompson Bed is shown in Figure 17. The species centroids associated with a given vegetation unit are outlined with an ellipse marked as Val, Vsp, Vch, Vsh, or Vfo to indicate the unit. Figure 17 shows that the Vch and Vsh series—Chenopod scrub and Shadscale, respectively—are not as clearly separated by their species composition as Vfo and Val—Four-wing saltbush and Allscale scrub. Salinity and soil texture gradients are also marked along the axes on the figure. The vegetation gradient along the x-axis indicated a separation of communities along an increasing salinity gradient: Val – Vfo – Vsp – Vsh – Vch. The y-axis appears to be separating communities along a decreasing soil particle size gradient: Vfo – Val/Vsh – Vch – Vsp.

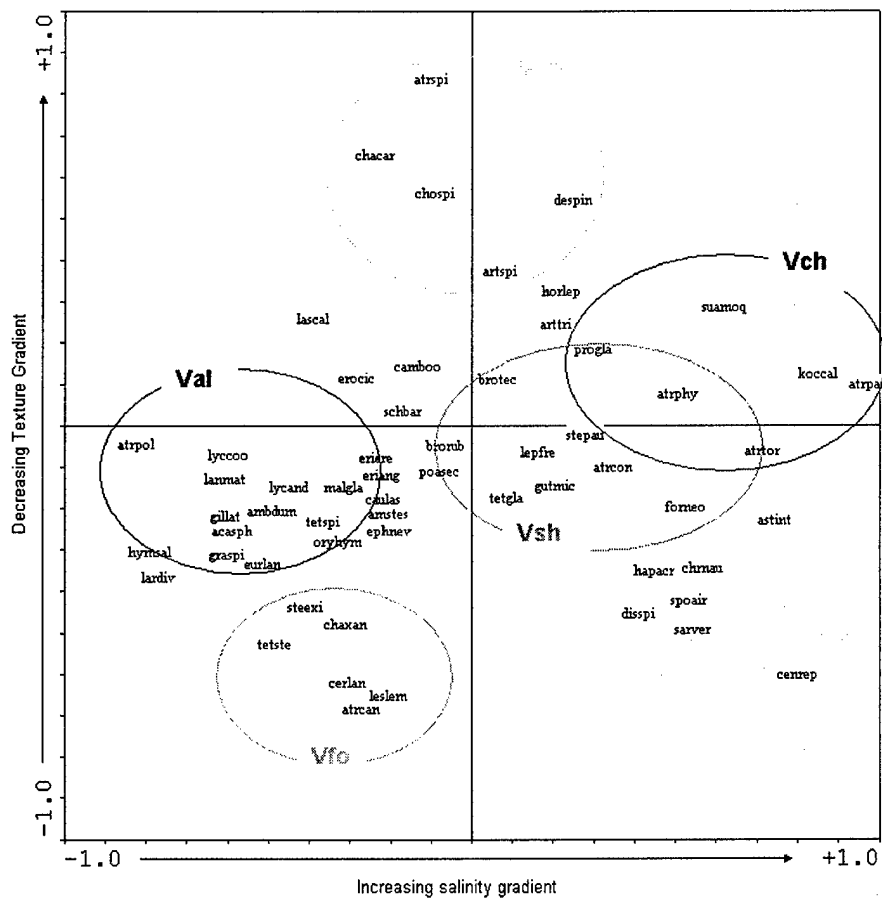


Figure 17. RA plot of species centroids with major vegetation unit clusters and potential axes gradients for Pleistocene Lake Thompson Bed.

Canonical Correspondence Analysis (CCA) was used to identify species and sample associations with significant chemical and/or environmental gradients. A CCA plot of species with environmental variables is shown in Figure 18. Means and standard deviations for each variable by ecoseries are shown in Table C2 in Appendix C. All variables shown are significant at $p = 0.05$ for the ordination and contribute at least 10% to the overall CCA model. The CCA using environmental variables alone does not provide any strong gradients among the environmental variables included. The strongest gradient is in the direction of the *Beddpt* (bed depth) variable and away from the *Crkwdt* (crack width) and *Chnlwdt* (channel width) variables. A second gradient, less obvious than the first, appears along the axis with *%Dune* and *%Pores*.

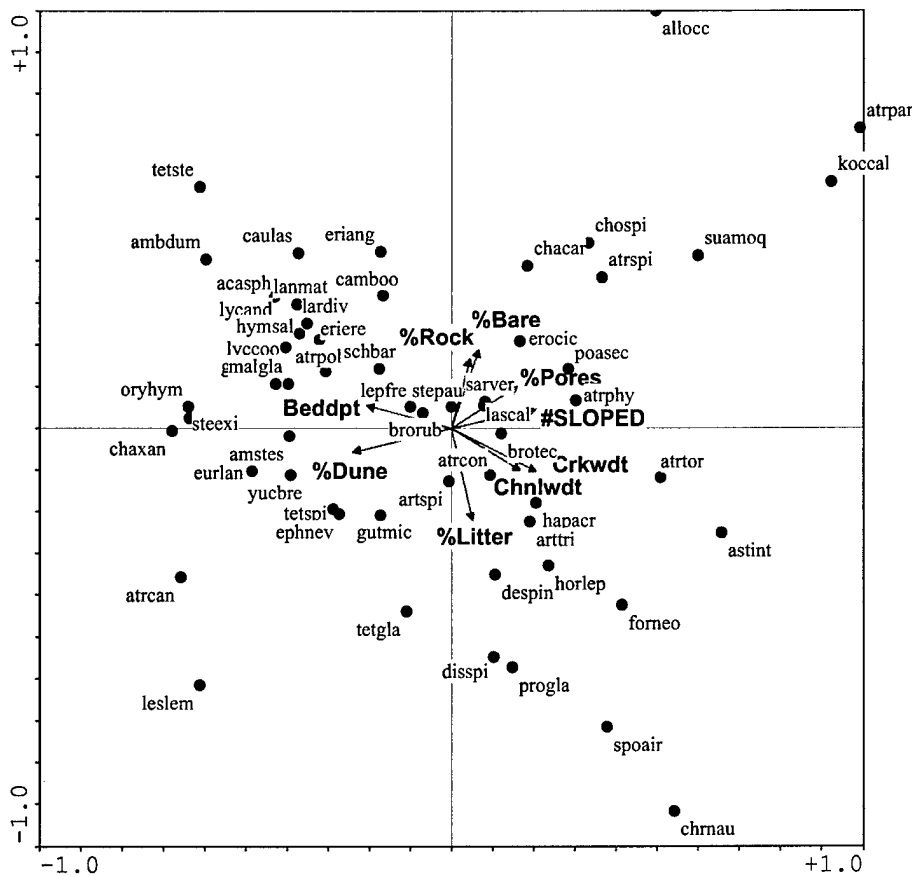


Figure 18. CCA plot of species by significant environmental variables for Pleistocene Lake Thompson Bed. Appendix A provides complete scientific names for the abbreviations used in the CCA figures.

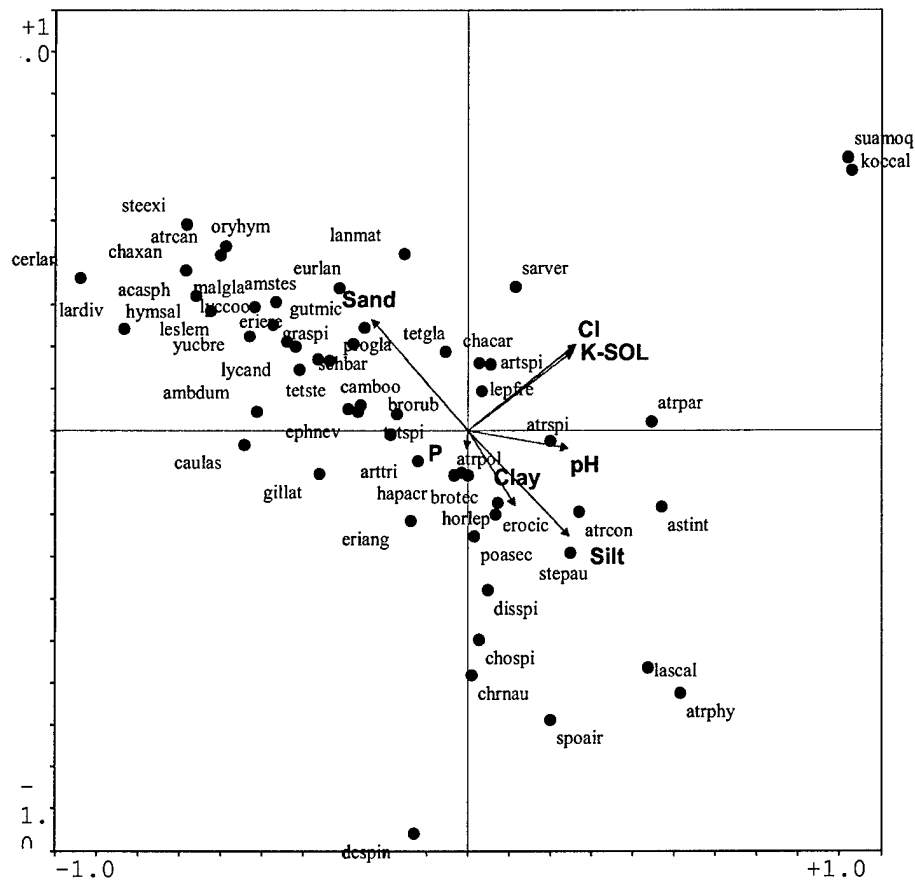


Figure 19. CCA plot of species by significant chemical variables for Pleistocene Lake Thompson Bed.

A CCA of chemical variables by species shows a strong gradient along the Sand/Silt/Clay axis (Fig. 19). The visible gradient is aided by having fewer variables included in the analysis. A second gradient affecting a large number of species is the pH axis. The impact of P, Cl, and K are much smaller, with P contributing almost nothing (the shorter arrow indicates a smaller contribution) and very little separation of species along K and Cl. The proximity of the K and Cl vector indicates a close connection and probably the presence of KCl as a major salt on Lake Thompson Bed.

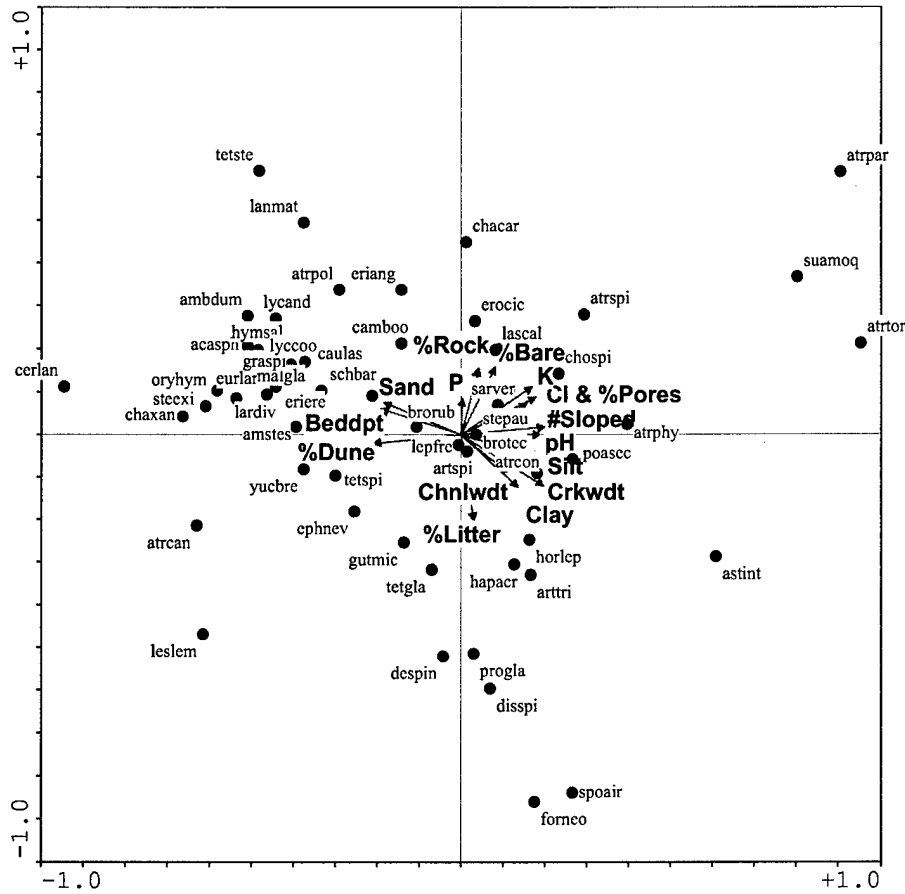


Figure 20. CCA plot of species by significant chemical and environmental variables for Pleistocene Lake Thompson Bed.

The CCA of the combined variables from the above analyses (Fig. 20) maintains the sand/silt/clay gradient but results in little overall separation of the other variables. Almost all the chemical and environmental variables explained a significant portion of the species data when analyzed using only one variable, and the multiple-variable models did not reduce the number of significant variables appreciably. Most variables were eliminated because of their percent contribution to the model or the investigators' determination of importance.

5 DISCUSSION

Overview of Pleistocene Lake Thompson Bed Relationships

The patterns and relationships observed between the geomorphic surfaces and vegetation are best explained by describing the genesis and weathering of the Pleistocene Lake Thompson Bed. Lake Thompson was likely a shallow lake about 18 m in depth that formed during one or more pluvial periods of the late Quaternary (12,000 to 25,000 B.P.) (Kane 1999, Orme 2004). The elevation at maximum was about 310 m (1,017 ft). During the mid-Holocene (5,000 B.P.), Lake Thompson stabilized at a depth of 10 m. During this period the separate lakebeds of Rogers, Buckhorn, and Rosamond were independent water bodies. After the stabilization, several other high-water stands probably occurred in the late Holocene. These events elevated pluvial waters near the borders of the separate lakebeds. Winds were at a greater velocity during the middle Holocene, allowing for the formation of the barrier beaches at different elevations associated with the separate lakebeds. The large dune fields east of Rosamond and north of Rogers Lake developed during this time. The remainder of Lake Thompson Bed, the plain, was then covered by dune fields and was further eroded and reworked by fluvial processes. The present dune fields have been reworked many times since their original deposition. Dunes are largely a mixture of materials derived from the deflating lakebeds and the reworking of existing dune fields.

Models

Using the results from soil, vegetation, and geomorphology analyses, we have developed a conceptual model to explain the processes responsible for vegetation distribution. Overall, it appears that soil texture plays an important role in the development and relationships with geomorphology, soil chemistry, and vegetation (Fig. 21). Geomorphic units develop as a result of separation of soil textures through differential transport and deposition of sand, silt, and clay. Soil texture controls the soil chemistry through differential bonding capabilities and water permeability. It controls the plant community through permeability and by influencing geomorphic and chemical parameters. Geomorphic features control soil chemistry because of differences in soil particle types, and they control vegetation as a result of landscape position. Finally, soil chemistry controls vegetation through plant physiological processes. This, of course, is not an absolute model of interaction, as each piece feeds back to influence its predecessor, such as the plant community's influence on soil chemistry. However, we believe that this model represents the major influences driving the Lake Thompson Bed landscape.

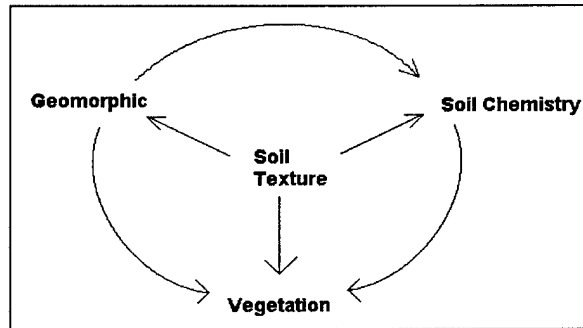


Figure 21. Conceptual model linking sampled parameters, with arrows indicating the direction of influence.

We propose the following model to explain the genesis of the current patterns of vegetation distribution over the Lake Thompson Bed. Figure 22 outlines the development of the bed surface features through the late Pleistocene into the Holocene.

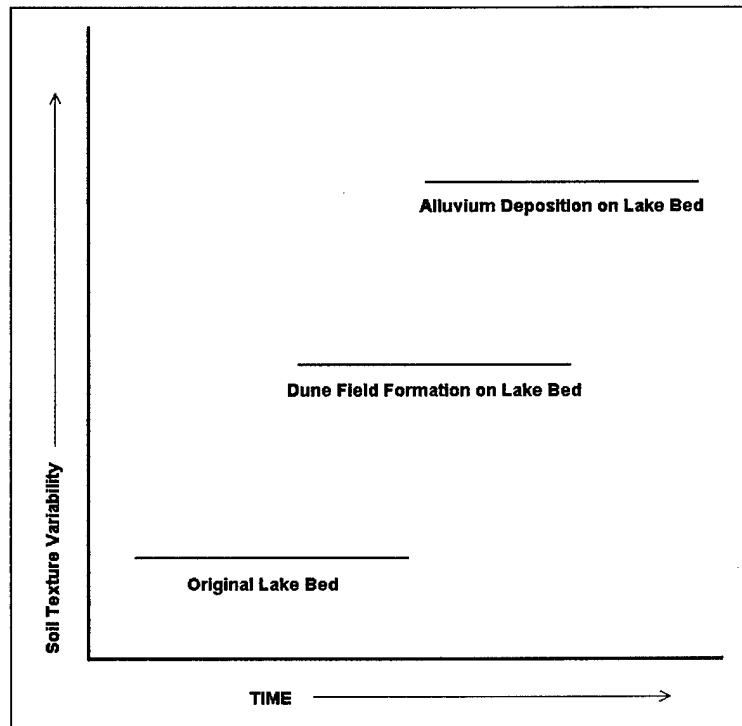


Figure 22. Proposed model of current lakebed genesis.

Geologically, the playa surface was less heterogeneous initially, in terms of geomorphic units. As Lake Thompson Bed began to dry out in response to climate changes, dunes began to form through saltation of sand grains. The playa surface and sand dunes were further modified by the continued expansion of alluvial fans carrying sediments from adjacent mountain ranges onto the playa surface, and the playa surface was further eroded in several places as a result of fluvial processes. The result of these geologic processes was a landscape with a higher degree of soil texture variability than had existed on the initial lakebed surface. The sorting by soil texture across the landscape, combined with climate changes, drove the current distribution patterns of vegetation.

Patterns

Figures 23–28 illustrate the relationships of major vegetation and geomorphology units across the study area. Patterns observed on these maps are summarized in Table 6, with a brief hypothesis to explain the pattern based on the sample results.

Spinescale associations (Vsp) were distributed over several geomorphic surfaces and did not dominate the coverage on any of the major geomorphic units (Fig. 23, 24, 29, 30). The maximum cover of Vsp occurred in aeolian sand sheet/dune (Qe) units, which were highest in sand content (Fig. 10). Soils with higher sand content are negatively correlated with concentrations of all chemical parameters measured, probably because of better drainage and fewer bonding surfaces. These results indicate that Vsp communities are responding to increased sand and to the lower salt and nutrient concentrations associated with coarser soils.

Chenopod scrub (Vch) had the most limited distribution of the five major vegetation units examined (Fig. 23, 25, 29, 30). Vch is typically found on the immediate edge of the playas and clay pan shorelines. Its association with alluvial channels (Qa) and former lake system (Ql) surfaces, and the relationship of those surfaces to the environmental data (Fig. 10, 16, 18–20), indicate that Vch establishes on soils with a larger component of finer soil textures, higher levels of salts and nutrients, and higher moisture content. It is interesting that the geomorphic surfaces that support a greater diversity of vegetation units tend to support Vch communities (Fig. 29 and 30).

Although Shadscale associations (Vsh) appear to be non-specific because they occur on all major geomorphic surfaces (Fig. 23, 26, 29, 30), there were some patterns associated with Vsh distribution. As noted in the results (Fig. 4), soil samples in Vsh units had slightly higher silt contents than soils found in other vegetation units. This trend explains why Vsh dominated coverage on Ql surfaces (Fig. 29), which tended to be higher in finer soils associated with salt

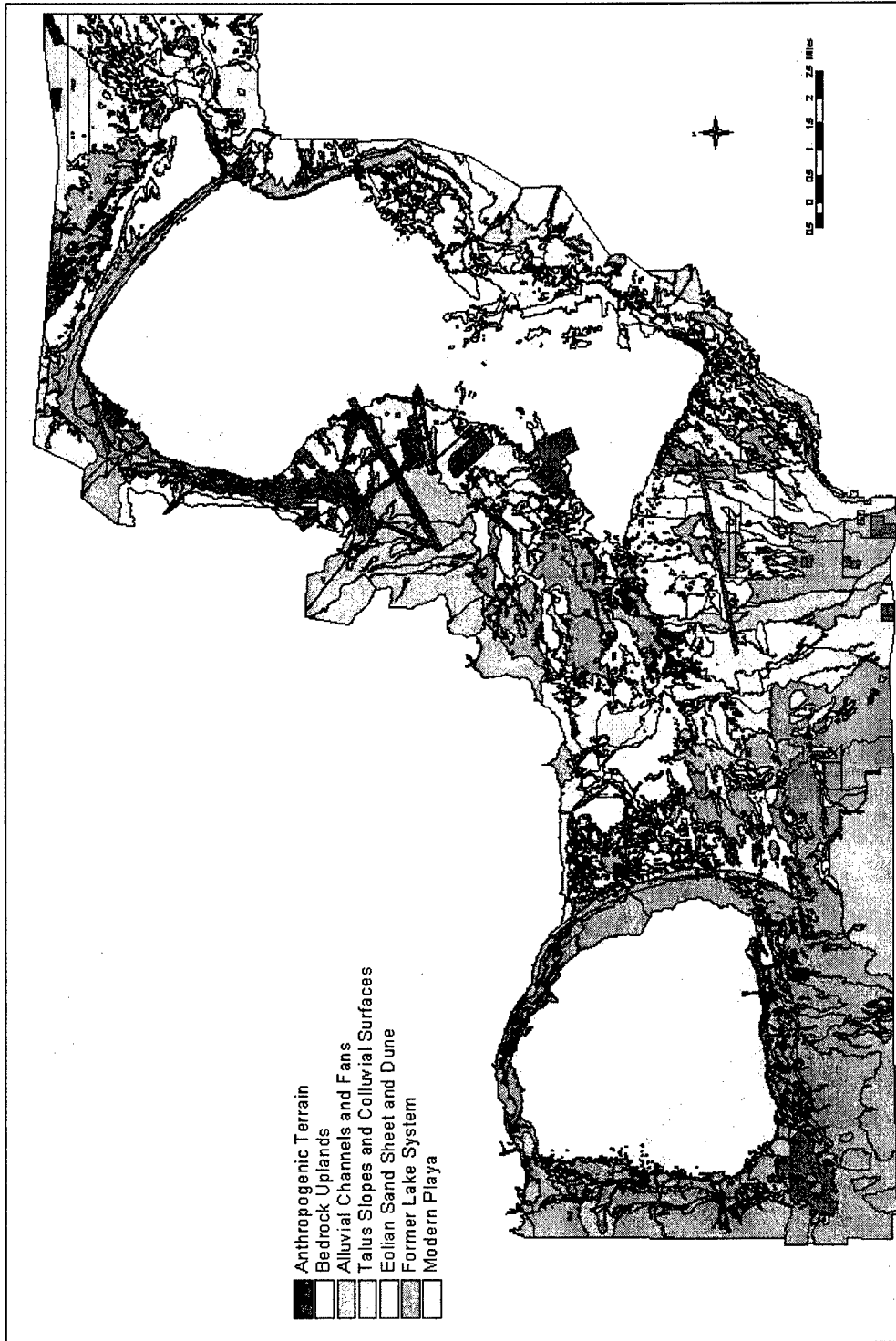


Figure 23. Major geomorphic units within Pleistocene Lake Thompson Bed.

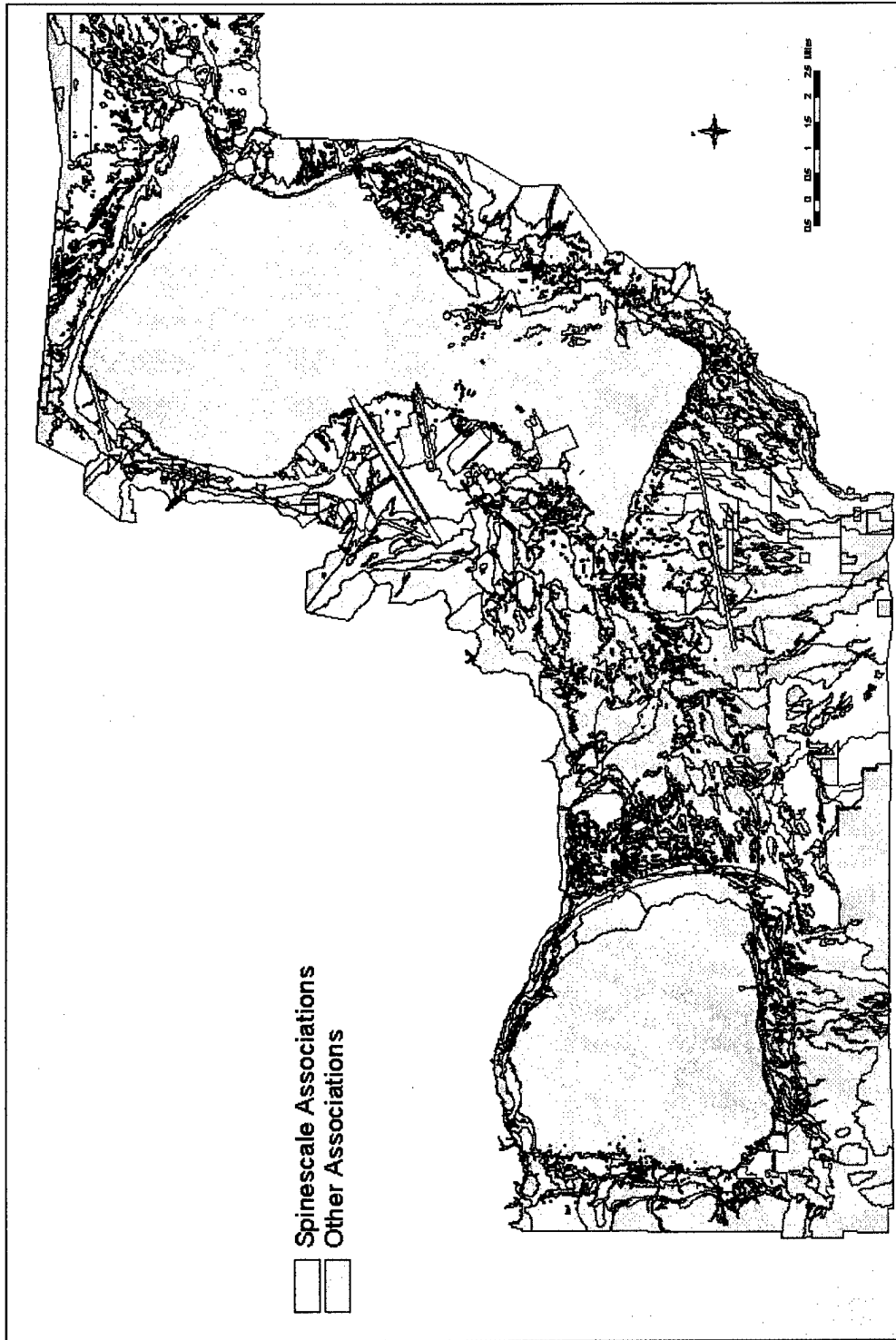


Figure 24. Spinescale association within Pleistocene Lake Thompson Bed.

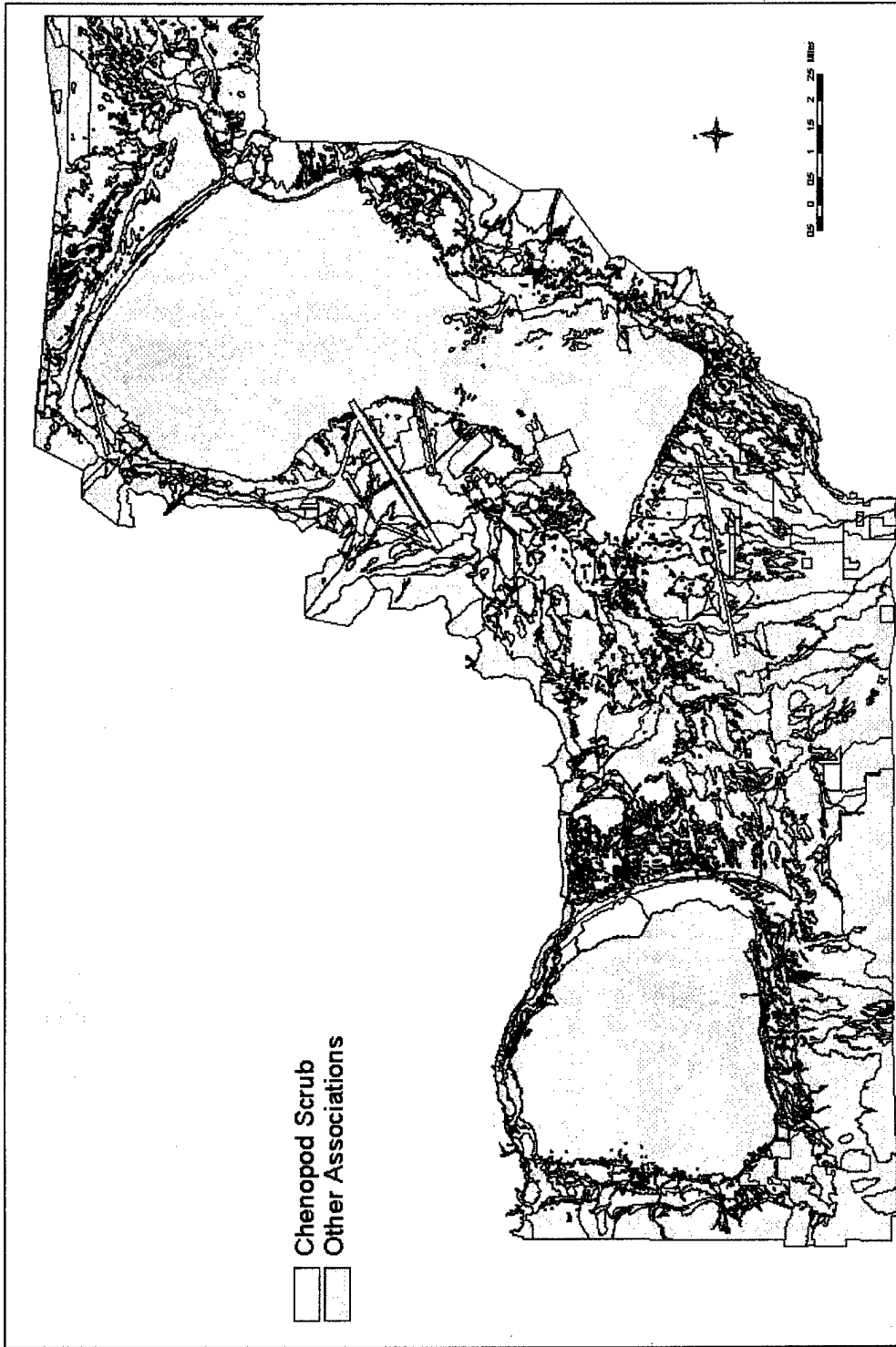


Figure 25. Chenopod scrub within Pleistocene Lake Thompson Bed.

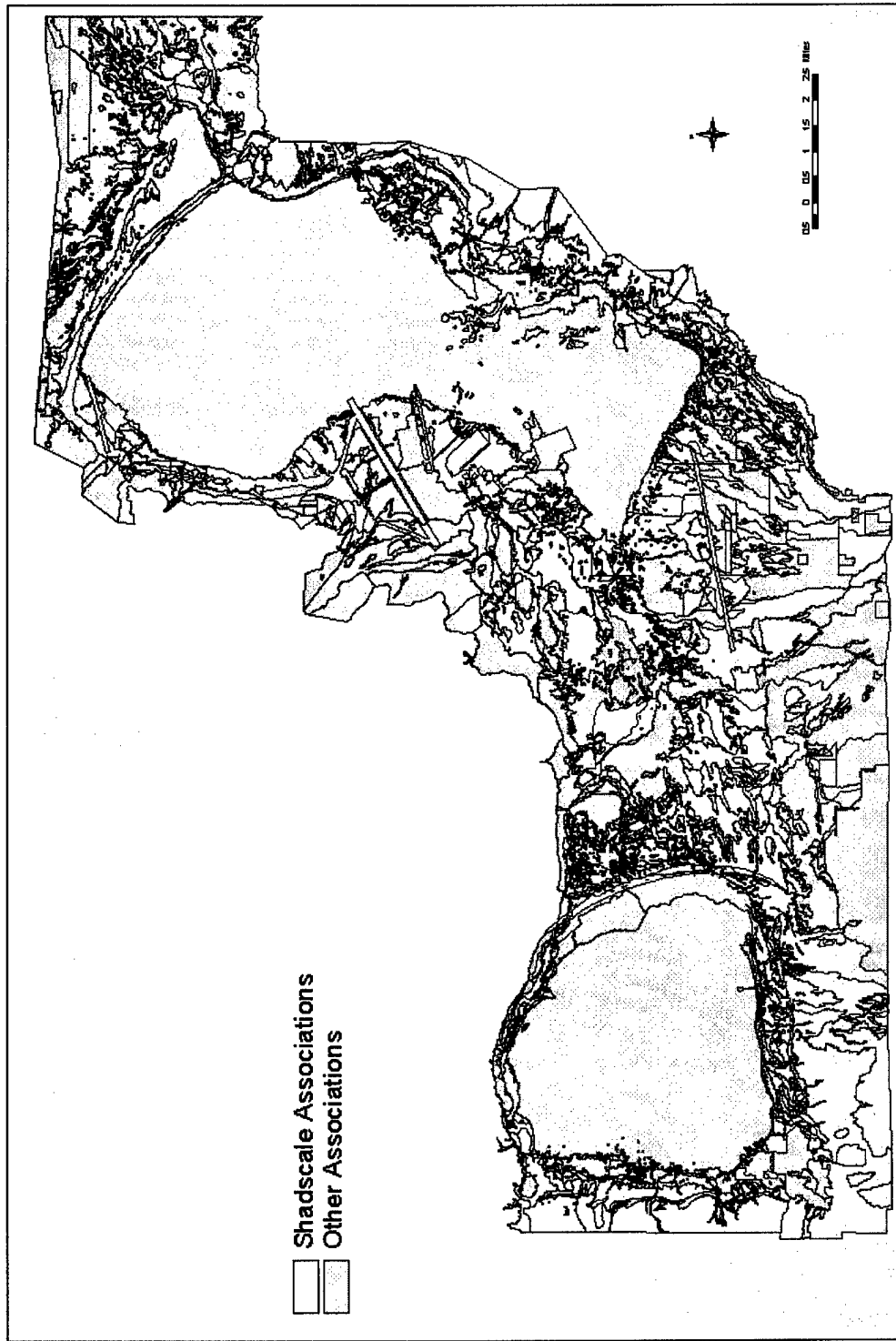


Figure 26. Shadscale associations within Pleistocene Lake Thompson Bed.

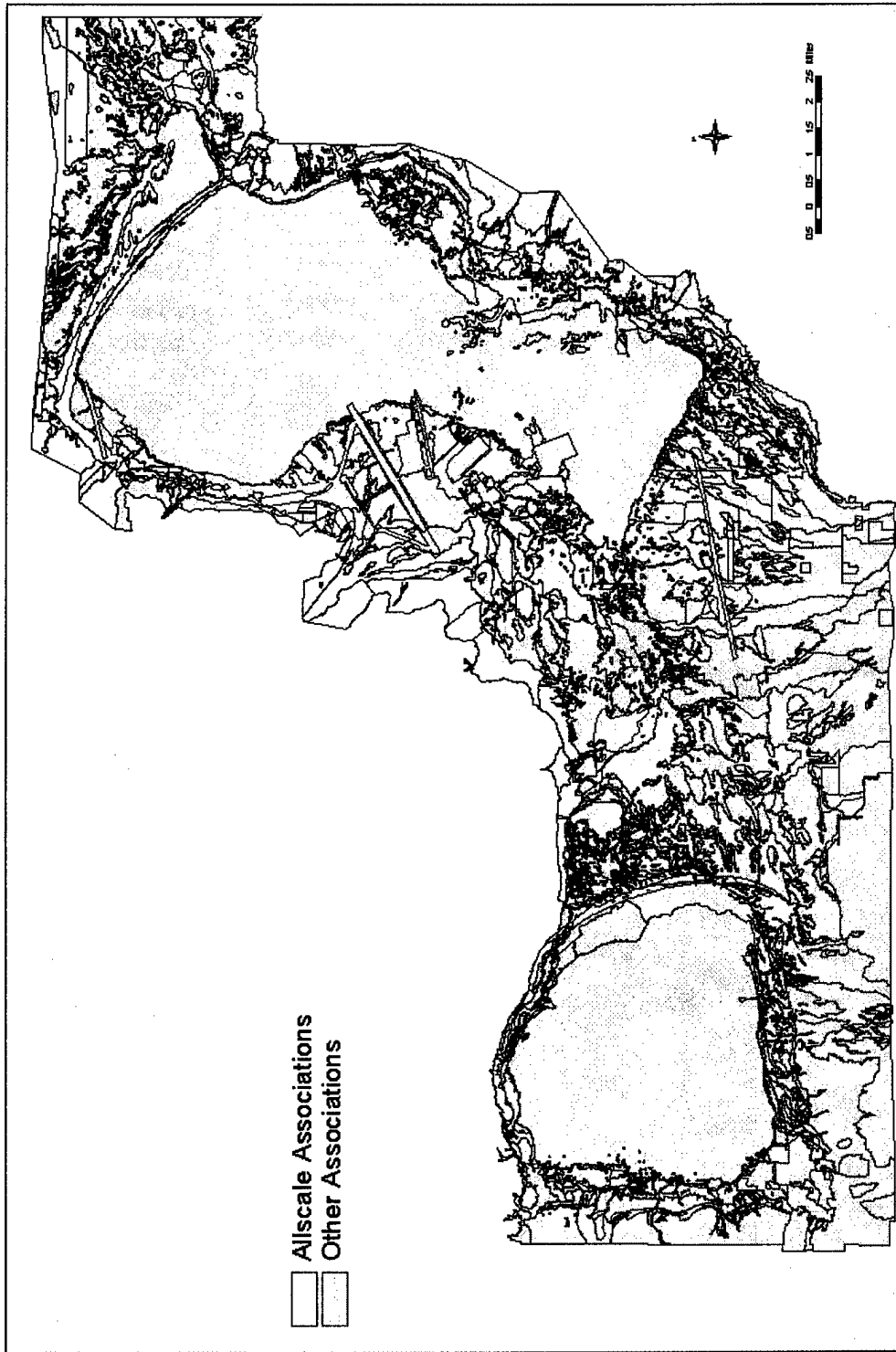


Figure 27. Allscale associations within Pleistocene Lake Thompson Bed.

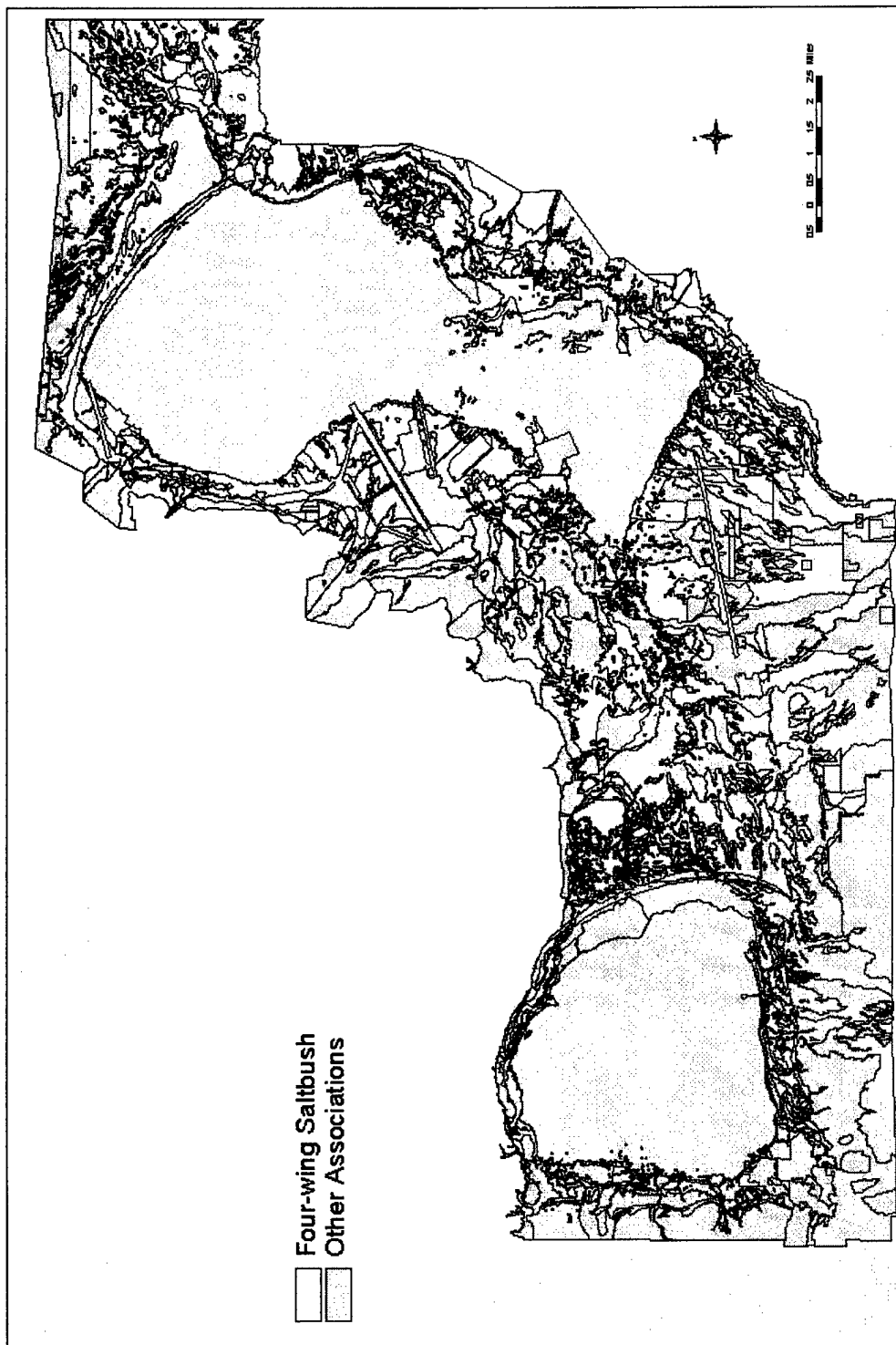


Figure 28. Four-wing saltbush within Pleistocene Lake Thompson Bed.

Table 6. Summary of vegetation distribution and explanatory hypothesis.

Vegetation unit	Distribution pattern	Hypothesis
Vsp	1) On recent Holocene deposits resulting from higher water levels around small dry lakes 2) Alluvial fan activities on Qea 3) Shallow sands adjacent to lake beds	1) Caused by concentration of salts and fines during recent geologic high water event 2) Lake bed materials with low salts and fine material exposed as a result of sheet flow activity 3) Sorting on sands with higher salt content during recent geologic periods
Vch	1) Alluvial Channels 2) Qlp materials adjacent to large playas	1) High salt and clay concentrations from hydrological activity: lower elevation 2) High salt and clay concentrations from hydrological activity: lower elevation
Vsh	1) Established on Qlp and Qea units	1) Generalist community able to thrive on multiple geomorphic surfaces
Val	1) Barrier beaches with sand and some gravel 2) Alluvial fans with gravelly soils 3) Salty sands	1) Well drained soils without fines 2) Well drained 3) Unknown
Vfo	1) Stable sand dunes 2) Barrier beaches	1) Sand with less salt and fewer fines 2) Sand with less salt and fewer fines

and nutrient sinks than other surfaces. Vsh reached its maximum acreage on Ql and Qe (Fig. 30). Moisture and soil chemistry may explain some of the distribution of Vsh, but Vsh does not conform to our general model for the influence of soil texture.

Allscale associations (Val) were the dominant cover type on Qa and colluvial (Qc) surfaces (Fig. 23, 27, 29, and 30). Qa and Qc surfaces did not display a common trend for chemical variables, but the Val association with Qa and Qc surfaces, along with the CCA results showing a significant increase with depth to impermeable layer, implies that Val outcompetes other units on moderate to well-drained substrates dominated by deeper sand and gravel. In terms of total acres in the study area, Val was most abundant on Qe and Qa surfaces (Fig. 30).

Four-wing saltbush (Vfo) was found predominately on Qe (Fig. 23, 28, and 30) but did not dominate coverage on this or any other geomorphic unit (Fig. 29). As mentioned above, soil samples from these geomorphic units tended to have a higher sand content, which is negatively correlated with salt and nutrient concentration. The CCA for the entire study area showed an increase in Vfo species in response to increases in dune coverage (Fig. 18 and 20). Vfo species also

increased with increasing depth of the impermeable layer and species richness. In the case of Vfo units, soil texture and moisture regime appear to be the most important parameters controlling distribution.

Overall, our model of environmental control of vegetation distribution provided a reasonable explanation of vegetation sorting. That three of the five major vegetation units (Vch, Val, and Vfo) responded in some way to soil texture supports our distribution model and provides general insight into the distribution of vegetation across Lake Thompson Bed. However, more research is needed to address the inconsistencies and develop a model that works for all five major vegetation units. Specifically, finer-scale sampling and analysis may be required to tease apart more complex biotic/abiotic interactions affecting distribution.

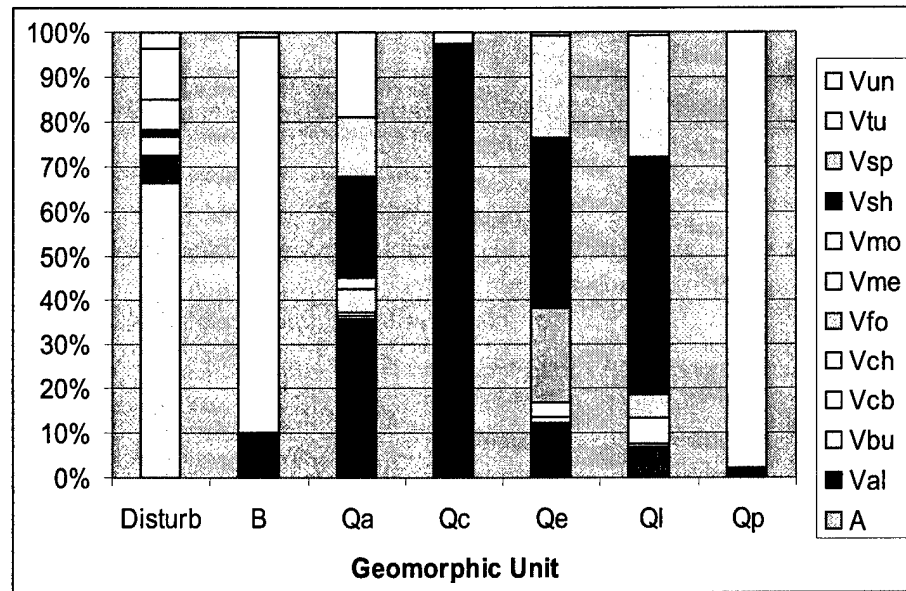


Figure 29. Dominant geomorphic units and percent cover of associated vegetation units.

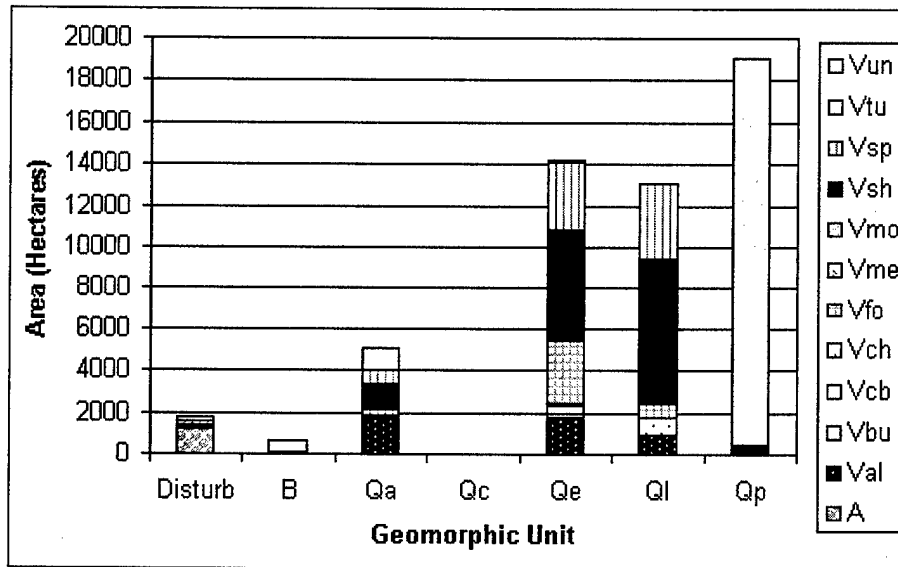


Figure 30. Dominant geomorphic units and cumulative cover of associated vegetation units.

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APPENDIX A. VEGETATION SPECIES LISTS

Table A1. Scientific and common names for all plants listed.

<i>Acamptopappus sphaerocephalus</i> (A. Gray) A. Gray	Goldenheads
<i>Acroptilon repens</i> (L.) DC.	Russian knapweed
<i>Allenrolfea occidentalis</i> (S. Watson) Kuntze	Iodinebush
<i>Ambrosia dumosa</i> (A. Gray) Payne	Burrobush
<i>Amsinckia tessellata</i> A. Gray	Bristly fiddleneck
<i>Artemisia spinescens</i> D. Eaton	Budsage
<i>Artemisia tridentata</i> Nutt. spp. <i>parishii</i> (A. Gray) H.M. Hall & Clements	Parish sagebrush
<i>Atriplex canescens</i> (Pursh) Nutt.	Four-wing saltbush
<i>Atriplex confertifolia</i> (Torrey & Fremont) S. Watson	Shadscale scrub
<i>Atriplex lentiformis</i> (Torrey) S. Watson ssp. <i>torreyi</i> (S. Watson) H.M. Hall & Clements	New mexico saltbush
<i>Atriplex parryi</i> S. Watson	Parry saltbush
<i>Atriplex phyllostegia</i> (Torrey) S. Watson	Arrowscale
<i>Atriplex polycarpa</i> (Torrey) S. Watson	Allscale
<i>Atriplex spinifera</i> J.F. Macbr.	Spinescale
<i>Bromus matritensis</i> L. ssp. <i>rubens</i> (L.) Husnot	Red brome
<i>Bromus tectorum</i> L.	Cheat grass
<i>Bromus trinii</i> Desv.	Chilean chess
<i>Calochortus striatus</i> Parish	Alkali mariposa lily
<i>Camissonia boothii</i> (Douglas) Raven	Woody bottle washer
<i>Camissonia campestris</i> (E. Greene) Raven	Suncups
<i>Canbya candida</i> C. Parry	Dwarf white poppy
<i>Chamomilla occidentalis</i> (E. Green) Rydb.	Pineappleweed
<i>Chorizanthe spinosa</i> S. Watson	Mojave spineflower
<i>Chrysothamnus nauseosus</i> (Pallas) Britton	Rabbitbrush
<i>Coleogyne ramosissima</i> Torrey	Blackbrush
<i>Coreopsis bigelovii</i> (A. Gray) H.M. Hall	Coreopsis
<i>Cressa truxillensis</i> Kunth	Alkali weed
<i>Cryptantha circumcissa</i> (Hook. & Arn.) I.M. Johnston	Capped cryptantha
<i>Cryptantha pterocarya</i> (Torrey) E. Greene	Wing-seed forget-me-not
<i>Cymopterus deserticola</i> Brandegee	Desert cymopterus
<i>Distichlis spicata</i> (L.) E. Greene	Salt grass
<i>Ephedra nevadensis</i> S. Watson	Mormon tea
<i>Eriastrum eremicum</i> (Jepson) H. Mason	Sapphire flower
<i>Ericameria cooperi</i> (A. Gray) H.M. Hall	Coopers goldenbush
<i>Eriogonum angulosa</i> Benth.	Skeletonweed
<i>Eriogonum pusillum</i> Torrey & A. Gray	Yellow turbans

<i>Erodium cicutarium</i> (L.) L'Her	Red-stem filaree
<i>Erysimum capitatum</i> (Douglas) E. Greene spp. <i>capitatum</i>	Desert wallflower
<i>Forestiera pubescens</i> Nutt.	Desert olive
<i>Frankenia salina</i> (Molina) I.M. Johnston	Alkali pink
<i>Gilia latiflora</i> (A. Gray) A. Gray	Broad-flowered gilia
<i>Gilmania luteola</i> (Cov.) Cov.	Spiny yellow cape
<i>Grayia spinosa</i> (Hook.) Moq.	Spiny hopsage
<i>Gutierrezia microcephala</i> (DC.) A. Gray	Matchweed
<i>Heliotropium curassavicum</i> L.	Chinese pusley
<i>Hemizonia pungens</i> (Hook. & Arn.) Torrey & A. Gray	Spikeweed
<i>Hordeum depressum</i> (Scribner & J.G. Smith) Rydb.	Foxtail barley
<i>Hordeum murinum</i> L. spp. <i>leporinum</i> (Link) Arcang.	Foxtail barley
<i>Hymenoclea salsola</i> A. Gray	Burrowbush
<i>Isocoma acradenia</i> (E. Greene) E. Greene	Alkali goldenbush
<i>Juncus balticus</i> Willd.	Baltic rush
<i>Juncus mexicanus</i> Willd.	Wiregrass
<i>Kochia californica</i> S. Watson	Molly
<i>Krascheninnikovia lanata</i> A.D.J. Meeuse & Smit	Winterfat
<i>Larrea tridentata</i> (DC.) Cov	Creosote bush
<i>Lasthenia californica</i> Lindley	Goldfields
<i>Lepidium fremontii</i> S. Watson	Desert alyssum
<i>Lepidium lasiocarpum</i> Torrey & A. Gray	Peppergrass
<i>Linanthus arenicola</i> (M.E. Jones) Jepson & V. Bailey	Sand linanthus
<i>Loeflingia squarrosa</i> Nutt. var. <i>artemisiarum</i> (Barneby & Twisselm)	Sage loeflingia
<i>Loeselliastrum matthewsii</i> (A. Gray) S. Timbrook	Desert calico
<i>Lycium andersonii</i> A. Gray	Water jacket
<i>Lycium cooperi</i> A. Gray	Peach thorn
<i>Malacothrix glabrata</i> A. Gray	Desert dandelion
<i>Melilotus alba</i> Medikus	Sweet clover
<i>Muilla coronata</i> E. Greene	Crowned onion
<i>Phacelia bicolor</i> S. Watson	Twocolor phacelia
<i>Phacelia cryptantha</i> E. Greene	Limestone phacelia
<i>Phacelia fremontii</i> Torrey	Fremont's phacelia
<i>Phacelia tanacetifolia</i> Benth.	Tansy phacelia
<i>Plagiobothrys bracteatus</i> (T.J. Howell) I.M. Johnston	Alkali popcorn flower
<i>Polygonum lapathifolium</i> L.	Water smartweed
<i>Populus fremontii</i> S. Watson	Cottonwood
<i>Potamogeton pectinatus</i> L.	Pondweed
<i>Prosopis glandulosa</i> Torrey	Mesquite
<i>Puccinellia simplex</i> Scribner	Annual alkali grass

<i>Rumex crispus</i> L.	Curly dock
<i>Salix exigua</i> Nutt.	Narrow leaf willow
<i>Salix gooddingii</i> C. Ball	Black willow
<i>Sarcobatus vermiculatus</i> (Hooke) Torrey	Greasewood
<i>Schismus barbatus</i> (L.) Thell.	Split grass
<i>Scirpus acutus</i> Bigelow	Tule rush
<i>Sporobolus airoides</i> (Torrey) Torrey	Alkali dropseed
<i>Suaeda moquinii</i> (Torrey) E. Greene	Inkweed
<i>Tamarisk chinensis</i> Lour.	Tamarisk
<i>Tamarisk ramosissima</i> Ledeb.	Tamarisk
<i>Tetradymia glabrata</i> Torrey & A. Gray	Horsebush
<i>Tetradymia spinosa</i> Hook. & Arn.	Cottonthorn
<i>Typha latifolia</i> L.	Broad-leaved cattail
<i>Urtica dioica</i> L. spp. <i>holosericea</i> (Nutt.) Thome	Stinging nettle
<i>Yucca brevifolia</i> Engelm.	Joshua tree

Table A2. Species acronyms in RA and CCA plots.

acasph	<i>Acamptopappus sphaerocephalus</i>	eurlan	<i>Eurotia lanata</i>
alocc	<i>Allenrolfea occidentalis</i>	forneo	<i>Forestiera neomexicana</i>
ambdum	<i>Ambrosia dumosa</i>	gillat	<i>Gilia latiflora</i>
amstes	<i>Amsinckia tessellata</i>	graspi	<i>Grayia spinosa</i>
artspi	<i>Artemisia spinescens</i>	gutmic	<i>Gutierrezia microcephala</i>
artri	<i>Artemisia tridentata</i>	hapacr	<i>Haplopappus acradenius</i>
astint	<i>Aster intricatus</i>	horlep	<i>Hordeum leporinum</i>
atrcan	<i>Atriplex canescens</i>	hymnal	<i>Hymenoclea salsola</i>
atrcon	<i>Atriplex confertifolia</i>	koccal	<i>Kochia californica</i>
atrpar	<i>Atriplex parryi</i>	lanmat	<i>Langloisia matthewsii</i>
atrphy	<i>Atriplex phyllostegia</i>	lardiv	<i>Larrea divaricata</i>
atrpil	<i>Atriplex polycarpa</i>	lascal	<i>Lasthenia californica</i>
atrspi	<i>Atriplex spinifera</i>	lepfre	<i>Lepidium fremontii</i>
atrtor	<i>Atriplex torreyi</i>	leslem	<i>Lessingia lemmonii</i>
brorub	<i>Bromus rubens</i>	lycand	<i>Lycium andersonii</i>
brotec	<i>Bromus tectorum</i>	lyccoo	<i>Lycium cooperi</i>
camboo	<i>Camissonia boothii</i>	malgla	<i>Malacothrix glabrata</i>
caulas	<i>Caulanthus lasiophyllus</i>	oryhym	<i>Oryzopsis hymenoides</i>
cenrep	<i>Centaurea repens</i>	poasec	<i>Poa secunda</i>
cerlan	<i>Ceratoides lanata</i>	progla	<i>Prosopis glandulosa</i>
chacar	<i>Chaenactis carphoclinia</i>	sarver	<i>Sarcobatus vermiculatus</i>
chaxan	<i>Chaenactis xantiana</i>	schbar	<i>Schismus barbatus</i>
chospi	<i>Chorianthe spinosa</i>	spoair	<i>Sporobolus airoides</i>
chrnau	<i>Chrysothamnus nauseosus</i>	steexi	<i>Stephanomeria exigua</i>
despin	<i>Descurainia pinnata</i>	stepau	<i>Stephanomeria pauciflora</i>
disspi	<i>Distichlis spicata</i>	suamoq	<i>Suaeda moquinii</i>
ephnev	<i>Ephedra nevadensis</i>	tetgla	<i>Tetradymia glabrata</i>
eriang	<i>Eriogonum angulosum</i>	tetspi	<i>Tetradymia spinosa</i>
eriere	<i>Eriastrum eremicum</i>	tetste	<i>Tetradymia stenolepis</i>
erocic	<i>Erodium cicutarium</i>	yucbre	<i>Yucca brevifolia</i>

APPENDIX B. VEGETATION CLASSIFICATION REPORT

INTRODUCTION

Lowland topography at Rosamond, Buckhorn, and Rogers playas includes eroded sand fields, longitudinal and barchan sand dunes, beach ridges, and pans. Such topographic variation affects the density and diversity of species present and forms unique plant habitats.

The interaction between wind and water erosion and deposition has resulted in a complicated pattern of vegetation that cannot be described using current lowland plant community descriptions. The existing vegetation pattern has been further complicated by intensive use of portions of the playa edge for home-steading, grazing, and farming. For this reason, a more detailed plant association classification system was developed for this project.

The vegetation classification system used here is based on existing systems that separate lowland desert communities into chenopod scrub, saltbush scrub, and alkaline meadow communities. The lowland plant communities on Edwards AFB are dominated by either succulent chenopods or shrubby saltbush species. Vegetation of similar composition is categorized by the visually dominant species into plant communities. Variation within these plant communities is described by dividing the communities into associations. Associations are described by listing the two species with the highest cover. This association identification system uses only common, native shrubby or perennial species; either common or scientific names can be used.

A breakdown in the normal zonation of the vegetation has occurred because of the long-term water and wind erosion occurring on the site. Erosional factors have resulted in an uneven depth of sand over the original playa surface and in surrounding edge areas. Catastrophic flood events washed away portions of the sand, and winds redeposited it in other areas. The thinnest sand veneer normally occurs closest to the playa edge and on the smaller pans. The thinnest soils are dominated by species adapted to these thin soils. These soils are high in clay, low in organic matter, and poorly drained. Since few plants are adapted to such harsh conditions, these areas have the lowest species diversity. Species adapted to the thinnest soils include inkweed (*Suaeda moquinii*), salt grass (*Distichlis spicata*), iodinebush (*Allenrolfea occidentalis*), New Mexico saltbush (*Atriplex lentiformis* ssp. *torreyi*), and Parry saltbush (*Atriplex parryi*).

The highest species diversity occurs on the largest dune systems. These dunes have the greatest soil depth to playa hardpan and therefore the highest water-holding capacity. Woody species dominating the deep sandy soils include four-wing saltbush (*Atriplex canescens*), allscale (*Atriplex polycarpa*), Joshua

tree (*Yucca brevifolia*), and many upland species including boxthorn (*Lycium andersonii* and *L. cooperi*), burrobush (*Ambrosia dumosa*), goldenheads (*Acamptopappus sphaerocephalus*), winterfat (*Krascheninnikovia lanata*), spiny hopsage (*Grayia spinosa*), and even creosote bush (*Larrea tridentata*). There are several types, sizes, and ages of sand dunes within the study area, all with subtle differences in plant diversity.

PLANT COMMUNITIES AND ASSOCIATIONS

Chenopod Scrub Community

Chenopod scrub (alkali sink scrub) is a zonal community that normally forms the first ring of vegetation around a lakebed shoreline. This plant community is not widespread nor clearly defined along the edge of Rosamond playa. It is not clearly defined because the diagnostic chenopod scrub species do not occur together, and some diagnostic species are widespread within the transition with saltbush scrub. The chenopod scrub occurs only as patches on the north, northeast, and northwest portions of Rosamond playa. The chenopod scrub can be differentiated from the saltbush scrub because it is made up primarily of stem- or leaf-succulent perennials or shrubs. The chenopod scrub at Rosamond playa is dominated by two stem- and leaf-succulent non-woody species, inkweed and molly (*Kochia californica*). *Suaeda* is the most widespread and common species of the chenopod scrub community. It has a wide environmental tolerance and also occurs adjacent to the small pans scattered around the main playa lakebed. Molly looks superficially similar to inkweed, but its distribution is limited to suitable depressions in old lagoons. Iodinebush, a stem succulent, is even less common, and it occurs in patches on the playa edge. Alkali pink (*Frankenia salina*) is an uncommon non-succulent perennial. Two non-succulent woody saltbush species, Parry saltbush and New Mexico saltbush, are not widespread but dominate portions of the chenopod scrub. New Mexico saltbush is strongly associated with specific environments and occurs as pure stands in clay washes and on the playa edge where drainages empty out into the playa. New Mexico saltbush is commonly associated with shadscale or spinescale in communities adjacent to washes. It also occurs in disturbed portions of the playa. Greasewood (*Sarcobatus vermiculatus*) is normally a member of the chenopod scrub in the Great Basin, where it is very common on valley floors. However, on Rosamond playa it is limited to deep loose sand and is associated with saltbush communities.

Annuals associated with poorly drained soils around the three playas include foxtail barley (*Hordeum depressum*), pineappleweed (*Chamomilla occidentalis*), and alkali popcorn flower (*Plagiobothrys bracteatus*). Herbaceous perennials include Chinese pusley (*Heliotropium curassavicum*), alkali pink, and alkali

weed (*Cressa truxillensis*). One noxious weed is associated with clay pan habitat, Russian knapweed (*Acroptilon repens*). It is a rhizomatous perennial that dominates in bladed pans and spreads quickly after establishment. Saltgrass, an alkaline meadow species, is often the only species occurring along the playa edges or within pans and has been placed with this community type. The only sensitive species associated with this community is alkali mariposa lily (*Calochortus striatus*), which occurs in clay drainages and on sandy hummocks.

The chenopod scrub community is divided into the four associations shown on Table B1.

Table B1. Associations of the Chenopod Scrub.

Scientific name designation	Common name of association	Map
<i>Kochia-Atriplex parryi</i>	Molly-parry saltbush	Vch1
<i>Allenrolfea-Frankenia</i>	Iodinebush-alkali pink	Vch2
<i>Suaeda-Atriplex lentiformis</i> ssp. <i>torreyi</i> -Shadscale	Inkweed-parry saltbush	Vch3a
<i>Suaeda-Kochia</i> -Shadscale	Inkweed-molly	Vch3b
<i>Suaeda-Atriplex lentiformis</i> ssp. <i>torreyi</i> -Shadscale	Inkweed-New Mexico saltbush	Vch3c
<i>Distichlis</i>	saltgrass	Vch 4

Kochia-Atriplex parryi Association (Vch1). This association occurs as patches within undrained basins located behind beach ridges and in highly eroded, light-colored soils. It occurs on the north and west sides of the lakebed as islands in undrained sinks within shadscale scrub. Parry saltbush and molly are codominants, with *Atriplex confertiflora* and *Suaeda moquinii* occurring as minor elements.

Allenrolfea-Frankenia Association (Vch2). Only one population of this community occurs on Edwards AFB. Iodinebush and alkali pink form phreato-phytic mounds with inkweed and New Mexico saltbush on the northeast corner of the playa. Pure stands of iodinebush occur on the northwest playa shore and on disturbed playa. Frankenia also occurs along the ecotone with spinescale on the north shore on the lower playa in hydrophobic soils, which saturate to only a few centimeters during the rainy season, carpeted with a thick layer of cryptobiotic crust.

Suaeda-Atriplex lentiformis ssp. *torreyi* Shadscale Association (Vch3c). Inkweed is the most widespread member of the chenopod scrub and occurs as a subdominant in many other associations. It occurs with New Mexico saltbush in clay drainages or in soils high in surface silicate cements. Both species dominate

in active washes and occasionally occur in dunes with shadscale or spinescale. Subdominants from other associations most often occurring with this association are greasewood and molly.

Distichlis Association (Vch4). Saltgrass has the highest ecological tolerance of any species in the lowland communities. It occurs in the pan bottoms and the most consolidated sands. It is the dominant cover species in alkaline meadows. When it occurs in undisturbed areas as solitary clumps near the playa shore, it is considered part of the chenopod scrub community.

The northeast corner of Rosamond lakebed contains a large, slightly raised barren area mapped as chenopod scrub. This area is dissected by several long winding washes that contain several inches of sand in the bottoms. Many of these washes are also barren, but portions contain closely growing New Mexico saltbush, shadscale, and saltgrass. These may occur as mixed associations or pure stands of New Mexico saltbush. These vegetated areas have not been considered separate associations. These isolated islands are most commonly associated with *Suaeda*, which occurs on the dune edges up to a quarter of a mile farther inland.

Saltbush Scrub Communities

Four diagnostic saltbush species dominate the associations adjacent to Rosamond playa. They form the four recognized saltbush plant communities: shadscale, spinescale, allscale (*Atriplex polycarpa*), and four-wing saltbush. The specific saltbush species present is determined primarily by topographic and soil conditions.

Shadscale occurs on shallow eroded sand fields adjacent to the playa. Shadscale is the most common woody species observed. It is common on the southern portion of Rosamond playa, all of Buckhorn playa, and the northern portion of Rogers playa. It rarely occurs in deep sands or within pans. Extensive, nearly pure stands of this species occur on the south, west, and eastern portions of Rosamond playa. It occurs with other species on the north and northeast sides of the lakebed.

Spinescale usually occurs on thin level soils on the west and south sides of the playa and in eroded areas with thin soils on the north and east. It is most common in nearly pure stands on the west, northwestern, northeastern and southeastern portions of Rosamond lakebed and northern and southern portions of Rogers playa.

Allscale occurs in disturbed areas and on well-drained rhyolitic slopes near Red Hill on the northern portion of Rosamond lakebed. Allscale can also codominate on deep sand dunes in the southwestern portion of Rosamond playa

and the northern portion of Rogers playa. Allscale occurs as the transition vegetation between lowland and upland plant communities.

Four-wing saltbush is most common on the east side of Rogers playa and between Rosamond and Buckhorn playas. It is locally common on the largest dunes with the deepest and least consolidated soil surfaces. It usually occurs as a mixed community with Joshua tree and many upland species more often associated with the upland creosote bush scrub community. This association is most common in the southeastern corner of the project area. Outside Edwards AFB, four-wing saltbush can be associated with deep sandy washes.

Shadscale Scrub

Shadscale scrub is the most widespread plant community on Rosamond playa and is important at Buckhorn and the southwestern and northern portions of Rogers playa. Shadscale rarely occurs with other woody species. It is most commonly associated with alkali dropseed (*Sporobolus airoides*), inkweed, or saltgrass. The most common woody species associated with this community are matchweed (*Gutierrezia microcephala*), budsage, and desert alyssum (*Lepidium fremontii*). These species are usually associated with shadscale only on stabilized dunes in the northeast corner of the study area. Shadscale occasionally occurs in dunes with Joshua tree and winterfat. In transitional (ecotonal) areas it mixes with allscale and spinescale. The most common annuals associated with this community are arrowscale (*Atriplex phyllostegia*), capped cryptantha (*Cryptantha circumcissa*), peppergrass (*Lepidium lasiocarpum*), and yellow throats (*Phacelia fremontii* and *P. bicolor*). Sensitive species occurring within the sandy hummocks include desert cymopterus (*Cymopterus deserticola*), sage loeflingia (*Loeflingia squarrosa* var. *artemisiarum*), spiny yellow cape (*Gilmania luteola*), and dwarf white poppy (*Canbya candida*). Weedy species are usually low in diversity but high in cover and include brome grasses (*Bromus matritensis* ssp. *rubens*, *tectorum*, and *trinii*), red-stem filaree (*Erodium cicutarium*), split grass (*Schismus barbatus*), and foxtail barley (*Hordeum murinum* spp. *leporinum*). Shadscale scrub has been subdivided and mapped into 15 associations (Table B2).

Table B2. Plant associations of the Shadscale scrub.

Scientific name	Common name	Map
<i>Atriplex lentiformis</i> ssp. <i>torreyi</i>	New mexico saltbush	Vsh1
<i>Chrysothamnus nauseosus</i>	Rabbitbrush	
<i>Artemisia tridentata parishii</i>	Parish sagebrush	
<i>Suaeda moquinii</i>	Inkweed	
<i>Distichlis spicata</i>	Saltgrass	Vsh2
<i>Suaeda moquinii</i>	Inkweed	Vsh3
<i>Atriplex spinifera</i>	Spinescale	
<i>Atriplex canescens</i>	Mixed four-wing	Vsh4a
<i>Krascheninnikovia lanata</i>	Winterfat	
<i>Yucca brevifolia</i>	Joshua tree	
<i>Krascheninnikovia lanata</i>	Winterfat	Vsh4b
<i>Atriplex canescens</i>	Four-wing	
<i>Atriplex lentiformis</i> ssp. <i>torreyi</i>	New mexico saltbush	Vsh4c
<i>Atriplex canescens</i>	Four-wing	Vsh4d
<i>Artriplex spinescens</i>	Spinescale	
<i>Isocoma acradenia</i>	Alkali goldenbush	
<i>Atriplex spinescens</i>	Spinescale	Vsh5
<i>Sporobolus airoides</i>	Dropseed	Vsh6
<i>Sarcobatus vermiculatus</i>	Greasewood	Vsh7
<i>Lepidium fremontii</i>	Desert alyssum	Vsh8
<i>Gutierrezia microcephala</i>	Matchweed	
<i>Artemisia spinescens</i>	Budsage	
<i>Yucca brevifolia</i>	Joshua tree	
<i>Atriplex polycarpa</i>	Allscale	Vsh9
<i>Forestiera pubescens</i>	Desert olive	Vsh10
<i>Lepidium fremontii</i>	Desert alyssum	
<i>Atriplex parryi</i>	Parry saltbush	Vsh11
<i>Isocoma acradenia</i>	Alkali goldenbush	Vsh12
<i>Atriplex parryi</i>	Parry saltbush	
<i>Ericameria cooperi</i>	Coopers goldenbush	Vsh13
<i>Ambrosia dumosa</i>	Burrobush	Vsh14

Atriplex confertiflora with *Chrysothamnus*, *Suaeda*, and *Artemisia* Association (Vsh1). Shadscale and all woody species commonly associated with washes have been lumped into this association. Each woody species dominates specific wash conditions. Washes with clay drainages and only a superficial layer of recent sandy deposits are dominated by New Mexico saltbush, alkali goldenbush, and Mojave rubber rabbitbrush. Washes with deeper sands are dominated by Parish sagebrush. This association only occurs in the western and southern portions of the lakebed.

Atriplex confertiflora–*Distichlis* Association (shadscale–saltgrass Vsh2). Shadscale is most commonly associated with grasses such as alkali dropseed or saltgrass. Saltgrass is a rhizomatous perennial grass that spreads significantly after high rainfall years. This association is not as common as dropseed because saltgrass rarely dominates dune areas. This community is most common in the southwestern corner of the lakebed south of Piute Ponds. Dropseed has been put in a separate association.

Atriplex confertiflora–*Suaeda* Association (shadscale–inkweed Vsh3). This association represents an ecotone between chenopod scrub and shadscale scrub primarily on the western, southern, and southeastern portions of the lakebed. It occurs on the most highly eroded areas where sand is limited to small hummocks. The vegetation is dominated by shadscale rather than inkweed. It is not unusual for some spinescale to occur in these highly eroded shallow soils and adjacent to pans.

Atriplex confertiflora–*Krascheninnikovia* Association (winterfat and winterfat–Joshua tree Vsh4a, Vsh4b). The northeast corner of the lakebed is dominated by large, active, sandy dunes with a stabilized surface. The foredunes are dominated by inkweed and shadscale. The ridges are dominated by a mixture of winterfat, spiny hopsage (*Grayia spinosa*), horsebush (*Tetradymia glabrata*), and cottonthorn (*Tetradymia spinosa*). Shadscale occurs in mixed stands on dunes with a partially consolidated surface and sandy soils too shallow to contain four-wing saltbush.

Atriplex confertiflora–*Atriplex* Association (*canescens*, *torreyi*, *spinescens*, *Isocoma acradenia* Vsh4c, Vsh4d). New Mexico saltbush, four-wing, mesquite, and spinescale are separated as associations.

Atriplex confertiflora–*Atriplex spinifera* and *Artemisia spinescens* Association (shadscale–spinescale Vsh5). Shadscale occurs as an ecotone with spinescale near the playa edge. This ecotone is widespread and has therefore been mapped as a separate association. It is most common on the southwestern portion of the lakeshore.

Atriplex confertiflora–*Sporobolus* Association (shadscale–dropseed Vsh6). This is the most widespread association on Rosamond playa. It dominates the south and southwestern portions. It is very closely related to the pure stands of shadscale and areas containing saltgrass.

Atriplex confertiflora–*Sarcobatus* Association (shadscale–greasewood Vsh7). Greasewood occurs in only a few patches on Edwards AFB, with only two patches occurring within the Rosamond playa study area. This species is a Great Basin Desert species, with the southwestern limit of its range east of Piute Ponds. Normally this species occurs on valley bottoms at much higher elevations. Its occurrence in dunes and on pans around Rosamond playa is unusual.

Atriplex confertiflora–*Lepidum*, *Gutierrezia* and *Chrysothamnus* Association (shadscale and desert alyssum, alkali goldenbush, budsage, matchweed, rabbitbrush Vsh8). This association is limited to the sandy ridgelines of a series of arching, highly eroded dunes on the northeast corner of the lakebed. This is a mixed community of shrubby species, with each dune dominated by a slightly different mix of species. This community also contains Joshua trees. It occurs with several sensitive species, including annual alkali grass (*Puccinellia simplex*) and sand linanthus (*Linanthus arenicola*). Desert wallflower (*Erysimum capitatum* spp. *capitatum*), a species that occurs almost nowhere else on base, occurs in this association.

Atriplex confertiflora–*Atriplex polycarpa* (shadscale–allscale Vsh9). This community occurs on the north side of Rosamond and Rogers lakebeds near either granitic or rhyolitic rock outcrops. It also occurs as a transition between lowland and upland vegetation near Complex Charlie.

Atriplex confertiflora–*Forestiera pubescens* (shadscale–desert olive–desert alyssum Vsh10). This community occurs in a diagonal band between Antelope Valley Junior College in Lancaster and the sewage treatment plant at South Base. It is a diverse shrub community on thin soils with well-defined pans but deflated dunes. It occurs with desert alyssum, matchweed, alkali rye, rubber rabbitbrush, and alkali goldenbush.

Atriplex confertiflora–*Atriplex parryi* (shadscale–Parry saltbush Vsh11). This community is uncommon in undrained basin on the east side of Rosamond playa.

Atriplex confertiflora–*Isocoma acradenia*–*Atriplex parryi* (shadscale–alkali goldenbush Vsh12). This community occurs in lagoon areas behind dunes in the southern portions of Rosamond and Rogers playas. It is associated with vegetated playas. It can occur with saltgrass, greasewood, and alkali dropseed.

Atriplex confertiflora–*Ericameria cooperi* (shadscale–Coopers goldenbush Vsh13). This community is usually associated with dune areas. They may be upland transition or very large dunes.

Atriplex confertiflora–*Ambrosia dumosa* (shadscale–burrobush Vsh14). This association occurs as a transition between upland and lowland. Burrobush is rare on dunes between Rosamond and Buckhorn to the north and much of the eastern and northern portion of Rogers lakebeds. Burrobush does not occur on common dunes on Rosamond, but it does on Rogers.

Spinescale Scrub

Spinescale occurs in nearly pure stands, and to a lesser extent as mixed stands, along the west side of Rosamond playa and behind dune ridges on the southern playa edge. Spinescale occurs with budsage and desert alyssum near the southern playa lakebed, where the topography is consistently low and flat with a sand veneer. Inland, the sandy veneer, which begins on the playa shore, splits into highly eroded areas with pans and sandy hummocks, a topography that is not suitable for spinescale. *Suaeda* dominates the pan edges that contain 3–6 cm of sand, and shadscale dominates the sandy hummocks. Goldfields (*Lasthenia californica*) is the dominant annual species associated with spinescale. Spinescale often occurs on hydrophobic soils that saturate to only a few centimeters during the rainy season. The soil surface remains moist throughout spring. These conditions favor the development of the blacktop form of cryptobiotic crust. Sensitive species observed in this community include Mojave spineflower (*Chorizanthe spinosa*) and crowned onion (*Muilla coronata*). The most common weedy species is red-stem filaree.

Atriplex spinifera–*Lycium* Association (spinescale–boxthorn association Vsp1). This association is very localized, small in scale, and difficult to map. Spinescale occurs with boxthorn at the base of dunes, on dune ridges, and in the ecotone with allscale primarily in the south and southeastern portions of the study site. The codominant plants consist of two species of boxthorn wolfberry (*Lycium andersonii*) and peachthorn (*Lycium cooperi*). This association has a high diversity of shrubs, with minor numbers of Mormon tea, Joshua tree, and horsebrush (*Tetradymia glabrata*).

Atriplex spinifera–*Artemisia spinescens* or *Lepidium fremontii* Association (spinescale–budsage–desert alyssum–dropseed Vsp2). As the thin veneer of sand on the playa lakeshore reaches approximately 10 cm deep near the western playa shoreline, spinescale becomes more of a mixed association with budsage, desert alyssum, and Mormon tea. As the soil gets thicker, the associated subdominant species (budsage, desert alyssum, and Mormon tea) become more common until the habitat becomes more suitable for shadscale.

Table B3. Associations of the Spinescale scrub.

Scientific Name	Common Name	Map
<i>Lycium andersonii</i> and <i>cooperi</i>	Boxthorn–mixed	Vsp1
<i>Artemisia spinescens</i>	Budsage	Vsp2
<i>Lepidium fremontii</i>	Desert alyssum	
<i>Sporobolus airoides</i>	Dropseed	
<i>Atriplex spinifera</i>	Spinescale	Vsp3
<i>Hymenoclea salsola</i> - <i>Sporobolus airoides</i>	Cheesebush	Vsp4
<i>Suaeda moquinii</i>	Inkweed	Vsp5
<i>Atriplex confertiflora</i>	Shadscale	
<i>Atriplex polycarpa</i>	Allscale	Vsp6
<i>Chrysothamnus nauseosus</i> - <i>Ambrosia dumosa</i>	Rabbitbrush–burrobush	Vsp7
<i>Atriplex confertiflora</i>	Shadscale	Vsp8
<i>Yucca brevifolia</i>	(mixed) Joshua tree	Vsp9
<i>Artemisia spinescens</i>	Budsage	
<i>Atriplex confertiflora</i>	Shadscale	

Atriplex spinifera Association (spinescale Vsp3). Spinescale occurs in pure stands or with minor amounts of budsage on playa edges, flat plains with thin soils, deeply eroded sand fields, and isolated islands on the southwestern corner of the playa.

Atriplex spinifera-*Hymenoclea* Association (spinescale–cheesebush Vsp4). Spinescale blends in its upper transition with allscale on rocky slopes and with allscale and cheesebush on sandy soils associated with washes or roadsides. This community is limited to the northern boundary of the study area.

Atriplex spinifera-*Suaeda* Association (spinescale–inkweed–shadscale Vsp5). Spinescale occurs with inkweed on its lower transition, in highly eroded soils on the southern playa shoreline, and on the eastern side, where it is associated with the larger pans.

Atriplex spinifera-*Atriplex polycarpa* (spinescale–allscale Vsp6). Spinescale occurs with allscale occasionally on Rogers lakebed on valley floors in tight soils. The two species look very similar in certain seasons.

Atriplex spinifera-*Chrysothamnus nauseosus*-*Ambrosia dumosa* (spinescale–rabbitbrush–burrobush Vsp7). This association occurs in dry loose

sandy soils. The gray subspecies of rabbitbrush is usually an indicator of disturbance, and burrobush an indicator of upland conditions. This association is rare on the south side of Rogers lakebed.

Atriplex spinifera–*Atriplex confertiflora* (spinescale–shadscale Vsp8). A transition between thin soils in which the dune sands are eroded by floods and replaced by fluvial soils. This association occurs on the south side of Rogers lakebed.

Atriplex spinifera–*Yucca brevifolia*–*Atriplex confertiflora*–*Artemisia spinescens* (Mixed spinescale Vsp9). This association is rare on the north side of Rogers lakebed. Spinescale and Joshua tree rarely occur together. The occurrence here is more closely related to subsurface water that channels from Leuhman Ridge.

Allscale Scrub

Allscale is most common along the cliff face at the northern boundary of the study site. Allscale is not very common on Rosamond playa; it is much more common on Edwards AFB north of Rogers playa. Allscale occurs in association with spinescale, rabbitbrush (*Chrysothamnus nauseosus hololeucus*), cheesebush (*Hymenoclea salsola*), and Mormon tea (*Ephedra nevadensis*). Allscale often occurs in mixed stands above spinescale scrub. Common annual species include goldfields, spikeweed (*Hemizonia pungens*), coreopsis (*Coreopsis bigelovii*), tansy phacelia (*Phacelia tanacetifolia* and *cryptantha*), and fiddleneck (*Amsinckia tessellata*). No sensitive species are directly associated with allscale.

Table B4. Associations of the Allscale scrub.

Scientific name	Common name	Map
<i>Chrysothamnus nauseosus</i>	Rabbitbrush	Val1
<i>Hymenoclea salsola</i>	Cheesebush	Val2
<i>Atriplex spinifera</i>	Spinescale–Mormon tea	Val3
<i>Atriplex polycarpa</i> – <i>Ericameria cooperi</i>	Goldenheads–Coopers goldenbush–Matchweed	Val4a
<i>Ericameria cooperi</i> – <i>Hymenoclea salsola</i>	Coopers goldenbush–Cheesebush	Val4b
<i>Ambrosia dumosa</i>	Burrobush	Val5
<i>Lycium cooperi</i> and <i>andersoni</i>	Boxthorn	Val6
<i>Atriplex polycarpa</i> – <i>A.</i> <i>confertiflora</i>	Allscale–shadscale	Val7

Atriplex polycarpa–*Chrysothamnus* Association (allscale–rabbitbrush Val1). Allscale occurs with rabbitbrush in disturbed areas. There are two subspecies of rubber rabbitbrush on Edwards AFB. The subspecies *hololeuca* only occurs in disturbed loamy to sandy soils. The other subspecies, *mohavensis*, is associated with riparian wash habitats with clay soils.

Atriplex polycarpa–*Hymenoclea* Association (allscale–cheesebush Val2). This association is limited to sandy soils of dunes, sand fields, and the edges of washes within the transition zone with upland plant communities. This community occurs along the northern boundary of the study area. Cheesebush is an indicator of sandy soils, and allscale occurs on rhyolitic outcrops and disturbed areas.

Atriplex polycarpa–*Atriplex spinifera* Association (allscale–spinescale–Mormon tea Val3). This association is transitional with spinescale at its lower elevations. Allscale is an important element in mixed stands on beach ridgelines along the southeastern playa shoreline. It also occurs with spinescale near the playa edge.

Atriplex polycarpa–*Ericameria cooperi*–*Acamptopappus sphaerocephalus* (Allscale–goldenheads–Coopers goldenbush matchweed Val4a or with cheesebush Val4b). Sand dunes in sandfields on the northwest side of Rogers lakebed contain these upland species.

Atriplex polycarpa–*Ambrosia dumosa* (allscale–burrobush Val5). This association occurs in dunes in the northeastern portion of Rogers lakebed.

Atriplex polycarpa–*Lycium cooperi*–*andersonii* (allscale–boxthorn Val6). This community occurs off Jones Road on large dunes associated with a fault zone.

Atriplex polycarpa–*Atriplex confertiflora* (allscale–shadscale Val7). This association is a transition between upland and lowland areas.

Four-Wing Saltbush Scrub

Four-wing saltbush is the smallest and most diverse community within the study site. It occurs as a mixed community in the southeast portion. Both shrub and annual species diversity is high. It occurs with winter fat, Joshua tree, Mormon tea, boxthorn, cheesebush, saltgrass, and winterfat. Several uncommon crescent-shaped barchan dunes with reddish brown soils on the east side have high densities of burrobush, an upland species. Annual species include desert dandelion (*Malacothrix glabrata*), skeletonweed (*Eriogonum angulosa*), yellow turbans (*Eriogonum pusillum*), gilia (*Gilia latiflora*), sapphire flower (*Eriastrum eremicum*), desert calico (*Loeselliastrum matthewsii*), thread stem (*Nemacladus* sp.), wing-seed forget-me-not (*Cryptantha pterocarya*), woody bottle washer

(*Camissonia boothii*), and suncups (*C. campestris*). No mappable associations were found within this community.

Atriplex canescens–*Yucca brevifolia*–*Atriplex confertiflora*, *Lepidium fremontii* (four-wing–Joshua tree–shadscale–alyssum Vfo1a). This community is common on the dunes along Mercury Blvd in the southeastern portion of Rogers lakebed. On the larger dunes on which four-wing occurs, it drops out on the lower dunes.

Atriplex canescens–*Yucca brevifolia*–*Lycium andersonii* (four-wing–Joshua tree, wolfberry Vfo1b). This community is found along the north and south Lake Thompson Bed boundary between Rosamond and Rogers Dry Lakes.

Atriplex canescens–*Atriplex polcarpa* (four-wing–allscale Vfo2). This is a transition community between sandy lowland and upland west of Complex Charlie and the northeastern corner of Rogers playa.

Atriplex canescens–*Hymenoclea salsola* (four-wing–cheesebush Vfo3). This community is a transition between sand dunes and sand fields in the northern portion of Rogers Lakebed.

Atriplex canescens–*Chrysothamnus nauseosus* (four-wing–rabbitbrush Vfo4). This is an unusual association in consolidated dunes near the shoreline in the southern portion of Rogers playa.

Mojave Desert Scrub

Atriplex lentiformis torreyi–*Artemisia tridentata parishii*–*Chrysothamnus nauseosus mojavensis* (New Mexico saltbush–sagebrush or rabbitbrush Vmo1). This community is related to the mesquite channels between Buckhorn and Rogers lakebeds in the extreme southern portion of the base. Sagebrush and rabbitbrush occur in the red clay channels that may contain or lack mesquite.

Atriplex lentiformis torreyi–*Prosopis glandulosa torreyi*–*Isocoma acradenia* (New Mexico saltbush–alkali goldenbush–mesquite Vmo2). The mesquite is associated with subsurface water that is channelized and entering Rogers lakebed from Big and Little Rock Creeks in the San Gabriel Mountains.

Chrysothamnus nauseosus–*Sporobolus airoides* (rabbitbrush–alkali dropseed Vmo3). This association is related to the New Mexico saltbush. These two species are associated with the channels. When mesquite and New Mexico saltbush drop out, these subdominants are left.

Hymenoclea salsola–*Yucca brevifolia* (cheesebush–Joshua tree Vmo4). This community is also associated with the sand fields in Mojave Creek. The creek appears to run periodically after localized showers in the area. Floods have occurred but not due to historic flooding.

Piute Ponds—Freshwater Marsh and Alkali Meadow

The highly disturbed aquatic habitat at Piute Ponds was not studied because it doesn't consist of natural vegetation. The shallow soils contain tule rush (*Scirpus acutus*), water smartweed (*Polygonum lapathifolium*), curly dock (*Rumex crispus*), cattails (*Typha latifolia*), and pondweed (*Potamogeton pectinatus*). The berm edges contain cottonwood (*Populus fremontii*), tamarisk (*Tamarisk chinensis* and *ramosissima*), narrow leaf willow (*Salix exigua*), black willow (*Salix gooddingii*), Russian knapweed, white sweet clover (*Melilotus alba*), and stinging nettle (*Urtica dioica* ssp. *holosericea*). Dense carpets of wiregrass (*Juncus mexicanus-balticus*), salt grass, and spikeweed (*Hemizonia pungens*) occur along seeps behind dikes and near the spillway.

Tule Rush

Scirpus acutus (tule rush Vtu).

UPLAND COMMUNITIES

Creosote bush dominates the upland communities, along with burrobush, which is more numerous but smaller in size. Burrobush occurs without creosote bush occasionally, but pure stands of creosote occur on granitic hillsides. As the soil matures and gets thicker, other species, such as burrobush, goldenheads, boxthorn, spiny hopsage, cottonthorn, and winter fat, occur with it. At present burrobush is associated with spinescale, allscale, and spinescale and boxthorn. Creosote bush is associated with burrobush, allscale, and Joshua tree (mixed).

Creosote Bush

Larrea tridentata–*Ambrosia dumosa* (creosote bush, burrowbush Vcb1).

Larrea tridentata–*Atriplex polcarpa* (creosote bush, allscale Vcb2).

Larrea tridentata–mixed (creosote bush, mixed Vcb3a).

Larrea tridentata–mixed *Yucca brevifolia* (creosote bush, mixed, Joshua tree Vcb3b).

Larrea tridentata (creosote bush Vcb4).

Burrowbush

Ambrosia dumosa–*Atriplex spinifera* (burrowbush, spinescale Vg1).

Ambrosia dumosa–mixed *Atriplex polycarpa* and *Atriplex spinifera* (burrowbush, mixed allscale, and spinescale Vg2).

Mesquite Bosque

Prosopis glandulosa (mesquite Vme).

APPENDIX C. ENVIRONMENTAL VARIABLE DESCRIPTIONS AND SUMMARY STATISTICS

Table C1. Features characterized within sample plots.

Feature	Units	Explanation
Aspect	degrees	Direction of insolation may affect soil temperatures and, therefore, plant stress.
Bare ground	% of plot	Areal extent of bare ground reflects inhospitable rooting environment.
Channels	# per plot	Channels are scars left by flowing water with a distinct bed and bank. Channel beds may be either the same or different material than the adjacent landform. Minimum channel size was approximately 20 cm.
Channel width	cm	Channel width was measured from bank to bank. Wider channels carry (or carried) more water than narrower channels.
Crack width	cm	Crack width reflects cracking history and soil texture. Within the same parent material, wider cracks are found in pans that are wetter for longer durations.
Depth to impermeable layer	cm	This was measured with a spade; maximum depth recorded was 40 cm, the length of a sharpshooter blade. Like dune thickness, this measurement reflects water-holding capacity and aeration, both of which are necessary for healthy plant growth.
Depth to lake bed	cm	This measurement reflected our judgement of whether an impermeable layer was the lakebed or a local pan. These decisions were subjective and depended on landscape interpretation.
Dune coverage	% of plot	Dunes were defined as accumulations of wind-blown sediment supporting vascular plants. Uniform, level sheets of sediment without topographic relief were excluded. Loose sand holds and transmits more water than finer textures and impermeable sediment.
Dune orientation	degrees	Dune orientation was measured along the axis of the dune. Given the constant prevailing winds at Edwards Air Force Base, dune orientation reflects sand source and dune morphology (longitudinal, barchan, parabolic).
Litter	% of plot	Areal extent of litter was measured as a percentage of the ground that was covered with litter. High litter cover indicates high floral production.
Pans, level, number	# in plot	Pans are indurate areas from a few m ² to several acres. Pans with slopes of 0.5% or less were called level. Many level pans in a plot indicated a patchy mosaic of vegetation cover and shallowness to an inhospitable indurated layer with potential for holding water.
Pans, level, percent	% in plot	Level pans are defined in previous row. Reflects extent of ground capable of ponding water, but inhospitable to plant growth.
Pans, sloping, number	# in plot	Pans are indurate areas from a few m ² to several acres. Pans with slopes of 2% or more were called sloping. Many sloping pans in a plot indicated a patchy mosaic of vegetation cover and shallowness to an inhospitable indurated layer that is too steep to hold water.
Pans, sloping, percent	% in plot	Sloping pans are defined in previous row. Areal extent in plot reflects conditions too harsh for plant growth and too sloped to hold water.

Table C2. Means (standard deviations) of quantitative variables for each ecoseries.

	B/Va1 (n = 1)	B/Vc (n = 4)	Qa/Va (n = 5)	Qa/Vc (n = 1)	Qa/Vf (n = 2)	Qa/Vm (n = 1)	Qa/Vs (n = 1)	Qe/Va (n = 4)
Slope	3.00 (n/a)	4.33 (2.08)	5.40 (2.07)	2.00 (n/a)	3.00 (0.00)	1.00 (n/a)	11.00 (n/a)	2.25 (1.26)
Imper	0.00 (n/a)	3.33 (5.77)	2.60 (4.34)	8.00 (n/a)	0.00 (0.00)	30.00 (n/a)	0.00 (n/a)	2.50 (5.00)
Beddpt	0.00 (n/a)	0.00 (0.00)	0.60 (1.34)	1.00 (n/a)	15.00 (21.21)	30.00 (n/a)	0.00 (n/a)	0.00 (0.00)
% pores	40.00 (n/a)	0.00 (0.00)	7.00 (13.04)	15.00 (n/a)	2.50 (3.54)	0.00 (n/a)	0.00 (n/a)	1.25 (2.50)
Porediam	40.00 (n/a)	0.00 (0.00)	0.60 (0.89)	1.00 (n/a)	0.50 (0.71)	0.00 (n/a)	0.00 (n/a)	0.25 (0.50)
Crack width	0.00 (n/a)	0.00 (0.00)	2.40 (4.34)	8.00 (n/a)	2.00 (0.00)	12.00 (n/a)	0.00 (n/a)	6.00 (9.52)
% veg cover	20.00 (n/a)	45.67 (16.77)	41.40 (17.13)	20.00 (n/a)	15.00 (0.00)	76.00 (n/a)	20.00 (n/a)	25.25 (13.07)
% litter cover	2.00 (n/a)	6.00 (1.73)	8.20 (4.15)	4.00 (n/a)	3.50 (0.71)	20.00 (n/a)	8.00 (n/a)	3.50 (1.29)
% rock cover	90.00 (n/a)	40.00 (26.46)	28.00 (6.71)	60.00 (n/a)	6.00 (2.83)	0.00 (n/a)	5.00 (n/a)	31.50 (32.95)
% bare ground	80.00 (n/a)	31.67 (29.30)	36.00 (18.51)	80.00 (n/a)	85.00 (0.00)	8.00 (n/a)	80.00 (n/a)	46.50 (45.08)
Species richness	8.00 (n/a)	11.67 (1.53)	11.60 (1.95)	8.00 (n/a)	8.00 (4.24)	17.00 (n/a)	8.00 (n/a)	8.00 (3.65)
Dune height	0.00 (n/a)	0.00 (0.00)	0.00 (0.00)	0.00 (n/a)	75.00 (106.07)	0.00 (n/a)	0.00 (n/a)	0.00 (0.00)
% ponded pan	0.00 (n/a)	0.00 (0.00)	0.00 (0.00)	0.00 (n/a)	1.00 (1.41)	1.00 (n/a)	0.00 (n/a)	22.00 (42.68)
% sloped pan	0.00 (n/a)	0.00 (0.00)	10.60 (17.20)	80.00 (n/a)	31.50 (40.31)	7.00 (n/a)	0.00 (n/a)	24.00 (47.34)
% dune	0.00 (n/a)	0.00 (0.00)	0.00 (0.00)	0.00 (n/a)	10.00 (14.14)	0.00 (n/a)	90.00 (n/a)	3.50 (7.00)
No. of pipes	0.00 (n/a)	0.00 (0.00)	0.00 (0.00)	0.00 (n/a)	0.00 (0.00)	6.00 (n/a)	0.00 (n/a)	17.00 (40.67)
No. of channels	6.00 (n/a)	0.67 (1.15)	4.80 (7.43)	10.00 (n/a)	5.50 (7.78)	0.00 (n/a)	0.00 (n/a)	2.83 (5.98)
Channel width	20.00 (n/a)	10.00 (17.32)	43.00 (37.01)	40.00 (n/a)	10.00 (14.14)	0.00 (n/a)	0.00 (n/a)	2.67 (2.66)
No. of ponded pans	0.00 (n/a)	0.00 (0.00)	0.00 (0.00)	0.00 (n/a)	1.00 (1.41)	1.00 (n/a)	0.00 (n/a)	40.00 (39.50)
No. of sloped pans	0.00 (n/a)	0.00 (0.00)	7.80 (15.79)	2.00 (n/a)	6.50 (9.19)	8.00 (n/a)	0.00 (n/a)	1.33 (1.63)

Table C2 (cont.). Means (standard deviations) of quantitative variables for each ecoseries.

	Qe/Vfo (n = 6)	Qe/Vg2 (n = 1)	Qe/Vsh (n = 46)	Qe/Vsp (n = 14)	QI/Val (n = 12)	QI/Vcb (n = 2)	QI/Vch (n = 5)	QI/Vfo (n = 6)
Slope	2.17 (1.83)	0.00 (n/a)	2.70 (3.99)	5.29 (4.87)	1.67 (1.30)	13.50 (17.68)	5.00 (6.00)	0.83 (0.41)
Imper	0.00 (0.00)	0.00 (n/a)	93.09 (283.24)	223.07 (421.27)	336.08 (490.36)	0.00 (0.00)	2.40 (5.37)	9.33 (10.93)
Beddpt	0.00 (0.00)	0.00 (n/a)	166.80 (358.70)	227.79 (419.21)	335.25 (490.97)	200.00 (282.84)	525.60 (587.18)	354.67 (806.24)
% pores	0.00 (0.00)	30.00 (n/a)	8.37 (14.26)	11.07 (17.56)	9.58 (14.84)	0.00 (0.00)	3.00 (6.71)	3.67 (6.22)
Porediam	0.00 (0.00)	2.00 (n/a)	0.41 (0.69)	0.64 (0.93)	0.75 (1.22)	0.00 (0.00)	0.40 (0.89)	0.33 (0.52)
Crack width	4.00 (2.10)	3.00 (n/a)	2.65 (2.77)	1.21 (1.67)	1.67 (1.87)	1.00 (1.41)	1.40 (1.34)	4.67 (5.01)
% veg cover	35.67 (22.37)	28.00 (n/a)	38.20 (22.58)	44.64 (17.54)	52.08 (21.09)	34.00 (22.63)	25.80 (12.05)	44.00 (9.98)
% litter cover	11.67 (10.21)	4.00 (n/a)	9.17 (7.14)	8.93 (6.67)	9.58 (5.00)	4.50 (3.54)	4.00 (3.24)	4.17 (1.83)
% rock cover	0.50 (0.84)	20.00 (n/a)	2.85 (5.63)	6.64 (18.37)	2.08 (2.27)	0.50 (0.71)	6.80 (7.95)	0.67 (0.82)
% bare ground	62.50 (20.68)	60.00 (n/a)	49.76 (26.23)	44.50 (21.72)	30.58 (16.45)	59.50 (27.58)	63.60 (9.40)	51.33 (9.75)
Species richness	13.67 (8.55)	10.00 (n/a)	12.65 (7.58)	15.71 (5.21)	15.25 (94.41)	20.50 (17.68)	11.60 (1.67)	15.83 (4.12)
Dune height	167.17 (265.46)	0.00 (n/a)	115.11 (244.17)	150.00 (143.53)	102.50 (115.06)	187.50 (159.10)	13.00 (21.68)	60.83 (54.81)
% ponded pan	5.67 (11.96)	5.00 (n/a)	6.15 (15.07)	2.64 (5.68)	7.33 (13.24)	17.50 (24.75)	1.60 (3.58)	2.00 (3.16)
% sloped pan	41.33 (37.85)	450.00 (n/a)	23.00 (30.43)	15.00 (16.07)	3.33 (8.54)	22.50 (24.75)	2.00 (3.16)	5.83 (9.17)
% dune	17.00 (40.67)	8.00 (n/a)	41.57 (38.10)	64.14 (40.37)	55.83 (45.82)	55.00 (7.07)	5.83 (9.17)	51.83 (45.79)
No. of pipes	2.83 (5.98)	0.00 (n/a)	0.96 (2.91)	0.07 (0.27)	0.00 (0.00)	0.00 (0.00)	51.83 (45.79)	0.00 (0.00)
No. of channels	2.67 (2.66)	0.00 (n/a)	3.17 (7.94)	1.71 (2.20)	0.33 (0.49)	1.50 (2.12)	0.00 (0.00)	1.17 (1.60)
Channel width	40.00 (39.50)	0.00 (n/a)	37.59 (53.77)	22.50 (25.93)	111.67 (343.93)	50.00 (70.71)	1.17 (1.60)	137.50 (277.38)
No. of ponded pans	1.33 (1.63)	1.00 (n/a)	3.02 (6.00)	1.86 (3.78)	3.58 (5.79)	4.50 (6.36)	137.50 (277.38)	1.00 (1.55)
No. of sloped pans	3.00 (2.76)	3.00 (n/a)	3.46 (5.65)	7.50 (10.17)	2.17 (3.74)	7.00 (2.83)	1.00 (1.55)	3.50 (6.12)

Table C2 (cont.). Means (standard deviations) of quantitative variables for each ecoseries.

	QI/Vsh (n = 47)	QI/Vsp (n = 16)	Qp/Bar (n = 2)	Qp/Vsh (n=1)	Qp/Vsp (n = 1)	Qp/Vun (n = 15)
Slope	5.64 (9.55)	0.69 (1.08)	2.00 (1.41)	14.33 (22.28)	1.00 (n/a)	4.53 (4.12)
Imper	682.77 (991.71)	5.19 (10.89)	25.00 (35.36)	0.00 (0.00)	15.00 (n/a)	68.07 (140.77)
Beddpt	1031.74 (963.98)	437.56 (813.91)	750.00 (1060.66)	333.33 (577.35)	2000.00 (n/a)	766.73 (852.92)
% pores	1.17 (5.23)	2.25 (6.56)	0.00 (0.00)	0.00 (0.00)	0.00 (n/a)	0.00 (0.00)
Porediam	0.09 (0.35)	0.19 (0.40)	0.00 (0.00)	0.00 (0.00)	0.00 (n/a)	0.00 (0.00)
Crack width	1.72 (4.21)	5.69 (7.09)	0.00 (0.00)	0.00 (0.00)	0.00 (n/a)	2.67 (3.98)
% veg cover	44.21 (14.39)	38.00 (16.12)	31.00 (4.24)	23.67 (5.51)	38.00 (n/a)	33.47 (12.23)
% litter cover	5.43 (4.22)	8.13 (5.97)	10.00 (7.07)	2.00 (1.00)	6.00 (n/a)	4.40 (1.84)
% rock cover	6.85 (14.47)	2.31 (6.54)	7.50 (10.61)	10.00 (10.00)	2.00 (n/a)	8.93 (16.32)
% bare ground	51.02 (18.52)	57.19 (17.17)	53.00 (15.56)	55.33 (38.42)	62.00 (n/a)	62.33 (15.33)
Species richness	15.83 (4.93)	13.75 (5.34)	12.00 (1.41)	8.33 (3.06)	14.00 (n/a)	14.53 (5.18)
Dune height	133.13 (234.16)	98.75 (87.45)	200.00 (282.84)	470.00 (498.70)	500.00 (n/a)	234.00 (194.34)
% ponded pan	1.74 (6.18)	20.44 (28.40)	0.00 (0.00)	3.33 (5.77)	0.00 (n/a)	4.73 (10.05)
% sloped pan	4.85 (13.85)	10.56 (24.82)	0.00 (0.00)	0.00 (0.00)	0.00 (n/a)	12.33 (28.76)
% dune	50.11 (45.02)	57.25 (43.21)	50.00 (70.71)	96.67 (5.77)	100.00 (n/a)	61.13 (44.47)
No. of pipes	0.09 (0.46)	0.19 (0.75)	0.00 (0.00)	0.00 (0.00)	0.00 (n/a)	0.20 (0.77)
No. of channels	0.57 (1.54)	0.38 (0.81)	0.00 (0.00)	0.33 (0.58)	0.00 (n/a)	0.80 (1.61)
Channel width	21.38 (47.05)	20.13 (74.80)	0.00 (0.00)	26.67 (46.19)	0.00 (n/a)	20.00 (33.59)
No. of ponded pans	1.23 (4.18)	2.63 (4.54)	0.00 (0.00)	1.67 (2.89)	0.00 (n/a)	1.13 (2.67)
No. of sloped pans	3.26 (11.01)	1.13 (1.93)	0.00 (0.00)	0.00 (0.00)	0.00 (n/a)	1.33 (2.69)

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14. ABSTRACT A four-year study was undertaken in 1997 to understand ecosystem relationships between vegetation and edaphic features at Edwards Air Force Base, California (Edwards AFB). This report presents the comprehensive analysis and discussion for the entire Lake Thompson Bed contained within Edwards AFB. This study used the ecological land classification (ELC) method for developing ecosystem maps. The concept of an ELC is to integrate ecosystems and landforms into one coherent system with functionally related parts. The study area for the ecosystem map is the boundary of the Pleistocene Lake Thompson Bed within Edwards AFB. The ELC maps are secondary products developed from primary field data. Two mapping teams independently mapped the vegetation communities and the landforms of the study area. The characteristics of the landform and vegetation map units were used to create and describe map units for ELC maps. Samples were collected around Pleistocene Lake Thompson Bed to characterize soil chemistry, vegetation, geomorphic, and other descriptive environmental features. Analyses of the data attempted to test the interaction between geomorphic features, vegetative communities, and sampled environmental parameters. Overall, it appears that soil texture plays an important role in the development and relationships with geomorphology, soil chemistry, and vegetation. Geologically the playa surface was less heterogeneous initially, in terms of geomorphic units. As Lake Thompson Bed began to dry out in response to climate changes, dunes and alluvial fans began to form. The result was a landscape with a higher degree of soil texture variability than had existed on the initial lakebed surface. Soil texture sorting across the landscape, along with climate changes, drove the current distribution pattern of vegetation.								
15. SUBJECT TERMS <table style="width: 100%; border: none;"> <tr> <td style="width: 33%; text-align: center;">Ecosystems Geomorphology</td> <td style="width: 33%; text-align: center;">Mojave Desert Playas</td> <td style="width: 33%; text-align: center;">Saltbush Vegetation</td> </tr> </table>						Ecosystems Geomorphology	Mojave Desert Playas	Saltbush Vegetation
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