RAYTHEON Autometric

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FINAL REPORT

A PILOT DATA COLLECTION EFFORT IN THE CALIFORNIA DESERT

Prepared for

BUREAU OF LAND MANAGEMENT
California State Office
Riversiae District

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SECTION 1

INTRODUCTION

This report documents the background, technical approach and results of the project, Pilot Data Collection Effort of Natural Resources in the California Desert, Contract number 08550-CT-4.

Like many other natural resources in our country, the California Desert has been used and abused for sometime and it has been only within the last 10 years that the opposing forces of accelerated abuse and environment concern have come together to focus attention on its ecological survival. Recognizing the public concern for the deserts and their responsibility to manage the public lands within this area, the U. S. Department of Interior, Bureau of Land Management (BLM) embarked on the development of a Desert-wide Management Program. As a measure of the program's importance, the BLM State Director, Russell J. Penny, made the committment of establishing a planning task force in the Riverside District Office with the express purpose of developing a viable plan. However, in consideration of the size of the area, the myriad of natural and cultural resources involved and the magnitude of public use, decision to develop a workable plan of this type is much easier to make than develop and implement.

The Desert Planning Staff began by defining three phases or stages:

1. A Desert Plan Overview, in which the intent was to gather desert-wide information to provide the staff with a broad understanding of the desert resources, their current land use, problems faced by District personnel and a "feel" for the level of effort required to develop a definitive plan; and

2. an Interim Desert Plan, to provide a framework for critical management activities pending completion of the operational plan, which will include a Land Use Options Plan (to delineate land use areas

and establish policies for management decisions), a Desert-wide Work Plan Guide (to align work plans of the Riverside and Bakersfield Districts with desert-wide planning objectives), a Special Activity Plan (to identify areas requiring immediate management attention), and a Catalog of Other Plans and Programs (to identify plans and programs of other government agencies and also to summarize recommendations submitted by user and conservation organizations); and

3. a <u>Desert Plan</u> where the components of stage 2 are defined in an operational framework for implementation.

The questions of priorities, or where intensive inventory and planning should begin, was answered by conducting discussions with area managers and resource specialists, by evaluating available resource and land use data, and by holding open hearings for which public participation was solicited. Two key areas were identified: the Yuha Desert-Carrizo Area, south of the Anza-Borrego State Park and west of the Imperial Valley, and the Trona-El Paso Mountain-Rand Mountain Area, in the Mojave Desert. They were considered to be the most heavily affected by recreation activities of all kinds: desert motorcycle racing and other off-road vehicle activity, rock specimen collecting, camping, amateur archeology, hunting and backpack country exploring.

Having determined the general areas where more resource data was necessary, the next questions were how large an area within the general areas should be considered in a pilot program and how should the task be accomplished. The decision was made to use aerial photograph interpretation and mapping techniques, with contractor assistance, to perform an inventory of soil and vegetation units over portions of the two desert areas -- the total study area to equal approximately one million acres.

The Raytheon Company, Autometric Operation began working with the BLM in 1972 with the general objective of determining realistic levels of resource data inventory for the desert areas by compiling appropriate resource maps from exploitation of remotely sensed imagery.

SECTION 2
TECHNICAL APPROACH

2.1 General

Based upon a proposal by Autometric, the contract and subsequent project included seven tasks:

1. Specification of Aerial Photograph Acquisition
2. Review and Acceptance of Imagery
3. Preliminary Field Surveys
4. Photo Analysis
5. Field Validation
6. Preparation of Analysis Keys and
7. Preparation of Thematic Overlays.

An eighth task, construction of digital files from thematic overlays prepared under Task 7 and computer processing of higher order graphics based on Ecological Unit Associations, was not a specific part of this program but related to a concurrent natural resource information system development program with the Bureau of Indian Affairs.

The first two tasks were advisory in that we recommended the photo acquisition parameters and basic standards for imagery acceptance. Very early in the program we had to make a fundamental decision concerning the basic tools, i.e., the aerial photographs. Since the California Desert covers some 25 million acres, the pilot study area had to be sufficiently large and varied to reach valid conclusions regarding the application of similar or related inventory techniques to the total area. On this basis, we recommended a true color or natural color emulsion and a scale of 1:20,000. We realized that 1:20,000 scale was the threshold for recognition of some desert shrubs and sub-threshold for grasses and forbs. However, the true color emulsion would facilitate estimates of the site quality through the use of green tones and it would also help in the differentiation of soil parent materials.

In addition to the parameters of scale, Autometric personnel assisted with the determinations of altitude, ground coverage, side and end lap, orientation of flight lines and approximate number of photographs to be acquired.

When the proposal was prepared we anticipated a formal role in the review and acceptance of imagery. In practice it was more realistic for the BLM to make the determination since they were in closer proximity to the aerial photo contractor. During the process of interpreting the images, however, we did assess factors such as overlap and side lap, scale consistancy tip and tilt and color rendition.

Regarding the results of this effort, we feel that the overall acquisition parameters were adhered to, however, photometric quality control on hues was marginal. The hues on the Yuha Area photos were much better controlled than those over the Mojave Area. This will be evident as BLM personnel study the analysis keys prepared under Task 6 and uses the other color photographs for specific planning and management applications.

Tasks 3, 4 and 5 dealt with the problems of preparing resource classification systems, image analysis/delineation and field validation.

Tasks 6 and 7 involved the transformation of image analyses to contract deliverable items - analysis keys and the thematic overlaps. The analysis keys consisted of some 20 sets (2-3 photos per set) of photos, a soil and vegetation overlay for one of the photographs, locational information (photo number, flight line number, U.S.G.S. quadrangle, etc.) and a description of resources delineated. The thematic overlays consisted of transparent foils keyed to the appropriate U.S.G.S. quadrangles.

Since the first two tasks were ancillary to the project, the remaining part of this report will emphasize the soil and vegetation analysis procedures and the processing of analysis keys and resource overlays.

2.2 Soil Mapping

Several difficulties are inherent in resource mapping by means of aerial photography, the principal one being that, in analyzing an image of the resource rather than the resource itself, it is impossible to directly observe the intrinsic characteristics of the resource. In the case of soil mapping, for example, the image analyst is denied access to the physical, chemical, and biological properties that are routinely observed in the field and laboratory and used as the basis for classifying and naming a soil unit. Therefore, the task of the image analyst, being unable to classify and name, is to delineate and describe; that is, to differentiate between soil units on the basis of surface phenomena and to designate them by means of a symbolic enumeration of their attributes.

The principal photo-pedologic operation, was to differentiate between soil units on the basis of certain criteria. These criteria must satisfy two conditions: 1) they must be observable on the aerial photographs, and 2) they must be surrogates of naming and classifying phenomena; that is, they must be outward and visible signs of intrinsic physical, chemical, and biological conditions. In the pilot California Desert Mapping Program, five differentiating criteria were employed: 1) parent material; 2) landform; 3) condition of fluvial erosion; 4) slope and 5) color. Table 1 contains a full description of the subsets of these criteria and of the symbols used to denote them.

The rationale for selecting these criteria is as follows:

Parent Material* - In desert areas, where there is a relatively high degree of physical disintegration and a relatively low degree of chemical decomposition, the soils retain a minerologic composition more similar to that of the parent material than in humid areas. That different parent materials produce different soils is indicated by the frequently

*The term "parent material" as used in this mapping program, refers to consolidated as well as unconsolidated rock material. Thus, bare rock has been mapped as a "soil unit" as have been unconsolidated deposits with little or no horizen development.

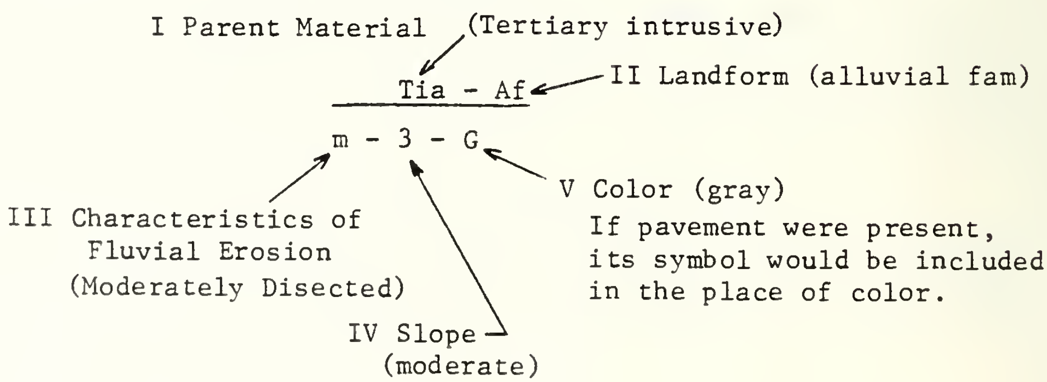
TABLE 1 - SOIL DIFFERENTIATION SYSTEM FOR ARID AREAS

DIFFERENTIATING CRITERIA	SYMBOL
I PARENT MATERIAL	Two-letter symbol modified from "Geologic Map of California", 1:250,000, Division of Mines and Geology
SEE TABLE 2	
II LAND FORM	
A. Plains	
1. Alluvial plain (piedmont plain, between foot of mountain or fan, and playa)	Pa
2. Stratigraphic plain	Ps
3. Lava plain	Pb
4. Ash plain	Pv
5. Playa	Pl
B. Negative Topographic Forms	
1. Arroyo bottom (flat-bottom channel between steep slopes)	Ab
2. Valley bottom (flat or concave portion below line of tangency with slope)	Vb
3. Swale	Sw
4. Crater	Cr
5. Caldera	Ca
6. Deflation hollow	Dh
C. Positive Topographic Forms	
1. Alluvial fan	Af
2. Alluvial terrace	Te
3. Dune - created by wind	Du
- created by waves & wind; beach dune	Bd
4. Talus	Ta
5. Hilltop (concave or flat portion above line of tangency with hillside)	Ht
6. Hillside (between lines of tangency with hilltop & valley bottom; also used for sloping plains and scarps)	Hs

TABLE 1 - CONTINUED

DIFFERENTIATING CRITERIA	SYMBOL
III CHARACTERISTICS OF FLUVIAL EROSION	
A. Undisected	U
B. Moderately disected	M
C. Severely disected	S
D. Concentrated run-off (areas of small, closely spaced or braided streams	C
IV SLOPE	
A. Flat-lying	1
B. Gentle	2
C. Moderate	3
D. Steep	4
V COLOR	
A. Brown	B
B. Gray	G
C. Orange	O
D. Purple	P
E. Tan	T
VI PAVEMENT	
A. Pavement covers entire surface	W
B. Pavement covers half of surface	H

Explanation of soil symbol content and format:



observed fact that changes in vegetation occur at boundaries of soils that are identical in every respect excepting that of parent material. Parent material symbology is Shown in Table 2.

Landform - Landforms are the interim results of erosional and depositional forces acting on the composition, structure, and original topographic position of the parent material. It is reasonable to expect, therefore, that different landforms will produce different soils, and this expectation has been re-enforced by abundant empirical evidence. For example, everyone is well aware that the soil of an alluvial fan is different from that of its continuous alluvial plain, and the soil of the plain is in turn, different from that of its contiguous playa.

Condition of Fluvial Erosion - The extent to which a soil unit is disected, that is, its drainage density -- is a function, among other things, of its permeability and, therefore, of its texture. Drainage density, then, is an approximate surrogate for two important soil classification criteria.

Slope - That the degree of slope influences horizon development and thickness is axiomatic in soil science.

Color - In most cases color differences were obviously the result of differences in parent material (alluvial material derived from granite was markedly different in color from that derived from basalt) or of differences in landform (in going from upper to lower bajada, a gradational color change usually accompanied a gradational landform and textural change). Not infrequently, however, soil units that appeared identical in parent material, landform, erosional characteristics, and slope had a different color. Sometimes the cause of the color difference could be confidently deduced, such as in an alluvial plain with a subtle swell-and-swale configuration where the orange tinge of the swells could be ascribed to oxidation and the grayish tinge of the swales to reduction. In other instances, however, the color difference was purely conjectural, and the only criterion for differentiating between two otherwise apparently identical soils was color.

TABLE 2 - SYMBOLS FOR PARENT MATERIAL

(Symbols are in alphabetic rather than stratigraphic order)

SYMBOL	ROCK UNIT
BI	Basic intrusive
GM	Pre-Cenozoic granite & metamorphic rocks
GR	Mezozoic granitic rocks
Mm	Pre-Cretacious metamorphic rocks
Mn	Upper Miocene nonmarine
Mp	Miocene pyroclastic rocks
Ms	Pre-Cretaceous metasedimentary rocks
Mv	Miocene volcanic rocks
Pb	Pliocene basalt
Pc	Paleocene nonmarine
Pg	Precambrian gneiss
Pl	Pliocene nonmarine
Pm	Precambrian metamorphic rocks
Pn	Middle and/or lower Pliocene nonmarine
Ps	Precambrian schist
Pv	Pliocene volcanic rocks
Qa	Quaternary alluvium
Qb	Pleistocene basalt
Qc	Quaternary channel deposits
Ql	Quaternary lake deposits
Qn	Pleistocene nonmarine
Qp	Plio-Pleistocene nonmarine
Qs	Quaternary salt deposits
Qt	Quaternary non-marine terrace deposits
Qv	Pleistocene volcanic rocks
Ti	Tertiary intrusive rocks
Tn	Tertiary nonmarine
Tv	Tertiary volcanic rocks
Zm	Paleozoic metavolcanics
Zn	Paleozoic marine

There is a sixth differentiating criterion that would have been used had this program been involved only with mapping soils. This criterion is, of course, vegetation, which was mapped as a separate entity. However, when the soil and vegetation maps are combined to form a synthesized map of "ecological units," a soil unit that is found to support two different types of vegetation will be subdivided along the vegetational boundary with the reasoning that, either an unidentified soil difference caused the vegetation difference or the differing biological activities of the vegetation have changed the soil characteristics.

2.2.1 Mapping Practice Procedure

In actual mapping practice, all of the land surface was mapped, rather than only those surfaces with a developed soil profile. Thus barren areas such as bedrock and saline playas were assigned a parent material, landform, erosional state,slope, and color, and were delineated as a "soil" unit. This procedure was realistic in that it ensured that all of the land under BLM control, soil or not, carried a meaningful descriptor. It was all the more realistic in that it was found that very little of the land was truly barren -- even boulder fields supported vegetation in soil pockets among the rocks, and steep bedrock slopes carried vegetation, sometimes relatively dense, in fractures.

The mechanical operation of the mapping was not the step-by-step, methodical process that had been anticipated. It was expected, before the start of the program, that a parent material would be identified, that it would be subdivided on the basis of landform, and that it would be further subdivided on the basis of erosion, slope, and color, thereby producing a uniquely defined polygon of soil. However, the brain is a good pattern detector and works faster than that, combining disparate visual phenomena into attributes of a single whole. For example what would frequently be seen -- at a glance, without analysis -- would be a steep-sided, jagged, pink, granite mountain, or a smooth,rolling, tan, alluvial plain. In other words, it often happened that all five differentiating criteria would be synthesized by eye to form a single entity. The analytical process would then consist of checking to see if the parent material really were "granite" or "alluvium", of converting "smooth" or "jagged" to an erosion category, and of converting "rolling" or "steep-sided" to a slope category. This was indeed, a methodical, step-by-step process that was carried out as follows:

Step One - The parent material was identified by means of a geological map. (The state of California is covered by an excellent series of 27 map sheets at a scale of 1:250,000). The photos, at 1:20,000 showed many small lithologic units that could not be shown on the small-scale map. These were easily identified using the map as a "key".

Step Two - The landform, seen in stereo with an exaggerated third dimension, was identified.

Step Three - The degree of erosion was specified. This, unlike parent material and landform, was a subjective criterion, no attempt having been made to assign a numerical value to "undisected," "moderately disected," and "severely disected". This could be done, of course, but it would involve making a measurement for each soil unit, a procedure that would add considerably to the cost of the survey.

Step Four - A slope category was assigned. This, like erosion, was subjective, and, like erosion, could be made a measurable, numerical quantity at the expense of some time and economy.

Step Five - The color of the soil surface was specified. In most cases, this step was not necessary since the preceeding four differentiating criteria had already provided a unique discrimination between the soil polygon being described and all surrounding polygons. However, since this legend was digitized, it was necessary to provide a symbol for each criterion whether applicable or not.

Although the color of a soil unit often changed from one flight line to another, this did not present a problem since the color per se was not important. The purpose of including color as a differentiating criterion was to show that a difference existed between two otherwise similar, adjacent units.

In the case of soil units upon which a partial or complete desert pavement had developed, the color symbol was omitted, and a symbol for pavement was inserted in its place. Two pavement symbols were used -- one indicating that pavement occupied less than half of the surface area and the other indicating more than half.

Once each soil unit had been differentiated and mapped, it was then identified by means of five symbols, one for each of the differentiating criteria. An example of the identification symbology (exclusive of parent material symbology) is shown in Table 1.

A connotative legend was adopted for parent material and landform. This was both for the sake of brevity, which is an important cost consideration if the mapping results are to be digitized, and because no widely accepted non-connotative system of landform classification exists.

As an example of the brevity that was achieved by using a connotative, rather than digital, legend, it is instructive to look at a time-rock type used on the Geologic Map of California. The lithologic type "Middle Miocene Marine" is identified by the symbol Mm. In order to identify this unit by a universal, non-connotative, numerical system would require one digit for "Cenozoic", another for "Tertiary", a third for "Miocene", a fourth for "Middle", and a fifth for "marine". In addition, a universal system would require that the rock type be denoted. The Monterey Formation of the Middle Miocene Marine is described as being of sandstone, siltstone, and shale. To denote this unit, at least two digits would be required for "Monterey Formation", one for "sedimentary", and two each for "sandstone", "siltstone", and "shale", for a total of nine. Adding nine for the rock type and five for the age give a grand total of 14 digits that would have to be needed to describe a rock unit that can otherwise be described with two.*

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* The Geologic Map of California uses from one to four letters to identify each rock type. A minimum of two letters is required to uniquely identify each of the 82 types mapped. Therefore, a two-letter system was adopted, following the map legend as closely as possible. (See Table 2.)

An example of a complete soil mapping symbol, as used in this program is shown on the bottom of Table 1.

The purpose of mapping soils by means of aerial photography is to provide a base map that can be validated on a selective basis by field crews. The field crews will have two tasks: 1) to determine whether the differentiating criteria do, in fact, differentiate between soil units (It is quite possible that a soils developed on an Eocene rhyolite will not differ in any significant way from one developed on an Oligocene rhyolite.); and 2) to determine the inherent soil properties that cannot be determined by image analysis and, on this basis, to classify and name the soils.

2.3 Vegetation Mapping

Traditionally, vegetation has been mapped using physiognomy (appearance) and floristic composition (species present) characteristics. In his text on vegetation mapping, Kuckler defines vegetation as "the mosaic of plant communities in the landscape." A plant communitv being considered as a part of the vegetation that is relatively uniform in structure and floristic composition. Munz, recognizes some 29 plant communities in California, of which only five were present in the pilot area (Shadscale Scrub, Creosote Bush Scrub, Alkali Sink, Pinyon - Juniper Woodland and Joshua Tree Woodland).

As in the case of soil mapping, the vegetation image analyst is denied continued ground access to the morphology of individual plants and therefore has to rely on their macro-features or on the physiognomy of plants in groups. Unlike the soil scientist's situation, in which he cannot classify and name soil units but must delineate and describe, the vegetation analyst can identify certain individual plants or groups of plants and identify units to a specified level. Such units are not completely definitive, however, since they are dependent on the image characteristics and the specific classification system selected for inventory units.

In keeping with the concept that this study was not a comprehensive inventory of soil and vegetation resources, but one in which units could be subdivided further or aggregated into larger groups depending on data needs, an existing BLM classification system was selected.

The BLM uses some 18 vegetative types for evaluating range using ocular reconnaissance techniques. These types are based on "aspect" or dominant and co-dominant species as seen from an overall ground vantage point. The classification is amenable to photo interpretation techniques in that the dominant vegetation characteristics of size and shape are readily translated in the vertical view.

The vegetation classification scheme goes beyond the plant communities defined by Munz but does not extend to the true plant association level in that the dominant species are classified while leaving out the forbs and grasses. The legend (Table 3) was ultimately developed by using seven of the 18 BLM types and further sub-dividing by adding a third digit for co-dominant vegetation and a fourth digit for extent of plant cover or density; for example a 112-3 would designate a Creosote Bush (Ladi)* and Bursage (Frdu) association with a ground cover of six to 10 percent. (See Appendix I for a description of vegetation units used in the study.)

2.4 Manuscript Production

The soils and vegetation units were delineated on transparent overlays using alternate photographs in each flight line. The problem of compiling composite map overlays from the mosaic of individual overlays was accomplished in two ways. In the Mojave area, manual projection techniques were employed to prepare draft manuscripts for later photo reduction and scribing. In the Yuha area, a matrix of California State Plane Grid intersections at 5000 foot intervals were developed and transferred to photographs and overlays. The control points, line segments and attributes of the resource

* BLM uses a four-letter symbol to designate species by combining the first two letters of the genus and species name, e.g., Larrea divaricata = Ladi.

TABLE 3
VEGETATION LEGEND FOR CALIFORNIA DESERT PROGRAM

080		Barren
090		Pinyon (Pimo) - Juniper (Juca) Associations
	091	Juniper (Juca) - Prunus (Prfa) - Yucca (Yusc)
	092	Juniper (Juca) - Creosote Bush (Ladi)
	093	Juniper (Juca) - Ratany (Krgr) - Agave (Agde)
	094	Pine (Pisa)
110		Creosote Bush (Ladi) Associations
	111	Creosote Bush (Ladi) Consociation
	112	Creosote Bush (Ladi) - Bursage (Frdu)
	113	Creosote Bush (Ladi) - Bursage (Frdu) - Ocotillo (Fosp)
	114	Creosote Bush (Ladi) - Bursage (Frdu) - Agave (Agde)
	115	Creosote Bush (Ladi) (Shrub Mixture) - Smoketree (Dasp) - Catclaw (Acgr) - Desert Willow (Chli) - Cheesebush (Hysa)
	115 (A)	Creosote Bush (Ladi) (Shrub Mixture) - Saltbush (Atco) - Mesquite (Prju) - Tamerisk (Tape)
	115 (B)	Creosote Bush (Ladi) (Shrub Mixture) - Scalebroom (LeSg) Bladderpod (Isar) - Saltbush (Atca, Atpo) - Cheesebush (Hysa)
	115 (C)	Creosote Bush (Ladi) (Shrub Mixture) - Horsebrush (Test) Spiny Hopsage (Grsp) - Box-Thorn (Lyca) - Saltbush (Atca, Atpo)
	116	Creosote Bush (Ladi) - Saltbush (Atpo, Atco, Atca)
	117	Creosote Bush (Ladi) - Bursage (Frdu) - Brittlebush (Enfa)
	118	Creosote Bush (Ladi) - Cheesebush (Hysa)
	119	Creosote Bush (Ladi) - Cheesebush (Hysa) - Bursage (Frdu)
120		Mesquite (Prju) Associations
	121	Mesquite (Prju) Consociation
	122	Mesquite (Prju) - Creosote Bush (Ladi)
	123	Mesquite (Prju) - Saltbush (Atpo, Atca) - Creosote Bush (Ladi)
	124	Mesquite (Prju) - Saltbush (Atpo, Atca)

130		Saltbush (Atca, Atco, Atpo) Associations
	131	Saltbush (Atca, Atco, Atpo) Consociation
	132	Saltbush (Atca, Atco, Atpo) - Creosote Bush (Ladi)
	133	Saltbush (Atca, Atco, Atpo) - Winterfat (Eula)
	134	Saltbush (Atca, Atco, Atpo) - Alkali Blite (Sufr) - Iodine Bush (Aloc)
140		Greasewood (Save) Associations
	141	Greasewood (Save) - Saltbush (Atco, Atco, Atpo)
160		Desert Shrub Associations
	161	Ocotillo (Fosp) - Creosote Bush (Ladi) - Bursage (Frdu)
	162	Joshua Tree (Yubr) - Creosote Bush (Ladi)
	163	Mountain Shrub- Brittle Bush (Enfa) - California Tea (Epca) - Ratany (Krgr) - Yucca (Yush) - Buckwheat (Erfa) - Rabbit Brush (Chte) - Black Brush (Cora) - Creosote Bush (Ladi))
	164	Tamarisk (Tape)
	165	Tamarisk (Tape) - Creosote Bush (Ladi)
	166	Crucifixion Thorn (Haem)
	167	Joshua Tree (Yubr) - Saltbush (Atco, Atpo)
	168	Joshua Tree (Yubr) - Juniper (Juca) - Bladder Sage (Same) Lycium (Lyan) - Cotton Thorn (Teax) - Buckwheat (Erfa)

DENSITY LEVELS

PERCENT GROUND COVER	NUMERAL
0 - 5	1
6 - 10	2
11 - 15	3
16 - 20	4
Over 20	5

unit polygons were digitized directly from the photographs, processed by a computer, and printed out, in rectified form by an on-line plotter. Several key accomplishments were realized through this process. Large groups of individual overlays can be "mosaicked" together for each theme (soils and vegetation), which essentially creates two large overlay composites. In this process, all type boundaries are rectified linearly in respect to each of four control points. From these digital files it is then possible to use an output plotter to create draft manuscripts keyed to 1:24,000 or 1:62,500 USGS maps and if desired to measure acreages of each resource unit by specified geographic area and resource units, using available NRIS software.

2.5 Analysis Keys

During the course of the program two types of analysis keys were developed: 1) preliminary and, 2) final. The preliminary keys were made following the first extensive period of field work in January and consisted of field notes, ground photographs and photo annotations. These were used to correlate the field identified shrubs with the annotated images for developing a legend of vegetation and soil units. The final keys were made following the image analysis and delineation phase. They are designed as training aids for future analysis work to emphasize the spectrum of soil and vegetation relationship prior to using the resource overlays in the field.

The initial plan was to prepare the keys as mounted stereo pairs. However, after some thought, an alternate approach was taken. Rather than cut out part of a photograph we felt that more information could be provided the image analysis by selecting a full frame and providing soil and vegetation transparent overlays. With this approach the analyst could study the photos without annotations, with either the soil and vegetation delineation or correlate delineations for both resource themes.

A total of 20 keys or "image sets" were selected to represent the variety of vegetation and soil conditions encountered within the two study areas. Each set consists of a stereo pair or stereo triplet with transparent overlays for soils and vegetation and a text describing significant aspects of the scene. The key package is amenable to reproduction. Additional color prints can be acquired from the aerial survey company, the text is page size (8-½" x 11") and can be duplicated on a copy machine and the transparent overlays can be used to produce more transparencies either in color or black and white foils.

SECTION 3
CONCLUSIONS

3.1 Conclusions

1. The 1:20,000 scale true-color aerial photograph proved to be the optimum medium for extracting soils and vegetation data to satisfy the range of data required by the BLM Desert Planning Staff and District Managers. Had the scale been smaller, the resource units would have had to be more generalized had it been larger, the cost effectiveness of larger area coverage would have been reduced.

2. The soils/vegetation classification system provided a framework for the development of more definitive units or for aggregation into more generalized units.

APPENDIX I

DESCRIPTIVE LEGEND FOR VEGETATION UNITS
IN THE SOUTHERN CALIFORNIA DESERT.

DESCRIPTIVE LEGEND FOR VEGETATION
UNITS IN THE SOUTHERN CALIFORNIA DESERT

080 Barren

Although the vegetation density range begins at"0", for all practical purposes when the density drops below 1 percent an area is considered barren. Typical sites include badlands, playas, dunes, and areas of man's activity (e.g. cultivation, burning, mining, etc.)

090 Pinyon (Pimo) - Juniper (Juca) Association

Three of the four sub-associations were found in the southwest corner of the Yuha area and the fourth, 094 was found in small patches on the highest elevations in the west-central part of the Mojave study area.

091 Juniper (Juca) - Prunus (prfa) - Yucca (Yusc)

The prominent species in this community are Juniperous Californica, Prunus fasciculata and Yucca schidigera. The overall vegetation is rich in variety and density and some of the highest shrub densities in the Yuha were found within this group -- forbs and grasses were also present. Elevation ranged from 3000-4000 feet.

092 Juniper (Juca) - Creosote Bush (Ladi)

This is a transition zone between the 091 group and the Creosote Bush - Bursage communities found at lower levels.

As with most units in the legend only the aspect dominant species are given in the group title while a larger number of shrubs, forbs and grasses are ever present, sometimes in larger numbers than the dominants.

093 Juniper (Juca) - Ratany (Krgr) - Agave (Agde)

This is also a transition community between the higher elevations and the desert floor and is common to rocky north facing slopes in the Yuha area. Prominent species are Juniperous californica, Krameria Grayi and Agave deserti.

094 Pine (Pisa)

This is the only pine species found in either of the study areas and occurred in the higher mountains west of Koehn Lake. Its scientific name is Pinus Sabiniana and common name digger pine. It is more common to the Foothill Woodlands than the Pinyon-Juniper Community and commonly occurs on dry slopes and ridges below 4500 feet.

110 Creosote Bush (Ladi) Association

It is axiomatic that the Creosote bush and its various associations dominate the Southern Californian Desert. This dominance is expressed throughout the vegetation legend and most obvious in this largest group. There are some twelve "types" within this group with Creosote Bush - Bursage being the most common association. There are four mixtures, also creosote bush dominated used in wash complexes (115, 115A, 115B and 115C). While the use of an additional letter departs from the general system it serves to distinguish very quickly this particular environment. Units 116-119 are transition groups between the Saltbush and Mountain Shrub Association.

111 Creosote Bush (Ladi) Consociation

This unit was included to cover those situations where Creosote Bush only was present. In actual practice it was used very little or not at all since Creosote Bush did not occur in pure stands over extensive areas.

112 Creosote Bush (Ladi) - Bursage (Frdu)

This is the most common association throughout the study areas. Larrea divaricata and Franseria dumosa are the prominent species and together they are found on well-drained hills, slopes, fans and valleys below 3500 feet.

113 Creosote Bush (Ladi) - Bursage (Frdu) - Ocotillo (Fosp)

This particular group was common to the Yuha area but was not found in the Mojave. Munz describes the Ocotillo as occurring on dry mostly rocky sites below 2500 feet. However it occurred with the two associated species over many of the well-drained, sandy flats as well.

114 Creosote Bush (Ladi) - Bursage (Frdu) - Agave (Agde)

This association was found in the Yuha but not in the Mojave area. It occurred in middle elevations between the 112 types on the lower elevations and the 093 and 163 (Mountain shrub) Associations on the higher elevations. The vegetation density was generally high and easily recognizable on the color aerial photographs.

115 Creosote Bush (Ladi) - Shrub Mixture

For convenience these four "wash complexes" will be handled as one group. The "115" was first established to handle washes in the higher and middle elevations in the Yuha area where the smoke trees, desert willows, and Acacia predominate. It was soon realized that other species such as saltbush, mesquite and tamerisk were more common in washes on the lower elevations. When work began in the Mojave area it was discovered that other species such as scale broom (Lepidospartum squamatum) were commonly found in washes on the higher elevations while Horsebrush (Tetradymia stenolepis) and saltbush species were common to the lower elevations. Other species were common to the lower elevations. Other species such as cheesebrush are more universally distributed throughout most washes and also were found on more well-drained slopes at higher elevations.

116 Creosote Bush (Ladi) - Saltbush (Atpo, Atco, Atca)

This association occurs very infrequently and then only as a transition zone between the Creosote Bush and more saline tolerant shrubs at lower elevations and between the shadscale scrub and Creosote bush at higher levels. Units that had been typed 116's on the lower part of the Mojave area were later changed to 112's after field checking.

117 Creosote Bush (Ladi) - Bursage (Frdu) - Brittlebush (Enfa)

This type was used to denote the transition between the 112's on the slopes and alluvial fans and the 163's on the higher elevations. It was common on north-facing slopes between 2000 and 3000' elevation in the Mojave area.

118 Creosote Bush (Ladi) - Cheesebush (Hysa)

119 Creosote Bush (Ladi) - Cheesebush (Hysa) - Bursage (Frdu)

Neither of these units were seldom or ever used in the inventory. They were included in the legend based on the field survey. However in actual practice there were no image characteristics that would allow separation of the Cheesebush from the Bursage shrubs hence all such units were probably given the designation 112.

120 Mesquite (Prju) Association

All of these associations were found in the Yuha Area only and occurred primarily as a transition zone between the Creosote Bush on the higher elevations and the Alkali sink or "playa related" Saltbush communities in the lower elevations.

121 Mesquite (Prju) Consociation

In certain parts of the Yuha Area, mesquite was found in pure stands and thus assigned this type.

122 Mesquite (Prju) - Creosote Bush (Ladi)

123 Mesquite (Prju) - Saltbush (Atpo, Atca) - Creosote Bush (Ladi)

124 Mesquite (Prju) - Saltbush (Atpo, Atca)

All three sub-associations fall within the transition category as described earlier and were used to express relative sub-dominance mixtures in predominantly mesquite types.

130 Saltbush (Atca, Atco, Atpo) Associations

These Associations are found in two widely divergent environments, the Shadscale Scrub and the Alkali Sink, plus some intermediate levels between. Since they do occur in such variable areas each unit warrants amplification.

131 Saltbush (Atca, Atco, Atpo) Consociation

This type is used to denote vegetation units on the higher elevations (Shadscale Scrub) as well as those nearer the desert floor (Alkali Sink). The shrubs Atriplex canescens and Atriplex confertifolia dominate the former while Atriplex polycarpa dominates the latter. Since the environments are completely different an individual should be able to determine from the mapped units what shrubs would likely be most dominant.

132 Saltbush (Atca, Atco, Atpo) - Creosote Bush (Ladi)

This is basically a transition type between the Shadscale Scrub on the upper levels and the Alkali sink fringe on the lower levels.

133 Saltbush (Atca, Atco, Atpo) - Winterfet (Eula)

This unit was added to the saltbush associates after the field survey. Like units 118 and 119 it did not seem possible to differentiate between Eurotia lanata and other saltbushes on the aerial photographs and therefore all of the areas of this combination were included in the 131 unit.

134 Saltbush (Atca, Atco, Atpo) - Alkali Blite (Sufr) - Iodine Bush (Aloc)

This type is common to the lowest levels on the desert floor called alkali sinks. Of the three saltbushes shown in the parentheses, Atriplex polycarpa would be found on the outer fringe of this environment while Suaeda fruticosa and Allenrolfea occidentalis would be found in the most saline areas supporting vegetation.

140 Greasewood (Save) Associations

141 Greasewood (Save) - Saltbush (Atca, Atco, Atpo)

This unit, like several others in the legend before it, was included as a result of the field work. One small Greasewood unit was found in the Trona part of the Mojave Area but the resource unit was not used in the mapping program.

160 Desert Shrub Association

This whole group is a mixture of non-related but significant vegetation units. Eight units are included with 163 (Mountain Shrub) having the most vegetation variety and also the widest distribution over the study areas.

161 Ocotillo (Fosp) - Creosote Bush (Ladi) - Bursage (Frdu)

This unit is very closely related to 113 where the vegetation is the same except for the relative distribution. This particular unit provides the opportunity to represent Ocotillo dominated sites.

162 Joshua Tree (Yuba) - Creosote Bush (Ladi)

This unit was included in the desert shrub category even though the Joshua trees may be very sparse and the site dominated by Creosote bush. This action was justified on the basis of the importance of scattered Joshua trees for bird life and the practical limitation of no Creosote Bush category being available.

163 Mountain Shrub - Brittle Bush (Enfa) - California Tea (Epca) - Ratany (Krgr) - Yucca (Yush) - Buckwheat (Erfa) - Rabbit Brush (Chte) - Black Brush (Cora) - Creosote Bush (Ladi)

As indicated previously this type includes a wide variety of shrubs, forbs and grasses growing on higher elevation (above 3500 feet) and north-facing slopes. This group is generalized on the basis that essentially no differentiating criteria are available in the imagery to sort out specific shrubs.

164 Tamerisk (Tape)

This type was found primarily along water courses and irrigated areas between the southeastern edge of the Yuha area and the cropland in the Imperial Valley west of El Centro.

165 Tamerisk (Tape) - Creosote Bush (Ladi)

This unit was used to show the transition between the previous unit (164) and the more creosote dominated units of the natural desert environment.

166 Crucifixion Thorn (Haem)

This shrub was included to accommodate the BLM-protected area in the southwestern part of the Yuha.

167 Joshua Tree (Yubr) - Saltbush (Atco, Atpo)

The transition zone between the Shadscale Scrub and Joshua Tree woodland is filled by this unit. The Joshua trees are generally more abundant than in the 162 since the elevation where this unit occurs is much higher. The saltbush species are generally atriplex confertifolia and atriplex polycarpa.

168 Joshua Tree (Yubr) - Juniper (Juca) - Bladdersage (Same) - Lycium (Lyan) - Cotton Thorn (Teap) and Buckwheat (Erfa)

This unit is generally referred to as the Joshua Tree Woodland and occurs at the higher elevations (above 3000') in the Mojave area.