PHOTO INTERPRETATION REPORT

USGS-NPS VEGETATION MAPPING PROGRAM

TUZIGOOT NATIONAL MONUMENT

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TUZIGOOT NATIONAL MONUMENT, ARIZONA
NBS/NPS VEGETATION MAPPING PROGRAM
AERIAL INFORMATION SYSTEMS PROJECT REPORT

I. INTRODUCTION

The National Park Service (NPS) in conjunction with the National Biological Service (NBS) has created a program to "develop a uniform hierarchial vegetation methodology" at a national level and to create a geographical information system (GIS) database for the parks under its management. The purpose of the data is to document the state of vegetation within the national park system during the 1990's thereby providing a baseline study for further analysis at either regional or national levels. Aerial Information Systems (AIS) was subcontracted by Environmental Systems Research Institute (ESRI), the prime contractor, to perform the photointerpretation for the program. The Nature Conservancy (TNC) was subcontracted by ESRI to conduct the field sampling effort and to support the development of the National Standard Classification.

A number of parks, representing different regions, environmental conditions and vegetation types, were chosen to be part of the prototype phase of the program. The initial goal of the prototype phase is to "develop, test, refine, and finalize the standards and protocols" to be used during the production phase of the project. This includes the development of a standardized vegetation classification system for each park and the establishment of photointerpretation, field, and accuracy assessment procedures.

Tuzigoot National Monument was designated as one of the prototype parks. The Monument represents a xeric climatic environment with a diverse range of vegetation types, ranging from desert scrub to wetland communities. For this park, AIS was responsible for the photointerpretation and automation of the vegetation units and TNC directed the field sampling effort and the classification assignments. Working in conjunction with the field biologists from TNC, AIS photointerpreted the vegetation units from stereo paired, color-infrared photography. This data was then input into an ARC/INFO GIS and rectified to a digital orthophoto image. The vegetation coverage was converted into the Standardized National Vegetation Classification System (SNVCS) using ecologist-assisted computer modeling techniques. The resulting vegetation map was reviewed and approved by TNC's Western Region director.

II. PHOTOINTERPRETATION MAPPING CONVENTIONS

One of the most important mandates of the Vegetation Mapping Program was the consistent capture and classification of vegetation types through the use of photointerpretation and field sampling methodologies. Because of the nature of the SNVCS, it is difficult to consistently classify the vegetation using conventional photointerpretation techniques. In order to meet the project goals, AIS developed the Layer Mapping method of photo-interpretation. This technique uses a set of basic physiognomic criteria to describe rudimentary aspects of the vegetation based on photo signature and available supplemental information. The vegetative units are described by their basic physiognomic and spatial properties, referred to as the photo primitives. They consist of stature type (tree, shrub or herbaceous), average height, density and floristic composition.

Another aspect of the Layer Mapping system is the ability to map multiple layers of vegetation, overstory, midstory and understory, when visible on the photo. The tallest life form is placed in layer 1, with the next tallest in layer 2, etc. For example, if trees were the tallest life form within a polygon, their attributes would be identified as layer 1. If shrubs were the next tallest, they would be placed in layer 2 and if herbaceous vegetation was present, it would be placed in layer 3. When a polygon only contains an overstory vegetation, with no understory visible, the overstory vegetation is identified as layer 1 regardless of the life form. This also applies to situations where shrubs are taller than trees, or grasses are taller than shrubs. Layers are identified by the height of the life forms, not the life forms themselves. Up to six layers can be mapped per polygon, although typically there are no more than three.

A set of photointerpretation mapping conventions was developed in order to consistently represent the vegetation during the photointerpretation process; they are listed below.

Stature

Stature describes the basic life or growth form of the vegetation. The code refers to the broad physiognomic divisions of vegetation.

- There are three classes of life forms identified during the photointerpretation effort; trees, shrubs and herbaceous. Other life forms, i.e. dwarf shrubs, vines, sub-shrubs, etc., can be derived from the project look-up table. The life form codes are identified by the color pentel used to code the floristic composition and characteristics on the photo overlays.

- Green pentel = Trees
- Red pentel = Shrubs
- Blue pentel = Herbaceous
- Black pentel = Land Use/Non-vegetated

- Trees are defined as single-stemmed woody plants, generally greater than five meters in height except in successional areas where maximum growth has not been attained or where dwarfed by environmental factors.

- Shrubs are defined as multi-stemmed woody plants, generally under 5 meters in height.

- Herbaceous vegetation is defined as plants containing little or no woody portions and it includes the grasses, other grass-like plants, and forbs.

- Trees, shrubs and herbaceous vegetation are mapped as separate layers within a polygon.

- Vegetation layers are determined by height and life form. Layer 1 will always be the tallest life form within a polygon, layer 2 the next tallest, etc. If two or more life forms are the same height within a polygon, then trees take precedence over shrubs, shrubs take precedence over herbaceous.

- The life form assigned to a species is determined by the life form of the mature plant under optimal environmental conditions. For example, pine seedlings will be mapped as trees, not herbaceous, krummholz pines in subalpine environments will be mapped as trees, not shrubs.

- Typically, a life form has to compose at least 5% of the vegetation cover within a polygon before it can be mapped. For instance, if a polygon contains 50% shrub cover, 25% herbaceous cover and 3% tree cover, the trees will not be listed in the height, density or floristic composition characteristics.

Height

Height describes the average height of the life form in each layer.

- Each layer will be assigned one height category, except as noted below.

- If height differences between the same life form does not skip an entire height class category, then the height category for each layer will be determined by the average (not the mean) height of the vegetation for that layer. To determine the average height of the vegetation, determine which percentage of the vegetation is at what height. If 10% of the trees are 100' tall and 50% are 120' tall, then they will fall into a height class category of 6 (35-50m). If 80% of the trees are 100' tall and 20% are 120' tall, then the height category assigned to the polygon will be a 5 (15-35 m).

- When the height differences between the same life form are so great that they skip one entire height category, the life form should be mapped as two separate layers. For instance, in the Smoky Mountains the Dogwood trees are much shorter (they skip at least one height category) than the hardwood tree overstory trees. On the photo overlays, the height, density and floristic composition information is drafted as two entries in green pentel separated by a slash. The slash indicates to the coder that the life form should be coded into a separate layer.

- The same species will be mapped as a single layer within a polygon regardless of height differences between them. For instance, if a polygon contains Pinus palustris seedlings <.5 m tall and mature P. palustris trees 30 m tall, they will be mapped as one layer.

Density

Density refers to the spacing of plants in the landscape. It represents the total coverage based on the percentage of crown or canopy cover. This figure is a qualitative estimate based on the aerial photography. Two methods are used to determine densities from aerial photographs; Absolute and Relative (Continual) Density. Absolute density refers to the sum total of the visible plant and non-vegetative cover within a given mapping unit. The total density cover for all visible over-, mid-, and understory vegetated and non-vegetated surfaces must equal 100% present. The unvegetated areas are not delineated unless they can be delineated at the project mmu. Vegetation not visible on the aerial photograph is not considered as part of the total plant density. For example; in a closed canopy forest the understory grasses and shrubs are not visible, therefore only the tree overstory is visible and the density code is based on the total tree cover present.

Relative density is used when the aerial photography allows the interpreter to see the understory vegetation due to the environmental conditions at the time of the photography or when detailed field notes are available. When mapping relative density, it is possible to arrive at total vegetation cover percentages well over 100%. For example; using winter photography to capture leaf-off conditions, a closed-canopy deciduous forest (over 60% crown cover) is visible along with the shrub and grass understories. In addition to the 60-100% tree cover, shrub and grass understory may make up an additional 60-100% understory cover, totaling at least 120% vegetation cover for that mapping unit.

Absolute crown density is normally the most accurate way of estimating plant coverage. In certain park specific situations where understory needs to be mapped, relative density estimates will be addressed if there is sufficient data. At the very least, aerial photography showing leaf-off conditions is necessary when mapping relative crown density.

- Closed/Continuous >60% = Canopies overlapping, touching or nearly touching in most of the mapping unit.

- Discontinuous 40%-60% = Canopies rarely touching, however spacing is fairly minimal, especially when plants are not evenly distributed throughout the polygon.

- Dispersed 25%-40% = An open or parkland situation where large spaces occur between trees and shrubs, or where grasses are fairly sparse throughout the mapping unit.

- Sparse 10%-25% = Trees or shrubs are widely spaced scattered throughout the polygon, or are clumped in very small areas making up a small percentage of the entire vegetative cover.

- Rare 2%-10% = Trees or shrubs are occur only occasionally and usually do not make up enough percentage to be considered evenly dispersed. Grasses coverage at this level is hard to detect on small scale aerial photography.

- Absolute density is used to determine the percentage of vegetation cover within a polygon, unless noted otherwise in the park specific mapping criteria.

- To determine the absolute density, assign percentages to the different life forms visible on the aerial photo, including non-vegetated areas. The total percent cover of trees, shrubs, herbaceous and non-vegetated should add up to 100%. Convert the absolute density percentages into the appropriate density class.

- Non-vegetated areas are not coded in the database unless they meet the minimum mapping resolution for the park and can be mapped as a stand-alone polygon. Otherwise, it is assumed that all vegetation polygons contain non-vegetated areas.

- Consider the coverage pattern of the vegetation before assigning a density code to the polygon. Estimating densities is more straightforward when plants occupying a particular strata are evenly distributed throughout the mapping unit. However when polygons contain populations of plants which are clumped or occurring only in portions of the polygon, the photointerpreter must consider the area not occupied by plant cover when determining coverage density. To insure consistency, it is helpful to count the plants in polygons with clumped and unevenly distributed vegetation and then compare them to similar sized polygons with an even distribution of plant cover.

- The vegetation stature type and scale of the aerial photography will determine the visibility of individual plants. Trees are usually visible as individuals and with larger scale photography so are shrubs. However, grasses are rarely seen as individual plants, regardless of the scale of the photography.

- The date of the aerial photography will also influence the densities assigned to vegetation types, especially herbaceous species. Subsequent field verification must take into consideration the following factors that can cause seeming discrepancies between the densities listed on the photo and those visible in the field.

- Seasonality - annual herbaceous vegetation visible on summer aerial photographs may be gone when conducting on-site field visits later in the year. The reverse is also true; fall and winter aerial photographs may not show the presence of annual herbaceous vegetation visible during spring or summer field visits.

- Different years - the environmental conditions at the time of the photography (wet vs. drought years, flooding, etc.) may affect the densities seen during the on-site field visits.

- Dry grasses tend to be less dense than they appear on the aerial photographs. To accurately depict the densities, the percent cover for dry grasses should be adjusted downward. This means that if the percent cover falls at the lower end of a density category, the polygon should be assigned the next density class down. For example, if the percent cover = 25%, the polygon should be assigned a density code of 4 (10-25%) instead of 3 (25-40%). If the percent cover falls within the middle of a density category, the polygon should be assigned that density class, i.e. the percent cover = 35%, the polygon is assigned a code of 3.

Floristic Composition

Floristic composition refers to the most detailed taxonomic name assigned to the vegetation photo signature.

- A floristics list will be developed for every park. This list will consist of floristic composition that can be identified through photointerpretation techniques. It does not represent the complete listing of all vegetation species found at that park.

- Up to three floristic designations per layer can be coded into the database.

- The floristic characteristics are listed using the same order and color codes as the life forms contained within the polygon. If a polygon contains trees, shrubs and grass, the tree floristics are listed first in green pentel, then shrubs in red pentel, and finally herbaceous in blue pentel. Within each life form, the dominant floristic type is listed first, then the next dominant, etc.

- The most detailed florisitic designation should be used whenever possible. If a species does not have an identifiable photo signature, the next level of detail can be used. Generic descriptions such as dry graminoid, shrubs, etc., should only be used when a more specific identification is impossible.

Aggregation

Aggregation is necessary when below mmu vegetation types are present within a polygon.

- Like life forms should be aggregated together; trees should be aggregated with other trees, shrubs with shrubs and herbaceous with herbaceous vegetation types.

- Wet vegetation types should be aggregated with other wet vegetation types, regardless of life form class. For example, on Assateague Island, Baccharis halimifolia and Iva frutescens sometimes form a below mmu band of vegetation between the marsh grasses and the Myrica shrub thicket. Since Baccharis/Iva is a wet vegetation type, it was aggregated into the marsh grasses rather than the Myrica shrub thicket.

- If a below mmu is completely surrounded by another vegetation type, form class, the below mmu is aggregated with the surrounding vegetation.

III. TUZIGOOT NATIONAL MONUMENT

The following describes the tasks performed and methodologies used by AIS during the vegetation data compilation for Tuzigoot National Monument. AIS was responsible for the photointerpretation, data rectification, automation, and in conjunction with TNC, the National Classification assignment.

Data Collection Visit

Data Collection is the first step in the photointerpretation process. The goals is to collect and evaluate the data sources available for the park. This includes reviewing the imagery, basemaps, and supplemental collateral sources, e.g. existing vegetation maps, soil surveys, etc.

The data collection visit to Tuzigoot National Monument occurred in March 1995. (Refer to the TUZIGOOT NATIONAL MONUMENT, AIS DATA COLLECTION REPORT dated May 15, 1995 for more information.) The two day visit consisted of a project meeting with park personnel to discuss the National Vegetation Mapping program and tour the Monument. During the meeting, existing photography, vegetation maps and geographical basemaps were reviewed and evaluated. Potential study area boundaries and the minimum mapping unit (mmu) were also discussed. The end result was the establishment of the digital orthophoto as the project basemap. The study area boundary was defined as the extent of the orthophoto image, and the mmu was set at 1/4 hectare. Project scale and aerial photography were to be determined after a review of exisiting 1992 aerial photography not available for the initial meeting.

Upon evaluation of the 1992 photography it was decided that new imagery should be acquired for the photointerpretation effort. The resulting project photography was color-infrared (CIR) stereo-paired diapositives, average scale 1:6,720, flown during September 1995. The project scale was established at 1:6720. A duplicate set of photo prints was sent to TNC for use in their field sampling effort.

Development of Mapping Criteria

The mapping criteria is a set of documented working decision rules to facilitate the maintenance of accuracy and consistency of interpretation in the database. They assist the user in understanding the characteristics, definition, and context for each vegetation category. A field reconnaisance visit is performed to familiarize the photointerpreters with the vegetation types and their photo signatures prior to the actual mapping process. The reconnaisance is an important step in the development of the photointerpretation criteria and signature key.
For the Tuzigoot mapping effort, the field reconnaisance task was not performed. Due to the small size of the study area, it was decided that enough information had been gathered during the initial visit to proceed with the photointerpretation process. The mapping criteria was developed using the standard mapping conventions (see section II) as a base. Additions to the criteria pertaining to specific situations found at the Monument are described below.

- Guterriezia sarothrae, classified as a sub-shrub, was placed in the herbaceous stature category.

- Prosopis velutina, which can occur as either a tree or a shrub, was mapped in both the tree stature and shrub stature categories. The tree form of Prosopis was mapped in the toeslope and bosque areas, while the shrub form was mapped in the drier desert plain locations.

Photointerpretation of Vegetation

Photointerpretation is the process of identifying map units based on their photo signature.
All land cover features have a photo signature. These signatures are defined by color, texture, pattern, and tone on the aerial photography. By observing the context and extent of the photo signatures associated with specific vegetation types, the photointerpreter is able to identify and delineate the boundaries of the vegetation. Additional collateral sources, e.g. exisiting vegetation map, supplemental photography, soil data, etc., can be of great utility to the photointerpreter. Understanding the relationship between the vegetation and the context in which they appear is very useful in the interpretation process. Familiarity with regional differences also helps interpretation by establishing a context for a specific area.

At Tuzigoot National Monument, the photointerpretion was done using a stereoscope to view the CIR stereo-paired diapositives. The delineations and codes representing the vegetation categories were annotated directly onto a mylar overlay registered to the CIR image. The delineations and codes were edgematched between photos to ensure a seamless coverage in the database. Any uncertain interpretations were flagged on the mylar overlay for review during the quality control step.

Quality Control of Photointerpretations

A quality control step is performed after the photointerpretation task to ensure the accuracy and consistency of the interpretations.

Once the initial mapping was completed for the Monument, the photo overlays with the delineations and attributes were given to senior interpreters for review and comment. The interpreted overlays were checked for completeness, consistency, and adherence to the mapping criteria and guidelines. For those polygons flagged by the photointerpreter, the reviewer either assigned the appropriate vegetation code or left the polygon flagged for field verification.

Field Verification

The field verification task ensures that the data layer produced is as error free as possible.
The photos and interpreted mylar overlays are taken into the field by the photointerpreters.
During the on-site visit, map units flagged during the photointerpretation effort are reviewed in the field and the necessary changes and corrections are made directly onto the photo overlays.

At Tuzigoot, the field verification task was conducted over a three day period concurrent with TNC's field sampling effort in the latter part of October 1995. In conjunction with the photo verification and field sampling effort, NBS personnel perfomed a locational accuracy test comparing the accuracy of a global positioning system (GPS) versus manual location techniques. The TNC biologist "pin-pricked" all of the sample site locations onto the aerial photos while the NBS staff captured the location using GPS. The "pin-pricked" locations were subsequently input into the GIS database for comparison against the GPS locations for the same site.

Data Conversion

Typically, the first step of the data conversion process is the manual rectification of the delineations from the unrectified aerial photos to a hardcopy of the project basemap. However, the hardcopy orthophoto for Tuzigoot was of such coarse resolution that manual rectification was impossible. The manual rectification task was bypassed and the delineations were manuscripted directly from the non-rectified photos and scanned. The scanned images were then rectified to the digital orthophoto image in the computer.

The computer rectification process included three major steps; the initial transformation where geographic coordinates were assigned to the data. This step involved picking a set of control points that corresponded to both the orthophoto image and the aerial photography. The second and third steps consisted of "refining" the rectified data. The second step consisted of selecting numerous "link" points in the computer over the entire study area to further tied the vegetation units to the orthophoto image. The third and final step was to locally adjust the vegetation units to the orthophoto image by repeating the "link" points procedure over small areas of the image.

One of the biggest challenges encountered during the Tuzigoot mapping project was the computer rectification of the delineations. The reason for this was the CIR imagery and the orthophotos were not concurrent with one another: the CIR imagery was taken in 1995; the orthophoto was created from imagery taken in 1992. Even under normal circumstances it is difficult to correlate between imagery taken in different years or even different seasons in some instances. However, the rapidly changing environmental conditions compounded the problem at Tuzigoot. For example; due to recent flooding, the Verde river has moved northward in the last three years. It's location was mapped according to the 1995 image which does not match the position of the river on the orthophoto. The user needs to be aware of the impact regarding this situation. Any questions regarding the delineation of vegetation polygons should be referenced back to the 1995 CIR imagery, not the orthophoto basemap.

The next task was to join the attribute data to the spatial information in the computer. Normally, this step is done prior to scanning and the spatial and attribute data are joined together during the automation process. In order to input the attribute codes for Tuzigoot, a plot was created of the vegetation delineations. The attribute data was transferred from the photo overlays to a mylar overlay code sheet (CS) registered to the plot. Each polygons was assigned a unique sequence number identification. The attributes were keypunched into a spreadsheet format and then joined with the spatial data in the GIS.

The attribute and spatial data were QC'd for accuracy and completeness of input. Edit plots were created for the vegetation delineations, the height, density and floristic composition characteristics and compared back to the original delineations and CS. Corrections were made as needed and input into the computer. A final quality control of the photointerpretation was performed by creating a "consist" program. The program pulled out inconsistencies in
the attribute coding, e.g. if tree taxa was listed for a polygon and there was no height/density attributes assigned, it would be flagged for investigation and correction.

Conversion of Photo Primitives to the Standardized National Vegetation Classification System

The final step of the mapping process is the conversion of the photo primitives to the SNVCS. Once the photo primitives were input into the GIS, they were converted to the SNVCS through ecologist supported computer modeling techniques. Using field sample site information, the Alliance/Association classes were extrapolated to polygons sharing like aspects in the same regional area. A preliminary vegetation map was created and then reviewed by TNC field biologists for accuracy. If necessary, revisions to the delineations or the computer model were made and another map was produced for review. This process was repeated until the TNC biologists approved of all classification assignments.

The photo primitives mapped for Tuzigoot National Monument were converted to the SNVCS during a two day meeting at AIS. A preliminary vegetation map with the SNVCS designations and sample site locations was produced using computer modeling techniques. TNC, working in conjunction with AIS, reviewed the preliminary map by comparing it back to the CIR photos and TNC's field data sheets. Additional delineations were added to the database, separating the classes on the basis of abiotic factors, e.g. landform type and past environmental conditions. The computer model was adjusted and another map was created, reviewed and revised, using the same methodology as described above. In all, there were five iterations of this process before the final classification assignments were completed. As a result of this process, the SNVCS for the Monument was revised to include four additional classes.

TUZIGOOT NATIONAL MONUMENT, ARIZONA
NBS/NPS VEGETATION MAPPING PROGRAM
AERIAL INFORMATION SYSTEMS PROJECT REPORT
DATA DICTIONARY

COVERAGE NAME: ..... TUZI_VEG
ORTHOPHOTOQUAD IMAGE NAME: ..... TUZIGOOT
Projection: ..... UTM Meters
RELATE FILE: ..... TUZI_VEG.LUT
RELATE NAME: ..... ALLIANCE

Relate name: ..... Alliance
Table: ..... Tuzi_veg.lut
Database: ..... Info
Item: ..... Seqno
Column: ..... Seqno
Relate Type: ..... Ordered
Relate Access: ..... RO

Column	Item Name	Wd.	Out.	Type
1	AREA	4	12	F
5	PERIMETER	4	12	F
9	TUZI_VEG#	4	5	B
13	TUZI_VEG-ID	4	5	B
17	SEQNO	4	4	I

Attribute Lookup Table (Relate file): Tuzi_veg.lut

Column	Item Name	Wd.	Out.	Type
1	SEQNO	4	4	I
5	ALLIANCE	3	3	I
8	MALLIANCE	3	3	I
11	LANDUSE	4	4	C
15	PROFILE1	1	1	C
16	STATURE1	1	1	C
17	SPECIES1	2	2	C
19	HEIGHT1	1	1	C
20	DENSITY1	1	1	C
21	PROFILE2	1	1	C
22	STATURE2	1	1	C
23	SPECIES2	2	2	C
25	HEIGHT2	1	1	C
26	DENSITY2	1	1	C
27	PROFILE3	1	1	C
28	STATURE3	1	1	C

Column	Item Name	Wd.	Out.	Type
29	SPECIES3	2	2	C
31	HEIGHT3	1	1	C
32	DENSITY3	1	1	C
33	PROFILE4	1	1	C
34	STATURE4	1	1	C
35	SPECIES4	2	2	C
37	HEIGHT4	1	1	C
38	DENSITY4	1	1	C
39	PROFILE5	1	1	C
40	STATURE5	1	1	C
41	SPECIES5	2	2	C
43	HEIGHT5	1	1	C
44	DENSITY5	1	1	C
45	PROFILE6	1	1	C
46	STATURE6	1	1	C
47	SPECIES6	2	2	C
49	HEIGHT6	1	1	C
50	DENSITY6	1	1	C
	** REDEFINED ITEMS **			
15	REL2	36	36	C
15	CODE1	6	6	C
21	CODE2	6	6	C
27	CODE3	6	6	C
33	CODE4	6	6	C
39	CODE5	6	6	C
45	CODE6	6	6	C

PERTINENT ITEM DESCRIPTION:

Seqno: Polygon lookup number that ties back to the Coverage PAT
Alliance: Defined alliance value for that particular polygon
Malliance: Manual override alliance - as defined by NBS & TNC based on geomorphological & other criteria.
Landuse: Landuse code
Profile1: Profile Number
Stature1: Stature name
Species1: Dominant species for that profile
Height1: Average crown height
Density1: Absolute crown density

** REDEFINED ITEMS **

Rel2: Code string used to tie various frequency files
Code1: 6 string code for first profile

LAYER CHARACTERISTIC CODES

Stature (1 digit)

1 = Tree
2 = Shrub
3 = Herbaceous
8 = Water
9 = Land Use / Unvegetated

Height (1 digit)

1 = <0.5 meters
2 = 0.5 - 2 meters
3 = 2 - 5 meters
4 = 5 - 15 meters
5 = 15 - 35 meters
6 = 35 - 50 meters
7 = >50 meters
9 = Not Applicable

Absolute Crown Density (1 digit)

1 = Closed/Continuous: >60%
2 = Discontinuous: 40% - 60%
3 = Dispersed: 25% - 40%
4 = Sparse: 10% - 25%
5 = Rare: 2% - 10%
9 = Not Applicable

FLORISTIC COMPOSITION - Trees (3 digits) (Up to three floristic composition types per layer)

01 =	Populus fremontii	(Fremont's cottonwood)
02 =	Celtis reticulata	(Hackberry)
03 =	Quercus turbinella	(Oak)
04 =	Salix goodinggii	(Goodding's willow)
05 =	**(Not used)**	
06 =	Prosopis velutina	(Mesquite)
08 =	Dead	
09 =	Unvegetated	
98 =	Water body	

FLORISTIC COMPOSITION - Shrubs/Vines/Dwarf Shrubs (3 digits) (Up to three floristic composition types per layer)

01 =	Acacia greggii	(Catsclaw acacia)
02 =	Atriplex canescens	(Four-winged saltbush)
03 =	Baccharis salicifolia	(Seep willow)
04 =	Canotia holocantha	(Crucifixion thorn)
05 =	Chilopsis linearis	(Desert Willow)
06 =	**(Not used)**	
07 =	**(Not used)**	
08 =	Krameria parvifolia	(Range ratany)
09 =	Larrea tridentata	(Creosote bush)
10 =	Mahonia trifoliata	(Barberry)
11 =	Parthenium incanum	(Mariola)
12 =	Prosopis velutina	(Mesquite)
13 =	Eurotia lanata	(Winterfat)
14 =	**(Not used)**	
15 =	Shrubs	
16 =	Juniperus spp.	(Juniper)
17 =	Eriogonum deflexum	(Flat-top buckwheat)
18 =	**(Not used)**	
19 =	Celtis reticulata	(Desert hackberry)
88 =	Dead	
98 =	Water body	
99 =	Unvegetated	

FLORISTIC COMPOSITION - Herbaceous (6 digits) (Up to three floristic composition types per layer)

01 =	Ambrosia ancanthicarpa	(Ragweed)
02 =	Aristida purpurea	(Purple three-awn)
03 =	Cynodon dactylon	(Bermuda grass)
04 =	Cirsium spp.	(Prickely thistle)
05 =	Distichlis stricta	(Saltgrass)
06 =	Aquatic	
07 =	Graminoid (dry)	
08 =	Graminoid (wet)	
09 =	Kochia scoparia	(Fireweed)
10 =	Muhlenbergia asperifolia	(Alkalai muhly)
11 =	Muhlenbergia porteri	(Bush muhly)
12 =	Salsola kali	(Tumbleweed)
13 =	Scirpus validus	(Bulrush)
14 =	Solanum douglassii	(Nightshade)
15 =	Typha angustifolia	(Cattails)
16 =	Forbs >.5 m in height	
17 =	Eleocharis parishii	(Spike rush)
18 =	Hordeum jubatum	(Foxtail barley)
19 =	Guterriezia sarothrae	(Snakeweed)
20 =	Eragrostis lehmanniana	(Lehmann's lovegrass)
88 =	Dead	
98 =	Water	
99 =	Unvegetated	

LAND USE (3 digits)

100 = Urban or Built-Up
- 110 = Residential
- 120 = Commercial and Services
- 130 = Industrial
- 140 = Transportation, Communications, and Utilities
- 150 = Mixed Commercial and Industrial
- 160 = Mixed Urban
- 170 = Under Construction
- 180 = Open Space and Recreation
- 190 = Vacant within Urban Context

200 = Agriculture
300 = Mining
400 = National Park/Monument Facilities
- 401 = Visitors Center
- 402 = Road
- 403 = Parking Area
- 404 = Archaeological Site
- 405 = Residence

500 = Water
600 = Vacant

National Vegetation Classification for Tuzigoot National Monument

100 = Populus fremontii Woodland Alliance
- 101 = Populus fremontii/ Salix gooddinggii Association
- 102 = Populus fremontii/Prosopis velutina Association
- 103 = Populus fremontii/Hordeum jubatum Association

110 = Juniperus erythrocarpa Woodland Alliance
- 111 = Juniperus erythrocarpa/Canotia holocantha Association

120 = Celtis reticulata Woodland Alliance
- 121 = Celtis reticulata/Quercus turbinella Association

130 = Canotia holocantha Shrubland Alliance
- 131 = Canotia holocantha/Aristida purpurea Association

140 = Larrea tridentata Shrubland Alliance
- 141 = Larrea tridentata/Aristida purpurea Association

150 = Chilopsis linearis Shrubland Alliance

160 = Atriplex canescens Shrubland Alliance
- 161 = Atriplex canescens/Muhlenbergia porteri Association

170 = Prosopis velutina Shrubland Alliance
- 171 = Prosopis velutina/Hordeum jubatum Association
- 172 = Prosopis velutina/Celtis reticulata Association
- 173 = Prosopis velutina/Distichlis stricta Association
- 174 = Prosopis velutina/Guterriezia sarothrae Association

180 = Aristida purpurea Herbaceous Alliance
- 181 = Aristida purpurea/Krameria parvifolia Association

190 = Typha angustifolia Herbaceous Alliance

200 = Cynodon dactylon Herbaceous Alliance

210 = Muhlenbergia asperifolia Herbaceous Alliance
- 211 = Muhlenbergia asperifolia/Eleocharis parishii Association

220 = Eragrostis lehmanniana Herbaceous Alliance

230 = Short perennial forb Formation
- 231 = Short perennial forbs (semi-natural)
- 232 = Short perennial forbs (semi-cultivated)

240 = Herbaceous vegetation - annual graminoids or forbs

250 = Intermittently flooded cold-deciduous shrubland

APPENDICES

NATIONAL BIOLOGICAL SERVICE / NATIONAL PARK SERVICE
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TUZIGGOT NATIONAL MONUMENT, ARIZONA
PHOTO SIGNATURE KEY

TAXA	STATURE	PHOTO SIGNATURE (9-95) (1:6720 CIR)	LANDFORM CONTEXT	HEIGHT	OCCURENCE	ASSOCIATED TAXA	ALLIANCE/COMMUNITY	SPECIAL CONSIDERATIONS
Acacia gregii	Shrub	COLOR: Red-Orange CROWN SIZE: Small CROWN SHAPE: Irregular TEXTURE: Coarse irregular	Ridges and flats of upland desert areas.	1-3m	Common	*Prosopis velutina* *Atriplex canescens* *Krameria parvifolia*	*Prosopis velutina / Gutierrezia sarothrae* *Atriplex canescens* / Muhlenbergia porteri *Aristida purpurea / Krameria parvifolia*	Typically found in association with *Prosopis velutina* (except in the *Prosopis velutina* bosque).
Aquatic vegetation	Herbaceous	COLOR: Bright pink to Bright red CROWN SIZE: N/A CROWN SHAPE: N/A TEXTURE: Smooth	Open water	N/A	Rare	*Typha angustifolia* *Scirpus validus*	*Typha angustifolia*	Usually found in open water within stands of *Typha angustifolia.*
Aristida purpurea	Shrub	Photo signature not conclusive	Uplands	< .5m	Abundant	*Larrea tridentata* *Canotia holocantha* *Prosopis velutina* *Aristida purpurea* *Krameria parvifolia* *Gutierrezia sarothrae*	*Larrea tridentata/Aristida purpurea* *Canotia olocantha / Aristida purpurea* *Prosopis velutina / Gutierrezia sarothrae* *Aristida purpurea / Krameria parvifolia* *Juniperus erythrocarpa / Canotia holocantha*	Associated with most upland communities; photo signature is similar to other dry graminoids and small shrubs forming bunch patterns; occurs on the bluffs and mesas as a typical sparse desert grassland; forms an understory to taller shrubs.
Atriplex canescens	Shrub	COLOR: Pink CROWN SIZE: Small CROWN SHAPE: Round TEXTURE: Mottled	Xeric slopes on exposures of well-drained alkaline soils.	.5-2m	Common	Prosopis velutina Parthenium incanum Muhlenbergia porteri	*Atriplex canescens / Muhlenbergia porteri*	Occurs on the north and south facing slopes surrounding the ruins.

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Baccharis salicifolia	Shrub	Photo signature not conclusive	North of Verde river on remnant riverine flat.	1-2m	Uncommon	*Salsola kali* *Solanum douglassi* *Prosopis velutina*	*Prosopis velutina* / *Hordeum jubatum* *Populus fremontii* / *Hordeum jubatum*	Photo signature is indistinct - only identified from on-site field verification information.
Canotia holocantha	Shrub	COLOR: Brown CROWN SIZE: Medium CROWN SHAPE: Narrow, irregular TEXTURE: Slightly mottled	Gypsum soils - upland bluffs and mesas.	1-4m	Common	*Juniperus erythrocarpa* *Larrea divartica* *Aristida purpurea* Krameria parvifolia	*Canotia holocantha* / *Aristida purpurea* *Juniperus erythrocarpa* / *Canotia holocantha* *Larrea divartica* / *Aristida purpurea*	Common near top of bluffs east of the marsh where it associates with *Juniperus erythrocarpa* and the mesas where intermixes with *Aristida purpurea* and *Larrea divaricata.*
Celtis reticulata	Tree / Shrub	COLOR: Red-orange CROWN SIZE: Medium CROWN SHAPE: Rounded TEXTURE: Smooth	Toeslopes adjacent to steep bluffs in close proximity to the marsh or major canyons.	5-10m	Common	*Prosopis velutina* *Quercus turbinella* *Mahonia trifoliata*	*Prosopis velutina* / *Celtis reticulata* *Celtis reticulata* / *Quercus turbinella*	Photo signature cannot be differentiated from *Prosopis velutina* or *Quercus turbinella* - mapped from on-site field verification information.
Chilopsis linearis	Shrub	COLOR: Brown-Orange CROWN SIZE: Medium CROWN SHAPE: Narrow TEXTURE: Coarse-irregular	Adjacent to river channels on bars and flats, remnant river flats.	2-5m	Uncommon	*Salsola kali*	*Chilopsis linearis*	Significant stand along the southern bank of the Verde river.
Cynodon dactylon	Herbaceous	COLOR: Bright orange-red to yellowish orange CROWN SIZE: N/A CROWN SHAPE: N/A TEXTURE: Smooth	Abandoned agricultural fields; adjacent to wetland marsh vegetation	< .5m	Common	*Muhlenbergia asperifolia* *Eleocharis parishii* *Distichlis stricta* *Salsola kali* Solanum douglassi	*Cynodon dactylon* *Muhlenbergia asperifolia* / *Eleocharis parishii* *Salsola kali*	Usually indicative of wetter soils and growing conditions.

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Distichlis stricta	Herbaceous	COLOR: Brownish-red CROWN SIZE: N/A CROWN SHAPE: N/A TEXTURE: Slightly mottled	Transition areas between marsh and upland	< .5m	Fairly common	*Prosopis velutina* *Cynodon dactylon* *Muhlenbergia asperifolia* *Eleocharis parishii*	*Prosopis velutina* / *Distichlis stricta* *Muhlenbergia asperifolia / Eleocharis parishii* *Cynodon dactylon*	Indicative of saltier growing conditions; large area adjacent to southern marsh.
Eleocharis parishii	Herbaceous	COLOR: Pink-red CROWN SIZE: N/A CROWN SHAPE: N/A TEXTURE: Smooth	Transitional areas between wetlands and uplands	.5-1m	Common	*Muhlenbergia asperifolia* *Cynodon dactylon*	*Muhlenbergia asperifolia / Eleocharis parishii*	Occurs in sites which are fairly wet - usually adjacent to *Scirpus validus* or *Typha angustifolia*; abundant in the northern portions of the study area.
Eragrostis lehmanniana	Herbaceous	Photo signature not conclusive	Disturbed areas	< .5m	Uncommon	*Aristida purpurea*	*Eragrostis lehmannians*	Photo signature cannot be differentiated from other dry graminoids - mapped from field verification information; restricted to very disturbed sites in upland areas - most are along roadways.
Eriogonum deflexum	Shrub	Photo signature not conclusive	Uplands	.5-1m	Uncommon	*Aristida purpurea* *Acacia greggi*	*Aristida purpurea / Krameria parvifolia*	Photo signature cannot be differentiated from surrounding dwarf shrubs and dry graminoids - mapped from field verification information.
Forbs - undifferentiated	Herbaceous	This category is used when the photo signature does not identify distinct species and field verification information is not available.	Disturbed areas	.5-1.5m	Common	*Salsola kali* *Solanum douglassi* *Prosopis velutina*	Short perennial Forb Association semi-cultivated . Sort perennial Forb Association semi-natural. Intermittently flooded cold-deciduous shrubland	Abundant in the northern portions of the study area.

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Graminoid - dry	Herbaceous	This category is used when the photo signature does not identify distinct species and field verification information is not available.	Uplands	< .5m	Abundant	*Larrea tridentata* *Canotia holocantha* *Prosopis velutina* *Aristida purpurea* *Krameria parvifolia* *Gutierrezia sarothrae*	*Larrea tridentate* / *Aristida purpurea* *Canotia holocantha* / *Aristida purpurea* *Prosopis velutina* / *Gutierrezia sarothrae* *Aristida purpurea* / *Krameria parvifolia* *Juniperus erythrocarpa* / *Canotia holocantha*	Associated with most upland communities; occurs on the bluffs and mesas as a typical sparse desert grassland; forms an understory to taller shrubs.
Graminoid - wet	Herbaceous	This category is used when the photo signature does not identify distinct species and field verification information is not available.	Wetlands	< .5-1m	Common	*Cynodon dactylon* *Muhlenbergia asperifolia* *Eleocharis parishii* Distichlis *stricta*	*Cynodon dactylon* *Muhlenbergia asperifolia* / *Eleocharis parishii* *Prosopis velutina* / *Distichlis stricta* *Typha angustifolia*	
Gutierrezia sarothrae	Shrub / Herbaceous	Photo signature not conclusive	Desert plains and uplands.	< .5m	Common	*Prosopis velutina* *Acacia gregii* Aristida purpurea	*Prosopis velutina* / *Gutierrezia sarothrae*	Photo signature cannot be differentiated from other dry graminoids - mapped from field verification information; the *Prosopis velutina*/*Gutierrezia sarothrae* alliance is indicative of past disturbance, usually due to grazing.
Hordeum jubatum	Herbaceous	Photo signature not conclusive	Sandy substrate, active and remnant riverine flats.	< .5m	Common	*Prosopis velutina* *Populus fremontii*	*Prosopis velutina* / *Hordeum jubatum* Populus fremontii / *Hordeum jubatum*	Photo signature cannot be differentiated from other dry graminoids - mapped from field verification information; common understory to the *Prosopis velutina* bosque and the *Populus fremontii* woodland.

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Juniperus erythrocarpa	Shrub	COLOR: Red CROWN SIZE: Large CROWN SHAPE: Round TEXTURE: Smooth	Bluffs in shaded areas; upland mesa.	1-10m	Uncommon	*Canotia holocantha* *Aristida purpurea*	*Juniperus erythrocarpa* / *Canotia holocantha*	Widespread across the mesas but sparse - groups of over 5 individuals are rare.
Krameria parvifolia	Shrub	Photo signature not conclusive	Dry uplands and mesas.	< .5-1m	Common	*Aristida purpurea* *Larrea divartica* *Canotia holocantha*	*Aristida purpurea* / *Krameria parvifolia* *Larrea divartica*/*Aristida purpurea* *Canotia holocantha* / *Aristida purpurea*	Typically found on ridge east of the visitors center and the mesa top in association with other dwarf shrubs and dry graminoids.
Larrea divartica	Shrub	COLOR: Light orange-red CROWN SIZE: Medium CROWN SHAPE: Irregular, open TEXTURE: Mottled, irregular	Exposed limestone bluffs of shallow, rapidly drained soils and mesas.	1-2m	Common	*Parthenium incanum* *Aristida purpurea* *Krameria parvifolia* Canotia *holocantha*	*Larrea divartica* / *Aristida purpurea* *Canotia holocantha* / *Aristida purpurea*	Common on bluffs in association with *Parthenium incanum*, *Aristida purpurea* and other shrub species; occurs in pure stands on the mesas.
Mahonia trifoliata	Shrub	COLOR: Red-orange CROWN SIZE: Medium CROWN SHAPE: Rounded TEXTURE: Smooth	Toeslopes of bluffs adjacent to or in close proximity to the marsh or major canyons.	1-3m	Fairly common	*Prosopis velutina* *Celtis reticulata* *Solanum douglassi*	*Prosopis velutina / Celtis reticulata*	Photo signature cannot be differentiated from *Prosopis velutina* or *Celtis reticulata* - mapped from field verification information; also an indicator species for the *Prosopis velutina*/*Celtis reticulata* alliance.
Muhlenbergia asperifolia	Herbaceous	COLOR: Pinkish-white CROWN SIZE: CROWN SHAPE: TEXTURE: Mottled	Transitional areas between wetlands and uplands.	.5-1m	Common	*Eleocharis parishii* *Cynodon dactylon* *Distichlis stricta*	Muhlenbergia asperifolia / Eleocharis parishii	Occurs in sites which are fairly wet - usually adjacent to *Scirpus validus* or *Typha angustifolia*; abundant in the northern portions of the study area.

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Muhlenbergia porteri	Herbaceous	COLOR: Brown CROWN SIZE: Small CROWN SHAPE: Rounded TEXTURE: Mottled	North-facing slopes	1-2m	Uncommon	*Atriplex canescens* *Prosopis velutina* *Acacia greggii* *Aristida purpurea*	*Atriplex canescens* / *Muhlenbergia porteri*	Restricted to the slopes below the monument ruins - more abundant on the cooler north facing slope; prefers more mesic growing conditions, usually found growing under a shrub overstory.
Parthenium incanum	Shrub	COLOR: Light pink CROWN SIZE: Small CROWN SHAPE: Rounded TEXTURE: Smooth	Xeric slopes and upland areas.	< .5m	Fairly common	*Atriplex canescens* *Larrea divartica*	*Atriplex canescens* / *Muhlenbergia porteri* *Larrea tridentate* / *Aristida purpurea*	Found in dense stands below the ruins; also found in a horizontal band along the bluffs NE of the marsh.
Populus fremontii	Tree	COLOR: Orange-pink CROWN SIZE: Large CROWN SHAPE: Rounded TEXTURE: Mottled	Sandy substrate, active and remnant riverine flats.	15-35m	Fairly common	*Salix goodingii* *Prosopis velutina* *Hordeum jubatum*	*Populus fremontii* / *Salix goodingii* *Populus fremontii* / *Prosopis velutina* *Populus fremontii* / *Hordeum jubatum*	Usually present as individual trees or in small groups along the marsh and the Verde river.
Prosopis velutina	Tree / Shrub	COLOR: Red-orange CROWN SIZE: T=medium S=small CROWN SHAPE: Rounded TEXTURE: Smooth	Toeslopes of steep bluffs; desert plains; edge of riparian areas.	1-10m	Abundant	*Gutierrezia sarothrae* *Acacia greggii* *Celtis reticulata* *Mahonia trifoliata*	*Prosopis velutina* / *Hordeum jubatum* *Prosopis velutina* / *Celtis reticulata* *Prosopis velutina* / *Distichlis stricta* Prosopis velutina / Gutierrezia sarothrae	Occurs in tree form in the bosque and toeslopes; shrub form in other areas- *Prosopis velutina*/*Gutierrezia sarothrae* is an indicator of past disturbance - *Prosopis velutina*/*Celtis reticulata* is a typical ecotone between riparian and upland areas.
Quercus turbinella	Tree	COLOR: Red-orange CROWN SIZE: Medium CROWN SHAPE: Rounded TEXTURE: Smooth	Steep shaded bluffs in major canyons.	5-10m	Uncommon	*Celtis reticulata* *Canotia holocantha* *Prosopis velutina*	*Celtis reticulata* / *Quercus turbinella*	Photo signature cannot be differentiated from *Prosopis velutina* or *Celtis reticulata* - mapped from on-site field verification information.

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Salix goodingii	Tree	COLOR: Orange-pink CROWN SIZE: Medium CROWN SHAPE: Irregular TEXTURE: Mottled	Sandy substrate, active and remnant riverine flats.	5-20m	Fairly common	*Populus fremontii*	*Populus fremontii* / *Salix goodingii*	Usually present in association with *Populus fremontii* in narrow band-like units adjacent to water.
Salsola kali	Herbaceous	COLOR: Dark brown-brownish orange CROWN SIZE: Small CROWN SHAPE: Irregular TEXTURE: Mottled	Disturbed areas	1-2m	Common	*Solanum douglassi* *Cirsium* spp. *Chilopsis linearis*	Short Perennial Forb Association semi-cultivated Short Perennial Forb Association semi-natural Intermittently flooded cold-deciduous shrubland *Chilopsis linearis*	Common in disturbed and borderline wet sites; large concentrations are found south of the Verde river with Chilopsis linearis, on sandy sites north of the Verde river, and in areas by the old dairy in the northern part of the study area.
Scirpus validus	Herbaceous	COLOR: Red to orange-red (depends upon life cycle stage) CROWN SIZE: N/A CROWN SHAPE: N/A TEXTURE: Smooth	Wetlands	1-4m	Fairly common	*Typha angustifolia* *Muhlenbergia asperifolia* *Eleocharis parishii*	*Typha angustifolia*	Dominant/codominant vegetation type with *Typha angustifolia* in the northern part of the study area - sparse in the south.
Shrubs - undifferentiated	Shrub	This category is used when the photo signature does not identify distinct species and field verification information is not available.	Uplands	.5-2m	Abundant	*Larrea tridentata* *Canotia holocantha* *Prosopis velutina* *Aristida purpurea* *Krameria parvifolia* *Gutierrezia sarothrae*	*Larrea tridentate / Aristida purpurea* *Canotia holocantha / Aristida purpurea* *Prosopis velutina / Gutierrezia sarothrae* *Aristida purpurea / Krameria parvifolia* *Juniperus erythrocarpa / Canotia holocantha*	This category is used when recognized species do not form a dominant or codominant photo signature and/or there is no field verification information available; common on xeric sites throughout the monument.

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Solanum douglassi	Herbaceous	COLOR: Light-red CROWN SIZE: N/A CROWN SHAPE: N/A TEXTURE: Smooth	Disturbed areas	< .5m	Common	*Salsola kali* *Prosopis velutina*	Short Perennial Forb Association semi-cultivated Short Perennial Forb Association semi-natural Intermittently flooded cold-deciduous shrubland	Common in disturbed and borderline wet sites; large concentrations are found on sandy sites north of the Verde river, and in areas by the old dairy in the northern part of the study area; also forms part of the understory vegetation to *Prosopis velutina*/*Celtis reticulata.*
Typha angustifolia	Herbaceous	COLOR: Brilliant red-dark brown (depends upon life cycle stage) CROWN SIZE: N/A CROWN SHAPE: N/A TEXTURE: Very mottled	Wetlands	1-4m	Fairly common	*Scirpus validus* *Muhlenbergia asperifolia* *Eleocharis parishii*	*Typha angustifolia*	The dominant wetland emergent species of the marsh; commonly seen as pure stands or with Scirpus validus.