SWReGAP Land Cover Mapping Methods Documentation

Functional Unit or Mapping Zone: NV5 (Mojave Mapping Unit)

Organization: Lockheed Martin Environmental Services Office in association with the U.S. Environmental Protection Agency – Landscape Ecology Branch

Person Preparing Document: Todd Sajwaj

Date of Preparation: 23 November, 2004

1) Predictor layer preparation:

a) Image standardization:

Because of the insufficient number and quality of "dark objects" in the Nevada Landsat ETM+ imagery, a simple conversion of digital numbers to at-sensor reflectance was performed via the following equation:

$$\rho_{BandN} = \frac{\pi(L_{BandN} * Gain_{BandN} + Bias_{BandN}) * D^2}{E_{BandN} * (COS((90 - \theta) * \pi / 180))}$$

Where,

ρ_{BandN} = Reflectance for Band N

L_{bandN} = Digital Number for Band N

D = Normalized Earth-Sun Distance

E_{bandN} = Solar Irradiance for Band N

b) Image dates and mosaicking:

Images were mosiacked using ERDAS Imagine 8.6 Mosiac Tool with "no cutline" for *type*, and the "overlay" option for *overlap function*.

Image dates and scenes were as follows:

ETM+ Scene (path/row)	Summer (yr – Julian date)	Fall (yr – Julian date)
38/34	2000 – 165	1999 – 306
39/34	2000 - 188	None available
39/35	2000 – 156	1999 – 297
39/36	2000 – 124	1999 – 297
40/34	2000 - 163	1999 - 288
40/35	2000 - 163	1999 - 272
41/34	2000 - 202	2000 - 282

Spring scenes were not used due to the abundance of snow across a significant portion of the scenes. This snow rendered the spring imagery unsuitable for land cover modeling purposes.

Two coverages (summer and fall mosaics) showing overlap arrangement, date, and path/row can be found at:

/nv/archive/nv5/mosaic/NV5_SUMMER.zip - nv5_summer_mosaic.shp
/nv/archive/nv5/mosaic/nv5_fall.zip - nv5_fall_mosaic.shp

The six-band ETM+ mosaics can be found in:

/nv/archive/nv5/mosaic/mosaics.zip - nv5_summer.img
/nv/archive/nv5/mosaic/mosaics.zip - nv5_fall.img

c) Image derived datasets:

Landsat 7 ETM+ (Reflectance values): Once the digital numbers of the Landsat mosaic were converted to reflectance values, these "raw" bands were incorporated into land cover models. These images are labeled as *nv5_summer* and *nv5_fall*.

Tasseled Cap: Bright-ness, green-ness, and wet-ness band transformations were created for the summer and fall mosaics using coefficients derived from the Landsat 7 ETM+ sensor, by Huang et al. (2001b). An example of the *.gmd file can be found at: /nv/archive/nv5/img_files/. These images are labeled as *nv5_sum_tcap* and *nv5_fall_tcap*.

Multi-temporal Kauth-Thomas Transformation: "Stable" and "change" components of bright-ness, green-ness, and wet-ness were created from the Tasseled Cap transformations of the summer and fall mosaics by using the transformation coefficients of Collins and Woodcock (1996). The first three bands of this image represent stable elements of bright-ness, green-ness, and wet-ness, while the second three bands represent "change" elements of bright-ness, green-ness, and wet-ness. An example of the *.gmd file can be found at: /nv/archive/nv5/img_files/. This image is labeled as *nv5_mtk*.

Fractional Vegetation: The percent of ground covered by photosynthetic vegetation was estimated by the equation of Carlson and Ripley (1997). Reference values used in the equation were identified by examination of

NDVI histograms and locating known sites of bare soil and irrigated agricultural fields. An example of the *.gmd file can be found at: /nv/archive/nv5/img_files/. These images are labeled as *nv5_sum_fr* and *nv5_fall_fr*.

All image-derived datasets and corresponding *.gmd models can be found in:

/nv/archive/nv5/img_files/images1.zip
/nv/archive/nv5/img_files/images2.zip
/nv/archive/nv5/img_files/images3.zip

d) DEM derived datasets:

Aspect: The aspect image was derived from the original elevation grid via the *aspect* algorithm in the *topographic analysis* menu of ERDAS Imagine. Aspect values range from 0 to 361, where 361 indicates flat terrain. This image is labeled as *nv5_asp*.

Southwest-ness: Since tree models are sometimes confounded by circular variables (i.e. aspect), the aspect image was converted to a linear "southwest-ness" image. Values range from -1 (indicating northeast-facing slopes) to +1 (indicating southwest-facing slopes). An example of the *.gmd file can be found at: /nv/archive/nv5/img_files/. This image is labeled as *nv5_swness*.

Elevation: The elevation image was created by importing the original elevation grid to an ERDAS Imagine file format. This image is labeled as *nv5_elev*.

Slope: The slope image was produced from the original elevation grid via the *slope* algorithm in the *topographic analysis* menu of ERDAS Imagine. The units of the slope image are degrees and range from 0 to 90. This image is labeled as *nv5_slope*.

Landform: A 10-class landform was created from a topographic relative moisture (values ranging from 0-28) index grid (Manis et al. 2001). This image is labeled as *nv5_landf*.

For modeling purposes, all ARCINFO grids were converted to ERDAS Imagine .img files, and can be found at:

/nv/archive/nv5/img_files/images1.zip
/nv/archive/nv5/img_files/images2.zip
/nv/archive/nv5/img_files/images3.zip

2) Samples:

a) Sample collection methods:

All training site data was collected by Eastern Nevada Landscape Coalition (ENLC) field crews during the summer and fall of 2003 by the protocols described in the "Field Methodologies and Training Manual for Nevada Field Crews" (see http://www.epa.gov/nerlesd1/land-sci/pdf/training-manual.pdf for further details). Based on the floristic composition and ecological setting, each training site was assigned an *Alliance* and *Ecological System* label (Comer et. al. 2003).

NV090403BB02: Identifies a training site collected by an ENLC field crew. The site identification indicates it was sampled on September 4, 2003 by Brian Brost.

No other training data sources were available for the NV5 mapping unit.

b) Summary of samples:

A total of 2966 training sites were collected in the NV5 mapping unit. A polygon coverage containing all training site locations and their ecological system labels are found at:

/nv/archive/nv5/train_data/shapefiles.zip – nv5_sites.shp

S Code	# Samples	Ecological System Label
D02	8	Recently Burned
D04	29	Invasive Southwest Riparian Woodland and Shrubland
D07	7	Invasive Perennial Forbland
N11	111	Open Water
N81	149	Pasture/Hay Irrigated Agriculture
S016	175	North American Warm Desert Bedrock Cliff and Outcrop
S017	12	North American Warm Desert Badland
S018	2	North American Warm Desert Active and Stabilized Dunes
S019	7	North American Warm Desert Volcanic Rockland
S020	55	North American Warm Desert Wash
S021	21	North American Warm Desert Pavement
S022	7	North American Warm Desert Playa
S026	63	Inter-Mountain Basins Subalpine Limber-Bristlecone Pine Woodlands
S032	12	Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland
S034	87	Rocky Mountain Montane Mesic Mixed Conifer Forest and Woodland
S040	202	Great Basin Pinyon-Juniper Woodlands
S046	2	Rocky Mountain Gambel Oak-Mixed Montane Shrubland
S050	2	Inter-Mountain Basins Mountain Mahogany Woodland and Shrublands
S053	1	Great Basin Semi-Desert Chaparral
S054	42	Inter-Mountain Basins Big Sagebrush Shrublands
S055	8	Great Basin Xeric Mixed Sagebrush Shrublands
S060	605	Mojave Mid-Elevation Mixed Desert Scrub
S065	83	Inter-Mountain Basins Mixed Salt Desert Scrub
S069	588	Sonora-Mojave Creosote-White Bursage Desert Scrub
S071	38	Inter-Mountain Basins Montane Sagebrush Steppe
S078	1	Inter-Mountain Basins Big Sagebrush Steppe
S079	258	Inter-Mountain Basins Semi-Desert Shrub Steppe
S083	9	Rocky Mountain Subalpine Mesic Meadow
S090	10	Inter-Mountain Basins Semi-Desert Grasslands
S092	2	Rocky Mountain Subalpine-Montane Riparian Woodland and Shrubland
S094	35	North American Warm Desert Lower Montane Riparian Woodland and Shrubland
S096	3	Inter-Mountain Basins Greasewood Flats
S097	5	North American Warm Desert Riparian Woodland and Shrubland
S098	7	North American Warm Desert Riparian Mesquite Bosque
S100	14	North American Arid West Emergent Marsh
S102	14	Rock Mountain Alpine-Montane Wet Meadow
S114	65	Sonora-Mojave-Baja Semi-Desert Chaparral
TOTAL	**2966**	

3) Cover types:

a) Classification Tree modeled cover types:

The following cover type were modeled via the EROS Data Center's CART Module for ERDAS Imagine:

S Code	Ecological System Name
D02	Recently Burned
D04	Invasive Southwest Riparian Woodland and Shrubland
D07	Invasive Perennial Forbland
N11	Open Water
N81	Pasture/Hay Irrigated Agriculture
S016	North American Warm Desert Bedrock Cliff and Outcrop
S017	North American Warm Desert Badland
S018	North American Warm Desert Active and Stabilized Dunes
S019	North American Warm Desert Volcanic Rockland
S020	North American Warm Desert Wash
S021	North American Warm Desert Pavement
S022	North American Warm Desert Playa
S026	Inter-Mountain Basins Subalpine Limber-Bristlecone Forest and Woodlands
S032	Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland
S034	Rocky Mountain Montane Mesic Mixed Conifer Forest and Woodland
S040	Great Basin Pinyon-Juniper Woodlands
S046	Rocky Mountain Gambel Oak-Mixed Montane Shrubland
S050	Inter-Mountain Basins Mountain Mahogany Woodland and Shrublands
S053	Great Basin Semi-Desert Chaparral
S054	Inter-Mountain Basins Big Sagebrush Shrublands
S055	Great Basin Xeric Mixed Sagebrush Shrublands
S060	Mojave Mid-Elevation Mixed Desert Scrub
S065	Inter-Mountain Basins Mixed Salt Desert Scrub
S069	Sonora-Mojave Creosote-White Bursage Desert Scrub
S071	Inter-Mountain Basins Montane Sagebrush Steppe
S078	Inter-Mountain Basins Big Sagebrush Steppe
S079	Inter-Mountain Basins Semi-Desert Shrub Steppe
S083	Rocky Mountain Subalpine Mesic Meadow
S090	Inter-Mountain Basins Semi-Desert Grasslands
S092	Rocky Mountain Subalpine-Montane Riparian Woodland and Shrubland
S094	North American Warm Desert Lower Montane Riparian Woodland and Shrubland
S096	Inter-Mountain Basins Greasewood Flats
S097	North American Warm Desert Riparian Woodland and Shrubland
S098	North American Warm Desert Riparian Mesquite Bosque
S100	North American Arid West Emergent Marsh
S102	Rock Mountain Alpine-Montane Wet Meadow
S114	Sonora-Mojave-Baja Semi-Desert Chaparral

North American Warm Desert Active and Stabilized Dunes, North American Warm Desert Volcanic Rockland, Rocky Mountain Gambel Oak-Mixed Montane Shrubland, Great Basin Semi-Desert Chaparral, Inter-Mountain Basins Big Sagebrush Steppe, Rocky Mountain Subalpine-Montane Riparian Woodland and Shrubland, and Invasive Perennial Forbland cover types were withheld from the modeling process due to insufficient sample size.

b) Non CT modeled cover types:

The PASTURE/HAY IRRIGATED AGRICULTURE (S Code – N81) was screen digitized using Landsat ETM+ imagery at a scale of 1:24,000 and 1:100,000. PASTURE/HAY IRRIGATED AGRICULTURE is given the value "2" in this image.

The RECENTLY BURNED (S Code - D02) cover type was mapped by performing an unsupervised classification of Landsat imagery that was subsequently subjected to a density slice to identify those areas scarred by fire. RECENTLY BURNED is given the value "2" in this image.

The NORTH AMERICAN WARM DESERTS ACTIVE AND STABILIZED DUNES (S code – S018) cover type was developed by performing an unsupervised classification on the Landsat imagery. Each spectral cluster was assigned to a "dune" or "non-dune" class via visual inspection. INTER-MOUNTAIN BASINS ACTIVE AND STABILIZED DUNES was labeled as "2" while all other non-dune pixels were labeled as "1" or "0."

The RECENTLY MINED OR QUARRIED (S Code – D03) was screen digitized using Landsat ETM+ imagery at a scale of 1:24,000 and 1:100,000. RECENTLY MINED OR QUARRIED is given the value "2" in this image.

The DEVELOPED, LOW INTENSITY (S code – N21) and DEVELOPED, MED-HIGH INTENSITY (S code – N22) was developed by sub-setting the urbanized regions from a fractional vegetation layer, and performing a density slice of the fractional vegetation values to differentiate the two urban classes from natural vegetation. Within the nv2_urban.img file, DEVELOPED, LOW INTENSITY was labeled as "1" and DEVELOPED, MED-HIGH INTENSITY was labeled as"2."

The NORTH AMERICAN WARM DESERT VOLCANIC ROCKLAND (S Code – S019) was screen digitized using Landsat ETM+ imagery at a scale of 1:24,000 and 1:100,000. NORTH AMERICAN WARM DESERT VOLCANIC ROCKLAND is given the value "2" in this image.

The OPEN WATER (S Code - N11) cover type was mapped by a presence/absence model in which Open Water training sites were labeled as "1" while all other training sites were labeled as "0." A model was executed with the Image CART Module using the reflectance and topographic variables. The output was compared against the summer Landsat imagery to remove minor errors. OPEN WATER is given the value "2" in this image.

The image files depicting these non-modeled classes are found in:
/nv/archive/nv5/non_model/non_model.zip – nv5_agriculture.img
/nv/archive/nv5/non_model/non_model.zip – nv5_burns.img
/nv/archive/nv5/non_model/non_model.zip – nv5_dunes.img
/nv/archive/nv5/non_model/non_model.zip – nv5_mines.img
/nv/archive/nv5/non_model/non_model.zip – nv5_urban.img
/nv/archive/nv5/non_model/non_model.zip – nv5_volcanic.img
/nv/archive/nv5/non_model/non_model.zip – nv5_water.img

4) Summary of predictor layers used:

a) Multi band predictors:

nv5_summer.img	(ETM+ bands 1-5 & 7 – mixed 1999 & 2000 images)
nv5_fall.img	(ETM+ bands 1-5 & 7 – mixed 1999 & 2000 images)
nv5_mtk.img	(bands 1-3 = stable brightness, greenness, wetness; bands 4-6 = change brightness, greenness, wetness)
nv5_sum_tcap.img	(summer brightness, greenness, wetness)
nv5_fall_tcap.img	(fall brightness, greenness, wetness)

All multi-band predictors can be found at:
/nv/archive/nv5/img_files/images1.zip

/nv/archive/nv5/img_files/images2.zip
/nv/archive/nv5/img_files/images3.zip

b) Single band predictors:

nv5_slope.img	Continuous slope (units = degrees)
nv5_swness.img	Linear, continuous transformation of aspect
nv5_elev.img	Continuous elevation (units = meters)
nv5_sum_fr.img	Continuous fractional vegetation
nv5_fall_fr.img	Continuous fractional vegetation
nv5_landf.img	Categorical 10 class landform (from DEM)

5) Modeling Methods:

a) See5 Classification Tree modeling:

Training Data Sets: Once training site polygons were attributed with an ecological system label, 20% of the training sites for each land cover class were withheld for an accuracy assessment. Thus, two training data sets were produced:

1) An *80% training data set* used to produce a "preliminary" land cover maps (and subjected to an accuracy assessment)
2) A *total data set* used to create a "final" land cover map.

Data Set Generation: Twenty points were randomly located within each of the training site polygons of the *80%* and *total data sets* using the Random Points extension for ArcView. The two sets of random points were converted to ARCINFO grids and then to Imagine *.img files. Each Imagine pixel was attributed with the appropriate ecological system code. The *80% data set* contained 2,373 training site polygons that were converted by the process described above into 26,880 pixels for use in creating the "preliminary" land cover map via the CART modeling process. The *total data set* contained 2,966 training site polygons that were converted into 33,450 pixels for production of the "final" land cover map via the CART modeling process.

Sample pixels were "drilled" through each of the predictor data layers to produce a data set containing both predictor (imagery and DEM-derived) variables and the response variable (ecological system label code) using the *CART Sampling Tool* of the CART Module (EarthSatellite Corporation 2003). For both the *80%* and *total* data sets, 16 CART training data sets were prepared by the methodology described above where each CART training data set was composed of different numbers and sets of predictor variables. The training data sets developed the NV5 mapping unit are described below:

Model #	Model Name	# of Variables	Variable Labels
1	Sum	6	Summer
2	Fall	6	Fall
3	Mtk	6	Multi-temporal Kauth-Thomas
4	Topo	4	Slope, Southwest-ness, Elevation, Landform
5	Sffr_topo	5	Summer and Fall Fractional Vegetation, Slope, Southwest-ness, Elevation
6	Sftcap	6	Summer and Fall Tasseled Cap
7	Sum_topo	9	Summer, Slope, Southwest-ness, Elevation
8	Fall_topo	9	Fall, Slope, Southwest-ness, Elevation
9	Mtk_topo	9	Multi-temporal Kauth-Thomas, Fall, Slope, Southwest-ness, Elevation
10	Sftcap_topo	9	Summer and Fall Tasseled Cap, Fall,

			Slope, Southwest-ness, Elevation
11	Sftcap_sffr	8	Summer and Fall Tasseled Cap, Summer and Fall Fractional Vegetation
12	Sum_ftcap_topo	12	Summer, Fall Tasseled Cap, Slope, Southwest-ness, Elevation
13	Fall_stcap_topo	12	Fall, Summer Tasseled Cap, Slope, Southwest-ness, Elevation
14	Sum_fall_mtk	18	Summer, Fall, Multi-temporal Kauth-Thomas
15	Full	30	Summer, Fall, Multi-temporal Kauth-Thomas, Summer and Fall Tasseled Cap, Summer and Fall Fractional Vegetation, Slope, Southwest-ness, Elevation, Landform

The output files from the CART Sampling Tool (*.names, *.data, *.test) are located in:

/nv/archive/nv5/output/see5_files.zip

A different set of models were used with the *total data set* to create the final land cover map for NV2:

Model #	**Model Name**	**# of Variables**	**Variable Labels**
1	Sum	6	Summer
2	Fall	6	Fall
3	Mtk	6	Multi-temporal Kauth-Thomas
4	Sffr_topo	5	Summer and Fall Fractional Vegetation, Slope, Southwest-ness, Elevation
5	Topo	4	Slope, Southwest-ness, Elevation, Landform
6	Sftcap	6	Summer and Fall Tasseled Cap
7	Sum_topo	9	Summer, Slope, Southwest-ness, Elevation
8	Fall_topo	9	Fall, Slope, Southwest-ness, Elevation
9	Mtk_topo	9	Multi-temporal Kauth-Thomas, Slope, Southwest-ness, Elevation
10	Sftcap_topo	9	Summer and Fall Tasseled Cap, Slope, Southwest-ness, Elevation
11	Sum_ftcap_topo	12	Summer, Fall Tasseled Cap, Slope, Elevation, Southwest-ness
12	Fall_stcap_topo	12	Fall, Summer Tasseled Cap, Slope, Elevation, Southwest-ness
13	Sum_fall_mtk	18	Summer, Fall, Multi-temporal Kauth-Thomas
14	Sftcap_sffr	8	Summer, Fall, Slope, Southwest-ness, Elevation
15	Full	29	Summer, Fall, Multi-temporal Kauth-Thomas, Summer and Fall Tasseled Cap, Summer and Fall Fractional Vegetation, Slope, Southwest-ness, Elevation

The output files from the CART Sampling Tool (*.names, *.data, *.test) are located in:

/nv/archive/nv5/output/alldata/see5_files.zip

Classification Tree Construction: See5 data mining software (Release 1.8, http://www.rulequest.com) was used to construct 16 tree classifiers for both the *80%* and *total* data sets. Boosting was employed using 15 trials for the construction of each tree classifier. The output files (*.out, *.names.hst, *.set) from tree classifier construction are found at:

/nv/archive/nv5/output/80percent/see5_files.zip
/nv/archive/nv5/output/80percent/see5_files.zip

CART Classifer and Land Cover Map Creation: The *CART Classifier* of Imagine CART module was used to implement the tree classifier produced by the See5 software package and thus create a land cover map. A total of 16 land cover images were produced for the *80% data set*:

1) sum.img
2) fall.img
3) mtk.img
4) topo.img
5) sftcap.img
6) sum_topo.img
7) fall_topo.img
8) mtk_topo.img
9) sftcap_topo.img
10) sftcap_sffr.img
11) sum_ftcap_topo.img
12) fall_stcap_topo.img
13) sffr_topo.img
14) sum_fall_mtk.img
15) full.img

The 15 output land cover maps are found at:

/nv/archive/nv5/output/80percent/nv5_maps.zip

These 15 images were stacked in a single .img file with 15 bands, each corresponding to one of the 16 land cover maps. The STACK MAJORITY function was then used allow each land cover map to "vote" for the best ecological system label for every pixel. In other words, the 15 ecological system labels (one from each land cover map) for each pixel location are tallied, and the ecological system with the highest number of "votes" is entered into the output "preliminary" land cover map. The "pseudo-random forest" model (nv5_prf.gmd) and "preliminary" map resulting from this process (nv5_prf_v1.img) can be found at:

/nv/archive/nv5/output/80percent/nv5_maps.zip

This land cover classification, following the addition of non-modeled classes, was subjected to an accuracy assessment using the withheld data (198 reference sites).

b) Post-classification, recoding and other modeling steps:

Step 1: Discriminating S034-Rocky Mountains Montane Dry-Mesic Mixed Conifer Forests and Woodlands and S032-Rocky Mountains Montane Mesic Mixed Conifer Forests and Woodlands. The logic and parameters are as follows:

This model was used to differentiate S034-Rocky Mountains Montane Dry-Mesic Mixed Conifer Forests and Woodlands and S032-Rocky Mountains Montane Mesic Mixed Conifer Forests and Woodlands. NatureServe describes S032 to occur "*in cool ravines and on north-facing slopes. Elevations range from 1200 to 3300 m. Occurrences of this system are found on cooler and more mesic sites than Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland. Such sites include lower and middle slopes*

of ravines, along stream terraces, moist, concave topographic positions and north- and east-facing slopes which burn somewhat infrequently."

> Model Methods: The preliminary models were run to include only the S032-Rocky Mountains Montane Mesic Mixed Conifer Forests and Woodlands ecological systems. A conditional statement was applied to re-classify S034 pixels on moister, northerly facing slopes to S032.

Model 1a: Either S034 (IF *Modeled Vegetation* = S032 AND ((ASPECT GE 45) AND (ASPECT LT 275)) OR *Modeled Vegetation* OTHERWISE

Step 2: Upon inspection of the eco-regional transition between mapping units NV3 Lahontan region) and NV5 (Mojave Desert region), it was decided that transition overly abrupt and did not reflect the gradual transition of vegetation types between these eco-regions. It was decided to smooth this abrupt transition through the use of a Great Basin-Mojave transition model.

While the training data set for the NV3 mapping unit included a small number of training sites from the north limit of the Mojave eco-region, it was insufficient to produce a gradual transition between the eco-regions. Therefore, a broad overlap region was delineated to include adequate sample numbers of both Great Basin and Mojave vegetation types. The overlap region polygon can be found at:

/nv/archive/gb_mjav_transition/trans_region.aoi

The overlap region included approximately 3600 training sites. The abbreviated database containing the training site attributes can be found at:

/nv/archive/gb_mjav_transition/transition_sites.mdb

The shapefile containing the training sites used to classify the Great Basin-Mojave transition is located at:

/nv/archive/gb_mjav_transition/transition_sites.shp

The overlap region polygon was also used to subset a number of predictor variables including summer and fall reflectance data, summer and fall Tasseled Cap variables, slope and elevation.

The predictor variables are located at:

/nv/archive/gb_mjav_transition/images/images1.zip

The 3600 transition training sites were then used to classify the vegetation of the transition via the EDC CART module. A single model was constructed using the predictor variables listed above. The See5 output files generated during the modeling process are found at:

/nv/archive/gb_mjav_transition/images/output.zip

The resulting preliminary land cover map for the Great Basin-Mojave Transition (gb_mjav_transition.img) is located at:

/nv/archive/gb_mjav_transition/images/images1.zip

The resulting land cover map for the transition region was used in conjunction with the preliminary land cover map for the NV3 mapping unit (prf15_v2.img) to generate an "agreement" map. This map depicts only those pixels that share the same ecological systems label in both the original NV3 preliminary map and transition maps. As expected, most of

the pixels that were not retained ("disagreement" pixels that had conflicting ecological systems labels) were distributed along the southern border of the NV3 mapping unit.

To complete the process, a second model was created to retain the "agreement" pixel labels, and to then assign labels to "disagreement" pixels. A polygon was delineated that captured the highest density of "disagreement" pixels in the transition region between the Great Basin and the Mojave Desert eco-regions. This polygon is located at:

/nv/archive/gb_mjav_transition/transition_fill.aoi

It was decided the "disagreement" pixels to the north of the transition_fill.aoi polygon would be filled with labels from the original NV3 preliminary land cover map, "disagreement" pixels south of the transition_fill.aoi polygon would be filled with labels from the original NV5 (Mojave) land cover map, and "disagreement" pixels in the transition_fill.aoi polygon would receive labels from the Great Basin-Mojave Transition land cover map. The rationale was that pixels outside the area of disagreement would have a higher probability of being correctly modeled by the NV3 or NV5 land cover models since they are further away from the transition region. The region with the high density of "disagreement" pixels was filled with labels from the transition map since the transition land cover map was created with data from both eco-region's vegetation types, it should have a higher probability of being "correct" than the NV3 land cover map (whose training data contained very little Mojave vegetation types).

The resulting preliminary map (nv5_prf15_final_pixel.img) for the NV5 mapping unit is the result of this process.

c) Generalizing to MMU and map completion:

This final land cover map had non-modeled classes incorporated into it. This image was then subjected to the CLUMP function with 4 *connected neighbors*. This image then had the ELIMINATE algorithm run upon it to yield a land cover map generalized to the 2 hectare minimum mapping unit.

6) Validation:

a) CT model validation:

Twenty percent of the sample polygons were randomly selected and withheld from CT modeling. The preliminary CT models were run as described in section 5a using the remaining 80% of the training site data. The 20% withheld samples were used to ass the predictive capability of the CT modeled map via the kappa.avx extension for ArcView by intersecting the reference polygons through the CT modeled land cover map. This extension considers the site correctly mapped when the majority of pixels within the reference polygon agree with the reference label. Output from kappa.avx includes a *.txt, *.dbf, and *.shp file. The *.txt file contains the kappa statistic. The *.dbf file contains an error matrix indicating errors of omission and commission. The *.shp file contains the locations of the reference polygons whether the reference polygon was correct or incorrect, and the actual ecological systems label for the site. These files can be found at:

/nv/archive/nv5/validation

b) Final map:

A second set of 15 land cover images were produced for the *total data set*:

1) sum.img
2) fall.img
3) mtk.img
4) topo.img
5) sftcap.img
6) sum_topo.img
7) fall_topo.img
8) mtk_topo.img
9) sftcap_topo.img
10) sftcap_sffr.img
11) sum_ftcap_topo.img
12) fall_stcap_topo.img
13) sum_mtk_topo.img
14) fall_mtk_topo.img
15) sum_fall_mtk.img

The 16 output land cover maps are found at:

/nv/archive/nv5/output/alldata/nv5_input_maps.zip

These 15 images were processed by the methods described above. The "pseudo-random forest" model (nv5_prf16.gmd) and "final" map resulting from this process (nv5_prf15_v1.img) can be found at:

/nv/archive/nv5/output/alldata/prf_input_maps.zip

c) Discussion of mapped cover types: The following narrative provides qualitative assessments for each cover type mapped in the NV5 mapping unit. It is intended to elaborate on the quantitative results of the CT model validation from the perspective of those most familiar with the map and the mapping process and is hoped to be of value to potential map users.

N11 OPEN WATER: Quantitatively assessed, validation 95% (producers) and 86% (users) based on 20 independent samples. The number of reference sites was small, and not enough for a robust assessment of thematic accuracy. A qualitative assessment suggests that water has been mapped well, however the error matrix indicates some confusion between OPEN WATER and ephemeral water bodies and emergent wetlands.

N21 DEVELOPED, OPEN SPACE-LOW INTENSITY: Not qualitatively assessed. Qualitative assessment indicates that most low intensity developed areas contemporary with the date of the imagery are included. Some confusion is expected to occur with the N22 DEVELOPED, MEDIUM-HIGH INTENSITY class.

N22 DEVELOPED, MEDIUM-HIGH INTENSITY: Not qualitatively assessed. Qualitative assessment indicates that most low intensity developed areas contemporary with the date of the imagery are included. Some confusion is expected to occur with the N21 DEVELOPED, OPEN SPACE-LOW INTENSITY class.

N81 PASTURE HAY–IRRIGATED AGRICULTURE: Quantitatively assessed, validation 100% (producers) and 87% (users) based on 26 independent samples. In general, this system was mapped well though it might have been over-represented at the expense of INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLANDS and INVASIVE ANNUAL GRASSLANDS in some instances. There is also the possibility that some riparian grasslands have been mistaken for irrigated agriculture.

D02 RECENTLY BURNED: Quantitatively assessed, validation 50% (producers) and 50% (users) based on 2 independent samples. This system was confused with NORTH AMERICAN WARM DESERT LOWER MONTANE RIPARIAN WOODLAND AND SHRUBLANDS. This confusion is like due to differences in the dates of acquisition for the training data and satellite imagery.

D03 RECENTLY MINED/QUARRIED: Not quantitatively assessed. A qualitative assessment of this system suggests that most of the larger mines and quarries were adequately mapped, however smaller mines and quarries might have been confused with other sparsely vegetated systems.

D04 INVASIVE SOUTHWEST RIPARIAN WOODLANDS AND SHRUBLANDS: Quantitatively assessed, validation 86% (producers) and 100% (users) based on 6 independent samples. The number of reference sites was small, and not enough for a robust assessment of thematic accuracy. This system was confused with PASTURE/HAY that also tends to occur in the limited areas near surface water and riparian corridors.

D06 INVASIVE PERENNIAL GRASSLANDS: This system was not quantitatively assessed. Even qualitatively, this accuracy of this system is difficult to establish. Because this system is largely composed of seeded grasses (e.g. *Agropyron cristatum* Semi-Natural Herbaceous alliance) in areas formerly occupied by sagebrush-grass mosaics, this type of confusion is to be expected.

D08 INVASIVE ANNUAL GRASSLANDS: This system was not quantitatively assessed. This system is not common in the Mojave mapping unit and, given the paucity of training data, it is not likely that it has been accurately mapped in this region.

D09 INVASIVE ANNUAL AND BIENNIAL FORBLANDS: Quantitatively assessed, validation 100% (producers) and 100% (users) based on 1 independent sample. This is another ecological system that is associated with disturbance, and is thus difficult to map.

S009 INTER-MOUNTAIN BASINS CLIFF AND CANYONS: This system was not quantitatively assessed. This system will only occur in the northern fringe of the Mojave mapping unit, and since there was little training data, it may not be mapped with a high degree of accuracy. It may also be confused with the similar NORTH AMERICAN WARM DESERT BEDROCK CLIFF AND OUTCROP system.

S015 INTER-MOUNTAIN BASINS PLAYAS: This system was not quantitatively assessed. This system will only occur in the northern fringe of the Mojave mapping unit, and since there was little training data, it may not be mapped with a high degree of accuracy. It may also be confused with the similar NORTH AMERICAN WARM DESERT PLAYA system.

S016 NORTH AMERICAN WARM DESERT BEDROCK, CLIFF, AND OUTCROP: Quantitatively assessed, validation 68% (producers) and 70% (users) based on 28 independent samples. This ecological system was primarily confused with SONORA-MOJAVE CREOSOTE-WHITE BURSAGE DESERT SCRUB (5 of 28 reference sites). Much of the confusion can be attributed to the sparse vegetative cover and slope gradients of some of the bedrock outcrops.

S017 NORTH AMERICAN WARM DESERT BADLAND: This system was not qualitatively assessed. This system is not likely to have been well mapped due to the sparse vegetative cover and the heterogeneous topographic settings it occupies.

S018 NORTH AMERICAN WARM DESERT ACTIVE AND STABILIZED DUNES: Quantitatively assessed, validation 100% (producers) and 100% (users) based on 2 independent samples. Though this system appears to have been well mapped, it is probable that some smaller dune complexes were confused with other ecological systems.

S019 NORTH AMERICAN WARM DESERT VOLCANIC ROCKLANDS: Quantitatively assessed, validation 20% (producers) and 100% (users) based on 5 independent samples. This system was confused with SONORA-MOJAVE CREOSOTE-WHITE BURSAGE DESERT SCRUB (3 of 5 reference sites) which can occur commonly on volcanic substrates.

S020 NORTH AMERICAN WARM DESERT WASH: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 1 independent sample. This system was not mapped effectively due in large part to the subtle hydrological differences between it and adjacent upland ecological systems.

S021 NORTH AMERICAN WARM DESERT PAVEMENT: Quantitatively assessed, validation 100% (producers) and 25% (users) based on 1 independent sample. This system is very similar in appearance to other ecological systems of Mojave basins, with most of the ground cover being composed of soil elements.

S022 NORTH AMERICAN WARM DESERT PLAYA: Quantitatively assessed, validation 100% (producers) and 100% (users) based on 6 independent samples. Given its spectral and ecological similarity to the INTER-MOUNTAIN BASINS PLAYA system, it is expected there will be confusion between these systems in the northern extent of the NV5 mapping unit.

S026 INTER-MOUNTAIN BASINS SUBALPINE LIMBER-BRISTLECONE PINE WOODLANDS: Quantitatively assessed, validation 67% (producers) and 46% (users) based on 9 independent samples. This ecological system was confused with both ROCKY MOUNTAIN MONTANE DRY-MESIC MIXED CONIFER FOREST AND WOODLANDS (2 of 9 reference sites) and GREAT BASIN PINYON-JUNIPER WOODLANDS (1 of 9 reference sites) at the lower limits of its elevational range.

S032 ROCKY MOUNTAIN MONTANE DRY-MESIC MIXED CONIFER FOREST AND WOODLANDS: Quantitatively assessed, validation 38% (producers) and 32% (users) based on 16 independent samples. This system was confuse with GREAT BASIN PINYON-JUNIPER WOODLANDS (6 of 16 reference sites) at lower elevations and INTER-MOUNTAIN BASINS SUBALPINE BRISTLECONE-LIMBER PINE WOODLANDS (2 of 16 reference sites) at higher elevations.

S034 ROCKY MOUNTAIN MONTANE MESIC MIXED CONIFER FOREST AND WOODLANDS: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 13 independent samples. This system was confused with ROCKY MOUNTAIN MONTANE DRY-MESIC MIXED CONIFER FOREST AND WOODLANDS (8 of 13 reference sites) and INTER-MOUNTAIN BASINS SUBALPINE LIMBER-BRISTLECONE PINE WOODLANDS (2 of 13 reference sites) at higher elevations, and GREAT BASIN PINYON-JUNIPER WOODLANDS (2 of 13 reference sites) at lower elevations.

S040 GREAT BASIN PINYON-JUNIPER WOODLANDS: Quantitatively assessed, validation 45% (producers) and 49% (users) based on 40 independent samples. This system was confused with SONORA-MOJAVE-BAJA SEMI-DESERT CHAPARRAL (11 of 40 reference sites), INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE (3 of 40 reference sites), and NORTH AMERICAN WARM DESERT LOWER MONTANE RIPARIAN WOODLAND AND SHRUBLANDS (3 of 40 reference sites).

S046 ROCKY MOUNTAIN GAMBEL OAK-MIXED MONTANE SHRUBLANDS: This system was not qualitatively assessed. This system is included in the NV5 mapping unit due to the procedures used to model the Great Basin-Mojave transition. This system was sparsely mapped in the NV5 mapping unit as is fitting since it only occurs in the northern extent of the NV5 mapping unit. As its distribution was modeled on sparse data, it is improbable that it's thematic accuracy is high.

S053 GREAT BASIN SEMI-DESERT CHAPARRAL: This system was not qualitatively assessed. This system is included in the NV5 mapping unit due to the procedures used to model the Great Basin-Mojave transition. This system was sparsely mapped in the NV5 mapping unit as is fitting since it only occurs in the southern extent of the NV5 mapping unit. As its distribution was modeled on sparse data, it is improbable that it's thematic accuracy is high.

S054 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS: This system was not qualitatively assessed. This system is included in the NV5 mapping unit due to the procedures used to model the Great Basin-Mojave transition. This system was sparsely mapped in the NV5 mapping unit as is fitting since it only occurs in the southern extent of the NV5 mapping unit. As its distribution was modeled on sparse data, it is improbable that it's thematic accuracy is high.

S055 GREAT BASIN XERIC MIXED SAGEBRUSH SHRUBLANDS: This system was not qualitatively assessed. This system is included in the NV5 mapping unit due to the procedures used to model the Great Basin-Mojave transition. This system was sparsely mapped in the NV5 mapping unit as is fitting since it only occurs in the southern extent of the NV5 mapping unit. As its distribution was modeled on sparse data, it is improbable that it's thematic accuracy is high.

S060 MOJAVE MID-ELEVATION MIXED DESERT SCRUB: Quantitatively assessed, validation 78% (producers) and 91% (users) based on 77 independent samples. This ecological system was confused with GREAT BASIN PINYON-JUNIPER WOODLANDS (8 of 77 reference sites), INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE (2 of 77 reference sites), and INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS (2 of 77 reference sites). For a system that occurs at intermediate elevations, this system was mapped surprisingly well.

S065 INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB: This system was not qualitatively assessed. This system is included in the NV5 mapping unit due to the procedures used to model the Great Basin-Mojave transition. This system was sparsely mapped in the NV5 mapping unit as is fitting since it only occurs in the southern extent of the NV5 mapping unit. As its distribution was modeled on sparse data, it is improbable that it's thematic accuracy is high.

S069 SONORA-MOJAVE CREOSOTE-WHITE BURSAGE DESERT SCRUB: Quantitatively assessed, validation 59% (producers) and 84% (users) based on 70 independent samples. This system was confused with NORTH AMERICAN WARM DESERT WASH (7 of 70 reference sites), NORTH AMERICAM WARM DESERT BEDROCK CLIFF AND OUTCROP (6 of 70 reference sites), and SONORA-MOJAVE DESERT MIXED SALT DESERT SCRUB (5 of 70 reference sites).

S070 SONORA-MOJAVE DESERT MIXED SALT DESERT SCRUB: Quantitatively assessed, validation 67% (producers) and 29% (users) based on 3 independent samples. The number of reference sites was very small, and not enough for a robust assessment of thematic accuracy. This

system was confused with MOJAVE MID-ELEVATION MIXED DESERT SCRUB (1 of 3 reference sites).

S071 INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE: This system was not qualitatively assessed. Qualitatively, this system appears adequately mapped, however the montane sagebrush subspecies co-dominates with chaparral species, and will likely be confused with the chaparral ecological systems.

S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE: This system was not qualitatively assessed. This system is included in the NV5 mapping unit due to the procedures used to model the Great Basin-Mojave transition. This system was sparsely mapped in the NV5 mapping unit as is fitting since it only occurs in the northern extent of the NV5 mapping unit. As its distribution was modeled on sparse data, it is improbable that it's thematic accuracy is high.

S083 ROCKY MOUNTAIN SUBALPINE MESIC MEADOW: Quantitatively assessed, validation 67% (producers) and 100% (users) based on 3 independent samples. This ecological system was confused with INTER-MOUNTAIN BASINS SUBALPINE LIMBER-BRISTLECONE PINE WOODLANDS (1 of 3 reference sites).

S090 INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLANDS: This system was not qualitatively assessed. This system is included in the NV5 mapping unit due to the procedures used to model the Great Basin-Mojave transition. This system was sparsely mapped in the NV5 mapping unit as is fitting since it only occurs in the northern extent of the NV5 mapping unit. As its distribution was modeled on sparse data, it is improbable that it's thematic accuracy is high.

S094 NORTH AMERICAN WARM DESERT LOWER MONTANE RIPARIAN WOODLANDS AND SHRUBLANDS: Quantitatively assessed, validation 50% (producers) and 20% (users) based on 2 independent samples. Qualitatively, it tends to appear in linear patches, though it may be under-mapped.

S096 INTER-MOUNTAIN BASINS GREASEWOOD FLATS: This system was not qualitatively assessed. This system is included in the NV5 mapping unit due to the procedures used to model the Great Basin-Mojave transition. This system was sparsely mapped in the NV5 mapping unit as is fitting since it only occurs in the northern extent of the NV5 mapping unit. As its distribution was modeled on sparse data, it is improbable that it's thematic accuracy is high.

S097 NORTH AMERICAN WARM DESERT RIPARIAN WOODLAND AND SHRUBLANDS: This ecological system was not quantitatively assessed. It appears to be reasonably mapped in linear patches, however it is probably confused with other riparian ecological systems such as INVASIVE SOUTHWEST RIPARIAN WOODLAND AND SHRUBLANDS.

S098 NORTH AMERICAN WARM DESERT MESQUITE BOSQUE: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 1 independent sample. This ecological system appears to be adequately mapped in a few specific locations, particularly Ash Meadows. However, there may be other upland locations that were misclassified.

S100 NORTH AMERICAN ARID WEST EMERGENT MARSH: Quantitatively assessed, validation 100% (producers) and 67% (users) based on 2 independent samples. The number of reference sites was very small, and not enough for a robust assessment of thematic accuracy. Confusion with the Invasive Riparian system is likely due to the

similarity in spectral signatures and ecological settings of these systems.

S102 ROCKY MOUNTAIN ALPINE-MONTANE WET MEADOW: This ecological system was not quantitatively assessed. This small patch ecological system seems adequately mapped, though it is likely confused with ROCKY MOUNTAIN SUBAPLINE MESIC MEADOW.

S114 SONORA-MOJAVE-BAJA SEMI-DESERT CHAPARRAL: Quantitatively assessed, validation 40% (producers) and 15% (users) based on 5 independent samples. This ecological system was confused with GREAT BASIN PINYON-JUNIPER WOODLANDS (2 of 5 reference sites) and ROCKY MOUNTAIN MONTANE DRY0-MESIC MIXED CONIFER FOREST AND WOODLANDS (1 of 5 reference sites).

S118 GREAT BASIN FOOTHILL LOWER MONTANE RIPARIAN WOODLAND AND SHRUBLANDS: This system was not qualitatively assessed. This system is included in the NV5 mapping unit due to the procedures used to model the Great Basin-Mojave transition. This system was sparsely mapped in the NV5 mapping unit as is fitting since it only occurs in the northern extent of the NV5 mapping unit. As its distribution was modeled on sparse data, it is improbable that it's thematic accuracy is high.

7) Citations:

Carlson, T. N. and D. A. Ripley. 1997. On the relation between NDVI, fractional vegetation cover, and leaf area index. Remote Sensing of Environment. 62:241-252.

Chaves, P. S. Jr., 1988, An improved dark-object subtraction technique for atmospheric scattering correction of multispectral data.

Chavez, P. S. Jr., 1996, Image-based atmospheric corrections—revisited and revised. *Photogrammetric Engineering and Remote Sensing* 62(9): 1025-1036.

Collins, J.B. and C.E. Woodcock. 1996. An assessment of several linear change detection techniques for mapping forest mortality using multitemporal Landsat TM data. Remote Sensing of Environment 56:66-77.

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Mernard, M. Pyne, M. Ried, K. Schulz, K. Snow, and J. Teague. 2003. Ecological systems of the United States: A working classification of US terrestrial systems. NatureServe, Arlington, Virgina.

EarthSatellite. 2003. CART Software User's Guide, prepared by EarthSatellite Corporation for the US Geological Survey in support of the National Land Cover Database (NLCD) 2000. EarthSatellite, January 2003.

Manis, G., J. Lowry and R. D. Ramsey, 2001, Preclassification: An ecologically predictive landform model. GAP Analysis Bulletin No. 10. USGS.

Huang, C. L. Yang, C. Homer, B. Wylie, J. Vogelman and T. DeFelice, 2001a, t-sensor reflectance: A first order normalization of Landsat 7 ETM+ Images.

Huang, C., B. Wylie, L. Yang, C. Homer and G. Zylstra, 2001b, Derivation of tasseled cap transformation based on Landsat 7 at-satellite reflectance.