

## SWReGAP Land Cover Mapping Methods Documentation

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**Functional Unit or Mapping Zone:** NV1 (Sheldon 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:** 17 August, 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:

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

Where,

$\rho_{\text{BandN}}$  = Reflectance for Band N

$L_{\text{bandN}}$  = Digital Number for Band N

D = Normalized Earth-Sun Distance

$E_{\text{bandN}}$  = Solar Irradiance for Band N

**b) Image dates and mosaicking:**

Images were mosaicked using ERDAS Imagine 8.6 Mosaic Tool with "no outline" 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)
42/31	2000 - 209	1999 - 270
43/31	1999 - 181	2000 - 280
43/32	1999 - 197	1999 - 293

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/nv1/mosaic/mosaics.zip - nv1\_summer\_mosaic.shp  
/nv/archive/nv1/mosaic/mosaics.zip - nv1\_fall\_mosaic.shp

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

/nv/archive/nv1/mosaic/mosaics.zip - nv1\_summer.img  
/nv/archive/nv1/mosaic/mosaics.zip - nv1\_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 *nv1\_summer* and *nv1\_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/nv1/img\_files/. These images are labeled as *nv1\_sum\_tcap* and *nv1\_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/nv1/img\_files/. This image is labeled as *nv1\_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/nv1/img\_files/. These images are labeled as *nv1\_sum\_fr* and *nv1\_fall\_fr*.

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

/nv/archive/nv1/img\_files/images1.zip  
/nv/archive/nv1/img\_files/images2.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 *nv1\_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/nv1/img\_files/. This image is labeled as *nv1\_swness*.

**Elevation:** The elevation image was created by importing the original elevation grid to an ERDAS Imagine file format. This image is labeled as *nv1\_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 *nv1\_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 *nv1\_landf*.

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

/nv/archive/nv1/img\_files/images1.zip  
/nv/archive/nv1/img\_files/images2.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 NV1 mapping unit.

**b) Summary of samples:**

A total of 644 training sites were collected in the NV1 mapping unit. A polygon coverage containing all training site locations and their ecological system labels are found at:

/nv/archive/nv1/train\_data/shapefiles.zip - nv1\_sites.shp

<b>S Code</b>	<b># Samples</b>	<b>Ecological System Label</b>
D08	30	Invasive Annual Grassland
D09	10	Invasive Annual and Biennial Forbland
N11	16	Open Water
N31	14	Barren
N81	7	Pasture/Hay Irrigated Agriculture
S009	25	Inter-Mountain Basins Cliff and Canyon
S011	1	Inter-Mountain Basins Shale Badlands
S013	1	Inter-Mountain Basins Volcanic Rock and Cinder Lands
S015	12	Inter-Mountain Basins Playa
S023	14	Rocky Mountain Aspen Forest and Woodlands
S026	2	Inter-Mountain Basins Subalpine Limber-Bristlecone Pine Woodlands
S040	30	Great Basin Pinyon-Juniper Woodlands
S042	1	Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodlands
S050	14	Inter-Mountain Basins Mountain Mahogany Woodland and Shrublands
S054	174	Inter-Mountain Basins Big Sagebrush Shrublands
S055	74	Great Basin Xeric Mixed Sagebrush Shrublands
S065	43	Inter-Mountain Basins Mixed Salt Desert Scrub
S071	34	Inter-Mountain Basins Montane Sagebrush Steppe
S075	2	Inter-Mountain Basins Juniper Savannah
S078	9	Inter-Mountain Basins Big Sagebrush Steppe
S079	14	Inter-Mountain Basins Semi-Desert Shrub Steppe
S090	37	Inter-Mountain Basins Semi-Desert Grasslands
S096	49	Inter-Mountain Basins Greasewood Flats
S100	19	North American Arid West Emergent Marsh
S102	5	Rock Mountain Alpine-Montane Wet Meadow
S118	7	Great Basin Foothill Lower Montane Riparian Woodland and Shrublands
<b>TOTAL</b>	<b>644</b>	

**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:

<b>S Code</b>	<b>Ecological System Name</b>
D08	Invasive Annual Grasslands
D09	Invasive Annual and Biennial Forblands
N31	Barren
S009	Inter-Mountain Basins Cliff and Canyons
S015	Inter-Mountain Basins Playa
S023	Rocky Mountain Aspen Forest and Woodlands
S026	Inter-Mountain Basins Subalpine Limber-Bristlecone Forest and Woodlands
S040	Great Basin Pinyon-Juniper Woodlands
S050	Inter-Mountain Basins Mountain Mahogany Woodland and Shrublands
S054	Inter-Mountain Basins Big Sagebrush Shrublands
S055	Great Basin Xeric Mixed Sagebrush Shrublands
S065	Inter-Mountain Basins Mixed Salt Desert Scrub
S071	Inter-Mountain Basins Montane Sagebrush Steppe
S078	Inter-Mountain Basins Big Sagebrush Steppe

S079	Inter-Mountain Basins Semi-Desert Shrub Steppe
S090	Inter-Mountain Basins Semi-Desert Grasslands
S096	Inter-Mountain Basins Greasewood Flats
S100	North American Arid West Emergent Marsh
S102	Rocky Mountain Alpine-Montane Wet Meadow
S118	Great Basin Foothill Lower Montane Riparian Woodland and Shrublands

The IMB Shale Badlands, IMB Volcanic Rock and Cinderlands, and IMB Juniper Savannah 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 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 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 image files depicting these non-modeled classes are found in:  
/nv/archive/nv1/non\_model/non\_model.zip - nv1\_agriculture.img  
/nv/archive/nv1/non\_model/non\_model.zip - nv1\_burns.img  
/nv/archive/nv1/non\_model/non\_model.zip - nv1\_water.img

**4) Summary of predictor layers used:**

**a) Multi band predictors:**

nv1\_summer.img (ETM+ bands 1-5 & 7 - mixed 1999 & 2000 images)  
nv1\_fall.img (ETM+ bands 1-5 & 7 - mixed 1999 & 2000 images)  
nv1\_mtk.img (bands 1-3 = stable brightness, greenness, wetness; bands 4-6 = change brightness, greenness, wetness)  
nv1\_sum\_tcap.img (summer brightness, greenness, wetness)  
nv1\_fall\_tcap.img (fall brightness, greenness, wetness)

All multi-band predictors can be found at:

/nv/archive/nv1/img\_files/images1.zip  
/nv/archive/nv1/img\_files/images2.zip

**b) Single band predictors:**

nv1\_slope.img Continuous slope (units = degrees)  
nv1\_swness.img Linear, continuous transformation of aspect  
nv1\_elev.img Continuous elevation (units = meters)  
nv1\_sum\_fr.img Continuous fractional vegetation  
nv1\_fall\_fr.img Continuous fractional vegetation  
nv1\_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 513 training site polygons that were converted by the process described above into 6013 pixels for use in creating the "preliminary" land cover map via the CART modeling process. The total data set contained 644 training site polygons that were converted into 7476 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 for the NV1 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	Sftcap	6	Summer and Fall Tasseled Cap
6	Sum_topo	9	Summer, Slope, Southwest-ness, Elevation
7	Fall_topo	9	Fall, Slope, Southwest-ness, Elevation
8	Mtk_topo	9	Multi-temporal Kauth-Thomas, Fall, Slope, Southwest-ness, Elevation
9	Sftcap_topo	9	Summer and Fall Tasseled Cap, Fall, Slope, Southwest-ness, Elevation
10	Sftcap_sffr	8	Summer and Fall Tasseled Cap, Summer and Fall Fractional Vegetation
11	Sum_ftcap_topo	12	Summer, Fall Tasseled Cap, Slope, Southwest-ness, Elevation
12	Fall_stcap_topo	12	Fall, Summer Tasseled Cap, Slope, Southwest-ness, Elevation
13	Sum_mtk_topo	15	Summer, Multi-temporal Kauth-Thomas, Slope, Southwest-ness, Elevation
14	Fall_mtk_topo	15	Fall, Multi-temporal Kauth-Thomas, Slope, Southwest-ness, Elevation
15	Sum_fall_mtk	18	Summer, Fall, Multi-temporal Kauth-Thomas

16	Full	30	Summer, Fall, Multi-temporal Kauth-Thomas, Summer and Fall Tasseled Cap, Summer and Fall Fractional Vegetation, Slope, Southwest-ness, Elevation, Landform
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The output files from the CART Sampling Tool (\*.names, \*.data, \*.test) are located in:

```
/nv/archive/nv1/output/80percent/see5_files.zip
/nv/archive/nv1/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/nv1/output/80percent/see5_files.zip
/nv/archive/nv1/output/80percent/see5_files.zip
```

CART Classifier 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) sum\_mtk\_topo.img
- 14) fall\_mtk\_topo.img
- 15) sum\_fall\_mtk.img
- 16) full.img

The 16 output land cover maps are found at:

```
/nv/archive/nv1/output/80percent/prf_input_maps.zip
```

These 16 images were stacked in a single .img file with 16 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 16 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 (nv1\_prf16.gmd) and "preliminary" map resulting from this process (nv1\_prf16\_v1.img) can be found at:

```
/nv/archive/nv1/output/80percent/prf_input_maps.zip
```

This land cover classification, following the addition of non-modeled classes, was subjected to an accuracy assessment using the withheld data (131 reference sites).

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

No post-classification modeling was required for NV1.

**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 assess 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 area 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/nv1/validation

**b) Final map:**

A second set of 15 land cover images were produced for the *total data set* that was produced by using 100% of the training site data through the following models:

- 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/nv1/output/alldata/prf\_input\_maps.zip

These 15 images were processed by the methods described above. The "pseudo-random forest" model (nv1\_prf16.gmd) and "final" map resulting from this process (nv1\_prf15\_v1.img) can be found at:

/nv/archive/nv1/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 NV1 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 67% (producers) and 67% (users) based on 3 independent samples. The number of reference sites was very 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.

N31 BARREN: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 3 independent samples. The number of reference sites was very small, and not enough for a robust assessment of thematic accuracy. There is likely to be confusion between this class with the INTER-MOUNTAIN BASINS CLIFF AND CANYONS and INTER-MOUNTAIN BASINS PLAYAS classes since this class is composed of gravel-covered sites on alluvial fans, bajadas, and foothills.

N81 PASTURE HAY-IRRIGATED AGRICULTURE: Quantitatively assessed, validation 100% (producers) and 33% (users) based on 1 independent sample. Thematic accuracy cannot be assessed with a single reference site. A qualitative assessment suggests that agricultural lands have been mapped well, though they may have been over represented at the expense of INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLANDS and INVASIVE ANNUAL GRASSLANDS. There is also the possibility that some riparian grasslands have been mistaken for irrigated agriculture.

D08 INVASIVE ANNUAL GRASSLANDS: Quantitatively assessed, validation 40% (producers) and 50% (users) based on 5 independent samples. The number of reference sites was very small, and not enough for a robust assessment of thematic accuracy. This system was most commonly confused with INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS (2 of 5 reference sites) that might be attributed to differences between the dates of imagery and sample data collection.

D09 INVASIVE ANNUAL AND BIENNIAL FORBLANDS: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 2 independent samples. The number of reference sites was very small, and not enough for a robust assessment of thematic accuracy. This disturbance system appears to be associated with, and confused with, halophytic plant communities (e.g. INTER-MOUNTAIN BASINS GREASEWOOD FLATS and INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB) whose signatures are similarly driven by soil brightness rather than photosynthetic plant tissue

S009 INTER-MOUNTAIN BASINS CLIFF AND CANYONS: Quantitatively assessed, validation 40% (producers) and 33% (users) based on 5 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 GREAT BASIN PINYON-JUNIPER WOODLANDS and INTER-MOUNTAIN BASINS MOUNTAIN MAHOGANY WOODLANDS AND SHRUBLANDS that likewise occur on steep slopes and with relatively sparse vegetative cover.

S015 INTER-MOUNTAIN BASINS PLAYAS: Quantitatively assessed, validation 50% (producers) and 100% (users) based on 2 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 INTER-MOUNTAIN BASINS GREASEWOOD FLATS due to similarities of soil brightness and sparse vegetative cover.

S023 ROCKY MOUNTAIN ASPEN FORST AND WOODLANDS: Quantitatively assessed, validation 33% (producers) and 50% (users) based on 3 independent samples. The number of reference sites was very small, and not enough for a robust assessment of thematic accuracy. Qualitatively, this system appeared to map reasonably well, however it was confused with GREAT BASIN FOOTHILLS LOWER MONTANE RIPARIAN WOODLAND AND SHRUBLANDS which suggests possible errors in the assignment of ecological systems labels, or inadequate descriptions of the ecological setting of the training site data.

S026 INTER-MOUNTAIN BASINS SUBALPINE LIMBER-BRISTLECONE PINE WOODLANDS: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 1 independent sample. Thematic accuracy cannot be assessed with a single reference site. Since only a small number of INTER-MOUNTAIN BASINS SUBALPINE LIMBER-BRISTLECONE PINE WOODLANDS training pixels were available for modeling, this ecological system was not present in the preliminary land cover map that was assessed for thematic accuracy.

S040 GREAT BASIN PINYON-JUNIPER WOODLANDS: Quantitatively assessed, validation 83% (producers) and 63% (users) based on 6 independent samples. The number of reference sites was small, and not enough for a robust assessment of thematic accuracy. Qualitatively, this system appears to map well, except at higher elevations where it is over-mapped at the expense of INTER-MOUNTAIN BASINS SUBALPINE LIMBER-BRISTLECONE PINE WOODLANDS.

S050 INTER-MOUNTAIN BASINS MOUNTAIN MAHOGANY WOODLANDS AND SHRUBLANDS: Quantitatively assessed, validation 33% (producers) and 33% (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 is confused with INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE that sometimes occurs in similar ecological settings.

S054 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS: Quantitatively assessed, validation 80% (producers) and 54% (users) based on 35 independent samples. This system was most commonly confused with GREAT BASIN XERIC MIXED SAGEBRUSH SHRUBLANDS (2 of 35 reference sites). While this system was mapped very well, the accuracy assessment indicates that this ecological system is over-mapped at the expense of INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (6 of 52 reference sites), GREAT BASIN XERIC MIXED SAGEBRUSH SHRUBLANDS (4 of 52 reference sites), and INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLANDS.

S055 GREAT BASIN XERIC MIXED SAGEBRUSH SHRUBLANDS: Quantitatively assessed, validation 33% (producers) and 45% (users) based on 15 independent samples. The number of reference sites was insufficient for a robust assessment of thematic accuracy. This system is often confused with two ecological systems that inter-grade along the lake terraces, alluvial fans, and bajadas of the Great Basin: INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS (4 of 15 reference sites) and GREAT BASIN PINYON-JUNIPER WOODLANDS (1 of 15 reference sites). It is also confused at higher elevations with INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE (3 of 15 reference sites) suggesting possible errors in the assignment of ecological system labels.

S065 INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB: Quantitatively assessed, validation 33% (producers) and 50% (users) based on 9

independent samples. The number of reference sites was small, and not enough for a robust assessment of thematic accuracy. This system is confused with INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS at the upper margins of lake terraces and sometimes over-mapped at the expense of INTER-MOUNTAIN BASINS GREASEWOOD FLATS near the upper fringes of lake bottoms.

S071 INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE:

Quantitatively assessed, validation 86% (producers) and 40% (users) based on 7 independent samples. The number of reference sites was small, and not enough for a robust assessment of thematic accuracy. This system was mapped well, though it was over-mapped at the expense of GREAT BASIN XERIC MIXED SAGEBRUSH SHRUBLANDS and INTER-MOUNTAIN BASINS MOUNTAIN MAHOGANY WOODLANDS AND SHRUBLANDS.

S078 INTER-MOUNTAIN BASINS BIG SAGEBRUSH STEPPE: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 2 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 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS due to the similarity of the systems.

S079 INTER-MOUNTAIN BASINS SEMI-DESERT SHRUB STEPPE:

Quantitatively assessed, validation 0% (producers) and 0% (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 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS. This is likely due to the overlap of ecological setting these systems occur in, and the association of this system with disturbance of the INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS system.

S090 INTER-MOUNTAIN BASINS SEMI-DESERT GRASSLANDS: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 7 independent samples. The number of reference sites was small, and not enough for a robust assessment of thematic accuracy. This system has not mapped well, and is confused most commonly with the matrix community, INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS. This community tends to occur in patches among the matrix sagebrush systems.

S096 INTER-MOUNTAIN BASINS GREASEWOOD FLATS: Quantitatively assessed, validation 50% (producers) and 44% (users) based on 8 independent samples. The number of reference sites was small, and not enough for a robust assessment of thematic accuracy. This ecological system is confused with INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLANDS (2 of 8 reference sites) and INTER-MOUNTAIN BASINS MIXED SALT DESERT SCRUB (2 of 8 reference sites) along the fringes of lake terraces.

S100 NORTH AMERICAN ARID WEST EMERGENT MARSH: Quantitatively assessed, validation 25% (producers) and 100% (users) based on 4 independent samples. The number of reference sites was very small, and not enough for a robust assessment of thematic accuracy. This system appears to be mapped well despite confusion with OPEN WATER (1 of 4 reference sites) and INTER-MOUNTAIN BASINS GREASEWOOD FLATS (1 of 4 reference sites). This confusion is like due to differences in the dates of imagery and training site data collection.

S102 ROCKY MOUNTAIN ALPINE-MONTANE WET MEADOW: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 1 independent sample. Thematic accuracy cannot be assessed with a

single reference site. Even a qualitative assessment of map accuracy is difficult given the rarity and small patch size of this ecological system. It was confused with INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE.

S118 GREAT BASIN FOOTHILL LOWER MONTANE RIPARIAN WOODLAND AND SHRUBLANDS: Quantitatively assessed, validation 0% (producers) and 0% (users) based on 1 independent sample. Thematic accuracy cannot be assessed with a single reference site. Qualitatively, this system appears to be mapped well, however it was confused at higher elevations with ROCKY MOUNTAIN ASPEN FOREST AND WOODLANDS which exhibits a similar phenology despite occupying an upland ecological setting.

## **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.

Chavez, 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, Virginia.

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. Vogelmann 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.