Combining Terrestrial Ecosystem Survey Units to Assist in the Analysis of Existing Conditions for Forest Restoration at the Landscape Scale[1]

Background

In March 2010 the Ecological Restoration Institute (ERI) was approached by Bill Noble (Four Forest Landscape Assessment Team Member) for assistance in taking the old range data points (Parker 3-Steps) and summarizing them over the period of record. For utility at the landscape scale, this information will be displayed on either an individual Terrestrial Ecosystem Map Unit (TESU) basis or more commonly a combination of similar TESUs. To facilitate this process, Rory Steinke (Watershed Program Manager, Coconino National Forest) and Dave Brewer (NAU-ERI) met on April 5, 2010 to go over the ecological unit information and develop a strategy to combine comparable TESU to facilitate discussion of resource variables at a landscape scale. The initial work lead to identification of 17 strata and this information was presented to 4FRI Landscape Working Group meeting of April 22, 2010 (Appendix A, Table 2). Several members of the group remarked that the use of these strata to define existing conditions was applicable to their resource area, although they thought some refinement in the process was necessary. Specifically, the identification of plant association types (i.e., Habitat Types) was needed for each stratum. On May 4, 2010 Dave Brewer, Rory Steinke, and Kit MacDonald (Soil Scientist, Kaibab National Forest) met to review the original strata, revise or develop new strata as appropriate, and determine the plant association types, if applicable. It was also decided to include some interpretations (Appendix A, Tables 3 and 4), such as natural regeneration or reforestation, plant competition, erosion hazard, site index and potential herbage/forage production, with the thought that this information could be useful in the prioritization of treatment areas and in building the environmental effects analysis.

Further review of the preliminary stratification was conducted by Wayne Robbie (Regional Soil Scientist, R3) and George Robertson (Soil Survey Party Leader, Arizona), and they noted several potential problems. Their main comments revolved around three central items, including: 1) there should not be any grouping of dissimilar slope gradients (e.g., 0 to 15% slope gradients with 15 to 40%), 2) combinations of fundamentally different climatic regimes and potential plant communities (PPC) needed to be limited, and 3) more care needed to be exercised in the combinations of TESUs. As an example, when classifications denote higher current and potential productivity, these units should not be combined with soils representing lower production potentials. For the most part all of the

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recommendations provided by the second level review were incorporated into the revised document (Table 1).

A revised version, which incorporated the majority of recommendations, was sent out for review in November 2010. Further combinations or separations were noted and included:

- ✓ 13b (TESU 310a) and 13c (TESU 300a) should be combined with 13a (TESU 537). Although all three strata have some differences in taxonomic classification, they occupy a 15- to 40-percent slope range and represent less than 12,000 acres within the proposed project area (1 percent of the total). The soil erosion hazard and current/potential productivity are similar enough to warrant their combination.
- ✓ Combine 15c (TESU 564) into 15b (TESU 311). The rationale for this combination is that the soil classifications are virtually the same, climatic regime identical, and current and potential outputs uniform.
- ✓ Combine 15d (TESU 305 and 517) into 15. Both 15d and 15 occupy a 0- to 15-percent slope range with similar soil classification as well as current and potential production.
- ✓ Split TESU 10 from Strata 9. TESU 10 is unique in that it occurs in linear, concave valley plains and is subject to gullying under excessive ground disturbance, which is distinctively different from the other TESUs of these strata.
- ✓ Combined 16f (TESU 620) into 16c (TESU 555). Stratum 16f represents 185 acres within an 800,000-acre proposed project area. Since this stratum is also over 40 percent slope, the small acreage value does not warrant tracking it through this analysis process.
- ✓ Combine 16e (TESU 648) into (TESU 431)16b Similar soil classifications, low acreage value of 16b (less than 1,000 acres), and the identical climatic regime as well as potential plant community merit this combination.
- ✓ Strata 16a are dropped since there are no acres of this unit within the project area.

The group met on January 4, 2011 and agreed that the latest version accounts for the variability across the proposed project area and establishes a logical framework to conduct the NEPA analysis. It was recommended, and agreed to, that for clarification sake the subscript identification (e.g., a, b, c, etc.) will be dropped and the appropriate numerical identification assigned.

Introduction

When developing proposals to restore the ecological integrity of large landscapes there is a need to aggregate information from a small scale (e.g., range sites or timber stands) into the larger ones (e.g., watershed or landscape). This will facilitate broader-based discussions of existing and desired conditions (i.e., purpose of and need for action), establish parameters to be disclosed in the effects analysis, enable the development of a landscape-scale proposed action, and assist in identifying the boundary of the

cumulative effects analysis. Laing et al. (2005)[2] used geographic information systems (GIS) along with geology and existing vegetation maps to develop coverage on a 500,000-acre project area. Using these cartographic tools the planning area was stratified into distinct units suitable for modeling historic fire regimes and determining current condition classes. Host et al. (1996)[3] combined GIS and statistical analysis to integrate climatic, physiographic, and soil database information to produce a regional landscape classification of a 7,250,075 acre area in northwestern Wisconsin. In their analysis, climatic and physiographic coverage's were integrated to identify regional landscape ecosystems, which potentially differ in forest composition, successional dynamics, productivity, and other ecosystem-level processes. They concluded that continual improvement of both the standardized data sets and analytical methods will provide a clear basis for sound interpretation of forest management at multiple spatial scales.

The terrestrial ecosystem survey (TES) enables practitioners to assess broad landscapes since it consists of a systematic assessment, classification, and mapping of terrestrial ecosystems found in Region 3.[4] It is an integrated survey and hierarchical with respect to classification levels and mapping intensities. A TES represents the combined influences of climate, soil and vegetation, and correlates these factors with soil temperature and moisture along an environmental gradient.[5] Interpretations based upon TES incorporate 1) soil physical and chemical properties, 2) climatic considerations, 3) topographic position and slope, 4) vegetation and anthropogenic influences as well as animal impacts, 5) productive and successional potentials, and 6) geologic influences.[6] As such the TES can form the ecological basis for describing existing conditions for resource areas including watershed, wildlife, fire, and timber.

An example of this was a study that reconstructed the historical tree density on 53 1-ha (2.5- acre) plots spread across 100,000 ha (250,000 acres) within nine Terrestrial Ecosystem Survey Units (TESU) on the Coconino National Forest.[7] The information collected on each plot included pre-European settlement evidences, elevation, slope, percent rock, soil texture, pH, organic C, total N, and estimated bulk density. Study researchers determined there was a 19-fold variation in the measured parameters among the nine modeled TES mapping units. The analysis indicated that using four soil or climatic variables explained 65-74 percent of the variation in historical tree density. Results from this study indicate that 1) environmental variation constrained historical forest structure, 2) ecosystem classification is a useful reference framework for quantifying spatial variation in ponderosa pine forests, 3) there is as much variation in reference conditions (density, understory plants, canopy covers) within landscapes as

[2] Laing, L.E., D. Gori, and J.T. Jones. 2005. The Development of Landscape-Scale Ecological Units and their Application to the Greater Huachuca Mountains Fire Planning Process. USDA Forest Service Proceedings RMRS-P-36. Pp. 251-255.
[3] Host, George E., P.L. Polzer, D.J. Mladenoff, M.A. White, T.R. Crow. 1996. A Quantitative Approach to Developing Regional Ecosystem Classification. *Ecological Applications* 6(2):pp 608-618.
[4] USDA-Forest Service. 1991. Forest Service Manual 2500, Region 3, Supplement 2500-91-1. Watershed and Air Management, Region 3, Albuquerque, NM.
[5] Ibid.
[6] Ibid.
[7] Abella, S.R. and C.W. Denton. 2009. Spatial variation in reference conditions: Historical tree density and patterns in a *Pinus ponderosa* landscape. *Canadian Journal of Forestry* 39:2391-2403.

among landscapes, and 4) determining previous tree spatial variation can assist resource managers in developing ecosystem-specific management strategies within landscapes.

Another illustration of the use of TES and specific terrestrial ecosystem survey units (TESU) to assess reference and current conditions can be found in an analysis that looked at the characteristics of the Woolsey plots in northern Arizona. In this study, researchers concluded that the plots were neither historically nor contemporarily representative of the entire study area, although they may be considered traditionally descriptive of the site-specific TESU.[8]

TES information was also used on a study of a 34,000-acre watershed where four management alternatives were disclosed. The goals of this study were to determine presettlement and current forest conditions and structure, current and presettlement water flows, and how different scenarios would not only influence these parameters but also sedimentation, on-site erosion, and the risk of stand-replacing wildfire.[9] To support this effort, the area was stratified by combining similar TESU. Variables that were used to develop the stratums included soil classification, soil depth, climatic class, potential plant community, rockiness, and texture. A total of 18 TESU were found in the project area and based on similarity of vegetation, soil physical properties, and soil classification this was narrowed down to eight unique strata.[10] These groupings reflected similar TESU with respects to environmental variables such as potential water yield, species diversity, tree growth, and understory forage production.

These studies reinforce the use of TES as a method to assist in taking rather large, complex landscapes and conveying not only historic, but current information on ecological parameters including tree species, tree density, structure, soil influences, and understory diversity.

Methods

The Four Forest Restoration Initiative (4FRI) is expected to eventually analyze ponderosa pine forests across the Kaibab, Coconino, Apache/Sitgreaves, and Tonto National Forests. However, the first large-scale NEPA work will take place on the Kaibab and Coconino National Forests (Noble, personnel communication, 2010). The area includes essentially all the ponderosa pine ecosystems within the Tusayan and Williams Ranger Districts of the Kaibab National Forest and, primarily, the Peaks and Mormon Lake Ranger Districts on the Coconino National Forest.

A review was conducted using the TES reports for the Coconino and Kaibab national forests. It was based on such items as the physical properties of the TESU (slope, soil depth, color, surface and internal rock content, and surface soil texture), soil classification, potential plant community (PPC), climatic class, and slope. The individual units were either placed into separate stratum or combined. The TES units that

[8] Bell, D. M., P.F. Parysow, and M.M. Moore. 2009. Assessing the representativeness of the oldest permanent plots in Northern Arizona ponderosa pine forests. *Restoration Ecology* 17(3):369-377. doi:10.111/j.1526-100x.2008.00377.x

[9] Miller, C.A. 2007. Analysis of Current and Historical Surface Flows and Hydrologic Response to Restoration Treatments in the Upper Lake Mary Watershed, Arizona. Ecological Restoration Institute, Flagstaff, AZ. 77 pages.

[10] Ibid

were combined within the individual strata are predicted to respond the same to management actions despite the potential of variability in existing conditions.

Results

Initially, a total of 94 unique TESU were identified for the proposed project area, which, based on similarities in soil variables and vegetation were condensed into 17 strata. Under this revised strategy the number of strata increased to 45, though the total TESU considered dropped to 91. Ten of the strata (1, 2, 3, 4, 5, 6, 7, 8, 9, and 10), which combine for 87,609 acres represent serial grassland and/or riparian communities, and are unsuitable for timber management, though invasion by ponderosa pine into these ecosystems has been noted. Twenty strata (11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 30, 31, 36, 37, 38, 39, 40, and 41) are either shallow over bedrock, occupy moderately steep to steep slope inclinations (15 to 40 percent), have a particle-size classification of cindery or ashy-skeletal and represent very young soils with low water holding capacities, or are on the dry side of the ponderosa pine ecosystem (climatic regime of 5-1). These strata are generally considered to have severe limitations with respects to timber management and occupy approximately 395,495 acres. Strata 42, 43, 44 and 45, which make up 19,267 acres of the project area, also have severe limitations for most management actions since these units occupy slopes greater than 40 percent. The remaining 11 strata (23, 24, 25, 26, 27, 28, 29, 32, 33, 34, and 35) represent those soils that have the highest production potentials, lowest restrictions to management activities, and the best reforestation/revegetation suitability. These units represent roughly 50 percent of the proposed project area or approximately 499,230 acres.

Table – 1: Revised Terrestrial Ecosystem Map Unit Groupings.

Stratum	TES Units Combined	Potential Plant Community from TES	Basis for Combination or Separation	Management Considerations
1	6, 9, 11, 53	Popr/Fear Popr/Agsm[11] Popr/Mumo[12]	Deep to very deep, medium- to fine-textured Mollisols normally associated with small, linear grasslands found within the ponderosa pine ecosystem. They are typically confined to cold-air drainages and represent Order 1 or 2 drainage channels with a 0- to 5-percent slope range.	This stratum is unsuitable for timber production. It is highly suitable for forage enhancement and due to added moisture in the form of runoff form adjacent slopes is seasonally wet or ponded. This promotes traffic problems in the form of compaction which can be avoided by limiting ground-disturbing activities to times when dry conditions prevail.
2	55	Popr/Fear Agsm	This TESU has as one of its major soil components being a Vertic intergrade. These soils present not only unique set of management problems (high shrink/swell) but also has led to a distinctive PPC (western wheatgrass).	Same as Above
3	513, 595	Fear/Mumo	Predominately deep, medium to fine-	This stratum is classified as a fire disclimax.

[11] Kentucky Bluegrass/Western Wheatgrass (Popr/Agsm)
[12] Kentucky Bluegrass/Mountain Muhly (Popr/Mumo)

Stratum	TES Units Combined	Potential Plant Community from TES	Basis for Combination or Separation	Management Considerations
			textured Mollisols associated with large grasslands like Garland, Hart, Government prairies, and Kendrick Park. Slope range is 0 to 15 percent. Climatic class is considered LSC 5 0.	Fire created and maintained the open park-like conditions of these grasslands. This unit is unsuitable for timber production and is well suited for domestic livestock grazing and wildlife habitat. This TESU is subject to compaction and rutting when wet.
4	440	Fear/Mumo	A 15 to 40 percent slope range. Climatic class is LSC 5 0.	Severe erosion hazard and current soil erosion rates above tolerance.
5	640	Fear/Mumo	An average slope percent of 12 percent, climatic class of LSC 6 0 (mixed conifer) and course textures in the control section.	Fire necessary to maintain open grassland conditions. Moderate soil erosion hazard with surface rock limiting management options.
6	566	Sihy/Arlo/Bogr2[13]	Climatic class is HSC 5 -1. Also, this unit occurs in linear and concave landscape positions of valley plains and basins.	This stratum is classified as zootic disclimax. Fire created the open grassland conditions, although it is now maintained by grazing.
7	594	Fear/Mumo	This stratum has a contrasting particle size (cindery) below 50 cm (20 inches). Climatic class is LSC 5 0.	This unit is classified as a fire disclimax. Revegetation potential is moderate due to limited soil moisture.
8	630	Fear/Mumo	Shallow to moderately deep, fine textured Alfisols. Climatic class is LSC 5 0.	Shallow soil depth of major component and high rock contents on soil surface and profile limit management activities to a large degree.
9	20, 50	CARE/Elco/Pola4/ Alge[14]	Deep to very deep, fine to very fine textured Mollisols with high concentration of semitic clays. Generally associated with closed basin topography. Considered a wet meadow, non-woody. Climatic class is LSC 5 0.	This stratum due to its landscape positions collects runoff in most years and is seasonally ponded. These ponded areas create excellent habitat for wildlife species. Management activities should take place when the soils are dry.
10	37	Popr/CARE/Fear	Deep to very deep Mollisols, coarse to medium textured with high concentrations of rock fragments in the profile. Associated with both woody and non-woody riparian species as well as grass plants. Typically has a perched groundwater table in normal runoff years.	Stratum is subject to seasonal flooding and fluctuating water table.
11	265, 519, 585	Pipo/Quga[15]	Very shallow to shallow, medium to fine textured Alfisols with high percentages of internal and surface rock fragment. Slope range is 0 to 15% and the climatic class is LSC 5 0.	Shallow soils and high rock content on surface rock will limit management activities.
12	579	Pipo/Jude/Quga	PPC with Jude as component will, with removal of ponderosa pine overstory, offer significant plant competition.	Same as above

[13] Squirreltail/three-awn/Blue Grama (Sihy/Arlo/Bogr2)
[14] Sedge/Spikerush/Longtongue Bluegrass/Water Foxtail (Carex/Elco/Pola4/Alge)
[15] Ponderosa Pine/Gambel Oak (Pipo/Quga)

Stratum	TES Units Combined	Potential Plant Community from TES	Basis for Combination or Separation	Management Considerations
13	275	Pipo/Pied/Quga/ Artr[16]	Very shallow to shallow, medium-textured Inceptisols. High amounts of surface and internal rock fragments with a slope range are 0 to 15%. The climatic class is LSC 5 -1.	This stratum occurs within the transition between commercial forests and woodlands. Reforestation and natural regeneration potentials are limited by dry climate. Timber production is low (site class III).
14	565	Pipo/Pied/Quga	Very shallow to shallow, fine textured Mollisols. High amounts of surface and internal rock fragments with a slope range are 0 to 15%. The climatic class is HSC 5 -1.	This stratum occurs within the transition between commercial forests and woodlands. Reforestation and natural regeneration potentials are limited by dry climate. Timber production is low (site class III). High rock content on surface and within profile will limit management activities.
15	520	Pipo/Pied/Quga	Very shallow to shallow, fine-textured Alfisols with high percentages of internal and surface rock fragment. Slope range is 0 to 15% and the climatic class is HSC 5 -1.	This stratum occurs within the transition between commercial forests and woodlands. Reforestation and natural regeneration potentials are limited by dry climate. Timber production is low (site class III). Low bearing strength, high shrink/swell, and rock content will limit management activities.
16	276	Pipo/Pied/Quga/ Artr	15 to 40% slope range with climatic class considered LSC 5 -1.	Slope, shallow soils and exposed bedrock within strata limit management opportunities.
17	266	Pipo/Quga	Very shallow to shallow, medium-textured Alfisols with high amounts of surface and internal rock fragments. Slope range is 15 to 40%. The climatic class is LSC, 5, 0.	Moderate to severe erosion hazard, low natural regeneration potential, and low production capacity limits activities within this strata.
18	530	Pipo/Jude/Qutu	Medium to shallow, fine textured Alfisols with high amounts of surface and internal rock fragments. Slope range is 15 to 40%. The climatic class is LSM 5 0.	Same as above
19	406	Pipo/Pied/Quga	Moderately deep to shallow, fine textured Alfisols typically associated with cinder cones. Slope range is 15 to 40%. The climatic class is HSC 5 -1.	This stratum occurs within the transition between commercial forests and woodlands. Reforestation and natural regeneration potentials are limited by dry climate. Timber production is low (site class III). Low bearing strength, high shrink/swell, and rock content will limit management activities.
20	407	Pipo/Quga	Climatic classification is LSC 5 0 with cindery particle size classification. Slope range is 15 to 40%.	Severe timber harvest limitation, low reforestation potential though revegetation is considered moderate.
21	513	Pipo/Pied/Jumo/ Fapa	Climatic classification is LSC 5 -1 with cindery particle size classification. Slope	This stratum occurs within the transition between commercial forests and

[16] Ponderosa Pine/Pinyon Pine/Gambel Oak/Big Sagebrush (Pipo/Pied/Quga/Artr)

Stratum	TES Units Combined	Potential Plant Community from TES	Basis for Combination or Separation	Management Considerations
			range is 15 to 40%.	woodlands. Reforestation and natural regeneration potentials are limited by dry climate. Forage and timber production potentials are considered low (Site Class III). Trafficability may be a problem due to loose, extremely cindery soil surface.
22	527	Pipo/Pied/Jude/ Come	PPC is unique and is typed as Pipo/Pied/Jude/Come. Climatic regime is considered HSC 5 -1 with 15 to 40% slope range. Also, shallow soil component.	This stratum occurs within the transition between commercial forests and woodlands. Reforestation and natural regeneration potentials are limited by dry climate. Timber production potentials are considered low (Site Class III). Soils contain significant amounts of calcium carbonates in the soil profile. Potential strata for browse enhancement.
23	290, 293, 401, 537, 582, 586, 557	Pipo/Quga	Moderately deep to deep, fine-textured Alfisols and Mollisols with variable concentrations of internal and surface rock fragments, although typically fewer than 15 percent. Slope range is 0 to 15%. The climatic class is LSC 5 0.	This stratum is subject to trafficability problems and soil damage (compaction) when wet. This problem can be mitigated by restricting ground-disturbing activities to times when the soils are dry or frozen. This unit is well suited to timber and forage production. Natural regeneration, reforestation and revegetation potentials range from moderate to high.
24	546	Pipo/Quga/Muvi	Unique PPC of Pipo/Quga/Muvi indicates higher productivity potentials due to higher than normal precipitation associated with geographic location of this unit. Slope range is 0 to 15%. The climatic class is LSC 5 0.	Potential timber productivity highest of all units considered in this analysis.
25	567, 578	Pipo/Jude/Quga	Listed species of Jude in PPC indicative of higher plant competition once overstory removal treatments implemented. Slope range is 0 to 15%. The climatic class is LSC 5 0.	This stratum is subject to trafficability problems and soil damage (compaction) when wet. This problem can be mitigated by restricting ground disturbing activities to times when the soils are dry or frozen. Jude may offer significant plant competition after overstory removal.
26	10	Pipo/Quga	TESU 10 occurs in linear, concave valley plains and is subject to gullying under excessive ground cover disturbance.	This stratum is subject to trafficability problems and soil damage (compaction) when wet. This problem can be mitigated by restricting ground disturbing activities to times when the soils are dry or frozen. This unit is well suited to timber and forage production. Natural regeneration, reforestation and revegetation potentials range from moderate to high.
27	304, 324, 401a, 536, 537a, 551,	Pipo/Fear	Moderately deep to deep, fine- to medium-textured Alfisols with minor amounts of Mollisols. Variable	This stratum is subject to trafficability problems and soil damage (compaction) when wet. This problem can be mitigated

Stratum	TES Units Combined	Potential Plant Community from TES	Basis for Combination or Separation	Management Considerations
	570, 582a		concentrations of internal and surface rock fragments. Slope range is 0 to 15%. The climatic class is LSC 5 0.	by restricting ground disturbing activities to times when the soils are dry or frozen. This stratum well suited for timber production or forage enhancement.
28	560	Pipo/Fear	These soils have contrasting particle size at depths ranging from 25 to 45 cm. Slope range is 0 to 15%. The climatic class is LSC 5 0.	Natural regeneration (trees), reforestation (artificial), and revegetation (grasses and forbs) potentials are moderate. Timber production potential is low (Site Class III) due to limited moisture retention.
29	325	Pipo/Fear	Low reforestation ranking. Slope range is 0 to 15%. The climatic class is LSC 5 0.	Low reforestation rating though natural regeneration and understory revegetation considered moderate.
30	558, 559	Pipo/Fapa	Moderately deep to deep, cindery-textured Inceptisols and Entisols with high concentrations of internal rock fragments. Slope range is 0 to 15%. The climatic class is HSC 5 -1.	Natural regeneration, reforestation, and revegetation are low due to limited soil moisture retention in upper 25 cm. Timber and forage production is considered low (Site class III and less than 100 pounds per acre potential forage production).
31	561	Pipo/Fapa	Slope range is 15 to 40%. The climatic class is HSC 5 -1.	Natural regeneration, reforestation, and revegetation are low due to limited soil moisture retention in upper 25 cm. Timber and forage production is considered low (Site class III) with moderate erosion hazard.
32	294, 402, 565, 584	Pipo/Quga	Moderately deep to deep, fine-textured Alfisols with variable concentrations of internal and surface rock fragments. Slope range is 15 to 40%. The climatic class is LSC 5 0.	This stratum is subject to trafficability problems and soil damage (compaction) when wet. This problem can be mitigated by restricting ground disturbing activities to times when the soils are dry or frozen.
33	291, 310	Pipo/Quga	Lower timber productivity class. Slope range is 15 to 40%. The climatic class is LSC 5 0.	This stratum is subject to trafficability problems and soil damage (compaction) when wet. This problem can be mitigated by restricting ground disturbing activities to times when the soils are dry or frozen.
34	300	Pipo/Quga	Lower timber productivity class and loamy-skeletal particle size class. Slope range is 15 to 40%. The climatic class is LSC 5 0.	Moderate to low revegetation and reforestation potential. Moderate erosion hazard.
35	553, 565a, 584a	Pipo/Fear	Moderately deep Alfisols and Mollisols with high concentrations of internal and surface rock. Inventoried with a 15 to 40% slope range. Climatic class is considered LSC 5 0.	This stratum is subject to trafficability problems and soil damage (compaction) when wet. This problem can be mitigated by restricting ground disturbing activities to times when the soils are dry or frozen.
36	300a, 310a, 537	Pipo/Fear	Shallow and moderately deep soils are dominated with loamy to clayey-skeletal textures. Inventoried with a 15 to 40% slope range. Climatic class is considered LSC 5 0.	Moderate erosion hazard. Shallow soils and high surface rock content limits most management activities. Natural regeneration, reforestation, and revegetation potentials are low. Timber production potential is low (Site class III).

Stratum	TES Units Combined	Potential Plant Community from TES	Basis for Combination or Separation	Management Considerations
37	283, 297	Pipo/Pied/Quga/ Artr	Moderately deep to deep, fine-textured Alfisols with varying concentrations of surface and internal rock. Slope range is 0 to 15% with Climatic class identified as LSC 5 -1.	This stratum is subject to trafficability problems and soil damage (compaction) when wet. This problem can be mitigated by restricting ground disturbing activities to times when the soils are dry or frozen. Low timber productivity class (Site class III) with low reforestation capability.
38	284	Pipo/Pied/Quga/ Artr	Slope range is 15 to 40 percent. Climatic class LSC 5 -1.	Same as above with addition of severe erosion hazard.
39	305, 405, 500, 505, 506, 517, 523, 563	Pipo/Pied/Quga Pipo/Pied/Jude/ Quga Pipo/Pied/Jumo/ Quga Pipo/Pied/Quga	Shallow to moderately deep, medium- to fine-textured Alfisols. Slope range between 0 to 15% with climatic class of HSC 5 -1.	This stratum occurs within the transition between commercial forests and woodlands. Moderate to high plant competition from Quga and Artr once overstory is removed. Low natural regeneration potential and low to severe erosion hazard.
40	510, 512	Pipo/Pied/Jumo/ Fapa	Cindery or ashy-skeletal particle size classes. Slope range between 0 to 15% with climatic class of HSC 5 -1.	This stratum occurs within the transition between commercial forests and woodlands. Reforestation and natural regeneration potentials are limited by dry climate. Timber production potentials are considered low (Site class III). Low erosion hazard.
41	311, 564	Pipo/Pied/Quga	15 to 40% slope class although climatic class still considered HSC 5 -1.	Same as above with severe erosion hazard applied to this unit.
42	320, 539, 575, 596, 681	Pipos Pipo/Quga	Shallow to moderately deep Alfisols, Mollisols, and Inceptisols occupying slopes ranges greater than 40 percent. High percentage of rock on surface and within soil profile. Climatic class is typed as LSC 5 0.	This stratum has a severe erosion hazard. Steep slopes, surface rock fragments and rock outcrop limit management activities.
43	431, 648	Pipo/Pied/Quga	Climatic class of HSC 5 -1.	This stratum occurs within the transition between commercial forests and woodlands. Reforestation and natural regeneration potentials are limited by dry climate. Severe erosion hazard, steep slopes, rock outcrops, and surface rock fragment limit management activities.
44	555, 620	Psmeg/ Pipos Psmeg/Pipo/Jude/ Quga	Climatic class of LSC 6 and LSC 6 -1	Severe erosion hazard, steep slopes, rock outcrops, and surface rock fragment limit management activities.
45	660	Quga/Rone	PPC Quga/Rone	This is considered a fire disclimax. Pipo is restricted from these strata through frequent fire and plant competition from both Quga and Rone. Severe erosion hazard, steep slopes, rock outcrops, and surface rock fragment limit management activities.

Although strata 37, 38, and 39 are all inventoried within the transition between the commercial forests and woodland zone, they do represent soils with some potential for restoration activities. They generally are moderately deep too deep over bedrock, fine- to medium-textured, and are strongly developed. The timber harvest restrictions are moderate, although the site index and natural regeneration is considered low. These units are surveyed on approximately 95,260 acres within the project area.

Discussions, Conclusions, and Recommendation

Overall, the initial area selected for large-scale restoration efforts has at least 50 percent of the area, or roughly 500,000 acres, that are well suited to timber and understory restoration activities. This does not mean the other strata are automatically excluded. What it does signify is that appropriate mitigation will need to be exercised since these units are either shallow over bedrock, occupy slopes greater than 15 percent, or are found between the commercial forests and woodland zone. At least for the initial identification of treatment zones, it is recommended that 23, 24, 25, 26, 27, 28, 29, 32, 33, 34, and 35 be given priority since these units will afford the greatest return on investment.

Although this analysis is focused on communicating existing conditions at the landscape scale for range (changes in species frequency and range trend over the period of record), watershed (changes in effective ground cover) and wildlife (habitat suitability for selected wildlife species), the use of the stratification will allow other specialists to define their existing conditions and enable discussion about restoration treatments at a landscape scale.

Appendix A

Original Strata Classification

Table – 2: Original Terrestrial Ecosystem Map Unit Groupings.

Stratum	TES Units Combined	Kaibab TESU	Coconino TESU	Potential Plant Community from TES	Plant Association	Basis for Combination
1	6, 9, 11, 53, 55 **(5)**	6, 9, 11	53, 55	Popr/Fear Popr/Agsm[17] Popr/Mumo[18]	NA	Deep to very deep, medium- to fine-textured Mollisols normally associated with small, linear grasslands found within the ponderosa pine ecosystem. They are typically confined to cold-air drainages and represent Order 1 or 2 drainage channels with a 0- to 5-percent slope range. Climatic class is LSC 5 0. Moderate plant competition from Popr, low natural regeneration potential, and slight erosion hazard
2	440, 513, 594, 595, 630, 640 **(6)**	440, 513, 630	594, 595, 640	Fear/Mumo	NA	Predominately deep, medium- to fine-textured Mollisols associated with large grasslands like Garland, Hart, Government prairies, and Kendrick Park. Slope range is 0- to 15-percent. Climatic class is considered LSC 5 0. Low plant competition, low natural regeneration potential, and slight erosion hazard
2a	566	NA	566	Sihy/Arlo/Bogr2[19]	NA	Deep, medium-textured Mollisols associated with ponderosa pine/pinyon pine ecosystems. Climatic class is HSC 5 -1. Not rated for plant competition, low natural regeneration, and slight erosion hazard.
3	20, 50 **(2)**	20	50	CARE/Elco/Pola4/Alge[20]	NA	Deep to very deep, fine- to very fine-textured

[17] Kentucky Bluegrass/Western Wheatgrass (Popr/Agsm)
[18] Kentucky Bluegrass/Mountain Muhly (Popr/Mumo)
[19] Squirreltail/three-awn/Blue Grama (Sihy/Arlo/Bogr2)
[20] Sedge/Spikerush/Longtongue Bluegrass/Water Foxtail (Carex/Elco/Pola4/Alge)

Stratum	TES Units Combined	Kaibab TESU	Coconino TESU	Potential Plant Community from TES	Plant Association	Basis for Combination
						Mollisols with high concentration of smetitic clays. Generally associated with closed basin topography. Considered a wet meadow, non-woody. Climatic class is LSC 5 0. Not rated for plant competition, low natural regeneration potential, and slight erosion hazard.
4	37	37	NA	Popr/CARE/Fear	NA	Deep to very deep Mollisols, coarse- to medium-textured with high concentrations of rock fragments in the profile. Associated with both woody and non-woody riparian species as well as grass plants. Typically has a perched groundwater table in normal runoff years. Climatic class is LSC 5 0. Moderate plant competition from Popr, low natural regeneration potential and slight erosion hazard.
5	265, 519, 579, 585 **(4)**	265, 519	579, 585	Pipo/Quga[21] Pipo/Jude/Quga[22]	Pipo/Quga/ Pipo/Quga	Very shallow to shallow, medium- to fine-textured Alfisols with high percentages of internal and surface rock fragment. Slope range is 0 to 15% and the climatic class is LSC 5 0. Plant competition rated as moderate to high from Quga or Jude, low natural regeneration potential, and slight erosion hazard.
6	275, 276, 565 **(3)**	275, 276, 565	NA	Pipo/Pied/Quga/Artr[23] Pipo/Pifa/JUNI/Qutu[24]	Pipo/Bogr	Very shallow to shallow, medium-textured

[21] Ponderosa Pine/Gambel Oak (Pipo/Quga)
[22] Ponderosa Pine/Alligator Juniper/Gambel Oak (Pipo/Jude/Quga)
[23] Ponderosa Pine/Pinyon Pine/Gambel Oak/Big Sagebrush (Pipo/Pied/Quga/Artr)
[24] Ponderosa Pine/Cliffrose/Juniper Species/Shrub-Live Oak (Pipo/Pifa/JUNI/Qutu)

Stratum	TES Units Combined	Kaibab TESU	Coconino TESU	Potential Plant Community from TES	Plant Association	Basis for Combination
				Pipo/Pied/Quga		Inceptisols, although there is a small percentage of both Mollisols and Alfisols found. All 3 orders are found with high amounts of surface and internal rock fragments with a slope range are 0 to 40%. The climatic class is LSC 5 -1. Plant competition considered severe from Quga and Artr, low natural regeneration potential, and slight to moderate (276) erosion hazard.
7	266, 402 **(2)**	402	266, 530	Pipo/Quga Pipo/Jude/Qutu	Pipo/Quga/ Quga	Very shallow to shallow, medium-textured Alfisols with high amounts of surface and internal rock fragments. Slope range is 15 to 40%. The climatic class is LSC, 5, 0. Severe plant competition from Quga, low natural regeneration potential and moderate to severe erosion hazard.
8	406, 407, 513, 527 **(4)**	406, 407	527, 513	Pipo/Pied/Quga Pipo/Quga Pipo/Pied/Jumo Pipo/Pied/Jude/Come	Pipo/Bogr	Shallow to deep Alfisols and Inceptisols typically associated with cinder cones. Soil textures range from coarse to fine with high amounts of surface and internal rock fragments. Slope range is 15 to 40%. The climatic class is LSC 5 -1 and HSC 5 -1. High plant competition from juniper species, low natural regeneration potential, and moderate to severe erosion hazard.
9	10, 290, 293, 401, 537, 546, 567, 578, 582, 586 **(10)**	10, 290, 293, 401, 537	546, 567, 578, 582, 586	Pipo/Quga	Pipo/Quga/ Quga	Moderately deep to deep, fine-textured Alfisols and Mollisols with variable concentrations of internal and surface rock

Stratum	TES Units Combined	Kaibab TESU	Coconino TESU	Potential Plant Community from TES	Plant Association	Basis for Combination
						fragments, although typically fewer than 15 percent. Slope range is 0 to 15%. The climatic class is LSC 5 0. Terrestrial ecosystem is considered Pipo/Quga. Moderate plant competition from Quga, moderate to high natural regeneration potential, and slight erosion hazard
10	304, 324, 325, 401a[25], 536, 537a[26], 551, 560, 570, 582a[27] **(10)**	304, 324, 325, 401a, 537a	536, 551, 560, 570, 582a	Pipo/Fear	Pipo/Fear	Moderately deep to deep-, fine-, medium- and ashy skeletal-textured Alfisols with minor amounts of Inceptisols and Mollisols. Variable concentrations of internal and surface rock fragments. Slope range is 0 to 15%. The climatic class is LSC 5 0. Low plant competition, moderate to high natural regeneration potential, and slight erosion hazard.
11	558, 559, 561 **(3)**	NA	558, 559, 561	Pipo/Fapa	Popr/Bogr/ Anha	Moderately deep to deep, fine- to cindery-textured Inceptisols and Entisols with high concentrations of internal rock fragments. Slope range is 0 to 40%. The climatic class is HSC 5 -1. Low plant competition, moderate to high natural regeneration potential, and slight erosion hazard.
12	291, 294, 300, 310, 565[28], 584, 620[29] **(7)**	291, 294, 300, 310	565, 584, 620	Pipo/Quga	Pipo/Quga/ Quga	Moderately deep, fine- to medium-textured Alfisols with variable concentrations of internal and surface rock

[25] Kaibab TESU north of I-40
[26] Kaibab TESU north of I-40
[27] Coconino TESU north of I-40
[28] Coconino TESU
[29] Coconino TESU, Kaibab TESU located only on NKRD

Stratum	TES Units Combined	Kaibab TESU	Coconino TESU	Potential Plant Community from TES	Plant Association	Basis for Combination
						fragments. Slope range is 15 to 40%. The climatic class is LSC 5 0. Moderate plant competition from Quga, moderate to high natural regeneration potential, and moderate to high erosion hazard.
13	300a, 310a, 537[30], 553, 565a[31], 584a[32] **(6)**	300a, 310a	537, 553 , 584	Pipo/Fear	Pipo/Fear	Shallow to moderately deep Alfisols and Mollisols with high concentrations of internal and surface rock. Inventoried with a 15 to 40% slope range. Climatic class is considered LSC 5 0. Low plant competition, moderate to high natural regeneration potential, and moderate to high erosion hazard.
14	283, 284, 297, 298 **(4)**	283, 284, 297, 298	NA	Pipo/Pied/Quga/Artr	Pipo/Quga	Moderately deep to deep, fine-textured Alfisols with varying concentrations of surface and internal rock. Units 284 and 298 mapped on 15 to 40 percent slope, whereas 283 and 297 are mapped on 0- to 15-percent slope class. Climatic class LSC 5 -1. Moderate to high plant competition from Quga and Artr, low to moderate natural regeneration potential and low to moderate erosion hazard.
15	305, 311, 405, 500, 505, 506, 510, 512, 517, 520, 523[33], 530, 563, 564	305, 311, 405, 563, 564	500, 505, 506, 510, 512, 517, 520, 523, 530	Pipo/Pied/Quga Pipo/Pied/Jude/Quga Pipo/Pied/Jumo/Quga Pipo/Pied/Jude/Fapa Pipo/Pifa/Jude/Qutu	Pipo/Quga	Shallow to moderately deep, coarse- to fine-textured Alfisols with minor amounts of Entisols and Mollisols.

[30] Coconino TESU
[31] Coconino TESU with Pipo/Fear
[32] Coconino TESU with Pipo/Fear
[33] Both survey areas have used this number. On Kaibab mapped as Argiustolls, 15 to 80% slopes, LSM 4 +1. This represents acres on Coconino NF TESU only.

Stratum	TES Units Combined	Kaibab TESU	Coconino TESU	Potential Plant Community from TES	Plant Association	Basis for Combination
	(14)					Slope range between 0 to 40%. Units 311, 530, 564 all mapped on 15 to 40%, remainder 0-15%. Climatic class is HSC 5 -1 and LSM, 5, -1. Moderate to high plant competition from Quga, Artr and Qutu. Low natural regeneration potential and low to severe erosion hazard.
16	271, 299, 320, 431, 539, 555, 575, 596, 621, 648, 660, 681 **(12)**	271, 299, 320, 431, 539, 621, 648, 660, 681	555, 575, 596	Pipos Psmeg	Pipo/Quga/ Quga	Shallow to moderately deep, fine- to coarse-textured soils; occupying slopes ranges greater than 40 percent. High percentage of rock on surface and within soil profile. Climatic class ranges from LSC 6, LSC 5 0, LSC 5 -1, and HSC 5 -1. Moderate to high plant competition from Quga, Artr and Jude, low natural regeneration potential, and severe erosion hazard.
17 Strata	**94 TESU**					

Appendix B

Table 3 and 4