

Chapter 4

Watershed Condition

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Introduction

Managers of the Prescott National Forest are obliged to evaluate the conditions of watersheds under their jurisdiction in order to guide informed decisions concerning grazing allotments, forest and woodland management, restoration treatments, and other management initiatives. Watershed condition has been delineated by contrasts between “good” and “poor” conditions (DeBano and Schmidt 1989). Good condition is characterized by vegetation and litter cover that is capable of absorbing precipitation, temporarily storing it, and slowly releasing it through a network of channels with minimal drainage density. Poor condition applies to areas where precipitation induces soil erosion and rapid sediment-laden runoff through an expanding network of channels. Evaluations of watershed condition face substantial challenges in attempting to determine a reference condition, the extent of departure from that condition, causes of that departure, and management actions that can return the watershed back toward the reference condition (McCammon and others 1998). These challenges are particularly great in watersheds of the arid and semi-arid Southwest, where flashy, sediment-laden runoff is a common natural condition.

Evaluation of watershed condition was a central topic in the Prescott National Forest’s biological evaluation on selected grazing allotments for the spikedace and the loach minnow on the UVR watershed (Prescott National Forest 2001; King 2002). The authors examined aquatic conditions (based on water quality, macroinvertebrate populations, fish populations, and substrate pebble counts), riparian conditions (based on proper functioning condition surveys and vegetation transects), soil conditions (based on data from the Terrestrial Ecosystem Survey [TES]), and resource impacts (tributary and gully systems, livestock grazing, roads and trails, pinyon/juniper woodlands, desert shrublands, and land use patterns). Through a subjective synthesis of those factors, the major subwatersheds were ranked in terms of high, medium, or low “integrity relative to potential.”

Attempting to reduce complex ecological relationships across a heterogeneous landscape could lead to faulty inferences. A critical element of watershed analysis is to demonstrate the chain of logic and assumptions used to form recommendation for treatments (McCammon and others 1998). This chapter addresses watershed condition using information from the TES (Robertson and others 2000) with the goals of distinguishing important ecological concepts and guiding management decisions for the UVR.

Methods

Study Area

The watershed of the UVR encompasses an area of diverse topography and lithology since it traverses the Transition Zone from highlands on the southwestern edge of the Colorado Plateau into a large basin that is more typical of the desert Southwest. This study is limited to lands within the Prescott National Forest (fig. 1.1) since those are the areas for which data are available and for which the Prescott National Forest makes management decisions. Tapco, just upstream of Clarkdale and below the UVR's confluence with Sycamore Creek, is used as the lower boundary of this analysis. This area coincides with the first of three reaches included in the biological evaluation by the Prescott National Forest (2001). The UVR watershed encompasses seven "5th code" hydrologic units (HUCs) from the Big Chino Wash downstream to Tapco. The Williamson Valley Wash (#1506020107), Hell Canyon (#1506020202), and Sycamore Creek (#1506020203) hydrologic units are true watersheds, but the Middle Big Chino Wash (#1506020106), Lower Big Chino Wash (#1506020108), Granite Creek/UVR (#1506020201), and Grindstone Wash/UVR (#1506020204) hydrologic units are not, because parts of their watersheds are contained by other HUCs. A major disadvantage of using HUCs that are not true watersheds is that their boundaries are arbitrary. Consequently, boundaries of some of the HUCs reported here do not coincide precisely with those used in the Prescott National Forest's biological evaluation.

Terrestrial Ecosystem Survey

The Prescott National Forest collected TES field data between 1992 and 1997 for classifying areas into similar map units through a systematic analysis of geology, soils, erosion, vegetative composition, and vegetative production (Robertson and others 2000). Designers of the Survey hoped to evaluate and modify land uses on the Forest according to the natural limitations and potentials of its natural resources. Accordingly, the TES is intended to provide a basis for evaluating watershed condition at a coarse scale across the Forest using criteria such as soil condition ratings and various soil loss rates.

Soil Condition—The TES evaluation of soil condition uses a three-way classification ranging from "unsatisfactory" (signifying that vital soil functions have been lost) to "satisfactory" (signifying that soil functions are proper, normal, and sustainable), with "impaired" representing an intermediate condition (Robertson and others 2000). The TES for the Prescott National Forest rated soil conditions based on three interrelated soil functions: hydrologic function, soil stability and nutrient cycling. This approach was more complex than surveys completed on other National Forests, which instead used a single indicator, soil stability or soil loss rate to evaluate soil condition (Barnett and Hawkins 2002).

However, it must be noted very clearly that the three soil condition ratings used in the Prescott National Forest TES do not necessarily imply a one-to-one correspondence with erosion rates or potential delivery of sediment to channels. They are simply a way of integrating ecological conditions of the landscape units. These ratings are more influenced by potential site productivity than by anything else.

The rates of soil loss used in the TES are predicted using the Universal Soil Loss Equation under different scenarios (Robertson and others 2000). The "natural" soil loss rate is the minimum rate of loss, which would be expected under a climax

vegetative state. “Current” soil loss rates reflect conditions under the current land management regime. The “potential” soil loss rate is the rate that would be expected when all vegetative ground cover is removed. The “tolerable” soil rate is the rate above which reductions in primary plant productivity would be expected. Short-term increases in herbaceous plant productivity might occur with soil losses above the tolerable level due to competition reduction. Also, soil cultivation might temporarily raise productivity due to improved soil structure and water-holding capacity (Neary and others 1990; Burger 2002).

Scale and Precision—Issues of scale and precision are very important when evaluating watershed condition. The soil condition metric may be useful at the large watershed scale, but it may not be an accurate reflection of the condition of specific points within smaller management units (Barnett and Hawkins 2002). Differences due to management can cause areas within the same map unit to have very different conditions. For example, different livestock management practices on individual range allotments can result in a soil unit being impaired on one allotment and satisfactory on another. Staff of the Prescott National Forest collected site-specific data to verify the TES data. Their results indicated that map units in the TES soil condition ratings were generally consistent with the individual site information (Prescott National Forest 2001). As a result of the verification process, Prescott National Forest staff changed only three of the dominant map unit ratings from the original TES ratings.

GIS Analyses of Watershed Condition—Because the various soil metrics in the TES provide different information about watershed condition, the results of using those metrics were compared to classify conditions across the UVR watershed. A Geographic Information System (GIS), with layers representing the different TES map units, provided a tool for evaluating these metrics. The Prescott National Forest GIS coordinator provided a layer with the TES map units along with a database containing the various soil ratings and loss rates, and another layer containing the 5th code HUC delineations made by the Natural Resources Conservation Service. By overlaying these layers, it became possible to query and represent the TES data within hydrologic units.

Soil Loss Analysis

The Prescott National Forest TES analysis estimated soil loss rates for each mapping unit that were based on soil rainfall-runoff erosivity, erodibility, length and steepness of slopes, ground cover information, and conservation practices factors that comprise the revised Universal Soil Loss Equation (Renard and others 1991). “Natural” soil loss refers to soil loss that would occur under conditions with an expected climax vegetation. “Current” soil loss refers to erosion rates with the existing ground cover. “Tolerance” soil losses are those that can occur without degrading site productivity. “Potential” soil loss rates are the maximum rates that would occur if litter and vegetation were completely removed. This level is usually seen only with high-severity wildfire.

Table 4.1 summarizes the acres, annual soil loss, and weighted average soil losses for the seven 5th code HUC watersheds within the boundaries of the Prescott National Forest. The total area was nearly equally divided among satisfactory, impaired, and unsatisfactory soil condition ratings. In terms of annual soil losses, over half (53.3%) of all estimated soil loss came from areas rated as satisfactory, while only one-fifth (20.3%) of estimated loss came from unsatisfactory areas.

Table 4.1—Acreage, annual soil loss, and weighted average soil loss (Mg ha⁻¹ yr⁻¹) for seven 5th code HUC units on the Prescott National Forest (PNF) (from Robertson and others 2000).

Area				Total for All	Portion of
Hydrologic unit	Satisfactory	Impaired	Unsatisfactory	Categories	Total Area
	ha				%
Middle Big Chino Wash	5937	7721	6290	19948	8.35
Williamson Valley Wash	18913	19173	14404	52490	21.97
Granite Creek/UVR	12793	3424	4049	20266	8.48
Grindstone Wash/UVR	23386	18457	17197	59040	24.71
Hell Canyon	2855	9688	14818	27361	11.45
Lower Big Chino Wash	17473	21603	11698	50774	21.25
Sycamore Creek	4559	1190	3332	9082	3.80
Total UVR within PNF	85917	81256	71787	238960	100.00
Overall %	35.95	34.00	30.04	100.00	

Annual Soil Loss				Total for All	Portion of
Hydrologic unit	Satisfactory	Impaired	Unsatisfactory	Categories	Total Area
	Mg yr ⁻¹				%
Middle Big Chino Wash	22755	11348	5950	40053	6.23
Williamson Valley Wash	42156	50286	33635	126077	19.62
Granite Creek/UVR	36775	9249	6572	52595	8.18
Grindstone Wash/UVR	131811	40804	37331	209946	32.66
Hell Canyon	17165	16733	18285	52183	8.12
Lower Big Chino Wash	65355	38136	15404	118896	18.50
Sycamore Creek	26761	3232	12999	42993	6.69
Total UVR within PNF	342779	169788	130175	642741	100.00
Overall %	53.33	26.42	20.25	100.00	

Average Soil Loss				Overall Average
Hydrologic unit	Satisfactory	Impaired	Unsatisfactory	Weighted by Area
	Mg ha ⁻¹ yr ⁻¹			
Middle Big Chino Wash	3.83	1.47	0.95	2.01
Williamson Valley Wash	2.23	2.62	2.34	2.40
Granite Creek/UVR	2.87	2.70	1.62	2.60
Grindstone Wash/UVR	5.64	2.21	2.17	3.56
Hell Canyon	6.01	1.73	1.23	1.91
Lower Big Chino Wash	3.74	1.77	1.32	2.34
Sycamore Creek	5.87	2.72	3.90	4.73
Total UVR within PNF	3.99	2.09	1.81	2.69

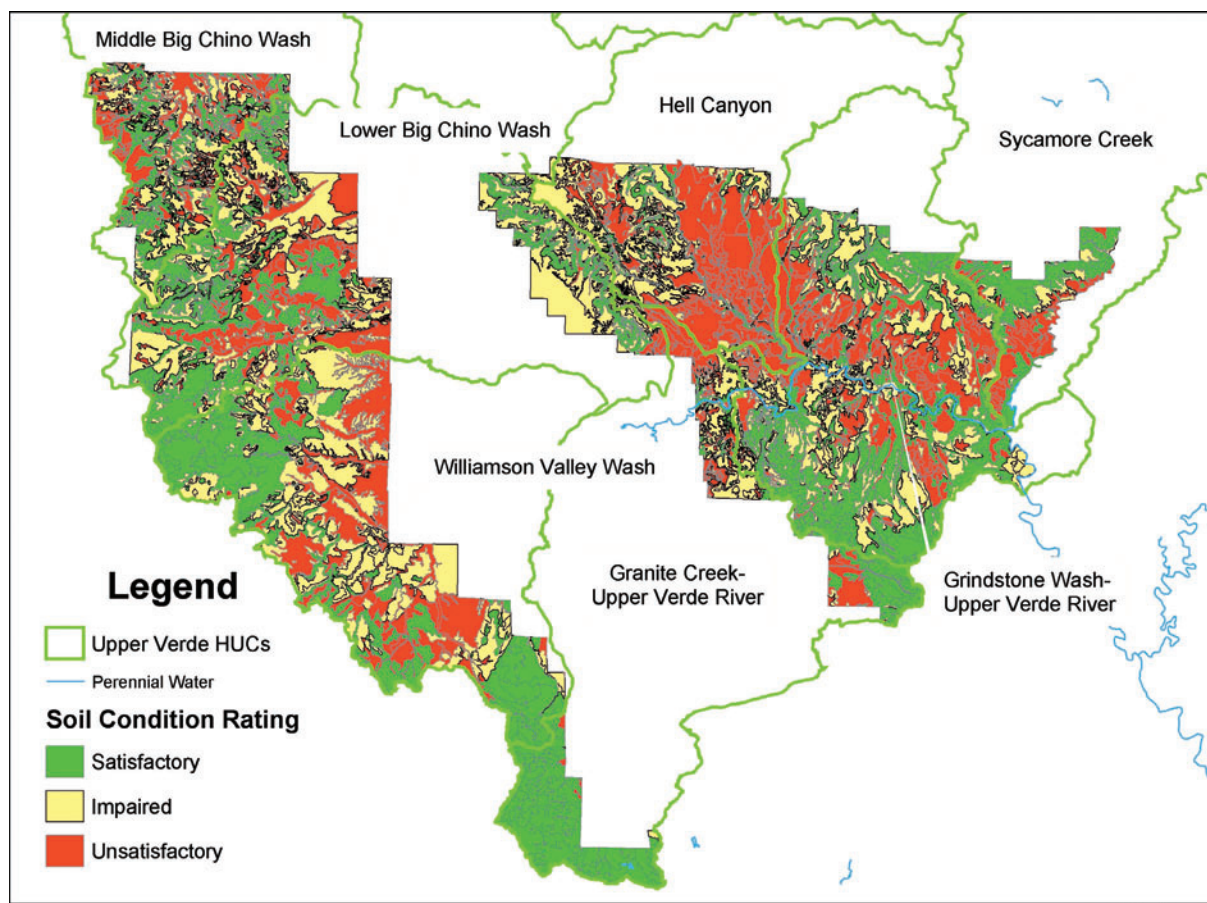


Figure 4.1—Soil condition ratings on the Prescott National Forest within the UVR watershed.

Satisfactory classification units had higher average erosion rates per unit area than did impaired or unsatisfactory map units in six of the seven hydrologic units because of their deeper soils. For example, in the Hell Canyon HUC, the average soil loss for soil units rated as satisfactory was nearly five times that of units rated as unsatisfactory. The latter soil units are shallow and rocky and, therefore, have less soil material to erode.

Unsatisfactory soils were fairly evenly distributed across the Forest, although the Hell Canyon watershed stood out for poor ratings (fig. 4.1). However, a map of current soil loss rates (fig. 4.2) yields a very different interpretation than the map of soil condition rating. For example, while only 10.4% of the area in the Hell Canyon watershed was rated as satisfactory, one half of the area was estimated to lose soil at a rate of less than 1 Mg ha⁻¹ yr⁻¹ (2.2 tons ac⁻¹ yr⁻¹). The areas of highest weighted average soil loss rates were in the Grindstone Wash/UVR and the Sycamore Creek HUCs (quantified in the bottom section of table 4.1), both of which include steep terrain.

The difference between current soil loss rates and natural loss rates (fig. 4.3) may point to areas that suffer from excessive soil erosion. By that measure, areas with relatively excessive soil loss rates occurred in the upper Williamson Valley Wash watershed, the lower part of the Big Chino Wash, and the lower part of the Grindstone Wash/UVR and Sycamore Creek HUCs. However, 81% of the areas on the Forest had current soil loss rates that were less than 1 Mg ha⁻¹ yr⁻¹ (2.2 tons ac⁻¹ yr⁻¹) above the estimated “natural” loss rates. The remaining 19% (44,600 ha or 110,210 ac), was estimated to produce 1 Mg ha⁻¹ yr⁻¹ (2.2 tons ac⁻¹ yr⁻¹) above

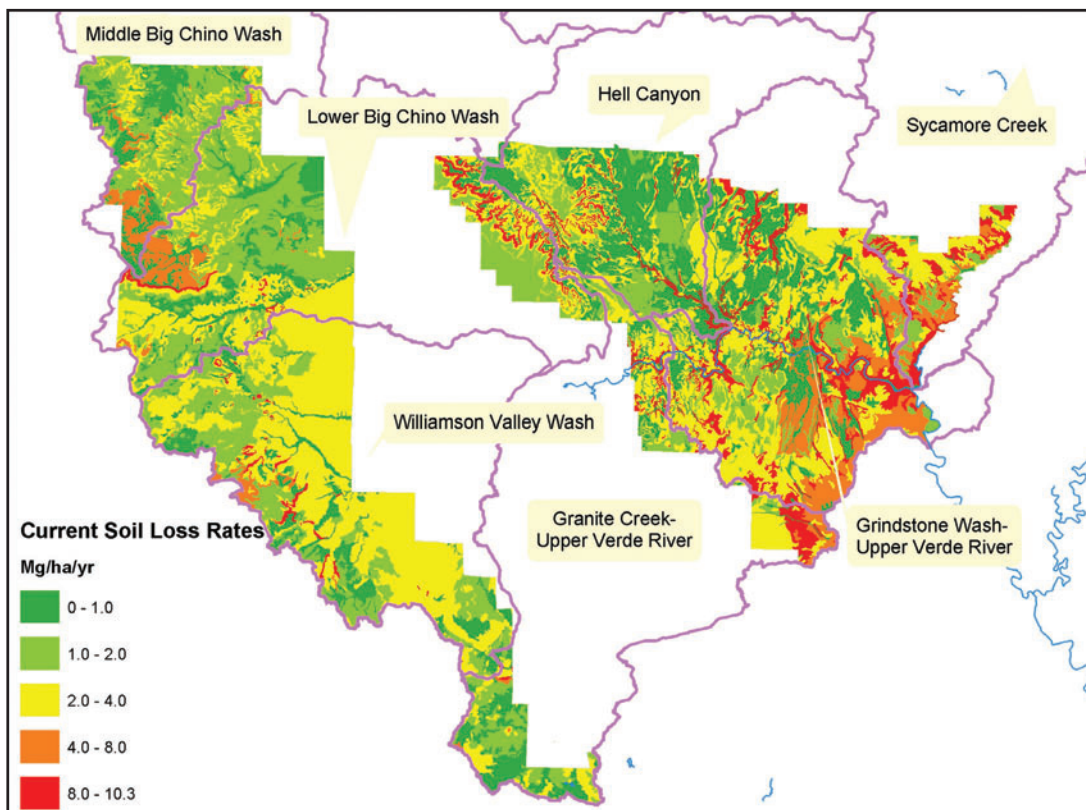


Figure 4.2—Estimated current soil loss rates in $\text{Mg ha}^{-1} \text{ yr}^{-1}$ on the Prescott National Forest within the UVR Watershed (Robertson and others 2000). Colors in red, gold, and yellow designate the higher erosion rates.

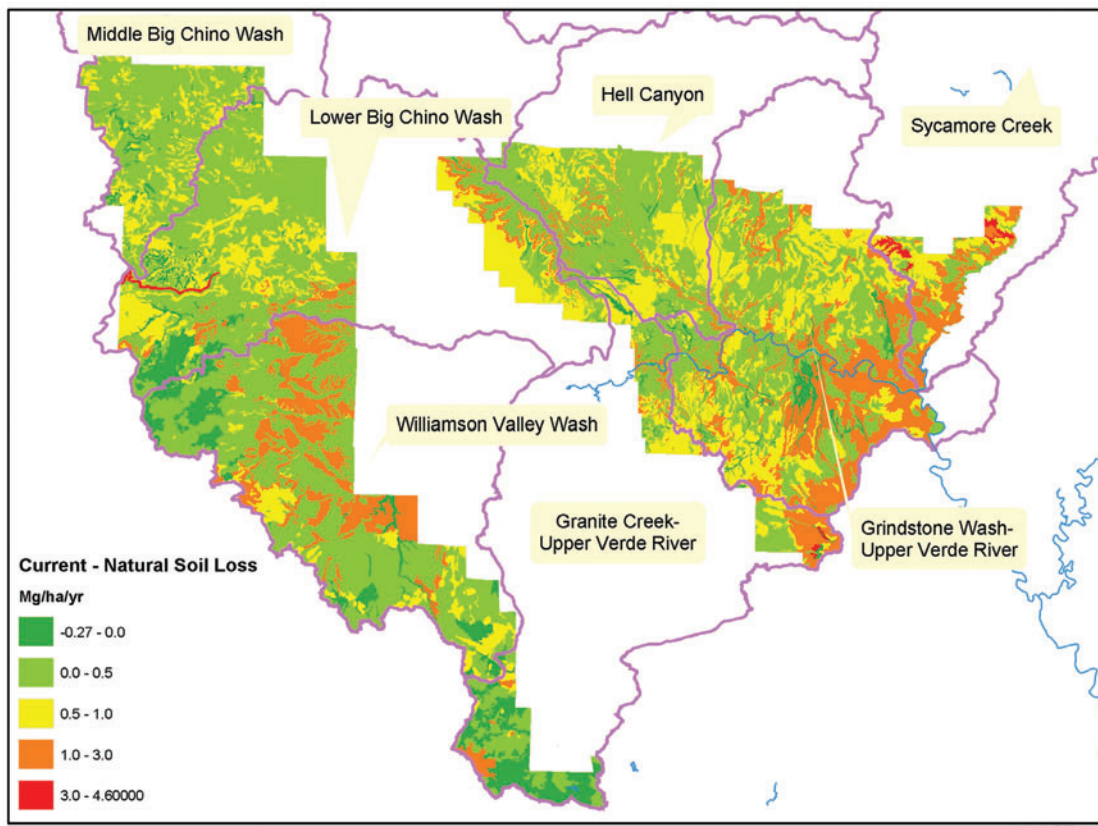


Figure 4.3—Estimated current soil loss rates minus natural soil loss rates in $\text{Mg ha}^{-1} \text{ yr}^{-1}$ on the Prescott National Forest within the UVR watershed (Robertson and others 2000). Colors in red, gold, and yellow designate the higher erosion rates.

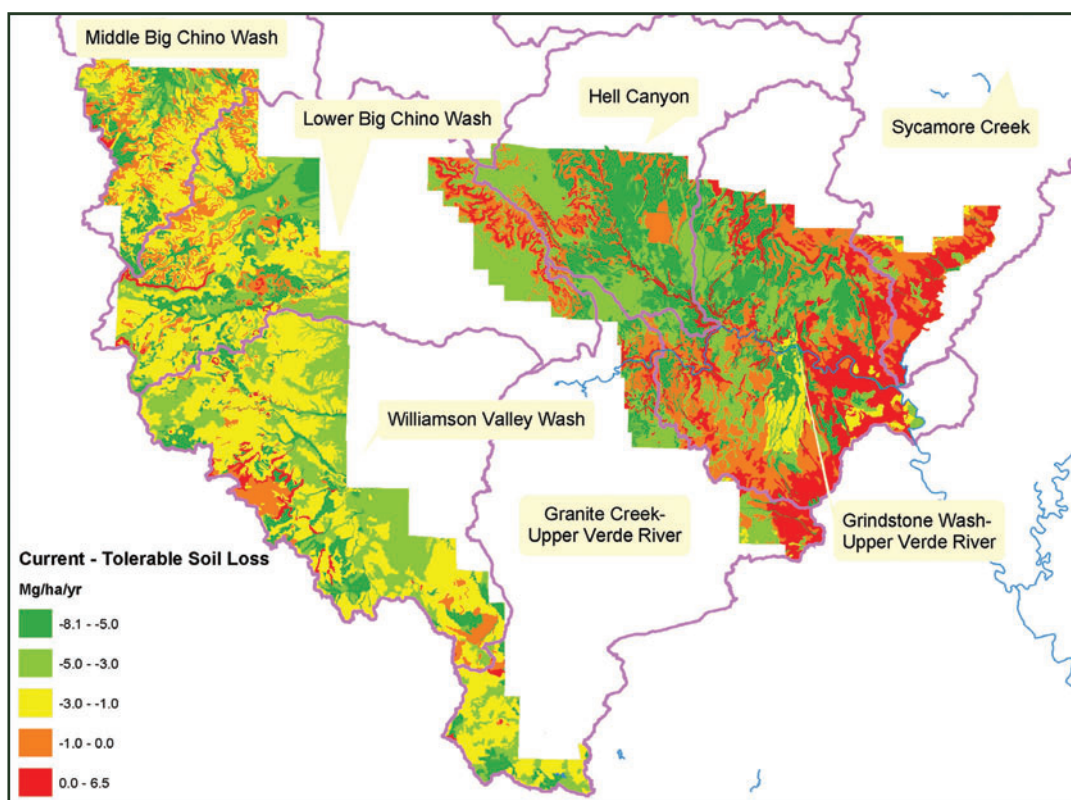


Figure 4.4—Estimated current soil loss rates minus tolerable soil loss rates in $\text{Mg ha}^{-1} \text{ yr}^{-1}$ on the Prescott National Forest within the UVR watershed (Robertson and others 2000). Colors in red, gold, and yellow designate the higher erosion rates.

estimated natural rates. Half of these areas were characterized by relatively steep slopes, but were rated as “satisfactory,” typically with a corresponding label of “inherently unstable.” Only 10% of the areas producing over $1 \text{ Mg ha}^{-1} \text{ yr}^{-1}$ ($2.2 \text{ tons ac}^{-1} \text{ yr}^{-1}$) of excess sediment above natural levels were rated as “unsatisfactory,” all corresponding to a single map unit (455).

Mapping the difference between current and tolerable soil losses (fig. 4.4) helps to identify areas where soil sustainability may be in jeopardy. This map presents a picture similar to fig. 4.3, indicating that the highest net losses were concentrated in the lower portion of the Grindstone Wash/UVR watershed and Sycamore Creek HUCs. However, 80% of the areas estimated to have current losses in excess of tolerable levels were also locations where natural soil loss rates exceeded tolerable rates due to steep slopes.

The vegetation types on the UVR watershed within the Prescott National Forest (fig. 4.5) are dominated by pinyon-juniper communities (87% of total area). Most of the grassland areas within the watershed are not located on National Forest lands, except for a small part of the central Plains grasslands in the eastern corner of the Lower Big Chino hydrologic unit and a moderate expanse of *Aristida* spp. (three-awn) subclimax grassland (primarily occurring in areas treated to reduce junipers) within the Hell Canyon watershed. The lower watershed areas that had the most elevated soil erosion rates are primarily covered with pinyon-juniper and chaparral. By contrast, high-elevation ponderosa pine forest had relatively low soil erosion rates.

Table 4.2 relates soil condition ratings to geology across the UVR watershed within the Prescott National Forest. Nearly half of the areas comprised of Older

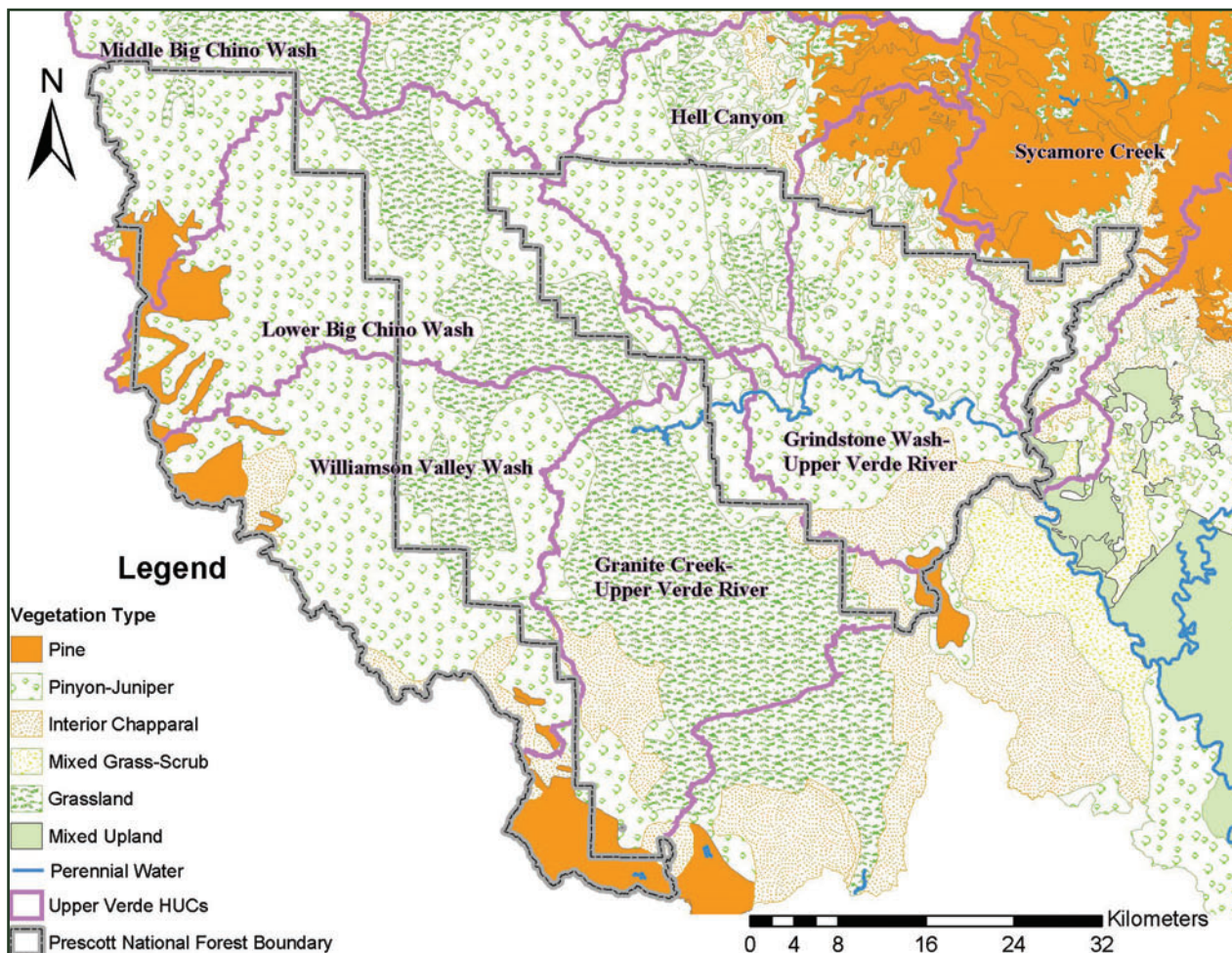


Figure 4.5—Vegetation types in the UVR watershed within and surrounding the Prescott National Forest.

Quaternary alluvium and the Tertiary Verde Formation were rated as having unsatisfactory conditions. The latter formation constitutes over 15% of the study area on the Prescott National Forest. Both of those geologic formations are relatively more abundant on private lands in the Verde watershed. The naturally erodible red sandstones and siltstones of the Paleozoic Supai Formation and the naturally less erodible Tertiary basaltic rocks also had unsatisfactory soil conditions across 42% of their areas. On the other hand, Precambrian crystalline rocks and the late Permian Kaibab and Coconino sedimentary rocks were typically in satisfactory condition. These formations generally lie at higher elevations under ponderosa pine forests.

Figure 4.6 compares estimated soil loss rates along the boundary between the Prescott National Forest and the neighboring Kaibab National Forest as a means of evaluating the consistency of TES data for particular areas. There is some topographic variation associated with the boundary, as terrain becomes steeper south of the Mogollon Rim. However, striking incongruities in the figure may also reflect high spatial variability within map units, sampling errors, or perhaps differences due to when the field data were collected (the Kaibab National Forest was sampled in the late 1980s, while the Prescott National Forest was sampled in the mid 1990s).

Table 4.2—Total hectares in each soil condition rating for different geologic types within the UVR Watershed on the Prescott National Forest (from Robertson and others 2000).

Geology	Condition			Total ha	Percent
	Satisfactory	Impaired ha	Unsatisfactory		Unsatisfactory %
Rocks					
Precambrian crystalline	29195	6687	5898	41781	14
Redwall Limestone	21954	24519	11179	57652	19
Supai Formation	6519	7828	10196	24544	42
Kaibab/Coconino Sandstones	5737	1994	872	8604	10
Formations					
Tertiary basaltic rocks	12498	12821	18570	43888	42
Tertiary volcanic rocks	1672	3235	1107	6014	18
Tertiary Verde Formations	5409	13423	16813	35646	47
Other Tertiary sedimentary	1502	3196	2771	7469	37
Older Quaternary alluvium	588	4043	4343	8974	48
Young Quaternary alluvium	842	3722	44	4608	1
Total	85917	81468	71794	239179	30

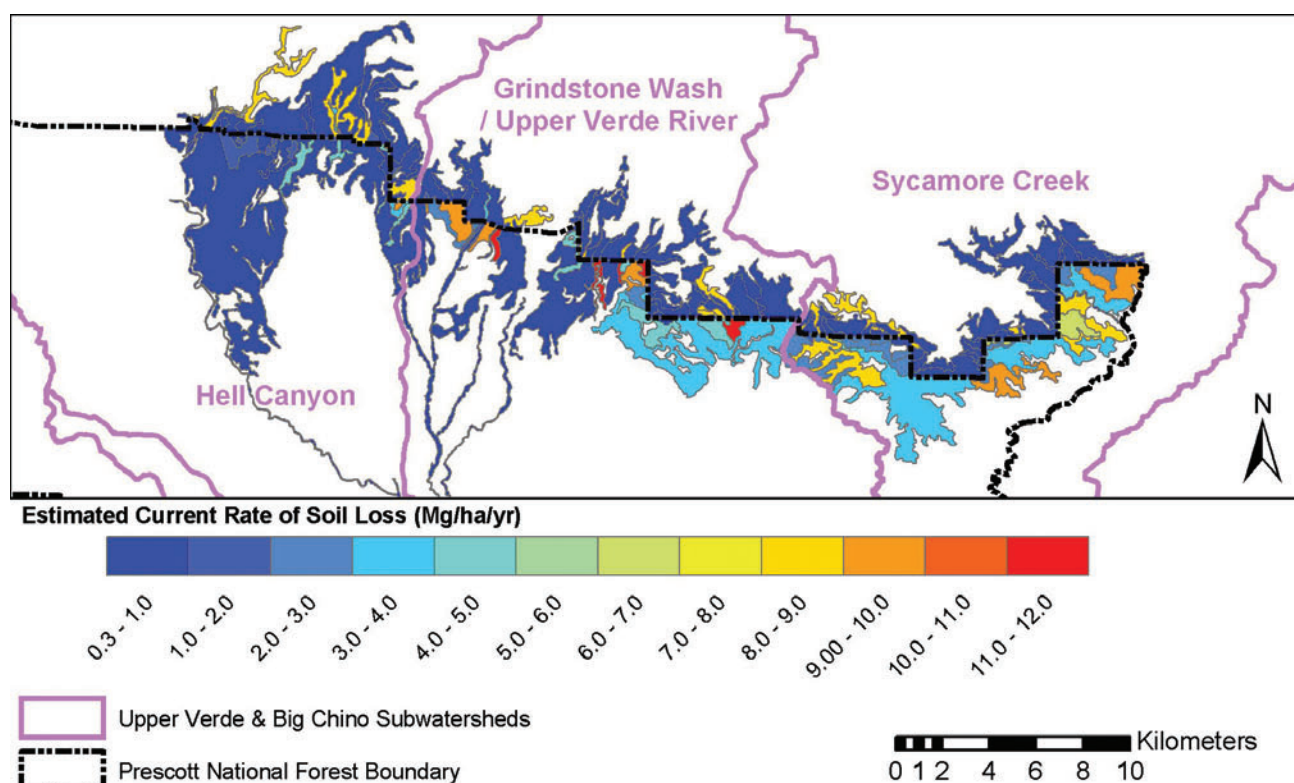


Figure 4.6—Comparison of estimated soil loss rates along the boundary between the Prescott and Kaibab National Forests. The estimated rates on the Prescott National Forest are substantially higher east of the Hell Canyon watershed. Current estimated soil losses in this figure grade from least (red) to most (blue). The Kaibab National Forest lies above the dashed line in the figure and the Prescott National Forest lies below the line.

Watershed Condition

Because watershed condition represents the complex interaction of sediment and water flows, it does not always directly correspond to watershed condition ratings. Basing management decisions solely upon categorical soil condition ratings is risky since cause-and-effect relationships and temporal factors are generally ignored when designating the ratings. Subjective categories such as “satisfactory” and “impaired” can mislead untrained users of TES data because such terms can be interpreted as evaluations of current management practices (Barnett and Hawkins 2002). An inexperienced interpreter of soil condition ratings might infer that a high level of unsatisfactory soil conditions implies poor watershed condition and excessive sedimentation that can threaten aquatic habitat. Watershed condition ratings developed during the TES process do provide positive information for Forest land managers to prioritize actions and resources needed to improve overall productivity of the Forest landscape. There are a number of uses for the Forest TES evaluation of watershed condition on the UVR, and these are discussed in the following sections.

Watershed Condition Evaluations

Identifying Inherently Unstable Geology and Soils—Firstly, the TES identified many areas as inherently erodible due to lithology and slope. An additional TES category of “inherently unstable” soils was needed to distinguish such soils from those that are unstable due to management practices (Barnett and Hawkins 2002). However, inherently unstable areas were assigned soil condition ratings ranging from satisfactory, to impaired, to unsatisfactory. The watershed condition assessment report prepared by the Prescott National Forest in 2001 (Prescott National Forest 2001) recognized that map units such as Unit 455 could be considered “satisfactory-naturally erosive” and would not be expected to change much over time due to “inherent instability and steep slopes.” There are areas of the Prescott National Forest landscape that are steep and rocky. They have been for centuries and most likely won’t change for centuries or be amenable to restoration. This is part of the natural state of affairs for a forest in a semi-arid, mountainous landscape. Those areas need to be adequately identified in order to recognize that management activities within the UVR Watershed in the past had no involvement with the current condition, nor are future restoration activities likely to change these landscape units to a better condition with any amount of restoration inputs.

Identifying Areas With Legacy Degradation—It is important to identify the size and location of legacy impacts in order to guide future Prescott National Forest management actions and current assessments. Soil condition ratings in the TES do not indicate at what time a decline in ecological function may have occurred. Indeed, undesirable watershed and soil conditions in the pinyon-juniper woodlands of the Prescott National Forest were evident almost a century ago (Leopold 1924). Consequently, while many unsatisfactory soil condition ratings are associated with historical degradation, an untrained user of the TES might assume that current land management practices are responsible. Unsatisfactory ratings were also applied to areas that had been intensively treated to remove juniper trees in previous decades (e.g., map units 470 and 471). This type of land management activity was halted at one point but has been initiated again to achieve well-defined ecological objectives.

Identifying Cause-and-Effect Relationships—Setting grazing policies based on current soil condition ratings rests on assumptions about how changes in grazing will ameliorate unsatisfactory conditions. However, decades ago, Leopold (1921) contended that changes in range controls alone would be insufficient to reverse erosion processes. The prevalence of unsatisfactory soil conditions in pinyon-juniper areas may support a call for active treatments to abate erosion. However, the pushing and chaining of pinyon-juniper communities does not appear to have substantially ameliorated these conditions, as the TES survey identified many of those treated areas as being in unsatisfactory soil condition. Pushing and chaining involves using bulldozer blades (pushing) or dragging large chains (chaining) to remove dense pinyon-juniper stands in a cost-effective treatment. Inter-tree cover in pinyon-juniper communities is often sparse, thereby increasing the probability of higher levels of erosion. Herbaceous cover recovery after pushing and chaining is often slow due to low rainfall rates and the lack of seed sources. Deeper tilling of soils is often required after pinyon-juniper removal to improve plant rooting depth and moisture holding capacity. Some dense pinyon-juniper woodland areas have exhibited changes, but not improvements, in soil condition as bare soils have been replaced by erosion pavements (Barnett and Hawkins 2002).

Unsatisfactory soil condition ratings may also be associated with inherent geologic or soil properties that impede recovery but do not necessarily indicate how the soils will respond to grazing or to rest from grazing. For example, some limestone-derived soils have high carbonate contents while some basaltic soils have high shrink-swell potential due to the presence of montmorillonitic clays. Soils with high montmorillonite contents shrink and crack when dried out and expand considerably when wet. These properties may be associated with a greater proportion of unsatisfactory soil conditions because they can impede herbaceous revegetation, reduce animal and vehicle trafficability, and limit water infiltration (O'Rourke and Odgen 1969; Clary 1971). As a result, an unsatisfactory rating might or might not warrant a change in grazing management.

It is even more difficult to extrapolate soil condition from an upland part of the landscape to conditions in the riparian zone of the UVR. While the soil condition ratings do present a snapshot of soil conditions and potential to generate sediment, estimated erosion rates need to be examined first before any conclusions can be drawn about the status of sedimentation in the UVR. In addition, in channel sediment delivery processes and sediment routing from lands off the Prescott National Forest need to be considered. Determining cause-and-effect from past or current land management practices must be done judiciously and by trained geosciences professionals.

Correlating Poor Soil Conditions with Stream Sedimentation—The soil condition ratings given by the Prescott National Forest TES do not directly measure sediment yield to stream channels (Robertson and others 2000). Map units classified as satisfactory often have an estimated higher rate of soil loss than those rated as impaired or unsatisfactory. Unsatisfactory areas may have already lost much of their erodible fine soils. Consequently, a soil with a satisfactory rating could be a higher priority for managing sedimentation. Decisions on management of such soil units need to be made on the basis of all the factors that go into the rating, not just erosion.

Alternative Metrics for Evaluating Soils and Watershed Condition

The TES provides several metrics that serve to distinguish among naturally erodible areas and areas that may be managed to reduce erosion. Natural soil loss

rates refer to estimates of soil loss due to erosion under conditions associated with a climax vegetation cover. Current soil losses occur with the existing vegetative ground cover. Tolerable soil loss rates refer to losses that could occur and still maintain inherent soil productivity. One way to evaluate unsustainable amounts of erosion is to determine where current soil loss rates exceed tolerable soil loss rates. The Prescott National Forest TES applied this relatively simple approach (Robertson and others 2000; Barnett and Hawkins 2002). By this standard, only 11% of the UVR watershed within the Prescott National Forest had current estimated soil loss rates in excess of tolerable levels, and the vast majority of those areas had natural soil loss rates that exceeded tolerable soil loss rates. For most areas that were rated unsatisfactory, current soil loss rates were estimated to be close to natural rates and well below tolerable loss rates.

Another approach for evaluating potential sedimentation is to subtract natural loss rates from current loss rates. This metric provides an estimate of excess soil erosion beyond postulated climax vegetative conditions. Standards based on estimated soil loss rates are intuitively easier to relate to evaluations of sedimentation problems than the complex soil condition ratings. However, these soil condition ratings may also be problematic because the estimates are rarely validated in wild-land situations and they may underpredict erosion losses on gentle slopes (Barnett and Hawkins 2002). The maps of potential problem areas in figs. 4.3 and 4.4 likely reflect a methodological bias toward steeply-sloped, naturally erodible areas. The estimated erosion rates in some of those areas were higher than in bordering areas on the Kaibab National Forest (fig. 4.6), reinforcing the possibility that the differences may be an artifact of methodology.

Greater understanding of ecological thresholds and dynamics are needed to evaluate the ecological significance of departures from postulated climax ground-cover conditions. Departures from climax vegetation should not necessarily be considered “abnormal,” since natural disturbances such as fires would have maintained patches of reduced vegetation and eroding soils. From an upland management perspective, Leopold (1921) claimed that differentiating “normal” from “abnormal” erosion was academic because he considered it desirable to curtail preventable erosion wherever possible. In a similar vein, the watershed assessment by the Prescott National Forest concluded that, “for the purpose of this assessment, [the naturally unstable map unit 455] has been considered unsatisfactory because it is a source of sediment to the Verde River.” This rationale, however, would tend to direct management resources toward remediation of a naturally unstable area where the prospects for improvement appear low.

Linkages to the River System—Maintaining “normal” levels of sedimentation, where normal is defined as within the natural range of variation for the given climatic conditions, may be a reasonable goal from a riverine management perspective. Influxes of sediment are important in maintaining or rebuilding habitat for native fishes and riparian plants (Medina and others 1997; Benda and others 2003; Long and others 2003). Conditions of channels downstream from the watersheds should indicate whether current sediment production rates are too high for the channels to process effectively. Results from morphology studies (Pearthree 1996; Beyer 1997; see also Chapter 5) do not indicate that reaches on the main stem of the Verde River are braiding or aggrading, which would be signs of excessive sedimentation. Although in-stream substrate dynamics vary considerably from reach to reach due to local geomorphic controls along the Verde River, the overall river system “conveys water and sediment in a fairly efficient manner” (Beyer 1997). Indeed, Beyer (1998) estimated that two-year flood events were capable of mobilizing most of the sediment in the low flow channel along its course.



Figure 4.7—Vertical streambank collapse as a source of sediment in the UVR.
(Photo by Daniel G. Neary.)

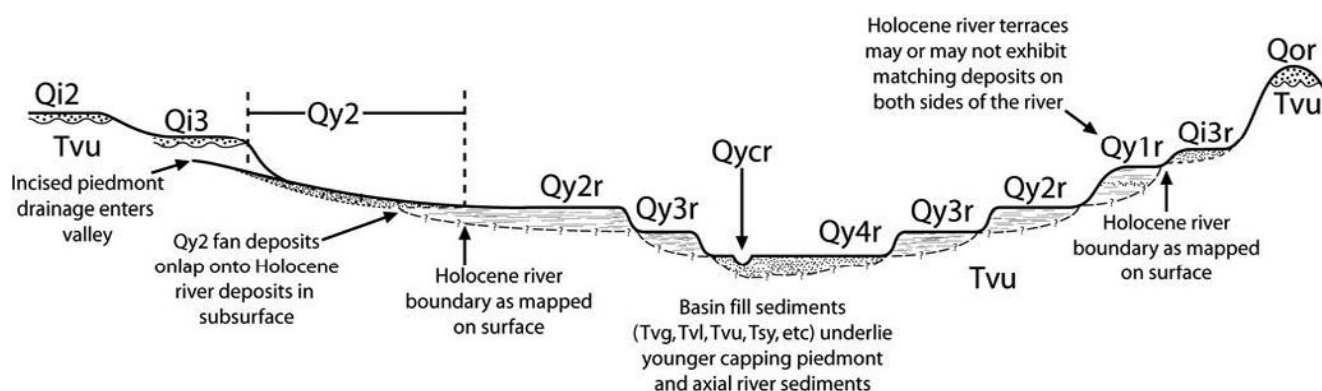


Figure 4.8—Generalized UVR cross section showing geomorphic relationships between Tertiary basin fill sediments, Pleistocene erosion fan and river deposits, and Holocene alluvial fan and river deposits (from Cook and others 2010).

Rather than being sediment-enriched, the Verde River may have experienced reduced influxes of fine sediment due to retention by Sullivan Dam and dams on Granite Creek (Medina and others 1997).

Another important source of sediment in the UVR that is usually excluded in watershed condition assessments is channel bank collapse (fig. 4.7). These river terrace sediments provide constant inputs of fine sediments into the UVR because of their close proximity to the current channels and vertical banks. They are classified as the Qy3r unit shown in fig. 4.8 and described in table 4.3 (Cook and others 2010a, 2010b, 2010c). This alluvium unit consists of historical river terrace deposits that occupy elevations of 2 to 3 m (6 to 10 ft) above the river. The sediments were deposited by paleofloods between A.D. 440 and 1650 according to radiocarbon dating. They are composed of poorly sorted sand, silt, pebbles, and cobbles capped by a layer of fine sand and silt. Gradual erosion of these deposits occurs with baseflow, and rapid erosion and channel widening are characteristic of flood flows. Rates of bank collapse and sediment input into the UVR channel are not known but they certainly contribute the bulk of suspended solids measured during baseflow on the UVR rather than upland sources.

Condition of Tributaries—In gravel-bed rivers affected by high rates of sediment input, surface grain size declines as inputs of fine sediments increase

Table 4.3—UVR sediment classification, age, and material source (from Cook and others 2010).

Unit Name	Sediment Origin		Sediment Deposit Source
	Epoch	Age -Years	
Qycr	Historical Holocene	A.D. 1993-2011	Current UVR Alluvium
Qy4r	Historical Holocene	A.D. 1650-1993	UVR Alluvium 1 st Terrace
Qy3r	Historical Holocene	A.D. 440-1650	UVR Alluvium 1 st -2 nd Terrace
Qy2r	Late Holocene	A.D. 430-1640	UVR Alluvium 3 rd Terrace
Qy1r	Late to Early Holocene	2,000-10,000 BP*	UVR Alluvium 4 th Terrace
Qy2	Late Holocene	1,000-2,000 BP	Upland Alluvium Erosion Fans
Qi3	Late Pleistocene	10,000-12,000 BP	Upland Alluvium Erosion Fans
Qi2	Middle to late Pleistocene	130,000 BP	Upland Alluvium Erosion Fans
Qi3r	Late Pleistocene	10,000-12,000 BP	UVR and Erosion Fans
Qor	Early Pleistocene	1-2 M BP	UVR Deposits on Alluvial Fans
Tvu	Late Miocene to Pliocene	5.3 M BP	Sandstone and Conglomerate

*YBP = Years before present

(Buffington and Montgomery 1999). Without temporal data, it is difficult to evaluate whether a particular stream reach is becoming sediment-enriched or whether it is naturally dominated by fine sediments. Moreover, pebble counts do not provide absolute indicators of sediment input, but instead can indicate increases in fine sediments relative to their water yield. For example, a large tributary could be a source of fine sediments, but that sediment contribution could be offset by a correspondingly high water yield (particularly in high-elevation tributaries such as Hell Canyon and Sycamore Creek).

The watershed evaluation by the Prescott National Forest used other criteria to evaluate sources of sediment to the UVR. Specifically, the report rated watershed condition as poor in the Hell Canyon-Grindstone Wash-MC Canyon-Bear Canyon complex based on the assertion that, “during high flows, all four tributaries carry huge sediment loads comprised primarily of large cobble. Channels are wide and shallow, often splitting into multiple channels and overflow channels.” The report seemed inconsistent however, first stating that “channel features at the mouth of Hell Canyon suggest tremendous flows, scouring and redepositing huge amounts of sediment,” but then stating, “flow events large enough to move this material probably occur rarely.” That discussion confused the size of particles being moved with the rate of sedimentation. The sediment size is large in Hell Canyon but huge amounts of sediment are not being moved into or through the canyon. There is very little fine sediment that is the usual indicator of high rates of erosion and sedimentation. The watershed evaluation is correct in reporting that flow events large enough to move the coarse sediments are rare. In the absence of these events the larger cobble and boulder material just remains in place.

The Hell Canyon watershed features an unusual drainage configuration, as four large drainages converge just above the confluence with the Verde River. The coarse particle sizes dominating those systems may reflect that unusual geomorphology as well as flashy runoff, but they do not necessarily indicate a sedimentation problem. The soil condition ratings in that watershed do not indicate that degradation has been extensive or that conditions would be substantially improved through changing management. Consequently, evaluating the condition of that watershed as particularly “unsatisfactory,” might lead managers in an unfruitful direction.

Gully Networks—Another important facet of identifying poor watershed condition is an expanding drainage network in the form of gullies. Sedimentation caused

by active gully erosion and by roads will be underrepresented in the TES because the Universal Soil Loss Equation is not designed to deal with those erosional processes. Most gully networks in the UVR watershed on the Prescott National Forest appear to have stabilized, although areas of active gully erosion are present such as Railroad Draw and Red Point Tank (Prescott National Forest 2001). Barnett and Hawkins (2002) also noted that portions of the Sheepshead subwatershed experienced dense networks of steeply walled gullies. In many cases, gully erosion may have begun due to roads and development rather than with grazing. Also, gullies may represent a legacy of past impacts rather than a reflection of present management. Such conditions warrant a site-specific assessment of causes, effects, and treatments rather than a landscape-level prescription for land use. As Leopold (1921) contended nearly a century ago, healing gully erosion requires active treatments in conjunction with abating the causes of gullying, which are often improper road drainage but may also include animal impacts.

Management Implications

Evaluating the condition of the UVR watershed based largely on TES data could lead to an inefficient allocation of management resources because inherently unstable units were not rated consistently and soil condition ratings do not have direct relationships to soil loss rates. TES data were not designed for making management decisions for particular rangeland sites. More detailed monitoring of key functional attributes—such as the amount of bare soil and litter; the amount, composition and vigor of range plants; and the extent of soil compaction, pedestal development, rill formation, and gully incision—provide appropriate information for guiding range management actions at the site level (USDI Bureau of Land Management 2000; O'Brien and others 2003). Discrepancies between ground cover data along the boundary between the Kaibab and Prescott National Forests suggests that increased monitoring and verification of ground cover data may improve the information available to managers. Rather than relying heavily on estimates of vegetative cover (litter plus total vegetative basal area), more sophisticated evaluations of groundcover conditions (based on cover and condition of desirable range species) would improve decision making.

Management efforts might yield greater returns by targeting areas where hydrologic conditions could be improved by increasing herbaceous cover on gently sloped uplands and by treating active gullies with rock-wire gabions, geotextiles, and plantings (Heede 1978). Pinyon-juniper woodlands are likely to be a focus on the Prescott National Forest given their wide distribution; general association with higher erosion rates; and the suggestion in the TES that soil erosion rates in many areas reflect historical grazing impacts, changes in fire regime, and past clearing efforts. Although juniper treatments continue on the Prescott National Forest, research demonstrates that the effects of past widespread efforts frequently lasted only a few years (Clary and Jameson 1981; Baker 1999).

Chaparral areas constitute another area where prescribed fire and reseeding may be effective in restoring herbaceous cover (Baker 1999), but such treatment effects have appeared less persistent than those in pinyon-juniper (Huebner and others 1999). Substantial landscape variation warrants against making generalizations about the potential to improve watershed condition across these communities. Instead, site-specific efforts need to be planned, monitored, and evaluated across the landscape through an adaptive management framework.

Summary and Conclusions

When examined at a coarse scale of analysis, the TES can suggest which sub-watersheds may be contributing unusually high amounts of fine sediment; such information, in turn, can direct field monitoring to validate whether tributaries are inducing sedimentation of the main river. A comparison of current sediment yields relative to natural yields (fig. 4.3) suggests that priority areas for reducing soil loss lie in the lower portions of the UVR watershed (Grindstone Wash/UVR hydrologic unit), the lower portion of Sycamore Creek watershed, and the Williamson Valley. Because the differences in soil losses that were calculated using the Universal Soil Loss Equation under current and hypothesized “natural” conditions are largely attributable to differences in ground cover, it is important to validate the relationships between ground cover and soil erosion for particular areas rather than relying on questionable assumptions.

In contrast to this analysis, the watershed assessment prepared by the Prescott National Forest suggested that the Tri-Canyon area (Hell Canyon HU) represented the greatest departure from potential watershed condition rating. The impaired rating for the Hell Canyon HU was apparently based on the high percentage of unsatisfactory/impaired soil condition ratings as well as the abundance of very coarse substrates in the tributary channels. Historic watershed degradation that induced a flashier watershed condition would account for the geomorphic condition of the channels and the widespread occurrence of “unsatisfactory” soil conditions. Past accounts of flash flooding in the UVR watershed and its tributaries extend to an early historic period (Barnett and Hawkins 2002). The potential to improve watershed conditions, particularly in steep, rocky, and relatively arid areas, is naturally quite limited. The paucity of precipitation and the presence of shallow, rocky soils are difficult to overcome no matter what future condition is desired.

The upland soil units of the UVR watershed have a range of watershed conditions that reflect the geology and semi-arid nature of the Prescott National Forest. There are units that have very skeletal and unproductive soils and that show evidence of significant erosion in the geologic past. However, linkages between these erosion processes, land management, and channel geomorphology are tenuous at best. This topic is discussed further in Chapter 5.