An Assessment of Watershed Condition and Possible Effects of Fire on Watersheds of Southeastern Arizona

Robert E. Lefevre[1]

The Peloncillo and Chiricahua Mountains are in Southeastern Arizona. The Peloncillo Mountains also are partially located in New Mexico. They range in elevation from about 4,500 feet to over 9,000 feet for the Chiricahuas and to 7,000 feet for the Peloncillos. Six major watersheds delineated by the U.S. Geologic Survey and identified by hydrologic unit codes (HUCs; see Table 1) are represented in these mountains: Willcox Playa, Whitewater Draw, Animas Creek, San Simon Creek, San Bernardino Valley, and Cloverdale Creek. These watersheds are large, with only small portions found within the mountain ranges considered in this assessment (Table 1).

Fire has been all but eliminated from these mountain ranges until very recently. Land managers are seeking to reintroduce fire to the ecosystems found in these ranges. This paper assesses the probable effects of reintroducing fire.

Riparian Areas

Riparian areas in both mountain ranges generally contain a large number of tree species; often less than half of these are riparian obligates. Young and mature age classes of riparian species are generally well represented, but old and decadent trees are frequently absent, probably because of their historical removal for mining or military operations.

It can be expected that more water, more sediment, and more nutrients will flow from a burned area after a fire (Baker 1988). The extents of these increases are discussed elsewhere in this paper, but are mentioned here because riparian areas will be the recipients. Even in cases where the increases are within prescribed standards, unsatisfactory riparian areas can be damaged by large quantities of water or sediment (DeBano and Schmidt 1989). DeBano and Schmidt (1989) also indicate that healthy riparian areas are able to thrive despite variations in water and sediment. Nutrients are regulated in riparian areas as well (Rhodes et al. 1985; Corbett and Lynch 1985; Kibby 1978). It is important to maintain satisfactory riparian area elements and to improve unsatisfactory riparian areas in order for reintroduction of fire in the system to be a positive influence on riparian resources.

Upland Watershed Condition

These watersheds have been analyzed separately to determine watershed condition. Watershed condition is assessed by comparing ground cover conditions observed in the field with ground cover conditions calculated to sustain favorable conditions of flow and soil productivity. Those calculated conditions are developed using Forest Service Southwestern Region Hydrology Note 14 (Solomon et al. 1981). Existing ground cover is compared to potential ground cover and tolerance ground cover to develop an index. The tolerance level is the level at which active gully formation and expanded channel density commence. The potential and tolerance levels vary among units, depending upon vegetation.

Table 1. Watershed acreage and HUC codes.

Watershed	Total Area (acres)	Total Area in Chiricahua and Peloncillo Mtns.
Willcox Playa (HUC 1505020149)	1,000,000	178,000
Whitewater Draw (HUC 1508030101)	900,000	68,000
Animas Creek (HUC 1504000331)	783,000	21,000
San Simon Creek (HUC 1504000644)	1,400,000	184,000
San Bernardino Valley (HUC 1508030202)	900,000	21,000
Cloverdale Creek (HUC1508030303)	80,000	18,000

[1]Coronado National Forest, Tucson, Arizona

Watershed condition assessments are summarized in Table 2. Acreage was derived from the Coronado National Forest GIS database, which is still being developed. A rating of zero or greater represents satisfactory conditions, and a rating of less than zero represents unsatisfactory conditions. Table 2 shows watershed-by-watershed indices for each vegetative type. The capability areas are described as follows (Coronado Land Management Plan, 1986):

Desert Scrub (vegetation type 1) lands are found at elevations of about 2,100 to 4,900 feet. Mean annual air temperature ranges from about 62E to 72E F. Mean annual precipitation ranges from about 8 to 11 inches. The dominant native vegetation is sahuaro (*Cereus giganteus*), palo verde (*Cercidium* spp.), creosotebush (*Larrea tridentata*), ocotillo (*Fouquieria splendens*), mesquite (*Prosopis juliflora*), catclaw (*Mimosa bifuncifera*), and brittle bush (*Encelia* spp.).

Desert Grasslands (vegetation type 2) are found at elevations of about 3,500 to 5,500 feet. Mean annual air temperature ranges from about 59E to 70E F. Mean annual precipitation ranges from about 11 to 14 inches. The dominant native vegetation are grasses including, but not necessarily limited to, bush muhly (*Muhlenbergia porteri*), Texas bluestem (*Andropogon cirratus*), tobosa (*Hilaria mutica*), curlymesquite (*Hilaria belangeri*), black grama (*Bouteloua eripoda*), sideoats grama (*Bouteloua curtipendula*), and hairy grama (*Bouleloua hirsuta*). Incidental to major overstory amounts of mesquite also occur. The exotic Lehmans lovegrass (*Erigrostis lehmanniana*) also is common.

Mountain Grasslands (vegetation type 4) are found at elevations above 7,500 feet. Mean annual air temperature ranges from 45E to 50E F. Mean annual precipitation ranges from about 24 to 30 inches. The dominant native vegetation is wheatgrass species (*Agropyron* spp.), long tongue muhly (*Muhlenbergia longiligula*), deergrass (*Muhlenbergia rigens*), bullgrass (*Muhlenbergia emersleyi*), pine dropseed (*Blepharoneuron tricholepis*), Junegrass (*Koeleria cristata*), and sedge species (*Carex* spp.).

Chaparral (vegetation type 5) are found at elevations of about 4,800 to 5,500 feet. Mean annual air temperature ranges from about 52E to 58E F. Mean annual precipitation ranges from about 16 to 21 inches. The dominant native vegetation is mountain mahogany (*Cercocarpus* spp.), desert ceanothus (*Ceanothus greggii*), manzanita (*Arctostaphylos* spp.), toumey oak (*Quercus toumeyi*), emory oak (*Quercus emoryi*), silver leaf oak (*Quercus hypoleucoides*), Arizona white oak (*Quercus grisea*), and a scattering of Chihuahua pine (*Pinus leiophylla*), pinyon pine (*Pinus cembroides*), and ponderosa pine (*Pinus ponderosa*). Turbinella oak (*Quercus turbinella*) may also be present.

Broadleaf Evergreen Woodlands (vegetation type 6) are found at elevations of about 4,800 to 5,400 feet. Mean annual air temperature ranges from about 52E to 58E F. Mean annual precipitation ranges from about 16 to 19 inches. The dominant native vegetation is emory oak (*Quercus emoryi*), Arizona white oak (*Quercus grisea*), alligator juniper (*Juniperus deppeana*), manzanita (*Arctostaphylos* spp.), and *Juniperus Erythrocarpa*.

Coniferous Woodlands (vegetation type 7) are found at elevations of about 5,000 to 6,000 feet. Mean annual air temperature ranges from about 50E to 58E F. Mean annual precipitation ranges from about 17 to 22 inches. The dominant native vegetation is pinyon pine (*Pinus cembroides*), emory oak (*Quercus emoryi*), Arizona white oak (*Quercus grisea*), alligator juniper (*Juniperus deppeana*), and Chihuahua pine (*Pinus leiophylla*).

Coniferous Forests (transition) (vegetation type 9A-) are found at elevations of about 6,500 to 7,700 feet. Mean annual air temperature ranges from about 49E to 55E F. Mean annual precipitation ranges from about 20 to 26 inches. The dominant native vegetation is a mix of manzanita (*Arctostaphylos* spp.), Arizona white oak (*Quercus grisea*), silver leaf oak (*Quercus hypoleucoides*), alligator juniper (*Juniperus deppeana*), pinyon pine (*Pinus cembroides*), Chihuahua pine (*Pinus leiophylla*), and ponderosa pine (*Pinus ponderosa*).

Coniferous Forests (mixed conifer) (vegetation type 9BC) are found at elevations of about 6,800 to 9,000 feet. Mean annual air temperature ranges from about 45E to 52E F. Mean annual precipitation ranges from about 22 to 26 inches. The dominant native vegetation is ponderosa pine (*Pinus ponderosa*), alligator juniper (*Juniperus deppeana*), gambel oak (*Quercus gambelii*), and Douglas-fir (*Pseudotsuga menziesii*).

Coniferous Forests (spruce-fir) (vegetation type 9D) are found at elevations of about 8,000 to 9,800 feet. Mean annual air temperature ranges from about 38E to 44E F. Mean annual precipitation ranges from about 30 to 35 inches. The dominant native vegetation is white fir (*Abies concolor*), Douglas-fir (*Pseudotsuga menziesii*), scattered aspen (*Populus tremuloides*), and in a few areas, high densities of Engelman spruce (*Picea englemannii*) and corkbark fir (*Abies lasiocarpa* var. *arizonica*).

Table 2. Watershed Condition by Vegetation Type

Watershed	Vegetation Type	Watershed Condition Index	Area (acres)
Animas Creek	2	–0.18	7958
HUC 1504000331	5	0.00	246
	6	0.78	10980
	7	0.70	7549
			26733
Total Area			
WCI		0.46	
San Simon Creek	2	–0.20	31438
HUC 1504000644	4	0.00	228
	5	0.69	12171
	6	0.12	65756
	7	0.22	38568
	9A	0.73	4550
	9BC	1.00	8290
	9D	0.94	856
Total Area			161857
WCI		0.19	
Willcox Playa	2	1.00	1293
HUC 1505020149	5	1.00	790
	6	1.00	32282
	7	–0.40	1915
	9A	0.59	8918
	9BC	0.50	6004
	9D	0.94	216
WCI		0.82	
Whitewater Draw	1	–2.00	74
HUC 1508030101	2	–0.82	14270
	5	–0.57	11355
	6	–0.89	26549
	7	–0.10	12130
	9A	1.00	5247
Total Area			69625
WCI		–0.54	
San Bernardino Valley	1	–2.00	808
HUC 1508030202	2	–0.51	11784
	5	0.29	1733
	6	0.11	5817
	7	0.63	10072
Total Area			30214
WCI		–0.01	
Cloverdale Creek	2	–0.27	6798
HUC 1508030303	5	–1.00	926
	6	0.67	8029
	7	0.70	2116
Total Area			17869
WCI		0.23	

WCI = Watershed Condition Index (weighted average).

I determined that watershed condition in the desert scrub and desert grasslands vegetation types (1 and 2) is generally unsatisfactory. My observations are that spaces between shrubs are generally bare ground or populated with annual grasses or perennial half-shrubs. It is my experience that the way to improve watershed condition in this vegetation type is to improve the perennial grass component of the community. It has been demonstrated that fire will cause a shift toward more perennial grass plants, but the shift is not necessarily permanent if poor management of cattle exists (Cable 1967, 1972; Bock and Bock 1988; Ffolliott 1988).

Mountain grasslands were determined to be satisfactory. However, they occupy a very small portion of these mountain ranges, and I do not recommend basing fire management decisions for the entire ranges on the effects they might have on watershed condition in mountain grasslands.

Chaparral is determined to be satisfactory in some areas and unsatisfactory in others. Maintaining chaparral in satisfactory condition cannot be accomplished with fire alone (Bock and Bock 1988). Other changes in management that will allow grasses or other herbaceous vegetation to grow between shrubs would have to be made (Bock and Bock 1988; DeBano 1988; Ffolliott 1988). Note that chaparral makes up a small portion of the vegetation communities in these ranges, and I do not recommend basing fire management decisions for the entire ranges on the effects they might have on long-term watershed condition in chaparral. However, chaparral can be an important source of erosion and sediment because it typically occurs on steep unstable topography (Baker 1988) and for this reason, the extent of chaparral present should be considered on a project-by-project basis.

As in chaparral, coniferous woodlands (pinyon-juniper) are determined to be satisfactory in some areas and unsatisfactory in others. Improving herbaceous vegetation will improve watershed condition. Fire is used to "reduce tree density and increase understory biomass" (Pieper and Wittie 1988). This seems to be more effective and longer lasting as a method for improving ground vegetation in pinyon-juniper communities than in chaparral (Pieper and Wittie 1988; Ffolliott 1988).

Broadleaf woodlands were found to be in satisfactory watershed condition. McPherson (1992) indicates that fire has been present in this vegetation type but has left no visible evidence. Based on that paper and my own observations, periodic fire (10 to 20 year intervals according to McPherson) will not adversely affect watershed condition in broadleaf woodlands.

The transition coniferous forest is found to be satisfactory except in some areas that have recently burned. In many areas, this vegetation type contains very dense vegetation including many small trees. The effect of dense stands of trees is that it puts this vegetation type at high risk to become nonfunctional as far as some hydrologic processes are concerned, including unnaturally high rates of runoff and soil erosion and unnaturally low water-infiltration rates on the soil surface. Rucker Canyon watershed, a sub-watershed of Whitewater Draw, was burned in 1994. In about one-third of that watershed, a dense stand of trees with abundant litter, but poor representation by plants, on the forest floor experienced a crown fire in which all the trees were killed and all the litter was consumed. With little seed source present, the ground has remained uncovered for the first 3 years following the fire. Rain and melting snow runs off quickly, resulting in soil movement from the site to the channel system. The high runoff, in turn, has sufficient energy to move soil and gravel quickly through the system, transporting material stored in the channel out and rapidly filling behind with new material. The main channel of Rucker Creek is full of sediment, and there is still little vegetation on the slopes. The pines of southeastern Arizona are adapted to low-intensity fire, and it is believed that periodic low-intensity fire is necessary to maintain this vegetation type in a healthy state (Zwolinski 1996). Zwolinski cautions land managers that reintroducing fire into this vegetation type must be done in increments to ensure that the tolerance for fire is not exceeded in any one event (killing all the trees and burning all the litter). Light fires will suppress shrubs that encroach on this vegetation type from lower elevations and white fir and Douglas-fir that encroach from higher elevations (Zwolinski 1996).

Mixed conifer and spruce-fir forest areas are found to be in satisfactory watershed condition. As in the transition conifer forest, much of this vegetation type contains dense stands of young trees. Burning in these areas can drastically impair watershed condition if the fire is too intense (Zwolinski 1996). Zwolinski indicates that some species here are quite fire resistant when mature (Douglas-fir and white fir), whereas others are sensitive to fire regardless of their size (Engelmann spruce and southwestern white pine). Aspen is generally top-killed quite easily by fire but will only regenerate in disturbance situations such as fire. The effect on watershed condition following a fire in mixed conifer forests is highly variable depending upon the severity of the fire; low-intensity fires produce no significant effects whereas high-intensity fires can result in temporary unsatisfactory conditions and produce negative effects on water quality and quantity (Zwolinski 1996).

Water Quality

Water quality is assessed by comparing existing conditions with desired conditions that are set by the states under the authority of the Clean Water Act. No Water Quality Limited Waters are identified in either the Chiricahua or Peloncillo Mountains (Arizona Water Quality Assessment, 1996 and New Mexico Environment Department 305(B) Report (1995). A water quality limited water "does not maintain surface water quality standards for its designated uses, and neither existing technology nor permit controls are sufficient to maintain water quality standards" (Arizona Water Quality Assessment 1996). The absence of water quality limited water designations infers that water quality is acceptable for designated uses in the Peloncillos and Chiricahuas. I make this inference with the knowledge that in spite of the fact that few water samples have been analyzed from streams originating in the Peloncillos, few of the "probable sources" of pollution cited for these watersheds are found in either the Peloncillos or the Chiricahuas. Those "probable sources," as listed in the Arizona Water Quality Assessment (1996) and the New Mexico Environment Department 305(B) Report (1995), are agriculture (including ranching and farming), silviculture, resource extraction (mining), land disposal, hydromodification (loss of riparian habitat), natural, and rangeland practices.

I have found no indication that silviculture, farming, mining, and land disposal activities take place in these ranges to a measurable degree. Maintaining satisfactory riparian and upland conditions and improving unsatisfactory riparian areas and uplands will reduce the threat of impaired water quality. In addition, satisfactory riparian conditions over most of the area provide some filtration and serve to produce high-quality water even from areas where rangeland practices are conducted.

Burning in a watershed can alter water quality by releasing sediment into the system as a result of increased soil erosion and by releasing nutrients into the system by making them more mobile through the process of burning (Baker 1988; DeBano et al. 1996). The likelihood of increased sediment and resulting increased turbidity appears to be the greatest threat to water quality following wildfire (Baker 1988).

Baker indicates that most evidence suggests that even after wildfires, sediment yields drop to near preburn levels within 3 to 5 years. Water quality will depend on the extent of area burned and location with respect to the channel. Managing toward potential conditions for upland and riparian areas will minimize short-term effects and have a favorable effect on overall water quality.

Water Quantity

My experience is that flows increase following fires. The importance of these expected increases to the overall hydrology of the Peloncillos and Chiricahuas can be understood better by reviewing some water yield studies. Ffolliott and Thorud (1975) report estimates of water yield increases for major vegetation types throughout Arizona. Of the vegetation types found in these ranges, chaparral, transition coniferous forest, mixed conifer, and spruce-fir are found to be important when considering water yield increases. These vegetation types are limited in extent on these ranges, making up only 2 percent of the Peloncillos and 20 percent of the Chiricahuas. Locally, however, these vegetation types may provide measurable changes in water yield if burned. Ffolliott and Thorud report that where about one-third of the overstory is removed from transition coniferous forest, water yield increases by about one-third. In this area, where water yield is currently about 2 inches per year in this vegetation type, such a reduction in the transition coniferous forest type could produce about 0.6 additional inches of water. Reducing the overstory by more than one-third will produce slightly more water. The mixed conifer forest type has similar water yield increases to the transition coniferous forest when up to one-third of the canopy is removed. As more canopy is removed beyond the one-third point, water yield increases at a more rapid rate in mixed conifer forests. Maintaining the reduced stand density is mandatory for maintaining that increase. The reduced stand density in a healthy forest can increase base flows because of reduced evapotranspiration through these vegetation types. It is important to note that severe burning will produce the same increase, but the resulting unsatisfactory watershed conditions will cause more of the increase to be in the form of overland flow rather than subsurface flow (DeBano and Neary 1996; DeBano et al. 1996; Rinne and Neary 1996). This is what causes the floods and high sediment loads after severe wildfires. Baker (1988) states that due to natural variations in moisture conditions, prescribed burns result in a mosaic pattern and consequently do not significantly affect (either spatially or temporally) the flow regime of a watershed. Wildfire, on the other hand, often consumes all the organic matter on the soil surface of a more extensive area, producing an important, immediate rffect on flow, and in some cases, for several years following a fire (Baker 1988).

Summary and Conclusions

Existing watershed conditions, including riparian areas, uplands, and water quality, are generally satisfactory in the Peloncillo and Chiricahua Mountains, with the exceptions of desert scrub and desert grasslands, and isolated areas of woodlands and chaparral. The absence of fire from many of the vegetation types represented in these ranges, however, has created a situation where these conditions are not sustainable due to risk of severe wildfire. Numerous studies cited in the literature, and observations following fires, indicate that if fire is reintroduced under uncontrolled conditions, water conditions will be degraded. The result of degraded watershed conditions can include high rates of erosion and losses of site productivity. Reintroduction of fire into these mountain ranges under controlled conditions, in order to maintain or improve watershed conditions, is recommended.

References Cited

Arizona Department of Environmental Quality. 1996. Water Quality Assessment.

Baker, Malchus B., Jr. 1990. Hydrologic and water quality effects of fire. Pages 31–42 in J. S. Krammes, technical coordinator. Effects of fire management of southwestern natural resources. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station General Technical Report RM-191. Fort Collins, CO.

Bock, Carl E. and Jane H. Bock. 1990. Effects of fire on wildlife in southwestern lowland habitats. Pages 50–64 in J. S. Krammes, technical coordinator. Effects of fire management of southwestern natural resources. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station General Technical Report RM-191. Fort Collins, CO.

Cable, Dwight R. 1967. Fire effects on semidesert grasses and shrubs. Journal of Range Management 20 (3): 170–176.

Cable, Dwight R. 1972. Fire effects in southwestern semidesert grass-shrub communities. Pages 109–127 in Proceedings Annual Tall Timbers Fire Ecology Conference.

Corbett, Edward S. and James A. Lynch. 1985. Management of streamside zones of municipal watersheds. Pages 187–190 in R. R. Johnson et al. (Technical Coordinators). Riparian ecosystems and their management: Reconciling conflicting uses. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station General Technical Report RM-120. Fort Collins, CO.

DeBano, Leonard F. 1990. Effects of fire on the soil resource in Arizona chaparral. Pages 65–77 in J. S. Krammes, technical coordinator. Effects of fire management of southwestern natural resources. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station General Technical Report RM-191. Fort Collins, CO.

DeBano, Leonard F., Peter F. Ffolliott, and Malchus B. Baker, Jr. 1996. Fire severity effects on water resources. Pages 77–84 in P. F. Ffolliott et al., technical coordinators. Effects of fire on Madrean Province ecosystems. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station General Technical Report RM-GTR-289. Fort Collins, CO.

DeBano, Leonard F. and Daniel G. Neary. 1996. Effects of fire on riparian systems. Pages 69–76 in P. F. Ffolliott et al., technical coordinators. Effects of fire on Madrean Province ecosystems. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station General Technical Report RM-GTR-289. Fort Collins, CO.

DeBano, Leonard F. and Larry J. Schmidt. 1989. Improving southwestern riparian areas through watershed management. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station General Technical Report RM-182.

Ffolliott, Peter F. 1990. Opportunities for fire management in the future. Pages 152–167 in J. S. Krammes, technical coordinator. Effects of fire management of southwestern natural resources. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station General Technical Report RM-191. Fort Collins, CO.

Ffolliott, Peter F. and David B. Thorud. 1975. Water yield improvement by vegetation management: Focus on Arizona. University of Arizona, Department of Watershed Management.

Kibby, Harold V. 1978. Effects of wetlands on water quality. Pages 289–298 in R. R. Johnson and J. F. McCormick, technical coordinators. Strategies for protection and management of floodplain wetlands and other riparian ecosystems. USDA Forest Service General Technical Report WO-12. Washington, D.C.

McPherson, Guy R. 1992. Ecology of oak woodlands in Arizona. Pages 24–33 in P. F. Ffolliott et al., technical coordinators. Ecology and management of oak and associated woodlands: Perspectives in the southwestern United States and northern Mexico. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station General Technical Report RM-218. Fort Collins, CO.

New Mexico Environment Department. 1994. New Mexico 305(B) Report.

Pieper, Rex D. and Roger D. Wittie. 1990. Fire effects in southwestern chaparral and pinyon-juniper vegetation. Pages 87–93 in J. S. Krammes (Technical Coordinator). Effects of fire management of southwestern natural resources. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station General Technical Report RM-191. Fort Collins, CO.

Rhodes, Jonathan, C. M. Skau, Daniel Greenlee, and David L. Brown. 1985. Quantification of nitrate uptake by riparian forests and wetlands in an undisturbed headwaters watershed. Pages 175–179 in R. R. Johnson et al., technical coordinators. Riparian ecosystems and their management: Reconciling conflicting uses. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station General Technical Report RM-120. Fort Collins, CO.

Rinne, John N. and Daniel G. Neary. 1996. Fire effects on aquatic habitats and biota in Madrean-type ecosystems: Southwestern United States. Pages 135–145 in P. F. Ffolliott et al., technical coordinators. Effects of fire on Madrean Province ecosystems. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station General Technical Report RM-GTR-289. Fort Collins, CO.

Solomon, Rhey, Jim Maxwell, Doug Shaw, and Larry Schmidt. 1981. Hydrology Note 14: Watershed condition hydrology overview. USDA Forest Service, Southwestern Region.

USDI Geologic Survey Topographic Map, Douglas: Arizona Quadrangle (1 x 2 degree series). 1959.

USDA Forest Service. 1986. Coronado land management plan (as amended).

Zwolinski, Malcolm J. 1996. Effects of fire on montane forest ecosystems. Pages 55–63 in P. F. Ffolliott et al., technical coordinators. Effects of fire on Madrean Province ecosystems. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station General Technical Report RM-GTR-289. Fort Collins, CO.