CANYON CREEK RIPARIAN RESTORATION PROJECT: REACH 4-5 FINAL REPORT 2005-2007

Dana D. Warnecke, Region VI Habitat Specialist
Canyon Creek Project Leader

Region VI, Field Operations Division
Habitat Branch, Wildlife Management Division
Arizona Game and Fish Department

Habitat Program
Program Chief: Josh Avey
Arizona Game and Fish Department
5000 W. Carefree Highway
Phoenix, Arizona 85086-5000

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Current address: [1]7200 E. University Ave., Mesa, Arizona, 85207

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EXECUTIVE SUMMARY

The Arizona Game and Fish Department (Department) was awarded a grant to conduct a riparian restoration project on Canyon Creek by the Arizona Water Protection Fund (AWPF) fall of 2005. The purpose of the project was to protect an approximate ½ mile of stream reach along Canyon Creek from the impacts of browsing and grazing by elk and livestock. The Canyon Creek watershed was severely impacted by the Rodeo-Chediski wildfire in 2002, and riparian vegetation along the stream corridor was burned. Fire induced disturbances of flooding and sedimentation created conditions that stimulated riparian plant recruitment. However browsing by elk was limiting the growth and recruitment of highly palatable riparian woody species. The Department collaborated with the Tonto National Forest (Forest) to construct the elk-livestock exclosure along a stream reach that showed high potential for riparian plant regeneration and recruitment. The project area had been previously excluded from livestock grazing as part of an allotment management plan.

This report summarizes 3 years of monitoring vegetation trend and channel morphology using comparative analyses. The monitoring was designed to quantify any beneficial effects the elk-livestock exclosure may have had on riparian habitat quality and stream channel morphology. After 2 full growing seasons, we have not yet detected vegetation trends within the 300 foot monitoring reaches that merit statistical analyses. However, across the entire exclosure we have qualitatively documented (photopoints) that riparian woody species recruitment is much higher inside the exclosure versus outside. We see that that both density (# of individuals) and size are increasing.

Within our monitoring reaches we measured very high plant diversity and species richness was higher than predicted (139%). Overall we recorded 115 species, 86 genera and 32 families in our Daubenmire plots on the floodplain and greenline features. We found that species diversity was similar inside and outside the exclosure on the fluvial features. Overall, species composition was predominantly native graminoid and forb species; with more riparian obligate or facultative wetland species along the greenline and more upland species on the floodplain. We documented few riparian tree and shrub species on both fluvial features, and detected no differences in canopy cover or composition inside versus outside the exclosure. Narrowleaf cottonwood, red willow, and Goodding willow typically provided <1% of the total canopy cover each. False indigo was the most dominant facultative wetland shrub, averaging 4% of the canopy cover within the floodplain.

By fall of 2007, total canopy cover had increased on the greenline feature from the 2005 baseline; but inside the exclosure increases were cumulative between years (51%, 69%, 98%) and outside they were variable (64%, 90%, 79%). Total canopy cover increases on the floodplain were also cumulative (67%, 72%, 85%) inside the exclosure and more variable (78%, 43%, 78%) outside the exclosure. Watercress dominated the greenline, moreso inside the exclosure (78% of the composition in 2007 inside versus 49% outside), and contributed greatly to the narrowing of the non-vegetated stream width (greenline-to-greenline width) and the increase in canopy cover on the greenline between 2005 and 2007.

Ground cover compositions within the floodplain were fairly constant between years, however the percentage of live basal vegetation was highest in 2007 inside the exclosure, and there was more silt inside the exclosure all 3 years. There were no measurable changes in the channel morphology and substrate compositions were dominated by cobble. There was some speculation that inside the exclosure; slightly greater increases in percent live basal vegetation ground cover and silt/clays on

the floodplain, combined with more total canopy cover on the floodplain and greenline, and a narrowing non-vegetated channel width inside the exclosure suggested a positive vegetative response to the exclosure. However, we conclude that subtle changes we measured after only 2 full growing seasons are more likely a reflection of the natural variability of a baseline condition, than any effects the riparian exclosure treatment may have had on riparian vegetation cover and composition.

The Department and Forest will continue to monitor and data will contribute to the decision making process of how long to keep the elk-livestock exclosure in place. This report fulfills the contractual obligations of the Department (grantee) to the AWPF, contract # 05-128WPF - task # 7.

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CANYON CREEK RIPARIAN RESTORATION PROJECT: REACH 4-5

Dana Warnecke, Kristen McBride, Grant Loomis, Janet Grove, Elizabeth Makings,
Debbie Cress and Curtis Gill

INTRODUCTION

Over the years, there has been considerable interest in angling and recreational opportunities at Canyon Creek on the Tonto National Forest (Forest). Canyon Creek was isolated and public use was low until the late 1970's, when the Forest Service improved access and camping facilities. In 1962 the Arizona Game and Fish Department (Department) wanted public access to the upper half of the creek at the OW Ranch. The land along the lower half of the creek was owned at that time by a group of sportsmen. They agreed that if a fly-fishing only regulation were enacted for a portion of the stream, they would allow public access. As a result, in 1963 a "fly-fishing only" restriction was passed by the AGFD Commission and public access was allowed. Since then, the Forest Service has acquired most of the private land, redesignating it National Forest. In 1970, the Department built the Canyon Creek Fish Hatchery at the headwaters of Canyon Creek. The hatchery relies on three springs for water and hydroelectric power and produces thousands of catchable rainbow trout annually.

The Canyon Creek watershed has a rich history of human habitation and over time has been highly valued for water, wildlife, fisheries, timber, livestock, recreation, and aesthetics. In 1993, the upper 5.4 miles of the stream were proposed eligible for inclusion in the Nation's Wild and Scenic River System and classified as Recreational Wild & Scenic. Canyon Creek was found to have outstandingly remarkable wildlife and ecological values. The eligible reach begins at Canyon Creek Springs where perennial flow in the creek begins and flows generally south and east for 5.4 miles through the Tonto National Forest until it enters the Fort Apache Indian Reservation. However, Canyon Creek has not been officially designated for it's inclusion into the National Wild & Scenic River System by Congress. Today, the Arizona Game and Fish Department promotes the area for fishing, hunting and watchable wildlife.

Over the years various activities have impacted Canyon Creek channel stability and suitability for self-sustaining populations of trout and native fish. Past logging, recreation, livestock management, agriculture and natural events such as floods had compounding effects to the watershed, stream channel and riparian vegetation associated with the channel. In 1986, the "*Canyon Creek Aquatic Habitat Improvement Project Operational Plan*" (Morgensen 1986) was developed by the Department, Tonto National Forest (TNF) and interested angling clubs, including Trout Unlimited (TU) and Anglers United (AU). The plan identified impacts and proposed solutions to minimize or alleviate them where possible. Between 1986 and 1989 an ambitious riparian management strategy was initiated which included building livestock exclosures along the creek, planting cottonwood and

willow trees, and constructing 65 in-stream fish habitat structures (log and boulder). Within two years brown trout reproduction responded and population densities increased three-fold.

As a result of access improvements and habitat improvement projects that improved the fishery, public recreation had increased over the years at Canyon Creek and the developed campsites. In 1970 there were 14,000 Recreation Visitor Days (RVD's) reported. By 1985 that had jumped to 66,500 and the Forest Service expected it to double again by the year 2025. This dramatic increase in public use included fishing activities as well. In 1981, 6,600 Angler Use Days (AUD) were spent on Canyon Creek and the average catch was 1.5 trout per angler per day. From the Department's extrapolation of 2001 fishing license sales, it was estimated that over 22,500 AUD's were spent at Canyon Creek in 2001. Total angler expenditures were estimated to be over $1,574,100 that year (calculated at $69.96/AUD). This valuable sportfishery to Arizona anglers has contributed significantly to the state and local economy of the area.

In late June of 2002 the Rodeo-Chediski Fire burned through the Canyon Creek watershed. The severity of the fire varied across the watershed, however it was severe in the upper watershed (Photo 1), including two major tributaries known as Mule Creek and Valentine Canyon. Immediately after the fire, summer monsoon season began. Due to the loss of canopy cover in the watershed the magnitude of the flooding was severe; higher water yields led to debris flows and excessive sedimentation into the stream channel. The stream structure and biotic functions were severely impacted. Sportfish and native fish populations suffered severe losses, estimated at 90% (Warnecke 2002). The loss of canopy cover and stream bank vegetation increased water temperatures and contributed to channel instability.

Photo 1. July 2002 photograph of upper Canyon Creek watershed immediately after Rodeo-Chediski fire.

Impacts to the upper watersheds of Canyon,Valentine and Mule Creeks resulted in nearly complete

loss of the Ponderosa Pine overstory. These impacts were the most severe, and have influenced the frequency and magnitude of flooding in Canyon Creek ever since. Fire impacts along downstream reaches of these creeks were less severe and vegetation along meadows and stream banks quickly resprouted. The Burned Area Emergency Rehab (BAER) Team for the Rodeo-Chediski Fire (U.S.D.A Forest Service, 2002) reported two positive effects that may have future implications to the success of this project.

1. The fire burned into meadows and riparian areas where ponderosa pine and juniper were encroaching. Restoration of the herbaceous component will prevent or slow the reestablishment of these species.
2. Long-term increase of watershed health via the reduction of high density timber stands that existed within the watershed and the subsequent release of water that these dense stands held.

However, post-fire vegetative monitoring indicated that resident and migratory elk were foraging on highly preferred riparian browse species and limiting the post-fire recolonization of these important species (TNF monitoring report, Fall 2003). Livestock grazing had been deferred from the watershed for a few years post-fire, and today is managed to protect the riparian corridor through a series of exclosures. Today, the primary limitations on the natural recolonization of riparian vegetation are a result of periodic flood events magnified by the post-fire watershed condition, and seasonal browsing by resident and migratory elk. In the future, salvage logging on adjacent Reservation and Forest lands may also contribute watershed scale impacts to Canyon Creek.

Recreational use has been limited since the 2002 fire. Until 2005, Forest Service closures were in place because of hazardous watershed conditions and for post-fire salvage logging activities. However in 2005, Canyon Creek access was opened to the public once again. Camping, fishing, hunting and other outdoor recreational values and activities have returned to the watershed. The vegetative cover in the portions of the burned watershed have increased dramatically and ecological processes are at work restoring ecosystem functions and values.

In 2004, the Department collaborated with the Tonto National Forest (Forest) to fund and implement the Canyon Creek Riparian Restoration Project. The project is the first step in a series of management strategies to enhance the post-fire recolonization of riparian vegetation, improve the quality of stream and riparian habitat for fish and wildlife, and restore a valuable sportfishery to the creek. In 2005, the Arizona Water Protection Fund Commission funded the construction of an elk-livestock exclosure for a half mile reach of Canyon Creek to protect riparian vegetation from browsing by elk and livestock. This final report details the work completed during the 3 year contract period to accomplish project goals and fullfill the terms and conditions of the grant. Monitoring results are presented along with a discussion on key findings.

GOALS AND OBJECTIVES

The goal of the Canyon Creek Restoration Project is to protect an approximate one-half mile reach of Canyon Creek from all grazing pressure to accelerate the post-fire (Rodeo-Chediski Fire) recovery and overall improvement of riparian vegetation cover and density, stream channel stability and water quality in support of the ultimate goal of restoring native fish populations and a self sustaining brown trout fishery.

The "desired future condition" is a riparian zone that has a resilient and densely vegetated/multi-canopied floodplain and greenline, with stable stream banks and overhanging cover, a narrowing channel, reduced suspended sediments and reduced stream channel embeddedness. With improvements in riparian and stream habitat quality (species diversity and structure) it is also reasonable to expect indirect benefits to common and special status wildlife species known to occur in the project area, such as native fish or Mexican spotted owls.

The project objectives focus on vegetative and stream channel response to deferment of all grazing ungulates (elk and livestock). There are three project objectives:

1. Increase vigor and regeneration of tree and shrub species identified within the project area including but not limited to: red willow, narrow-leaf cottonwood, Arizona alder, Goodding willow, false indigo, box elder, and arroyo willow.
2. Increase density of herbaceous species in the emergent zone and floodplain including but not limited to: rushes, cattails, sedges, horsetails, spike rushes, deergrass and introduced pasture grasses.
3. Improve the stream channel structure and function by: narrowing the channel, increasing the depth, improving the substrate composition for aquatic habitat, and widening the greenline.

STUDY AREA

PROJECT AREA

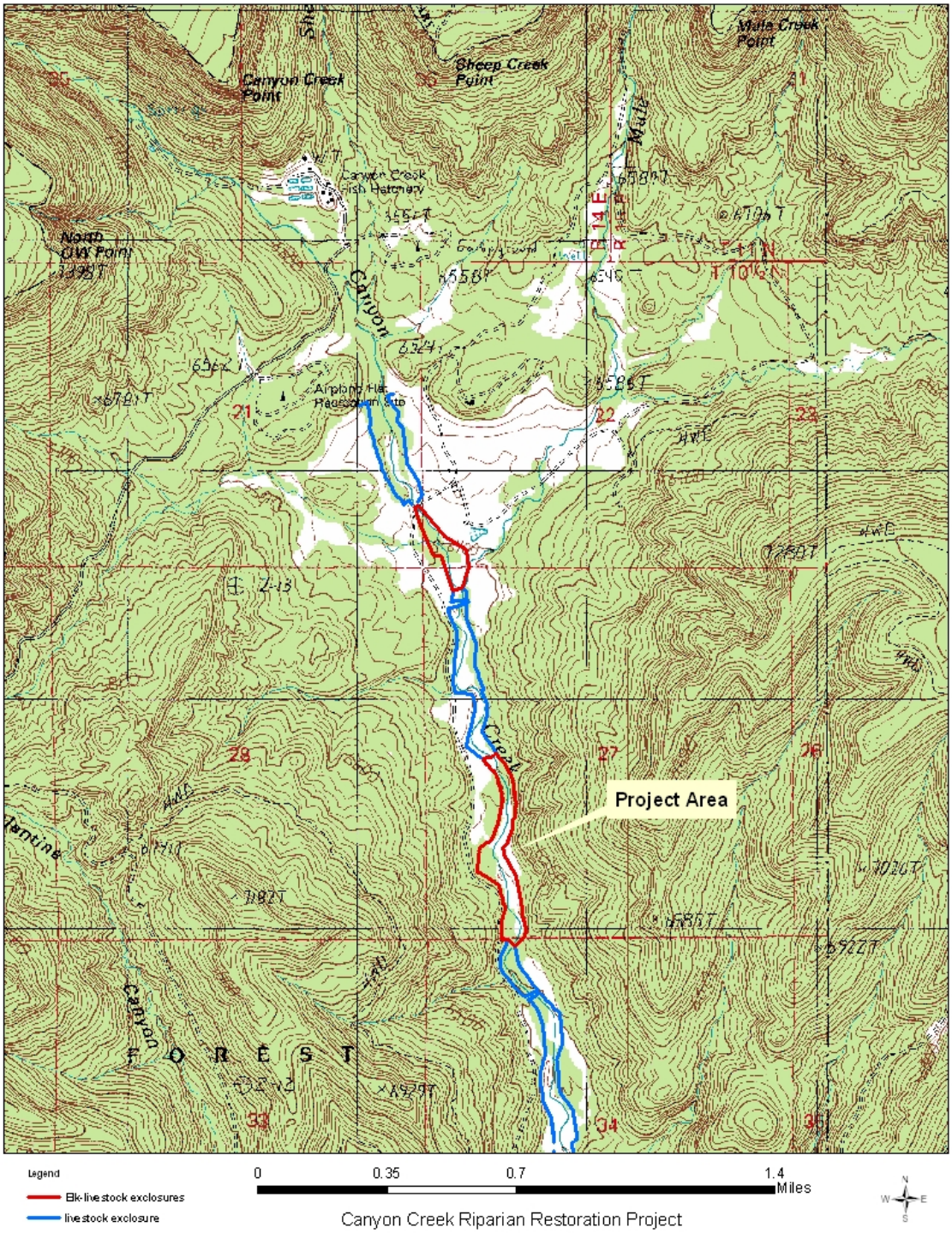
The Canyon Creek watershed is located about 16 miles northeast of the town of Young and 40 miles east of Payson; immediately below the Mogollon Rim in Gila County, Arizona. An approximate 25 sq. mile watershed contributes to perennial flow in upper Canyon Creek, where the project area is located. Elevation ranges from 6700 to 6200 feet. The entire Canyon Creek watershed is located within the Apache-Sitgreaves (A-S) and Tonto National Forests (TNF), except for a small portion on the eastern edge that is on the Fort Apache Indian Reservation. Private lands include Forest Lake Estates and 72 acres of private land that serves as the OW Ranch headquarters. Canyon Creek is a tributary of the Salt River. Perennial flow originates from several springs located in the streambed and from limestone sinks located immediately north and east on the Mogollon Plateau. Base flows downstream from the confluence with Mule Creek range between 3-6 cfs and are typical of flows within the project area (G. Loomis pers comm.). At this time, water and sediment load from the upper watershed can only be speculated on, as no studies are available to show the amount and type of input from this source. Mule

Creek is a tributary to Canyon Creek immediately upstream of the proposed project area. Flows in these high elevation streams are sustained by a bimodal precipitation pattern that delivers about 24 to 32 inches of mean annual precipitation. High flows are typically from summer monsoons and spring snowmelt. No stream gage is located on Canyon Creek, therefore discharges have been estimated using hydrology models (Natural Channel Design, Inc., 2002). Magnitude estimates for annual or biennial flood events are 166 and 404 (cfs) respectively. A 25-year event, such as the one experienced in 1993, may reach flows estimated at 5353 cfs. Although the entire Canyon Creek watershed was burned in the Rodeo-Chediski Fire, the watershed has recovered significantly and runoff patterns are believed to be at or near pre-fire condition (Grant Loomis, USFS, pers comm.) The exclosure encompasses approximately 17 acres of riparian habitat along a ½ mile reach of Canyon Creek, downstream of the OW Ranch (Map 1).

EXISTING CONDITIONS

Vegetation

The Canyon Creek watershed is dominated by a Ponderosa pine (*Pinus ponderosa*) forest interspersed with Gambel oak (*Quercus gambelli*), alligator bark juniper (*Juniperus deppeana*) and New Mexican locust (*Robinia neomexicana*). Rocky Mountain montane meadow grassland and riparian forest dominates the stream valley bottom downstream to the Forest boundary (Brown 1994). Ponderosa pine forest species are common along the riparian corridor. Riparian tree and shrub species (facultative and obligate wetland species) found along the stream course include: narrow-leafed cottonwood (*Populas angustifolia*), Goodding willow (*Salix gooddingii*), red willow (*Salix laevigata*), arroyo willow (*Salix lasiolepis*), Arizona alder (*Alnus oblongifolia*), false indigo (*Amorpha fruticosa*) and box-elder (*Acer negundo*). Native herbaceous graminoid and forb species that occur on the greenline and floodplain include: rushes (*Juncus* spp.), sedges (*Carex and Cyperus* spp.), horsetails (*Equisetum* spp..), spike rush (*Eleocharis*), watercress (*Nasturtium*), deergrass (*Muhlenbergia rigens*) and redtop (*Agrostis gigantea*) among others. Pasture grasses, including tall fescue (*Schedonorus phoenix*), orchard grass (*Dactylis glomeratus*), and love grasses (*Eragrostis* spp.), are also present and were probably introduced when the area was in private ownership. These species, particularly the more deeply rooted native rhizomatous and bunchgrass species, play a critical role in narrowing the stream channel by trapping sediments, and building undercut banks and floodplains. Currently, these species have moderately low cover on the greenline and portions of the floodplain, but the potential for them to increase is high.



Map 1. Project area and location of elk-livestock exclosure relative to other exclosures on Canyon Creek.

Water Quality

Canyon Creek was on Arizona's Water Quality Limited Waters List (303(d) list) between 1994 and 2002 for turbidity. In 2002 it was delisted by the Arizona Department of Environmental Quality (ADEQ) due to insufficient samples to support listing. Canyon Creek was on the planning list for 2007 watershed monitoring and assessment to develop a water quality management plan (TMDL), but that has not been completed to date. Suspended sediment concentrations continue to be a water quality concern for this creek, recently amplified by the impacts of the Rodeo-Chediski Fire.

Stream temperature has been a long-term concern for fisheries management in Canyon Creek. Water temperatures increase dramatically over the 5 mile reach of Canyon Creek, from its origin at the base of the Mogollon Rim to the Forest Boundary. Higher water temperatures in the meadow reaches are attributed to a wide and shallow channel with less canopy cover. Temperatures have been monitored by the Department between late spring, after snowmelt, and late fall. Temperatures range between winter lows of < 40 degrees Faranheit (F) to mid-summer highs averaging 74-75 degrees F, but occasionally peaking to as high as 78 degrees.

Channel Morphology

Canyon Creek is a single channel alluvial stream in a wide valley bottom and originates at the base of the Mogollon Rim from several springs. Reaches in the upper portion of the watershed, near the springs, are relatively steep and the channel is more confined to a narrow valley bottom. The channel substrate is dominated by cobble and boulders, forming frequent step-pool features. Downstream the channel meanders through a meadow and reaches are of lower gradient (average of 0.6 to 1.5% slope) and pool habitats are longer but often shallow. There are occasional split channels and flood channels. The stream channel has shifted across the valley bottom over the years in a few places, evidenced by abandoned channels. A recent watershed assessment (Natural Channel Design, Inc. 2008) characterized the stream within the project area as a relatively stable "C" type stream channel (Rosgen 1996) that is generally wide, and slightly entrenched with low to moderate sinuosity. Forest Service specialists had indicated vertical incision is much less evident than horizontal adjustments (channel widening) during a post-fire assessment (J. Grove and G. Loomis pers comm. 2003). Sediment deposition on pointbars and transverse bars after the fire created suitable sites for recruitment of riparian vegetation. The combination of floodplain and flood channels in the project area provides a broader area for recruitment of riparian vegetation, than in areas where the channel has downcut. Fire killed pine and cottonwood trees along the stream and floodplain are now starting to fall. The large woody debris on the floodplain is trapping sediment during floods, slowing flood flows and enhancing water recharge. Where logs have fallen across the channel, new pools are forming and sands and gravels are collected. These are positive changes for fish habitat.

Fish

Canyon Creek is actively managed as a trout fishery by the Department. Brown trout (*Salmo trutta*) populations are rarely augmented with stocked trout, but over the years have maintained through

natural reproduction. Rainbow trout (*Onchorhynkiss mykiss*) are stocked weekly between the months of April and September. Two native fish species, the speckled dace (*Rhinichthys osculus*) and Desert sucker (*Catastomos Clarki*) have persisted despite the presence of non-native trout species.

A fish population survey conducted in July 1998 (pre-fire) showed healthy fish populations in Canyon creek throughout the stream from the springhead to the Ft. Apache Indian Reservation (McMahon 1997). This was the last fish survey conducted prior to the 2002 Rodeo-Chediski fire. Surveyed species included reproducing populations of brown trout, speckled dace and desert suckers in a majority of the stream and stocked numbers of rainbow trout in the upper portion. Minimum density numbers gathered by habitat type and linear length of the stream estimated that there were an average of 840 brown trout/mile, 230 rainbow trout/mile, 900 dace/mile and 700 suckers/mile within the 4.3 miles of Canyon creek. Total standing crop estimates from Canyon creek were 11,480 fish.

Immediately after the fire a limited number of all species were confirmed still present. However, by the end of the 2002 monsoon season, sedimentation impacts to the stream were so severe that all fish populations were reduced by an estimated 90%. A June 2003 survey (Warnecke & Weedman 2003) indicated that native fishes were reproducing and rebounding from fire impacts. Brown trout populations showed a ten-fold decrease and there was no indication of natural reproduction. A one-time stocking of 900 rainbow and 500 brown trout was undertaken in April 2005 to augment trout populations. There was no indication of natural reproduction after the fire, until Fall of 2005, when 12 brown trout redds (nests) were first observed in the stream. By April 2006 hundreds of young fingerling brown and rainbow trout were found throughout Canyon Creek. The July 2006 survey found that 67% of the 203 brown trout collected were young of the year fish. This verified that brown trout were successfully increasing through natural reproduction. In fact, later that fall biologists observed 44 redds and by summer of 2007 brown trout densities had increased in all reaches of the stream over the 2006 estimates. And most important to the angling community, biologists found more large trout, >16 inches in length (20 collected in 2008 >16 inches compared to 10 in 2006), in many reaches of the stream.

Based on 2008 survey data, the minimum density numbers gathered by habitat type and linear length of the stream estimated that there were an average of 625 brown trout/mile, 387 rainbow trout/mile, 3551 speckled dace/mile and 1342 suckers/mile within the 4.3 miles of Canyon creek. Total standing crop estimates in 2008 have not been calculated yet. Pre-fire (1998) versus post-fire (2004-2008) survey data indicates that native fish populations have rebounded beyond pre-fire levels, and brown trout are still increasing. Rainbow trout are a stocked species, therefore population trends are not relative to natural reproduction (Table 1 and Figures 1 & 2).

With future habitat improvements such as deeper pools, overhanging banks and cooler water temperatures brown trout populations will likely increase to carry capacity. Rainbow trout populations are not expected to maintain through natural reproduction and will be augmented with hatchery reared stock annually.

Table 1. Comparison of average fish density (number of fish per mile) by species pre-fire (1998) and post-fire (2004-2008). AGFD surveys conducted June of every year (May in 2008); AGFD Region VI Fish Program.

Species	Average Density/Mile					
	1998	2004	2005	2006	2007	2008
desert sucker	511	17	324	2293	2245	1342
speckled dace	901	891	2231	6651	6103	3551
rainbow trout	231	264	361	575	511	387
brown trout	843	86	175	379	599	625

Wildlife

There are several special status species with federal or state designations that may occur within the project vicinity including: speckled dace (*Rhinichthys osculus*), desert sucker (*Catostomas Clarkii*), common black hawk (*Buteogallus anthracinus*), belted kingfisher (*Ceryle alcyon*), Mexican spotted owl (*Strix occidentalis lucida*) and northern goshawk (*Accipiter gentilis*) and wintering bald eagles (*Haliaeetus leucocephalus*). There are historical records for northern leopard frog (*Rana pipiens*) and narrow-headed gartersnake (*Thamnophis rufipunctatus*); however these species have not been detected in many years.

Common game species that occur in the area include: elk, white-tailed deer, mule deer, turkey, Abert's squirrel and black bear. The most visible predator is coyote. However mountain lion, bobcat, and gray fox may also occur in the area. Nongame species are abundant and include small mammals, migratory songbirds, raptors, amphibians and reptiles. A few examples of the more visible or evidenced are small mammals such as the vole and valley pocket gopher, raccoon, canyon tree frog, Arizona toad, and terrestrial gartersnake.

Historically beaver occupied Canyon Creek. However populations were suppressed in the late 1980's to facilitate riparian restoration objectives. Resident beaver were successfully translocated to streams outside the watershed post 1989. Since that time beaver activity has been sporadic. Beaver were present prior to the Rodeo-Chediski Fire, but dams and huts were burned in the fire. There has been very limited evidence of beaver activity post-fire and currently it appears they no longer occur along Canyon or Mule creeks, within the Forest boundary.

The project area lies within the northern boundary of the Department's Game Management Unit 23 (GMU 23) in Region VI and overlaps yearlong elk range. However, this range is also used seasonally (winter) by elk that migrate south off the Colorado plateau and the adjacent Fort Apache Indian Reservation. This complicates elk management efforts below the Mogollon Rim. Information gathered on seasonal elk ranges and migrations in Arizona (Brown, 1994) documents that winter elk range completely overlaps the summer and yearlong elk range, excluding some minor range extensions. Current population management objectives target the resident elk population below the Mogollon Rim to maintain or increase elk herds where suitable. Over past years, elk have impacted the riparian habitat along Canyon and Mule creeks.

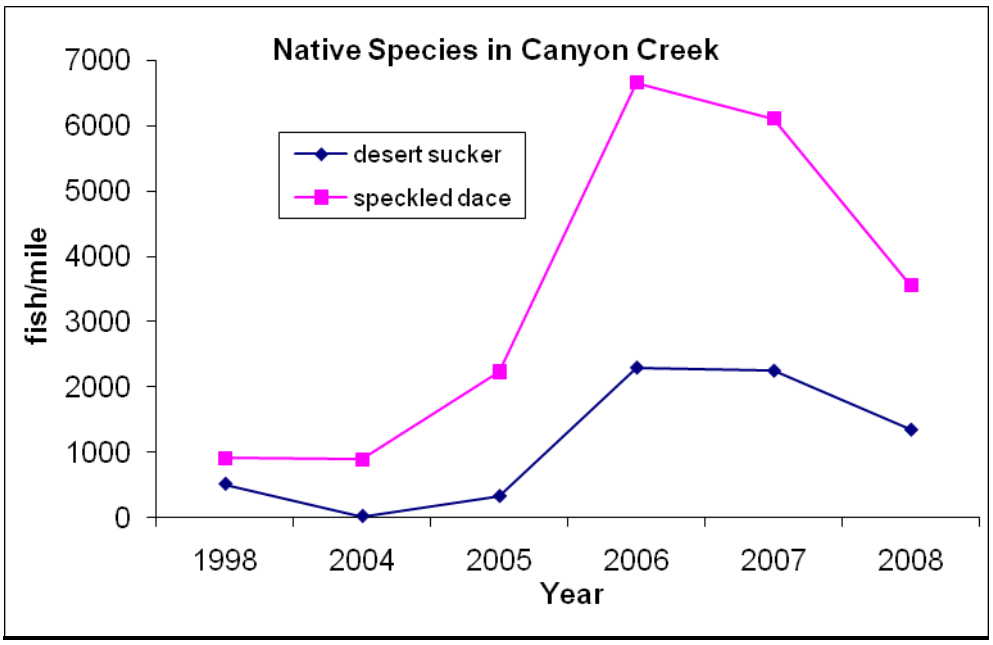


Figure 1. Comparison of average native fish density (number of fish per mile) by species pre-fire (1998) and post-fire (2004-2008). AGFD surveys conducted June of most years (May in 2008); AGFD Region VI Fish Program.

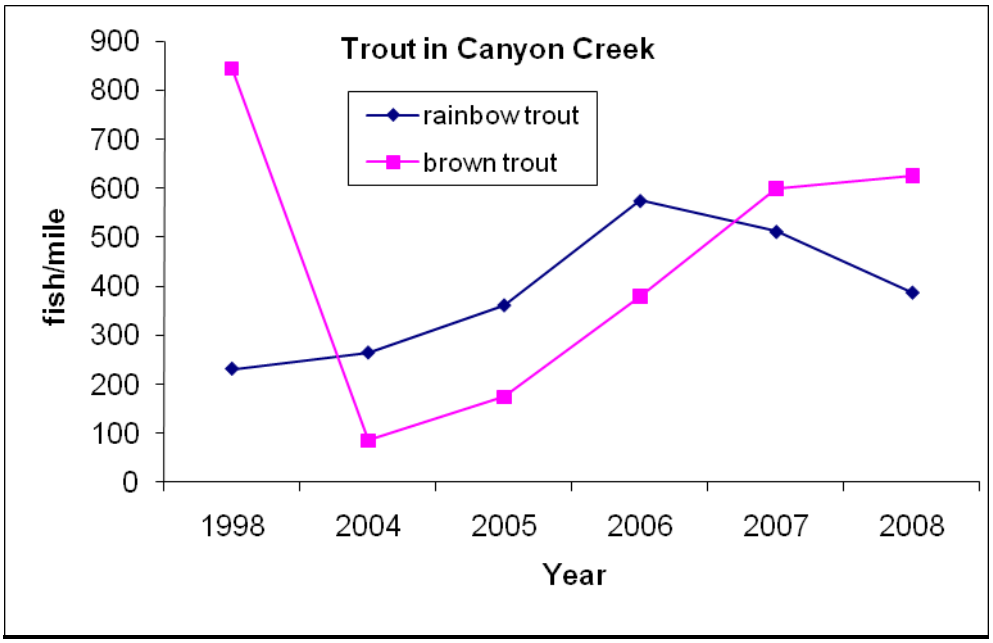


Figure 2. Comparison of average trout density (number of fish per mile) by species pre-fire (1998) and post-fire (2004-2008). AGFD surveys conducted June of every year (May in 2008); AGFD Region VI Fish Program.

The Forest and Department have conducted a limited utilization monitoring since the early 1990's in the Canyon and Mule Creek watersheds, and have measured a moderate to high range (30-95%) of browsing on key riparian woody species and a light to moderate level (20-40%) of use on herbaceous meadow species. Based on observations and utilization reports elk appear to have the greatest impact on the riparian vegetation during the early spring-early summer period (elk calving period). This is a particularly vulnerable time for woody species as it coincides with bud break and tends to limit the vigor of existing plants and new plant regeneration. Spring 2004 monitoring documented an average height of 18.5 inches on willow species in the project area. The arroyo willow (shrub) should attain a height of about 15 feet, and the red willow (tree) has a potential of over 25 feet in this vicinity. Spring of 2008, the Department monitoring data indicated that 30% of the palatable leaders on willows (below the 6 foot height) were browsed outside the exclosure. Since 1999, five riparian exclosures, including this project, have been constructed to exclude elk. Game management directives designed to specifically address elk management along Canyon Creek (and northern GMU 23) are: 1) Increase the harvest of migratory elk with late hunts in December. 2) Offer limited opportunity general elk hunts (cow) early August to mid-September to disrupt elk distribution habits along Canyon Creek. These population management strategies may decrease elk impacts along the Canyon and Mule Creek riparian corridors over time. Watershed conditions post-fire have resulted in a lush regrowth of many shrub and herbaceous species, offering significantly more foraging opportunity in the previously forested areas. This change may have since relieved some grazing pressure along the riparian corridors, but there is limited data to verify.

METHODS

CONSTRUCTION AND MAINTENANCE

The exclosure was constructed with two panels of 4 foot field fence for a total height of 8 feet. The field fence was secured to ten foot (1.33) t-posts using standard fence fasteners and the two panels of 4 foot field fence were secured to each other using heavy gauge wire hog rings every foot. All corners, bends, and pedestrian access points were constructed with 2 ½ inch black steel pipe welded with supports. Field fencing was attached directly to the steel pipe bracing. Extra bracing was also constructed in areas where topography created a need for extra support beyond the 10 foot t-posts. T-posts were set into the ground using a hydraulic fence post pounder. All steel pipe bracing was cemented into the ground at a minimum depth of 4-5 feet. The exclosure fence was set at a height of approximately 12-18" above the ground level to facilitate debris flows during floods and non-target wildlife movement through the exclosure. In areas with topographical features such as small drainages it was necessary to reinforce the fence and add field fence to ground level to prevent elk from pushing under. It may be necessary to retrofit areas that elk find topographically conducive to pushing under with additional fencing. Some adjustments were made in November immediately after the initial construction in locations that we found to have been tested by elk. These retrofits solved the problem and we also note that observations have been made that other species including

deer, turkey and coyote do pass under the exclosure with minimal obstruction. Further, the top of the exclosure was flagged with marker tape to help with visual detection of the fence by avian species including Mexican spotted owls and wintering bald eagles. At each of the four corners of the fence are pedestrian access and three additional access points are constructed along the length of the stream corridor. Two gates were constructed for use by the livestock permittee in the instance that livestock need to be cleared from the project area due to incidental trespass or emergency purposes. These gates are located on the upstream and downstream ends of the exclosure.

Construction of the water gap feature followed Department engineered designs with some additional upgrades to further reinforce the supporting structures called "deadmans" and the steel cable attachments. The deadmans and steel cable attachments were cemented into the ground with concrete footings set at a depth of > 6 feet and a width of >5 feet. Because of the size and depth of these concrete footings there will not be issues with flood flows undermining the water gap supports and footings. The swinging water-bar gates were constructed with #8 rebar pers the design detail and each gate weighs approximately 100 pounds. Because of the closed eye design used to hang these structures on the steel cable it was necessary for the contractor to string the water bar gates onto the cable prior to stretching the cable through the deadman support and securing to the cable attachment at ground level. There were approximately 10 water bar gates used to cover the width of the stream channel with the water gap feature. Once the steel cable was stretched it was necessary to also stretch a single panel of 4-foot field fence across the top of the water gap to maintain the necessary 8 foot height for effective elk exclosure. Photographs follow to illustrate the basic fence design components.

Photos 2 & 3. Left: Exclosure fence-2 panels of 4 foot field fence for a total height of 8 feet, secured to ten foot (1.33) t-posts. Right: Downstream water gap with swinging water bar gates on steel cable.

MONITORING

Strategy

The primary objective for short-term (between 2005-2007) and long-term monitoring (5-10 years) is to compare vegetative and channel changes inside the exclosure versus outside the exclosure, and determine to what degree goals and objectives for the project were attained. Long-term monitoring will determine the implementation period for the elk/livestock exclosure, after which time the exclosure will be converted to a livestock only exclosure.

The parameters measured include:

- Vegetation trend (canopy cover, ground cover, vertical volume and density of woody species) along the greenline and within the floodplain
- Greenline width
- Stream channel morphology (width, depth, slope, substrate) above, below and within the exclosure
- Baseline water quality (pH, temperature, conductivity, turbidity, dissolved and suspended sediments)
- Qualitative changes in riparian vegetation structure and density

Data were (and will continue to be) collected to test predictions and monitor riparian response to grazing deferment. The results will determine project success. The following predictions will be tested:

1. Woody plant density and vertical volume, (and canopy cover if the greenline becomes shrub dominated) will increase inside the exclosure at a greater rate than outside the exclosure (greenline and floodplain).

2. Perennial herbaceous plant canopy cover will increase inside the exclosure at a greater rate than outside the exclosure (greenline and floodplain).

3. Stream channel morphology (channel width, depth, substrate size class distribution) will begin to change. It is expected over time the stream channel will narrow and deepen and the floodplain will develop more resilient lateral and point bars inside the exclosure versus outside. Fine sediments that have been deposited in pools, runs and riffles should be more efficiently transported downstream; therefore a corresponding change in substrate size classes may be detectable.

A measurable positive increase for herbaceous and woody vegetation on the greenline and floodplain (inside versus outside the exclosure) will be the threshold at which the project is considered successful. Measurable differences in channel morphology inside versus outside the exclosure are expected to be slow and difficult to detect within the short-term (3 years). Episodic flood events may cause detectable short-term changes.

Permanent photopoints were established to provide a qualitative assessment of short and long-term changes. Photopoints were established to detect changes in canopy cover structure and abundance (woody, herbaceous and aquatic plant species) inside versus outside the exclosure. Photopoints were stratified to document changes along the greenline, floodplain, and in-stream cover.

Water quality measures were taken to establish a baseline water quality, but no additional water quality monitoring was conducted. Measurable improvements in water quality are not anticipated within the 3-year short-term monitoring period due to the degraded condition of the upper watershed from the Rodeo-Chediski Fire. There are significant sedimentation inputs from high and moderate intensity burn areas that will continue to impact water quality over time. However, it is reasonable to expect long-term improvements in water quality as vegetation canopy and ground cover increases and traps fine sediments along the greenline and floodplain.

Baseline monitoring was conducted fall of 2005, immediately after construction of the exclosure. Vegetation trend, channel morphology and photopoint monitoring was replicated at the end of the growing season (fall) in 2006 and 2007.

Methods

Vegetation Trend.--The sampling design follows the protocol outlined in "*Effectiveness Monitoring for Streams and Riparian Areas within the Upper Columbia River Basin*" (USDA Forest Service 2004). Some minor modifications were made to the protocol to accommodate regional differences in stream type.

The stream reaches selected for vegetation monitoring were paired with permanent stream channel cross sections, which are used to describe the channel morphology and condition. Cross section locations were selected at riffle locations with single thread channels, adjustable banks, and similar vegetation communities. Rebar was placed on either side of Canyon Creek to mark the start and end points of the cross-sections. The cross-sections marked the center of the sample reach for vegetation monitoring. Therefore, half of the plots were upstream and half were downstream of the cross-section (Figure 3). The total length of reach sampled was approximately 300 feet.

Vegetation was sampled on 2 features: the greenline and floodplain. Greenline transects run parallel along the water's edge on both sides of the channel and perpendicular transects run perpendicular to the general azimuth of the valley bottom. A Daubenmire frame (20 x 50 cm) was used to estimate canopy cover of plant species along the greenline and floodplain. This design does not capture all of the fluvial features within the valley bottom. Vegetation composition and some changes beyond the scope of these measurements were captured in the floristic inventory and photopoint monitoring.

Greenline transects were run on both sides of the stream, with 10 plots being placed 15 feet apart

upstream from the cross section and 11 plots being placed 15 feet apart downstream. The placement of the plot frame was determined by moving away from the water's edge until 25% cover provided by rooted, perennial or biennial vegetation was contained inside the frame (USDA Forest Service 2005). Floodplain transects were run perpendicular to the stream along transects placed at water's edge, extending onto the floodplain. Three plots were placed on the upstream side of each transect at 9.5, 18.5, and 27.5 feet from water's edge.

The canopy cover of all species hanging within a vertical projection of the plot frame was recorded. Canopy cover was recorded using Daubenmire (1958) cover classes. Percent canopy cover was calculated using the midpoint for each of the 6 cover classes for each species recorded. Canopy cover was used to determine species composition by feature (greenline and floodplain).

Ground cover in riparian areas can be helpful in assessing stream bank or greenline stability and the capability of the site to capture sediment. Ground cover was measured using the Daubenmire quadrat frame along the floodplain (perpendicular transects) only. Percent ground cover was estimated for Rosgen's (1996) sediment size categories, in addition to litter, litter >3", attached litter, live basal vegetation (McBride 2002).

When the data are collected, transects are divided by downstream right and left for both greenline and floodplain features; and data was recorded for all of the features separately. The results discussed below are based on calculations for similar features within and outside of the elk exclosure. For example, the downstream left and right greenline data inside of the exclosure were numerically combined to determine overall species cover and composition for that particular feature, as the plant community on both sides remained similar during all 3 monitoring years. As the plant community along Canyon Creek changes in response to the elk exclosure, it may be important to analyze plant community dynamics downstream left and right separately. Thus, that option continues to be available as long as the data is collected in the same way as years 2005-2007.

Woody Plant Density.--The woody vegetation that currently grows along Canyon Creek includes both riparian trees (narrowleaf cottonwood, Arizona Alder, Goodding willow, box elder) and shrubs (red and arroyo willow and false indigo); in addition to upland species. However, it is unclear as to what life form will dominate the greenline in the exclosure once grazing pressure is eliminated and recovery begins. Density, the number of individuals per unit area, is used to measure change in the age-size class structure of riparian areas that are primarily dominated by single-stemmed tree species. In riparian areas largely dominated by shrub species, canopy cover should be substituted for density. It is possible that both attributes will need to be measured. The following methodology will be used when we begin to detect woody plants within the monitoring reaches.

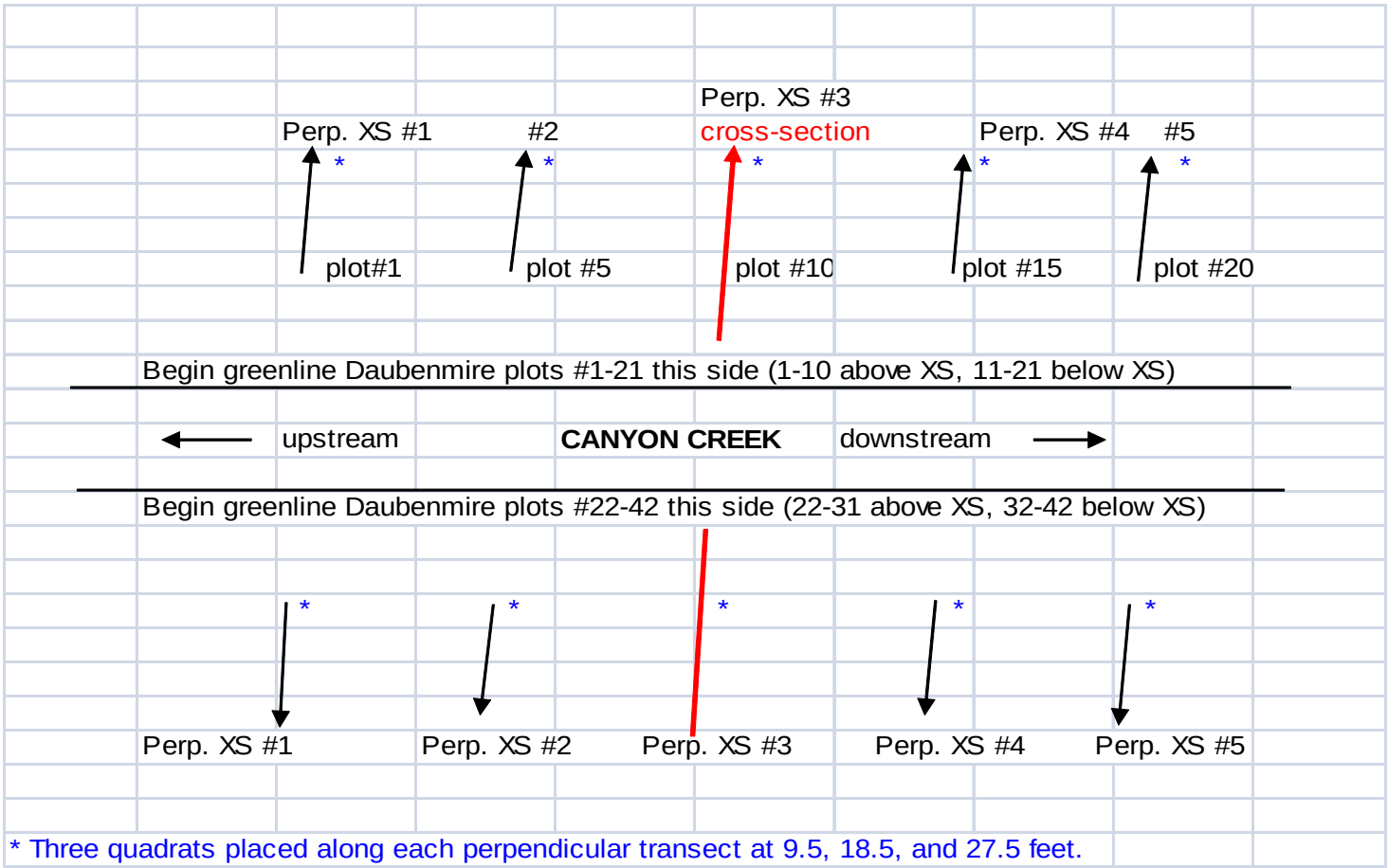


Figure 3. Sampling design of riparian vegetation trend monitoring used inside and outside of elk exclosure at Canyon Creek.

Woody plant density will be determined in two; 100 ft. x 6 ft. belt transects positioned parallel to the channel and overlapping the perpendicular transects. All single stemmed tree species will be counted and recorded by the size classes listed below:

Seedlings	**<1" or <4.5' tall**
Saplings	**1-5.0 - 9.0" dbh**
Pole trees	**5.0 - 9.0" dbh**
Medium trees	**9.0 - 21" dbh**
Large trees	**21 - 32.9" dbh**
Very large trees	**>33" dbh**

Canopy cover of shrubs will be estimated using the line-intercept technique. Two 100 ft. tapes will run parallel to the stream channel (on opposite sides) and positioned at half the width of the greenline vegetation. For example, if the greenline is about 9 ft. wide, the tape will be laid 4.5 ft. from either edge.

A 9.5 m Robel pole will be used to estimate vertical volume of the shrub and tree species. This measurement is intended to compliment the density and cover attributes to assess the vertical structure of the riparian plant community. The Robel pole will be placed every 10 ft. along the 100 ft. density or line-intercept transect. For every meter, the observer will count the number of decimeter sections that contain vegetation ("hits") hanging within a 10 cm. Radius around the pole. Hits will be recorded by species.

The vegetation trend transects will be photographed from the stream channel cross section. In addition, the end of the vegetation transect will be documented using GPS.

Botanical Inventory.--A botanical inventory of the reach inside the exclosure was conducted concurrent with the riparian monitoring effort in order to document the flora and capture species that were not noted in the plot data. In addition, many species were collected, vouchered and placed in the Forest Service Herbarium at the Tonto Forest Supervisor's Office.

Greenline to Greenline Width.--Narrowing of stream channels is viewed as an indicator of recovery (Cowley and Burton 2005). Commonly the width of channels is determined by measuring channel width at the bankful level. Though related to the bankful stage, the greenline is easier to identify. It is the first line of perennial vegetation near the channel's inner edge (Winward 2000). Cowley and Burton describe a protocol for measuring greenline to greenline width (GGW). It is the non-vegetated distance between the greenline on each side of the stream. Measurements are taken for each reach and averaged to yield a mean width. Typically as stream banks recover, the stream channel narrows and the average non-vegetated GGW will be reduced.

Fifty measurements were taken at six foot intervals along a 300 feet long reach (within and below the exclosure) centered on the permanent stream channel cross sections. Beginning at the upstream rebar ("0"), wire flags are located at six feet intervals on both sides of the channel. A tape is stretched across the channel between both flags (this line will not always be perpendicular to the stream). Moving from the center of the channel to both river right and left, Daubenmire frames are positioned where rooted perennial vegetative canopy cover equals 25% (Kershner et al. 2004). The long axis of the quadrat is placed parallel to the channel. The distance measurement between the two Daubenmire frames is the recorded greenline to greenline width. It is taken from the center mark of both quadrat frames on the long axes lying toward the center of the channel.

The number of points collected may vary depending on the variability of the individual samples, and may be adjusted to establish desired confidence levels that the change in the greenline has been accurately captured.

Channel Morphology.--Canyon Creek within the exclosure is expected to narrow over time as vegetation recovers from the exclusion of elk and livestock. To document this anticipated change four channel cross-sections were installed using procedures described in Harrelson (1994). At each cross section we recorded cross section data, longitudinal profile data (identifying as many fluvial features as possible), channel slope, and pebble counts. At channel cross-section locations we conducted qualitative assessments for stream channel stability (Pfankuch 1975) and a Bank Erodibility Hazard Rating (BEHI) (Rosgen, 1996) to further evaluate the condition and stability of stream banks. Two cross-sections were installed inside the exclosure; and one upstream and one downstream of the exclosure. The cross sections were monitored once per year or following greater than bankfull events.

Data for channel cross-sections, longitudinal profile and channel slope was collected with a laser level and tape. Cross sections were permanently monumented with rebar pounded into the ground at the cross section endpoints. Each monument location was photographed and a UTM location recorded using a GPS (Nad27). Longitudinal profiles extend upstream and downstream of the cross section at distances determined in the field. Pebble count information was collected with a ruler using the zigzag collection method described in Bevenger and King (1995). Cross sections were installed at riffle or run locations. Longitudinal profiles were extended through at least one riffle/pool sequence. The purpose of these monitoring methods was to document changes in channel width and depth, and changes in channel substrate over time.

We evaluated the change in cross sectional area over time by comparing the channel cross-section data. Change in specific fluvial features (i.e. greenline, bankfull feature, terrace features) can also be compared over time. Channels were classified under the Rosgen (1996) stream classification system. Longitudinal profiles were surveyed at each cross section to collect information about channel slope and relation of various fluvial features (e.g. thalweg, water surface, bank and terrace features) to each other. Pebble counts were collected at each cross section to characterize channel material (silt, sand, gravel, cobble, and boulder) and

detect whether particle size distributions change as the channel changes.

Water Quality Monitoring.--Water Samples were collected from two locations, one above the project area and one below. Samples were collected from a hydrologically well-mixed segment and composited both horizontally and vertically to insure that representative samples are collected. Conductivity, temperature, pH and turbidity were measured in the field. Total dissolved solids and total suspended solids were collected in one-liter bottles, placed on ice and transported to the laboratory for analysis. The following are the methods used for analysis with the corresponding references.

Water temperature data loggers were installed in pool locations between May and November beginning in 2004 to track summer peak temperature trends. Temperature was recorded hourly when loggers were working correctly. Data loggers were installed in several reaches between the stream origin, at the base of the Mogollon Rim, extending approximately 5 miles to the Forest Boundary. The data capture locations were selected to capture temperature changes influenced by stream channel morphology and canopy cover.

Table 2. Water quality parameters and analysis methods.

Parameter	Method
Conductivity	120.1[1]
pH	150.1(L) [1]
Turbidity	2130 B (L)[2]
Solids, total dissolved	2540 C (L) [2]
Solids, total suspended	2540 D (L) [2]

[1]*Methods for Chemical Analysis of Water and Wastes,* EPA-600/4-79-020, Environmental Monitoring and Support Lab. Cincinnati, OH, Office of Research and Development, U.S. Environmental Protection Agency, August 1993

[2]*Standard Methods for Examination of Water and Wastewater*, 19th Ed., American Public Health Association, 1995

Photopoint Monitoring.--Permanent photopoint sites were established post-construction to monitor vegetation changes over time above, within, and below the elk-livestock exclosure. Protocols and forms were taken from the Policies & Application Guidelines Manual (AWPF, 2005). Two different digital cameras were used to replicate photos; Canon Power shot S500 Digital ELPH and a NIKON Coolpix 950.

Photographic series at 12 permanent monitoring sites were established to capture the following types of changes inside versus outside the exclosure:

- Changes in vegetation abundance and canopy cover at the greenline.
- Changes in vegetation abundance and canopy cover on the floodplain.

- Changes in aquatic vegetation cover in-stream.
- Random photos to document specific observations

The following protocol and data was recorded for all sites:

1. Sites were monumented with rebar stakes and an aluminum reference tag.
2. The monument location was recorded as UTM at Datum NAD 27 using a GPS.
3. UTM locations were documented in the project GIS for future reference and mapping.
4. Reference points and landmarks were established for each photographic series and recorded on the *Initial Take-Permanent Photopoint Record Form* and in the project GIS database and photographed. Baseline photos were taken immediately after construction.
5. Replicate photos were taken on an annual basis at the end of the growing season (fall). Photos were replicated as near the time as vegetation trend data collection as feasible.
6. Random photos to document specific observations were documented with UTM, date, and location relative to exclosure and description.
7. Photo boards were set within the photograph view to document site ID and date.
8. Photos were taken with the digital camera on a tripod at a set height of 1 meter plus 10 cm. Photos were taken at a focal length of 35-50mm, depending on the lens equipped with the digital camera. Resolution settings were set to high and photos saved to a JPEG format. All pictures were taken with the camera on a tripod, standing directly over the monument stake.
9. Photos were stored electronically and as hard copy printouts on HP photo quality paper.

RESULTS

MONITORING

Riparian Vegetation Trend

Changes between the first, second, and third years of data collection did not support the need to perform statistical analyses. The results are summarized to characterize the existing plant communities and highlight changes that were biologically meaningful. Although we have begun to document differences inside the exclosure versus outside on various fluvial features, those differences are not yet detectable within the monitoring reaches. The sampling design captures changes along a 300 ft. reach of the approximate ½ mile exclosure and is a limited representation of changes that are occurring. However, we expect with time that we will be able to quantify vegetation differences inside versus outside the exclosure.

Overall species diversity was very high along Canyon Creek. The species diversity inside and outside of the elk-livestock exclosure was higher in 2006 and 2007 than 2005, compared to 2005. Overall, there were 115 species, 86 genera and 32 families represented at the two monitoring reaches during the 3-year monitoring period (Appendix A, Table 16). Species

diversity increased most notably between 2006 and 2007 (Table 3). The majority of the 115 species documented between the years contributed < 2% canopy cover each year.

Species diversity is similar inside and outside of the exlosure on both the greenline and floodplain features (Table 4), comprising a mixture of largely herbaceous species; with more riparian obligate or facultative wetland species along the greenline versus the floodplain (Figures 4a & b). However, we found variability in which particular species were most dominant on the two fluvial features between years, with no apparent trends. We will discuss those differences for the floodplain and greenline separately. In the future, with more data, it may be possible to analyze the plant community to look at ecological trends using multivariate analyses.

We detected very few tree or shrub species within monitoring reaches. Outside of the monitoring reaches, qualitative photopoint monitoring suggests composition and structure may include increasing amounts of shrub and tree species inside the exclosure and to a lesser degree outside (see photopoint results for further discussion).

Overall, species composition was predominantly native species. Introduced species were equally represented inside versus outside the exclosure. Introduced species represented a 3-year average of 16% of the species on the inside greenline and 20% outside; and 19% of the species on the floodplains (Table 4). However, a few of the introduced species contributed significantly to total canopy cover; Watercress (*Nasturtium officinale*), red top (*Agrostis gigantea*), tall fescue (*Schedonorus phoenix*), and crownvetch (*Securigera varia*). Therefore, even though composition was predominantly native, a significant portion of canopy cover was provided by introduced species on the greenline, more so than the floodplain (except in 2006; Figure 5a & b).

Table 3. Species diversity summary for 3-year monitoring period, in monitoring reaches inside and outside exclosure. 14 records for unidentified plants were not included in summary.

SURVEY YEAR	FAMILIES	GENERA	SPECIES
2005	17	54	63
2006	24	61	70
2007	24	70	93
3 YEAR TOTAL	**32**	**86**	**115**

Greenline.--Plant species diversity is lower along the greenline than on the adjacent floodplain, however a greater percentage of the plants were riparian obligate or facultative wetland. During the 3-year period 57 plant species were recorded inside the exclosure and 48 outside (Table 4) along the greenline. Overall, total canopy cover increased along the greenline between 2005 and 2007, inside and outside the exclosure. Baseline measurements in 2005 showed about 15% more total canopy cover outside the exclosure. However in 2007, canopy cover increased 42% inside the exclosure and decreased by 12% outside of the exclosure on the greenline (Figure 6). Between 40% and 70% of the species along the

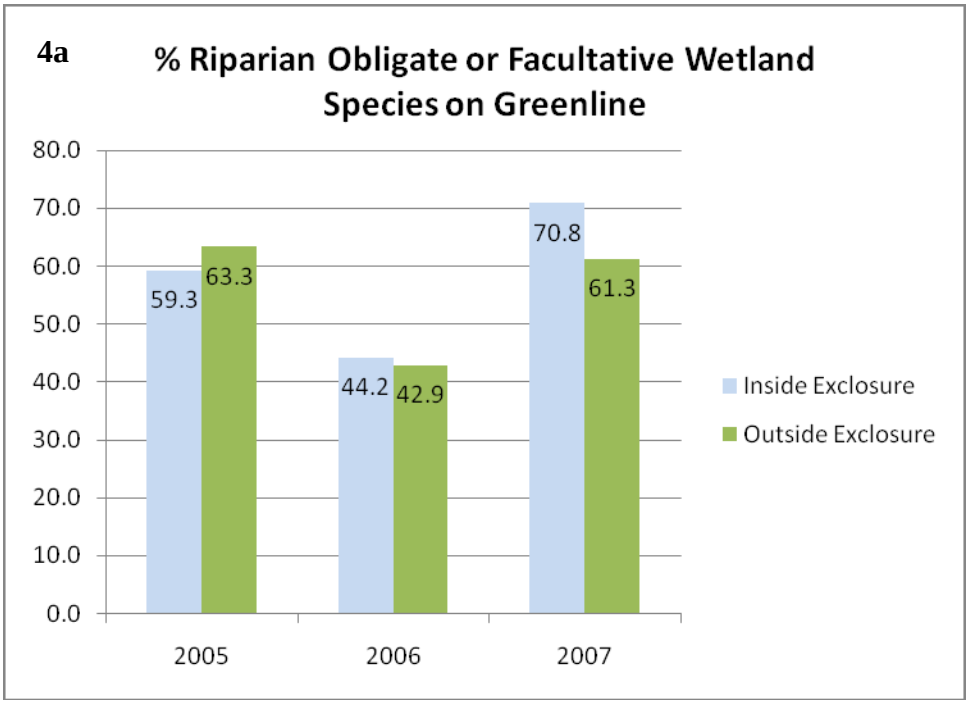
Table 4. Species diversity summary for 3-year monitoring period, comparing floodplain with greenline; inside and outside of exclosure. 14 records for unidentified plants were not included in summary.

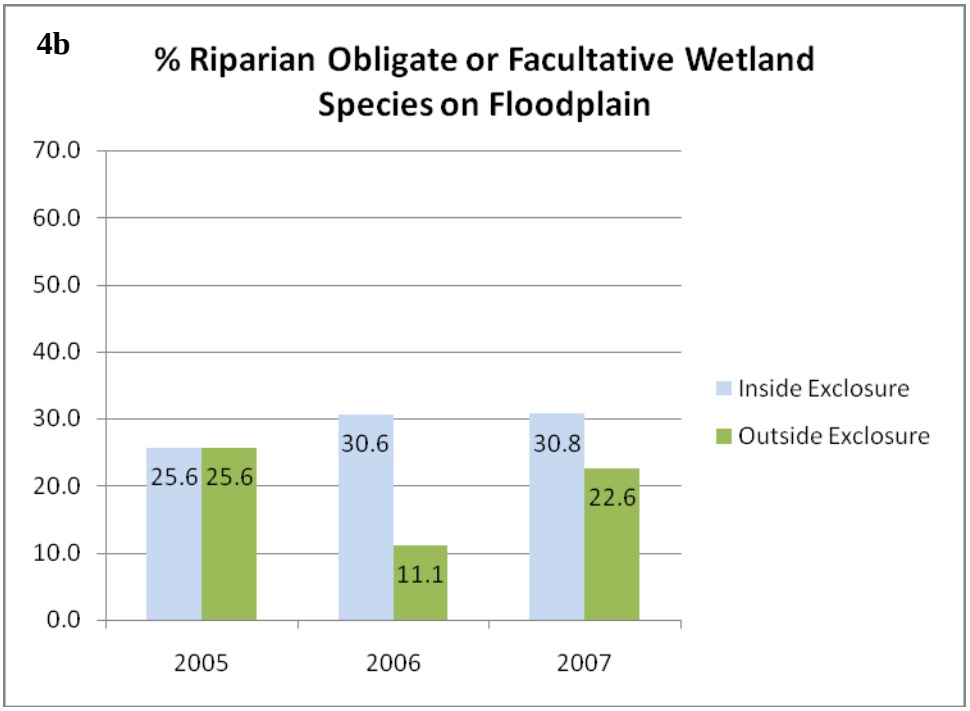
SURVEY YEAR	# SPECIES FLOODPLAIN		# SPECIES GREENLINE	
	Inside	Outside	Inside	Outside
2005	39	39	27	30
2006	49	27	43	28
2007	52	62	24	31
3 YEAR TOTAL	75	79	57	48
# SPP PRESENT ALL 3 YEARS	19	10	12	15
# INTRODUCED SPECIES 3-YEAR AVE	14	15	9	10

greenline were wetland species, depending on the year (Figure 4a). Although the proportion of native versus introduced species between years was fairly constant outside the exclosure, it fluctuated significantly inside the exclosure due to changes in percent cover of watercress (Figure 5a). Cover from wetland species was most abundant in 2007 and that was largely due to the increase of one species, and accounted for the sharp increase inside the exclosure in 2007 (Figures 4 & 5). The most dominant wetland species on the greenline for all 3 years, both inside and outside the exclosure, was watercress; contributing between 3 and 71% of the canopy cover, depending on the year. Watercress is an emergent-aquatic forb with a prostrate, spreading habit, rooting in the water and on the stream bank.

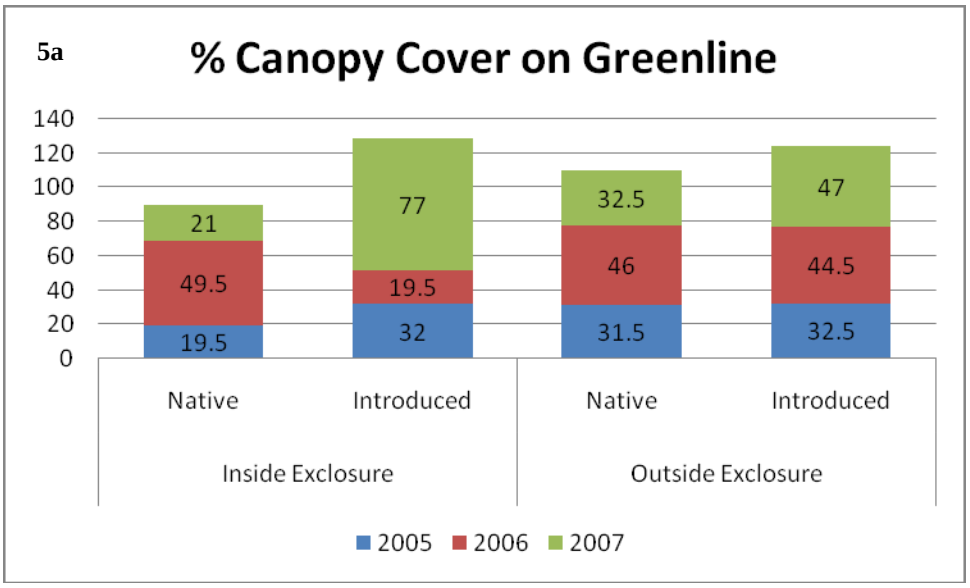
Photo 4 & 5. Downstream view of Canyon Creek inside of the elk exclosure at the monitoring reach. Watercress canopy cover increased by 68% between 2006 (left) and 2007 (right).

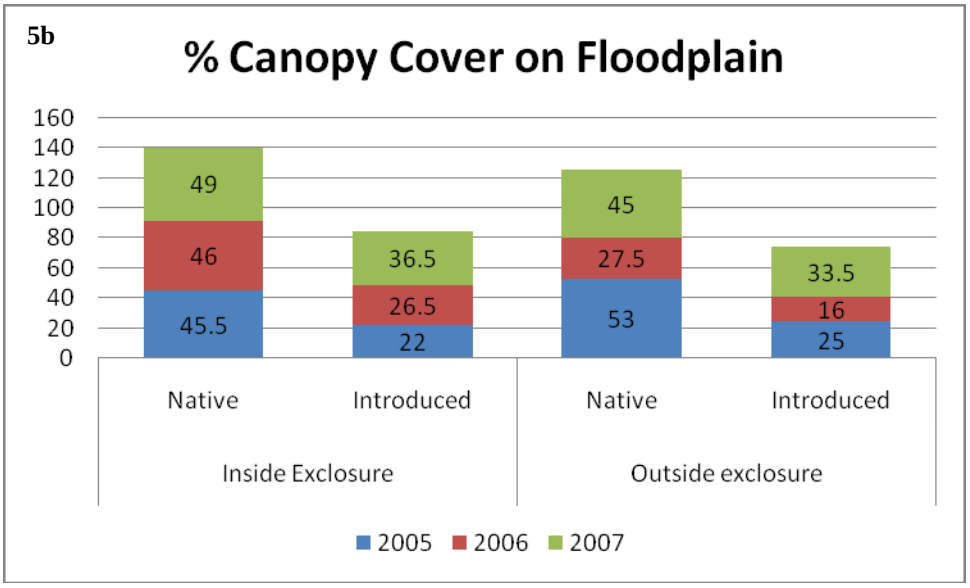
Figures 4. Percent of total species recorded over the 3-year monitoring period classified as obligate wetland or facultative wetland in the Southwest, U.S. (Reed 1988) a) greenline and b) floodplain.





Figures 5. Comparison of canopy cover that is introduced versus native species a) greenline and b) floodplain. Watercress is a significant portion of the introduced canopy cover on the greenline.





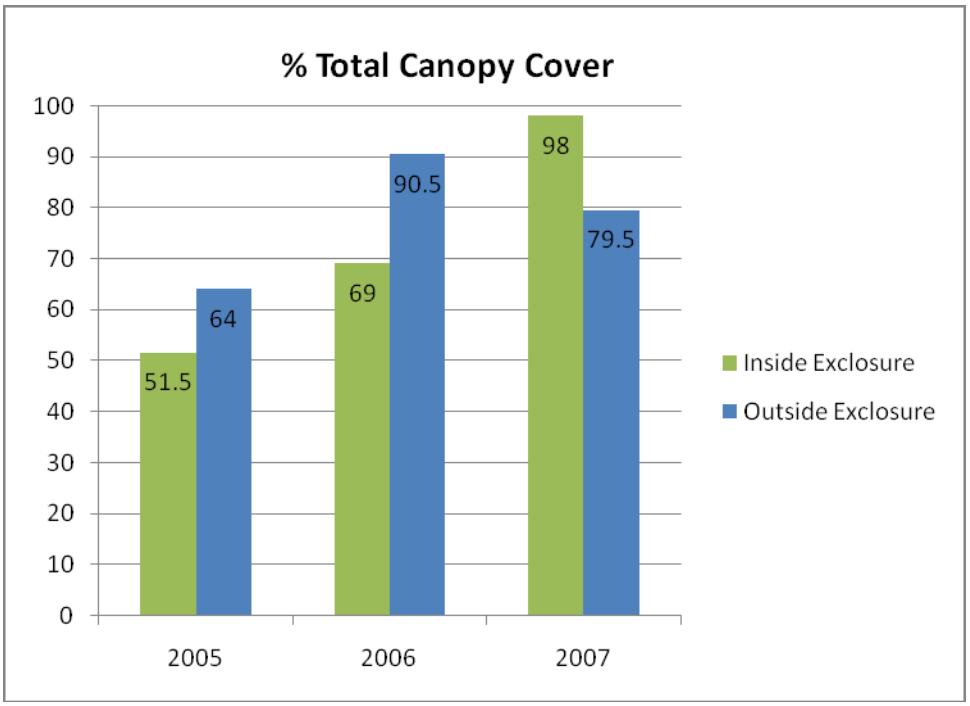


Figure 6. Total percent canopy cover measured in Daubenmire plots along greenline, inside versus outside exclosure 2005-07.

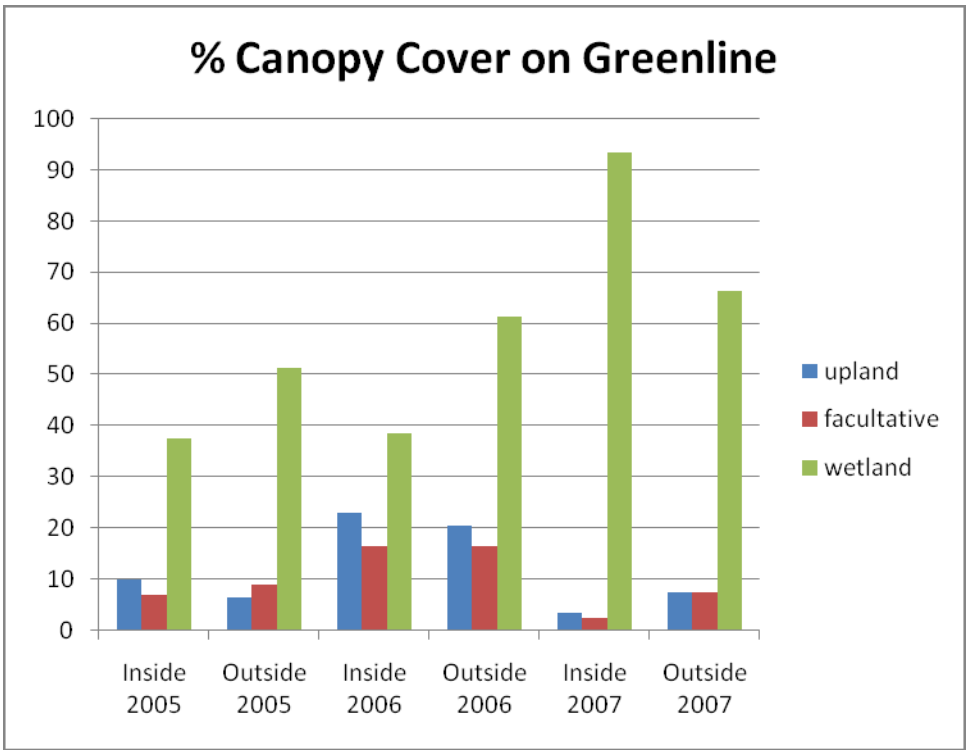


Figure 7. Percent canopy cover measured in Daubenmire plots along the greenline. The indicator categories follow Reed (1988) and were combined as follows: "wetland"= OBL, FACW, FACW+,

FAC+; "facultative"=FAC, FACW-; "upland"=FAC-, FACU, UPL and upland species not classified in the national list for the Southwest (Region 7).

Interestingly, the species diversity was more variable on the greenline inside the exclosure between years. Fewer species were consistently present all 3 years (21% versus 31% outside) inside the exclosure (Table 4). An additional 16 species were recorded in 2006 over the 2005 total; the same year watercress provided only 3% canopy cover. However, the count dropped again in 2007, due to the dominance of watercress at 71% cover. In contrast, a greater percentage of species were present all 3 years outside the exclosure (31%), the number of species present each year remained similar, and watercress did not increase outside the exclosure to the extent it did inside. The extent to which watercress had rooted and spread across the water surface, greatly influenced where the Daubenmire plots were placed. This should be considered when interpreting the perceived differences in species composition and diversity at the greenline. Many species may have still been present, but the greenline width had increased and they no longer fell within the plot area.

Less dominant wetland species, present every year, inside and outside the exclosure included: sand spikerush (*Eleocharis montevidensis*), fringed willow herb (*Epilobium ciliatum*), smooth horsetail (*Equisetum laevigatum*), Rocky Mountain rush (*Juncus saximontanus*), curlytop knotweed (*Polygonum lapathifolium*), and panicled bulrush (*Scirpus microcarpus*). Other wetland species that comprised <2% of the canopy cover and/or were rarely documented (they may have only been found in one year or along 1 transect) are listed in Appendix A with a wetland classification (Reed 1988) developed by the U.S. Fish & Wildlife Service and cooperatively reviewed by major federal agencies involved with wetland identification and management. Wetland obligate species that occurred on the greenlines, inside and outside, are listed in Table 5 below.

Inside Exclosure. Although total canopy cover increased between years inside the exclosure, in 2006 there was an increase in facultative and upland species, and no change in wetland species (Figure7). Watercress dominated the canopy cover in 2005 and 2007 (21% and 71% respectively). A trace amount of woody plants were observed along the greenline. Narrowleaf cottonwood was recorded in a Daubenmire plot at <1% cover in 2005 and 2006, and Goodding willow at <1% in 2007. The only shrub documented was false indigo, contributing <1% cover in 2005 and 2006. No other willow species were documented in Daubenmire plots along the greenline. Species that provided less than 1% canopy cover are not reported in the following year summaries.

In 2005, the greenline was dominated by 21% cover of watercress, 3% cover of red top, 3% cover of tall fescue, 3% cover of curlytop knotweed, 2% cover of field horsetail (*Equisetum arvense*), 2% cover of monkey flower (*Mimulus guttatus*), and 2% cover of common mullein (*Verbascum thapsus*).

In 2006, the greenline was dominated by 11% cover of creeping bentgrass (*Agrostis stolonifera*), 9 % cover of tall fescue, 5% cover of smooth horsetail, 5% cover of fringed willowherb, 4% cover of Rocky Mtn. rush (*Juncus saximontanus*), 3% cover of watercress, 2% cover of spearmint (*Mentha spicata*), 2% cover of cutleaf coneflower (*Rudbeckia*

laciniata), 2% cover Italian ryegrass (*Lolium perenne ssp. multiflorum*), and 2% cover hairy

Table 5. Percent cover for wetland obligate species recorded in Daubenmire plots along the greenline.

Wetland Obligate Species on Greenline		2005		2006		2007	
Scientific Name	**Common Name**	**Inside**	**Outside**	**Inside**	**Outside**	**Inside**	**Outside**
Carex senta	swamp carex (r*ough carex)*						6
Cicuta douglasii	western water hemlock					1	1
Juncus articus var. mexicanus	Arctic rush			<1%			
Juncus effusus	common rush (soft rush)	1	<1%			<1%	
Lemna sp.	duckweed						
Lolium perenne ssp. multiflorum	Italian ryegrass			2			
Mimulus guttatus	monkey flower	2	1			3	1
Nasturtium officinale*	watercress	21	19	3	15	71	36
Polygonum lapathifolium	curlytop knotweed	3	<1%	<1%	4	<1%	<1%
Potamogeton pusillus	small pondweed					<1%	
Salix gooddingii	Goodding willow					<1%	<1%
Schoenoplectus tabernaemontani	softstem bulrush			<1%	3	<1%	3
Scirpus americanus	American bulrush			<1%		<1%	<1%
Scirpus microcarpus	panicled bulrush	<1%	1	<1%	4	1	3
Veronica anagallis-aquatica	water speedwell	1	1	<1%		3	<1%

* *Introduced species.*

false goldenaster (*Heterotheca villosa var. pedunculata*), and 2% cover of blue grama grass (*Bouteloua gracilis*).

In 2007, the greenline was dominated by 71% cover of watercress (a 68% increase from 2006), 4% cover of red top, 4% cover of sand spikerush, 3% cover of monkey flower, 3% cover of water speedwell *(Veronica anagallis-aquatica*), and 2% cover of fringed willowherb. Two wetland obligate species, Goodding willow and western water hemlock *(Cicuta douglasii)* were detected for the first time (<1% cover and 1% cover respectively). The greenline to greenline measurements and photopoints further indicated watercress had rooted further into the middle of the stream channel, contributing largely to the change in species composition at the greenline since 2005 (Photo 4 & 5).

Outside Exclosure. Total canopy cover also increased outside of the exclosure between 2005 and 2007 along the greenline; however it decreased by 12% between 2006 and 2007. With the exception of 2007, wetland species comprised a greater % of the total canopy cover outside of the exclosure than inside (Figure 7). It is important to note that this was also the baseline condition in 2005. A trace amount of woody plants were observed along the greenline. Narrowleaf cottonwood was recorded in a Daubenmire plot at <1% cover in 2005 and 1% in 2006 and 2007. Two willow species were present. Goodding willow and red willow (*Salix laevigata*); each as <1% cover in 2007. The only shrub documented was false indigo at 1% cover in 2006. Species that provided less than 1% canopy cover are not reported in the following year summaries.

In 2005, the greenline was dominated by 19% cover of watercress, 16% cover of yellow nutsedge *(Cyperus esculentus),* 5% cover of red top, 3% cover of tall fescue, and 2% cover of field horsetail. This composition was very similar to inside the exclosure, with the exception of the yellow nutsedge. There were several other species in common with the inside exclosure greenline, but they comprised <1% of the canopy cover on the outside greenline. Common rush *(Juncus effusus)*, a wetland obligate, was detected at <1% of the cover.

In 2006, the greenline was dominated by 15% cover of red top, 15% cover of watercress, 14% cover of fringed willowherb, 8% cover of tall fescue, 6% cover of brown sedge (*Carex subfusca*), 4% cover of field horsetail, 4% cover of curlytop knotweed, 4% cover of panicled bulrush, 3% cover of softstem bulrush (*Schoenoplectus tabernaemontani*), and 2% cover of sand spikerush.

In 2007, the greenline was dominated by 36% cover of watercress, 6% cover of red top, 6% cover of swamp carex *(Carex senta),* 4% cover of field horsetail, 3% cover of sand spikerush, 3% cover of panicled bulrush, 3% cover of softstem bulrush, 2% cover of fringed willowherb, and 2% cover of crownvetch. Goodding willow and red willow were detected for the first time as previously discussed. Monkey flower (1%), western water hemlock (1%), and American bulrush (*Scirpus americanus*) (<1%) all wetland obligates; were detected for the first time outside of the exclosure.

Floodplain.--The plant community growing on the floodplain was predominantly herbaceous species, similar to the greenline. The factors influencing floodplain vegetation within the sample area (within 30 ft. of water's edge) such as soils, aspect and elevation remained largely unchanged during the 3-year monitoring period. We found that the moisture gradient away from the water's edge and the varying elevation of the floodplain relative to the active channel supported obligate wetland, facultative wetland, facultative upland and upland species found in drier environments (Photos 6 & 7). Thus, the species composition on this feature included a diverse assemblage of wetland and upland species. Both monitoring reaches, inside and outside, had right and left bank differences in elevation of the floodplain relative to the active channel. Inside the exclosure the left bank was steep and the vegetated greenline narrow; a terrace sat at a much higher elevation than the channel and vegetation on the terrace included primarily upland meadow species. The opposite bank was at similar elevation to the channel and the floodplain was extensive including an old channel (Photo 6). The same differences for right and left banks are true for the monitoring reach outside the exclosure (Photo 7). In the future, vegetation trends may need to be analyzed separately for right and left bank features in order to detect changes that may be a result of differing moisture gradients and floodplain elevations.

During the 3-year period 75 plant species were recorded on the floodplain inside the exclosure and 79 outside (Table 4). Between 10 and 30% of the species present were wetland species (Figure4b). Although the proportion of native versus introduced species between years was fairly constant, there were slightly more native than introduced species on the floodplain, inside and outside the exclosure (Figure 5b). Total canopy cover increased on the floodplain between 2005 and 2007 inside the exclosure, but was more variable outside (Figure 8). Canopy cover on the floodplain was dominated by upland species all 3 years (Figure 9). The proportion of wetland species to facultative species varied both inside and outside the exclosure between years. There was more cover from wetland species inside the exclosure in 2006 and 2007. Overall, western wheatgrass (*Agropyron smithii*), ragweed (*Ambrosia psilostachya*), and red top dominated the floodplain composition outside of the exclosure, comprising a between year average of 11.3%, 11% and 8.3% (respectively) of the plant community. Inside the exclosure we found that blue grama grass (12.3%), tall fescue (11.3%) and red top (7.6%) dominated, and to a lesser extent ragweed (6%) all 3 years (3-year averages). Redtop, tall fescue, and the horsetails represent the most dominant facultative wetland species to occur on the floodplain. Other species present every year on the floodplain, inside and outside the exclosure, although not always dominant included: yarrow (*Achillea millefolium*), bull thistle (*Cirsium vulgare*), yellow sweet clover (*Meliotus officinale*) and common plantain (*Plantago major*).

Photo 6. Upstream view of Canyon Creek inside of the elk exclosure, fall 2007. The greenline and floodplain features within the sampling area (≤ 30 ft of the water's edge) are dominated by a diverse plant community of predominantly herbaceous species.

Photo 7. Upstream view of Canyon Creek outside of the elk exclosure, fall 2006. The elevation of the floodplain varies along the sample reaches. Increases in elevation often result in drier conditions and the presence of upland species such as blue grama grass (Bouteloua gracilis).

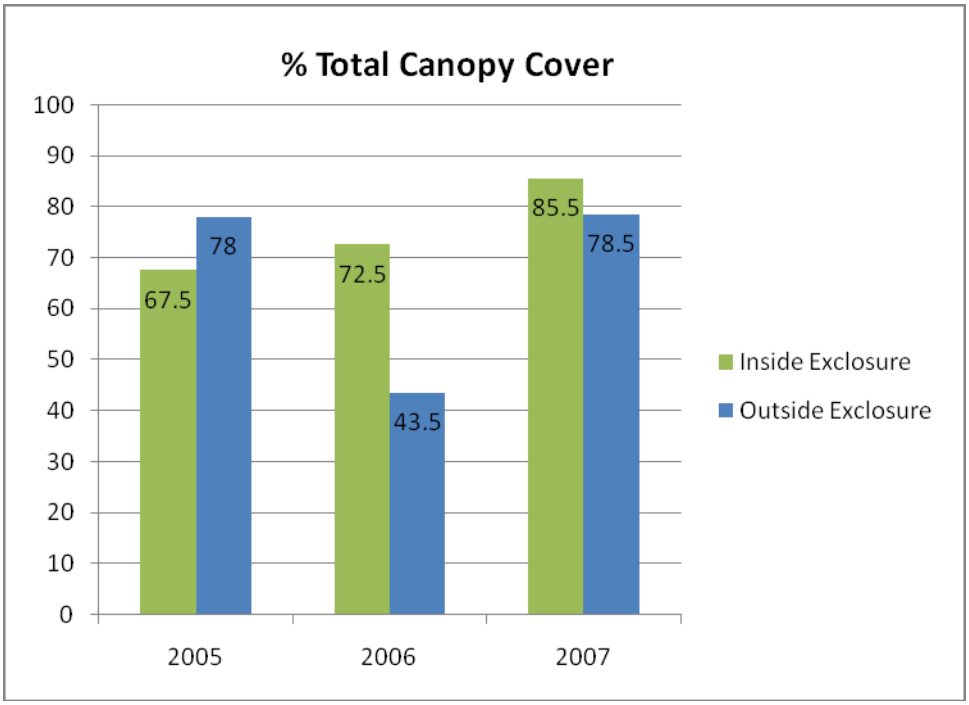


Figure 8. Total percent canopy cover measured in Daubenmire plots on the floodplain 2005-07.

Similar to the greenline, woody plants were infrequently encountered. Seedling narrowleaf cottonwood was present, but contributed only 1-2% to the overall composition between years. There are several stands of mature narrowleaf cottonwood (> 14" dbh) trees and many seedlings less than a year old (12" tall) growing throughout the valley bottom, but there are few saplings or poles of this species present. One exception is a small cottonwood stand inside the exclosure that has sprouted from mature trees burned in the fire (Photos 8a & b). We also observed seedlings of Arizona alder at a greater frequency inside the exclosure; however no alder were documented in the monitoring reaches (Photos 10a & b).

Photo 8. Re-sprouting narrowleaf cottonwood grove inside exclosure on Canyon Creek a) Left; Sept. 20, 2005 b) Right; June 25, 2008.

False indigo, a facultative wetland shrub, was the most dominant woody species, both inside and outside the exclosure, on the floodplain feature in 2005 and 2007. It comprised an average 5.7% of the composition and 4% of the canopy cover. It was not detected in 2006. Goodding willow and red willow each comprised an average of <2% of the species composition and were rarely observed on the floodplain inside and outside the exclosure, along the monitoring reaches.

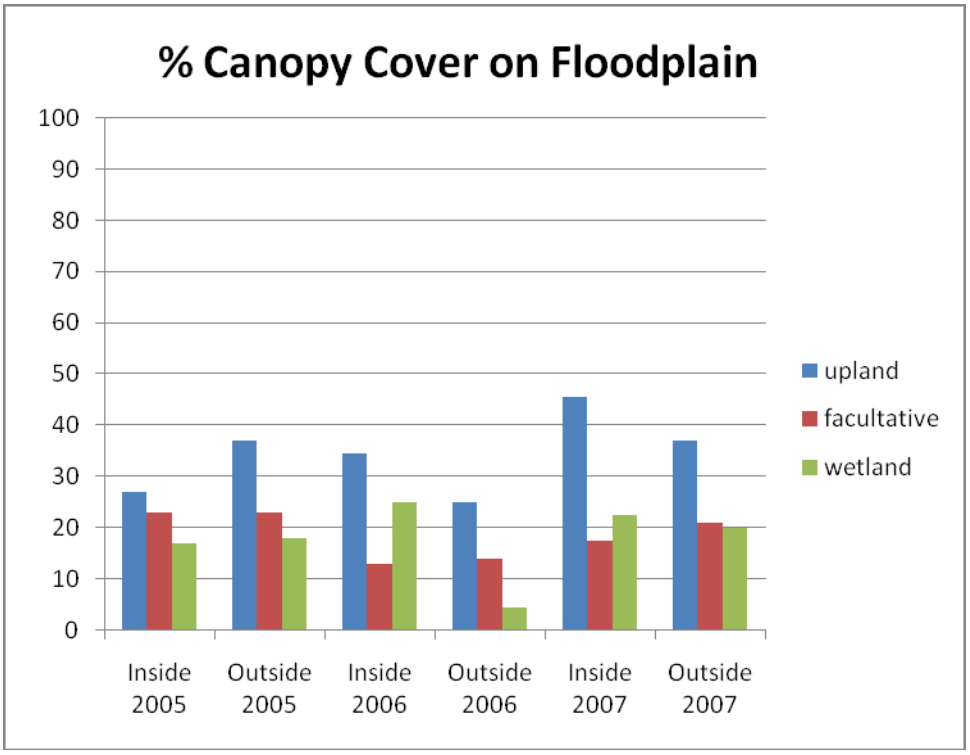


Figure 9. Percent canopy cover measured in Daubenmire plots on the floodplain. The indicator categories follow Reed (1988) and were combined as follows: "wetland"= OBL, FACW, FACW+; "facultative"=FAC, FAC+, FACW-; "upland"=FAC-, FACU, UPL and upland species not classified in the national list for the Southwest (Region 7).

Inside Exclosure. Total canopy cover on the floodplain increased steadily between years inside the exclosure, and exceeded amounts present outside of the exclosure in 2006 and 2007.

In 2005, the floodplain was dominated by a variety of upland, facultative and wetland species including: 8% cover of tall fescue, 7% cover of blue grama grass, 6% cover of ragweed, 5% cover of false indigo, 4% cover of red top, 3% cover of western wheatgrass, and 2% cover for each of the following: orchard grass (*Dactylis glomerata*), smooth horsetail, white panicle aster (Symphyothrichum lanceolatum spp. Hesperium, hairy false goldenaster, yellow sweetclover, Canada goldenrod (*Solidago canadensis*) and Kentucky bluegrass (*Poa pratensis*). Narrowleaf cottonwood contributed <1% to the canopy cover.

In 2006, composition on the floodplain remained similar to 2005. It was dominated by 8% cover of tall fescue, 7% cover of blue grama grass, 7% cover of redtop, 5% cover of western

wheat grass, 4% cover of smooth horsetail, 3% cover of deergrass (*Muhlenbergia rigens*), 3% cover of spike muhly (*Muhlenbergia wrightii*) and 2% cover for each of the following: orchardgrass, yellow sweetclover, common plantain, common mullen, white panicle aster (*Symphyotrichum lanceolatum* spp. *hesperium*) and 2% cover of sand spikerush (facultative wetland sp.). Other wetland species that contributed <1% cover each included: American bulrush, panicled bulrush, curlytop knotweed (obligate wetland sp.), arctic rush (*Juncus articus var. mexicanus*), Rocky Mtn. rush, and fringed willowherb. Narrowleaf cottonwood, Goodding willow, and red willow each contributed <1% to the canopy cover.

In 2007, a forb dominated the composition,11% cover of crownvetch, followed by: 10% cover of blue grama grass, 6% cover of tall fescue, 4% cover of smooth horsetail, 4% cover of redtop, 4% cover of soft brome *(Bromus arvensis)*, 4% cover of ragweed, 3% cover of deergrass, 2% cover of white sagebrush (*Artemisia ludoviciana ssp. sulcata*), 2% cover of Canadian horseweed, 2% cover of Kentucky bluegrass and 2% cover of common plantain. Once again, trees and shrubs were rare; we measured 4% cover of false indigo and a few individuals of Goodding willow and narrowleaf cottonwood (<1% cover each) in 2007. Other wetland species that contributed <1% cover included: American bulrush, softstem bulrush, arctic rush, fringed willowherb, sand spikerush, Rocky Mtn. rush, primrose (*Oenothera elata spp. hirsutissima*), common sheep sorrel (*Rumex acetosella*) and watercress.

Outside Exclosure. Total canopy cover on the floodplain was variable between years outside the exclosure. There was half as much cover in 2006 as in 2005 and 2007.

In 2005, the floodplain vegetation outside of the exclosure was comprised of a combination of wetland and upland species, similar to inside the exclosure. The floodplain was dominated by 8% cover of ragweed, 8% cover of western wheatgrass, 5% cover of false indigo, 4% cover of tall fescue, 4% black medick (*Medicago lupulina*), and 3% cover of each: red top, white sagebrush, redstem stork's bill (*Erodium cicutarium*), common plantain, curlytop knotweed, and threenerve goldenrod (*Solidago velutina*). Yarrow, field horsetail, Mexican lovegrass (*Eragrostis mexicana*), hairy false goldenaster, and yellow sweetclover provided 2% of the cover each. Trees and shrubs were rare; narrowleaf cottonwood provided 1% cover. Other wetland species that contributed 1% or less of cover each included: checker-mallow (*Sidalcea neomexicana*), common sheep sorrel, Italian ryegrass, fringed willow herb and smooth horsetail.

In 2006, there was less canopy cover on the floodplain and it was dominated by 6% cover of ragweed, 5% cover of *Bromus* sp., 5% cover of western wheatgrass, 2% cover of yarrow, and 3% cover of each: orchardgrass, black medick and red top. Other wetland species that contributed 1% or less of cover each included: common plantain, tall fescue, and field horsetail. Narrowleaf cottonwood contributed <1% cover.

In 2007, canopy cover increased and was dominated by 8% cover of red top, 6% tall fescue, 4% cover of ragweed, 4% cover of Southwestern cosmos (*Cosmos parviflorus*), 4% cover of squirrel tail (*Elymus elymoides*), 3% cover of each redstem stork's bill (*Erodium cicutarium*), and 2% cover of each; false indigo, blue grama grass, Canadian horseweed,

sand spikerush, Kentucky bluegrass, red clover and weeping lovegrass. Other wetland species that contributed 1% or less of cover each included: field and smooth horsetail, fringed willowherb, Rocky Mtn. rush, panicled bulrush, common plantain, common sheep sorrel, watercress, softstem bulrush, primrose and Italian ryegrass. Narrowleaf cottonwood contributed 1% cover.

Ground Cover.--The ground cover compositions were consistent between years on the floodplain inside and outside of the exclosure (Table 6). Inside of the exclosure, silt contributes over half of the composition. Outside of the exclosure, silt comprises one-third of the ground cover. Litter comprised the next greatest cover class, averaging 19% inside and 32% outside the exclosure, with decreases in 2007. While the floristic diversity at Canyon Creek was high, the ground cover composition indicated low densities of plants on the floodplain feature, within 30 feet of waters edge. In 2007, percent ground cover of live basal vegetation was 17.5% inside and 15.8% outside, the highest in the 3-year period. Over time we expect that "hits" on live basal vegetation may increase most significantly inside the exclosure.

Due to periodic floods we expect that silt, gravel and sand cover compositions may be highly variable. During our monitoring period sand and gravel cover compositions were far more variable than silt, and there are no trends to report. The percent ground cover of silt did increase between years, inside and outside the exclosure by approximately 7%. This slight increase was consistent with increases in live basal vegetation and suggests improving floodplain conditions. However, that improvement may be transient. During the winter of 2008 (post-monitoring), a significant flood scoured cobble bars along Canyon Creek and it appears that many fine sediments and gravels were removed and deposited downstream in new locations. Future monitoring will quantify the changes that flooding may have caused.

Table 6. Ground cover composition of the floodplain feature along Canyon Creek in 2005, 2006, and 2007.

	Inside Elk Exclosure			Outside Elk Exclosure		
Ground Cover Categories	**2005**	**2006**	**2007**	**2005**	**2006**	**2007**
Silt (<.062 mm)	50.0	60.0	56.7	35.8	37.0	42.5
Sand (.062 - 2 mm)	5.8	0.8	0.8	0.0	0.0	0.0
Gravel (2mm - 6.4 cm)	2.5	0.8	6.7	9.2	0.0	6.7
Cobble (6.4 - 25.6 cm)	8.3	13.3	5.8	13.3	22.2	8.3
Boulder (25.6 - 409.6 cm)	3.3	2.5	1.7	0.8	1.9	0.0
Bedrock (>409.6 cm)	0.0	0.0	0.0	0.0	0.0	0.0
Litter	24.2	21.7	10.8	34.2	34.3	26.7
Litter > 3"	1.7	0.8	0.0	1.7	2.8	0.0
Attached Litter	0.0	0.0	0.0	0.0	0.0	0.0
Live Veg. (basal)	4.2	0.0	17.5	5.0	1.9	15.8

Greenline to Greenline Width.-- Baseline data was collected in 2005, following construction of the exclosure and prior to the winter/spring elk use period. Both stream reaches (within and downstream of the exclosure) appeared to have similar greenline-to-greenline average widths and standard deviations (Table 7). Monitoring indicated a narrowing of the non-vegetated stream width both inside and outside the exclosure in 2006 (Figures 10 & 11). In 2007, the greenline-to-greenline width and standard deviation decreased within the exclosure. These changes corresponded to increases in total canopy cover inside the exclosure. Changes along the greenline inside the exclosure in 2007 were largely due to a 96% increase in canopy cover by watercress (3% cover in 2006 versus 71% cover in 2007).

Table 7. Comparison of greenline to greenline measurements between years.

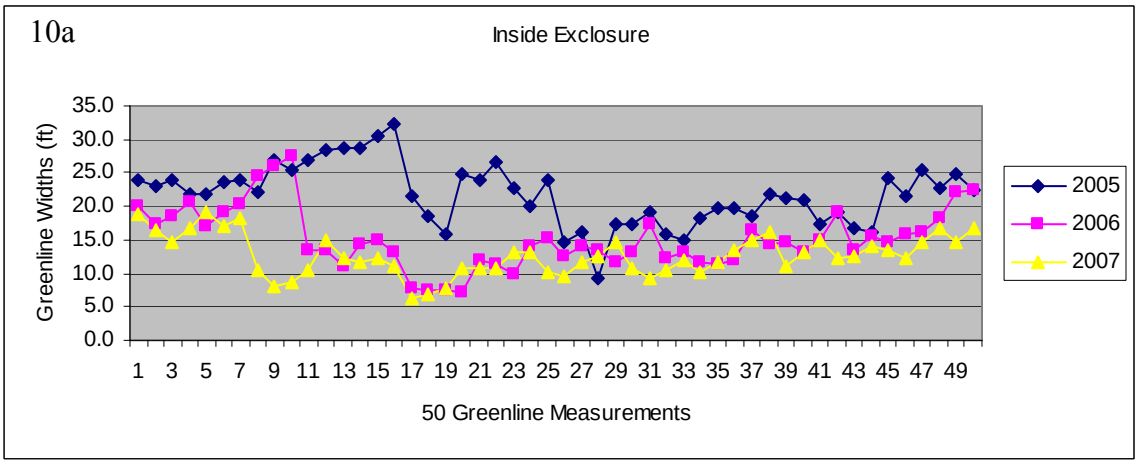
Survey Year	Average Width (ft.)		Stand Dev. (ft.)	
	Inside Excl	Outside Excl	Inside Excl	Outside Excl
2005	21.70	20.31	4.54	4.74
2006	15.17	15.36	4.52	5.28
2007	12.54	15.27	3.02	5.15

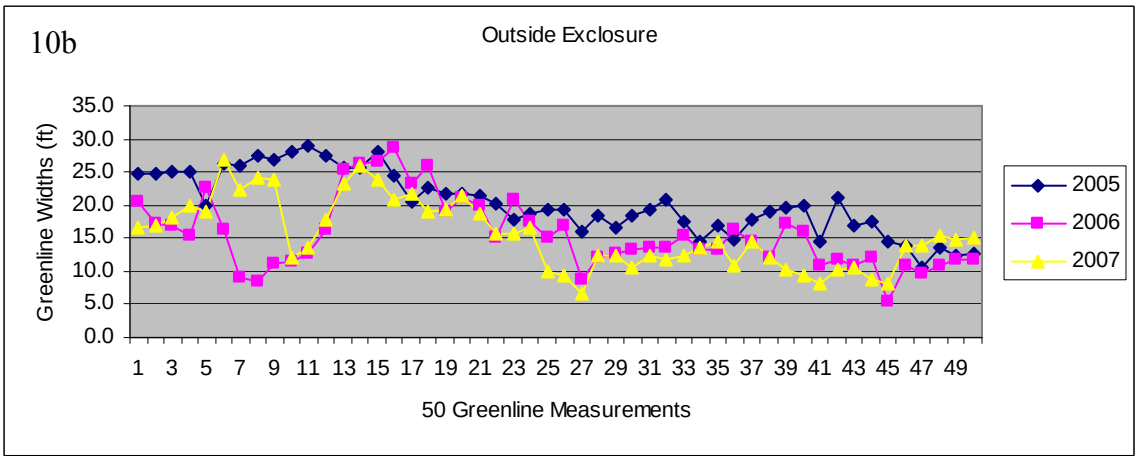
Woody Plant Density.--Woody plant density was not measured in 2005, 2006 or 2007 because there were only a few individuals and species; those were documented in the Daubenmire plots for the first time in 2006. Based on 2007 monitoring, future monitoring should include woody plant density transects to begin to capture baseline conditions. An evaluation of the appropriate belt width for transects should be considered, prior to implementing the proposed methodology.

Botanical Inventory.--The composition of the Canyon Creek flora represents the unique attributes of a wetland community including high diversity, obligate wetland species, underrepresented entities, and sensitive taxa. Perennial streams and wetland habitats are relatively rare on the Tonto National Forest, and conservation of vegetation in these areas is of special importance to wildlife. A botanical inventory was conducted concurrent with the riparian monitoring effort in order to document this flora and capture species that were not noted in the plot data. One hundred seventy-nine species in 49 families were identified from 4 collecting trips (summer/fall 2005, 2006, 2007; and spring 2008) One hundred twenty-five are vouchered and placed in the Forest Service Herbarium at the Tonto Supervisor's Office. These species numbers are indicative of the remarkable diversity of Canyon Creek and riparian areas of the Tonto. Though far from comprehensive, this list may serve as baseline data for future studies (Appendix B, Table 17).

Bowers and McLaughlin (1982) examined the factors that contribute to relative diversity among local floras in Arizona. They found that 77% of absolute diversity (i.e., the number of species in a flora) is a function of elevation range and collecting time. The remaining 23% appear to be related to vegetation community type, presence or absence of aquatic habitats, and presence or absence of canyon environments. They developed an equation to predict

Figure 10. Greenline to greenline widths measured at 50 6-foot intervals, centered on the channel cross sections a) inside exclosure and b) outside exclosure.





number of species expected based on elevation range and collecting time, where $\hat{S}$ = expected number of species, E = elevation range in meters, and T = collecting time to the nearest 0.5 year, shown below:

$$\hat{S} = 47 + 0.349E + 8.20T.$$

For the Canyon Creek flora, using conservative numbers, the following equation results:

$$\hat{S} = 47 + 0.349(10) + 8.20(3) = 75$$

The actual number of species observed (179), indicates that there are factors other than elevation range and collecting time contributing to the richness of the area. Bowers and McLaughlin went on to derive an expression of relative richness for the Arizona floras examined, where R = relative richness and S = observed number of species:

$$R = 100(S - \hat{S}) \div \hat{S}.$$

Applied to the Canyon Creek flora, the following equation results:

$$R = 100(179 - 75) \div 75 = 139.$$

R-values express the extent to which factors other than elevation range and collecting time contribute to the absolute diversity of the area. Therefore, an R-value of 139 means that there are 139% more species in the Canyon Creek flora than would be expected on the basis of elevation gradient and collecting time.

There are several factors that may explain the high levels of diversity in the Canyon Creek area; 1) Perennial water. Riparian areas constitute a small portion of the landscape but support a disproportionately large part of the total flora (McLaughlin 2000); 2) Geography. Canyon Creek is at a crossroads of several regional geographic elements and floristic provinces, which combine to increase diversity; 3) Longitudinal and latitudinal environmental gradients. Upstream as well as lateral environmental gradients contribute to heterogeneity of habitats. Plants detect and respond to fine scale changes in soil properties, soil moisture, competition, topography, etc. Boundary areas between ecotones are frequently high in diversity (Risser 1995); and 4) Fluvial dynamics. Flood patterns of variable magnitude, frequency, and duration increase successional stages, and therefore, species diversity (Ward & Tockner 2001, Pollack et al.1998).

Canyon Creek has many obligate wetland species with very limited distribution in Arizona. Graminoids include Mead's sedge (*Carex meadii*) awlfruit sedge (*Carex stipata*), small floating managrass (*Glyceria borealis*), and fowl mannagrass (*Glyceria striata*). Forbs such as water miner's lettuce (*Montia chamissoi*), western water hemlock (*Cicuta douglasii*), and checkerbloom (*Sidalcea neomexicana*) are similarly habitat-restricted.

There are also several examples of regional endemics such as swamp carex (*Carex senta*) bristle flax (*Linum aristatum*), Arizona valerian (*Valeriana arizonica*), and Macdougal verbena (*Verbena macdougalii*). Other notable collections from Canyon Creek include:

- Great Basin brome (*Bromus polyanthus*) – rare in Arizona.
- Nuttall's sunflower (*Helianthus nuttallii*) – rare in Arizona, only known from four other localities in Arizona.
- Field pepperweed (*Lepidium campestre*) – rare in Arizona, only known from four other localities in Arizona.
- Mexican muhly (*Muhlenbergia mexicana*) – rare in Arizona, only known from five other localities.
- Small pondweed (*Potamogeton pusillus*) – provides important aquatic habitat for microorganisms, invertebrates, fish, et al.
- Blackeyed susan (*Rudbeckia hirta*) – rare in Arizona, only known from one other locality in Arizona (Mohave Co., Mt. Trumbull area).

The personality of a flora is shaped by local physiographic attributes such as climate, geology, elevation, soils, etc. The Canyon Creek flora is a unique representation of some of the most important habitat on the Tonto National Forest. Twenty-two percent are obligate or facultative wetland species including many sensitive or rare taxa. Fourteen percent are introduced. Future botanical surveys will most certainly reveal other notable plants within the exclosure as species composition continues to change over time.

Channel Morphology

Cross Sections.--Four channel cross sections were installed to monitor changes both within and outside the exclosure. Cross section locations were selected, to the extent possible, at riffle locations within single thread channels, and that are lined with adjustable banks. It was not possible to find single thread channels that would contain the entire bankfull flow at most locations consequently some form of overflow channel exists at all but the below exclosure cross section. The below exclosure cross section may be located at a livestock water gap. Channel conditions at this location may be affected by livestock crossing the stream. Longitudinal profile data were not collected in 2007 because of the difficulty in relocating individual data point locations. Longitudinal profiles may not be a particularly meaningful monitoring tool. Cross section locations are displayed in Figure 11 below. Cross section data were presented as separate files in the 2005 (Bayer 2005), 2006 (Warnecke 2006) and 2007 (Warnecke 2008) project monitoring reports.

Although some of the ratios in the summary data presented in Table 8 have changed, this difference may be due to slight surveying differences between the monitoring years. Comparison of the cross section profiles does not suggest significant changes are occurring at this point in the monitoring program (Figures 12-15).

Measures from the cross section and longitudinal survey describe Canyon Creek as a C3 stream type (Rosgen 1996) within the project area. A C3 stream type is a slightly entrenched, meandering, large gravel-cobble dominated (alluvial) channel with a broad and well developed floodplain, gentle gradient (<2% slope) and characteristic point bars. According to a recent watershed assessment (Natural Channel Design, Inc. 2008) the predominant bedforms are runs and riffles, and few pools in the project area. They describe Canyon Creek having low to moderate sinuosity and a generally wide channel with good access to the floodplain and terraces. The "C" type stream can easily be "destabilized" by changes in watershed condition, flow regimes and stream bank condition (often referred to in terms of stability). In fact, there has been a long history of destabilizing events along Canyon Creek, with the most recent being the Rodeo-Chediski Fire.

Longitudinal Profiles.--Monitoring of longitudinal profiles was conducted at each of the cross section sites in 2005 and 2006. The longitudinal profile includes the elevation of various fluvial features, measured at sites perpendicular to locations on a tape stretched along the thalweg of the channel (Table 9). Repeat monitoring was conducted in 2006, at each of the locations identified on the tape in the original survey in 2005. The distance up and down stream of the cross section was used for establishing the repeat location of the tape. Judgement was needed to determine whether each monitoring site was perpendicular to the location on the tape and to identify the point on the fluvial feature that was recorded.

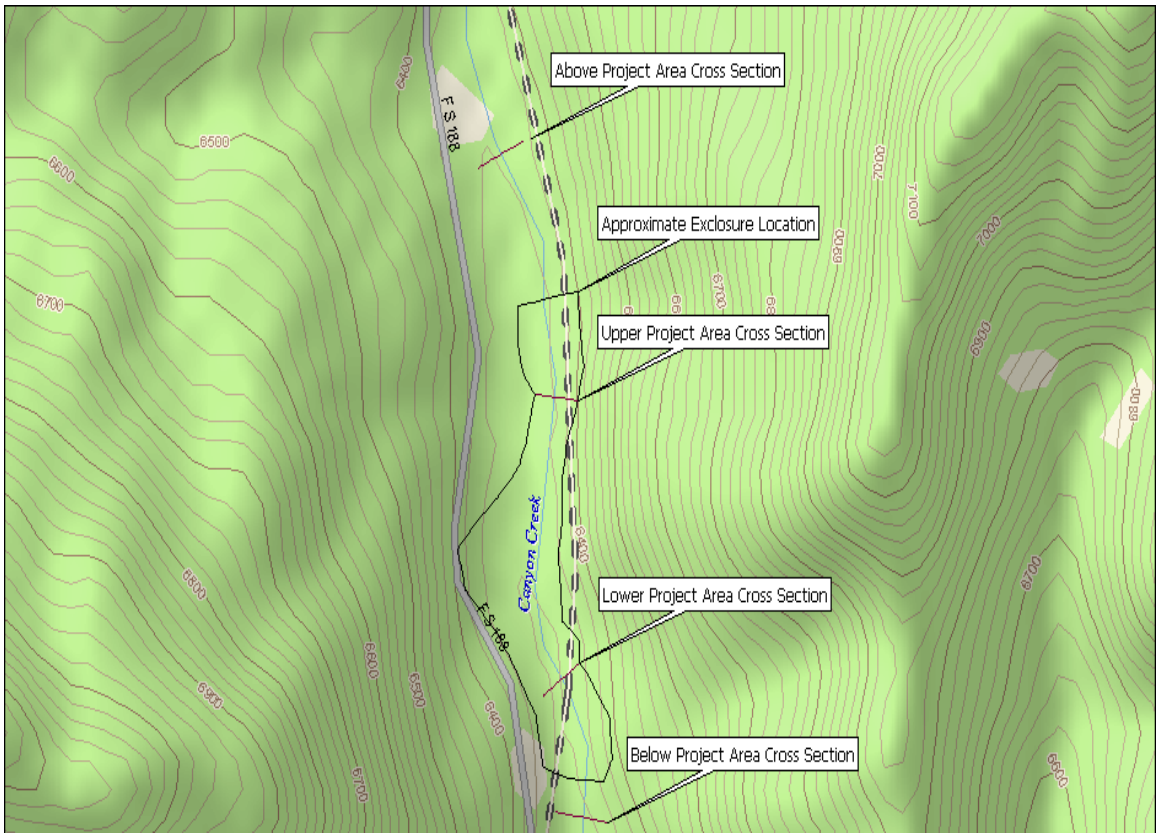


Figure 11. Cross section locations relative to the elk-livestock exclosure along Canyon Creek.

Table 8. Channel cross section summary for 3-year monitoring period at 4 channel cross section locations on Canyon Creek.

Cross Section ID	Year	Entrenchment Ratio	Width/Depth Ratio	Thalweg Slope	Dominant Channel Material	Stream Type
Upstream of Exclosure	2005	4.5	21.7	0.8%	Cobble	C3
	2006	5.0	16.9	1.2%	Cobble	C3
	2007	4.8	17.6	0.7%	Cobble	C3
Upper inside Exclosure	2005	2.0	46.2	1.5%	Cobble	B3c
	2006	1.9	48.4	1.3%	Cobble	B3c
	2007	2.0	53.5	1.8%	Cobble	B3c
Lower inside Exclosure	2005	>2.2	48.5	1.4%	Cobble	C3
	2006	>2.2	52.9	1.7%	Cobble	C3
	2007	>2.2	42.9	Error	Cobble	C3
Downstream of Exclosure	2005	2.6	27.3	0.6%	Cobble	C3
	2006	2.5	31.1	0.4%	Cobble	C3
	2007	2.2	35.1	0.9%	Gravel	C4

Difficulties with redefining the monitoring points in 2006 resulted in data that may not truly reflect changes occurring at the site. Longitudinal profile data were not collected in 2007 because of the difficulty in relocating individual data point locations. Longitudinal profiles may not be a particularly meaningful monitoring tool. Due to these difficulties no further interpretation of the data follows.

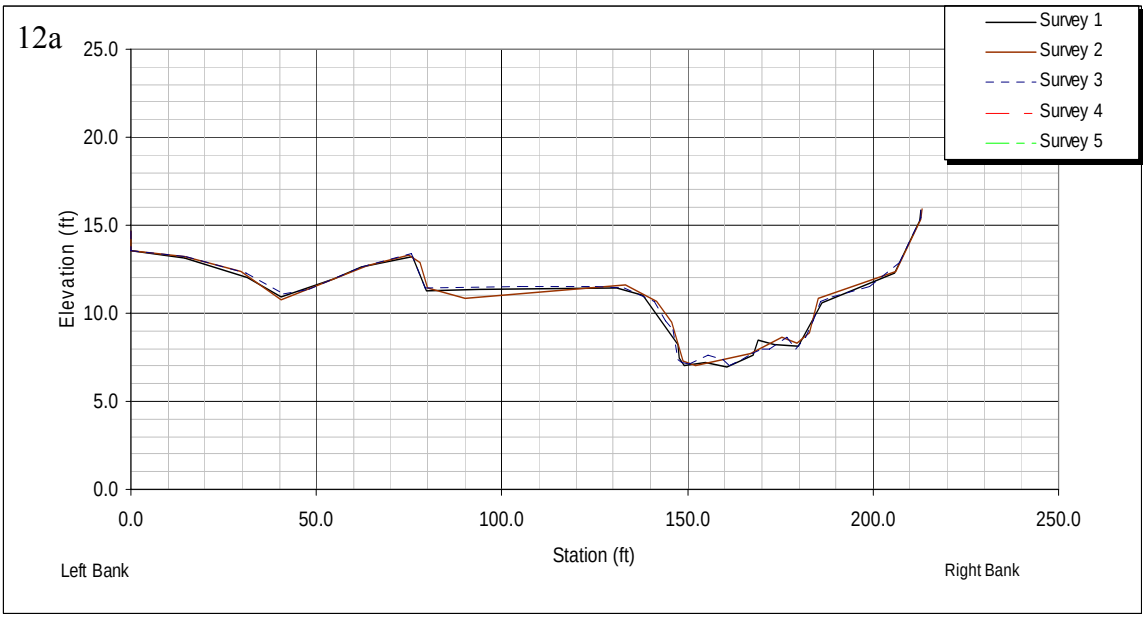
Establishment of additional cross sections is proposed as a method for more accurately identifying any changes that may be occurring in the elevations of fluvial features. In the future, additional channel cross sections, both outside the exclosure and inside the exclosure may be established to aid in detecting changes in the elevation of fluvial features.

Pebble Counts.--Pebble counts were collected at each of the cross sections in 2005, 2006, and 2007. Pebble count data are displayed in Table 10 and Figures 16-19.

Between 2005 and 2006, the percentage of silt/clay increased at all monitoring sites. The general impression of the monitoring sites was that emergent vegetation was present in greater volume and area extent than in the 2005 monitoring period. The emergent vegetation had trapped a substantial amount of silt/clay in the vegetation matrix and was probably the reason for the increase in the percentage of this particle size. The percentage of gravel as a component of the bed and banks was reduced at all monitoring sites except for the upper site within the exclosure. Gravel sized particles would be expected to deposit in sites of lower stream energy. It may be that the emergent vegetation also occupied these sites and the silt/clay sized particles trapped by the vegetation is forming a depositional layer on top of the gravels. Cobble remained the dominant component of the bed and banks.

Between 2006 and 2007, the percentage of silt/clay decreased at sites outside the exclosure and remained similar to the previous year within the exclosure. Emergent vegetation continued to trap fine sediments. The percentage of gravel as a component of the bed and banks increased at all monitoring sites except for the upper site within the exclosure, where it remained similar to the previous year. This development reversed the monitoring results from the previous year, but may not be significant (Statistical tests have not been developed for the data.). Gravel sized particles would be expected to deposit in sites of lower stream energy. Cobble remains the dominant component of the bed and banks at all sites except the site below the exclosure where there is a slightly higher percentage of gravel.

Figure 12. Cross section above exclosure a) Comparison of between year surveys: survey 1 is 2005, survey 2 is 2006, and survey 3 is 2007 b) cross section profile.



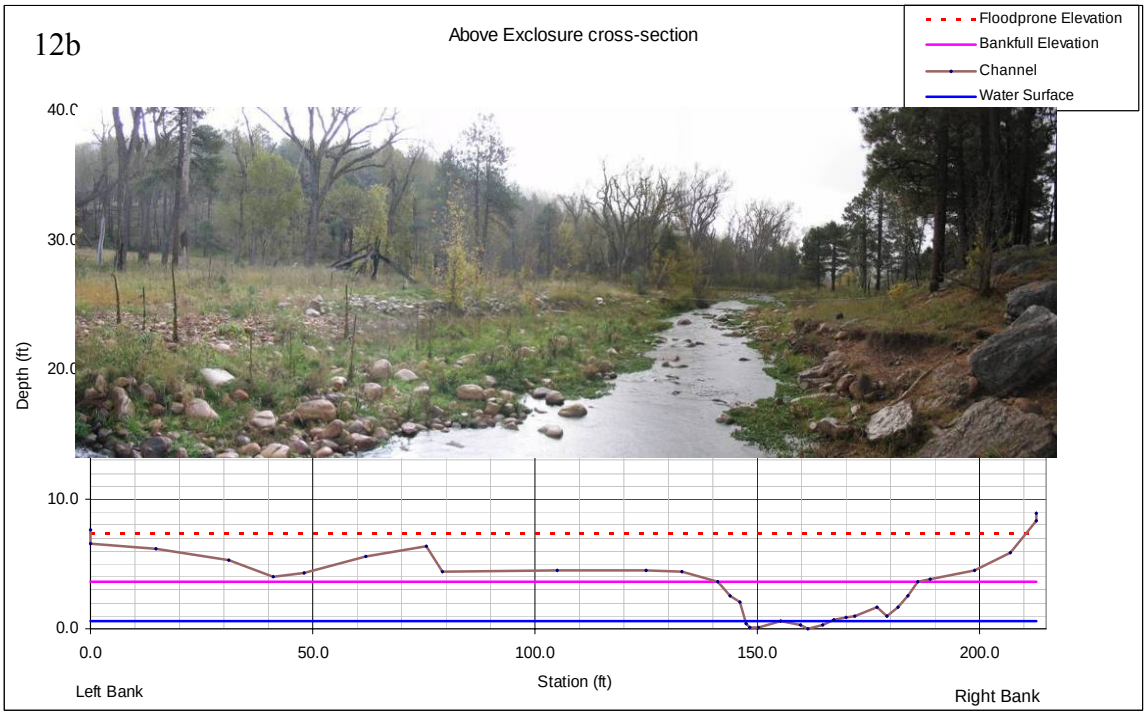
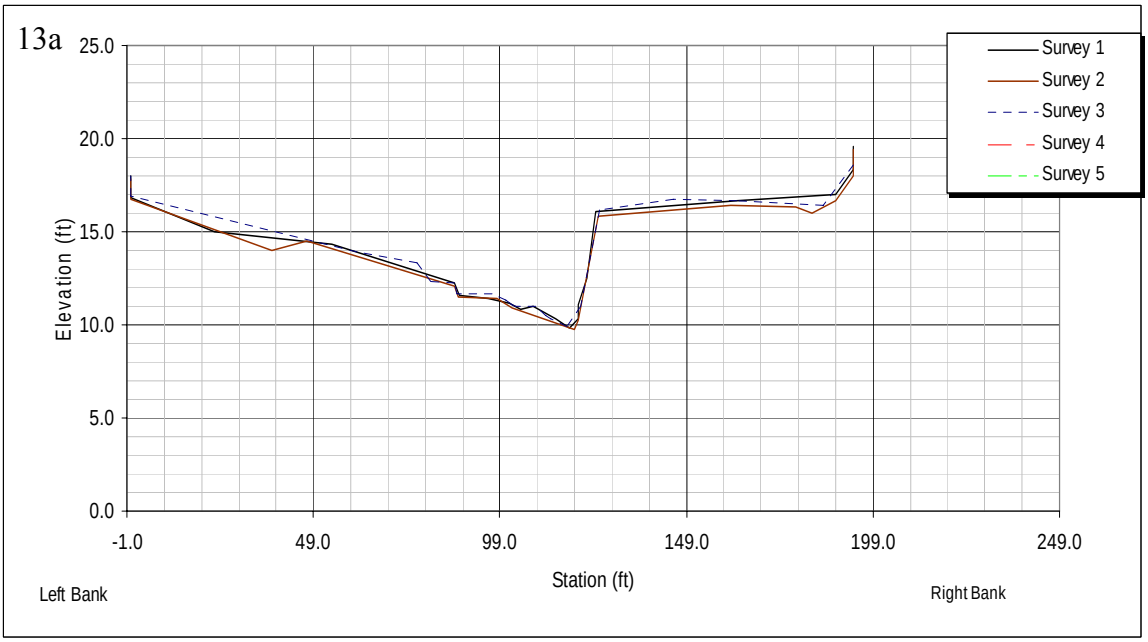


Figure 13. Cross section below exclosure a) Comparison of between year surveys: survey 1 is 2005, survey 2 is 2006, and survey 3 is 2007 b) cross section profile.



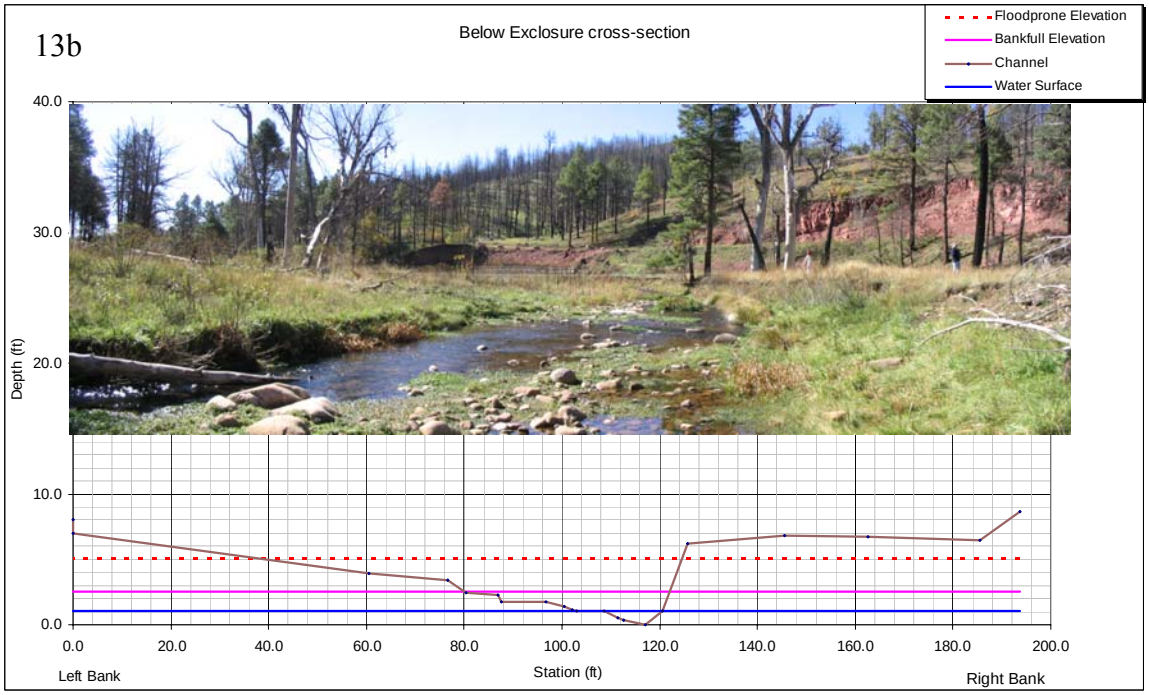
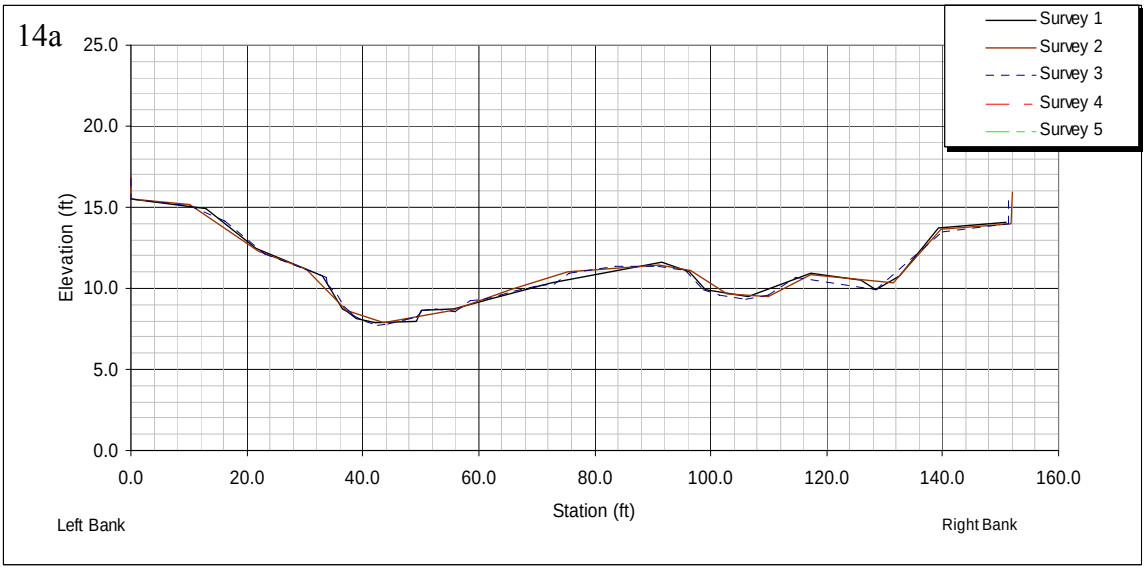


Figure 14. Upper cross section within exclosure. a) Comparison of between year surveys: survey 1 is 2005, survey 2 is 2006, and survey 3 is 2007 b) cross section profile.



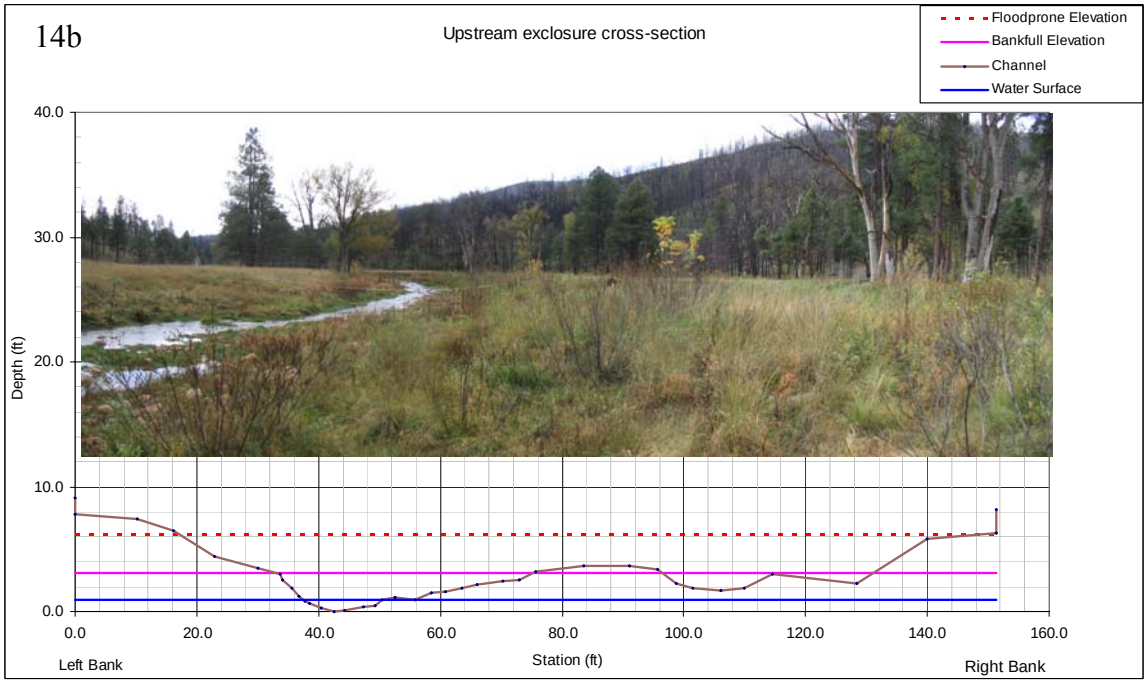
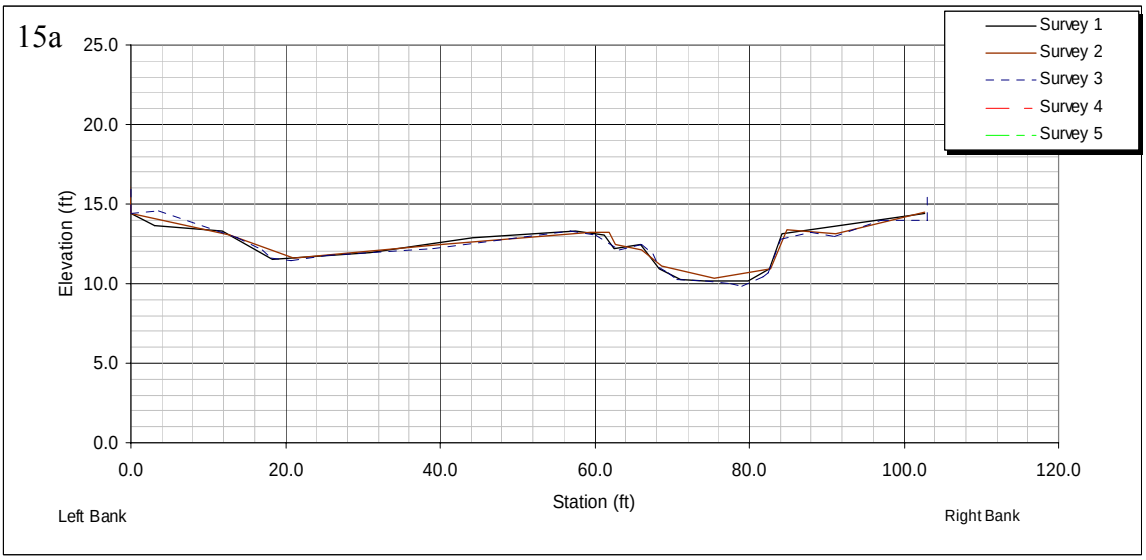


Figure 15. Lower cross section within exclosure. a) Comparison of between year surveys: survey 1 is 2005, survey 2 is 2006, and survey 3 is 2007 b) cross section profile.



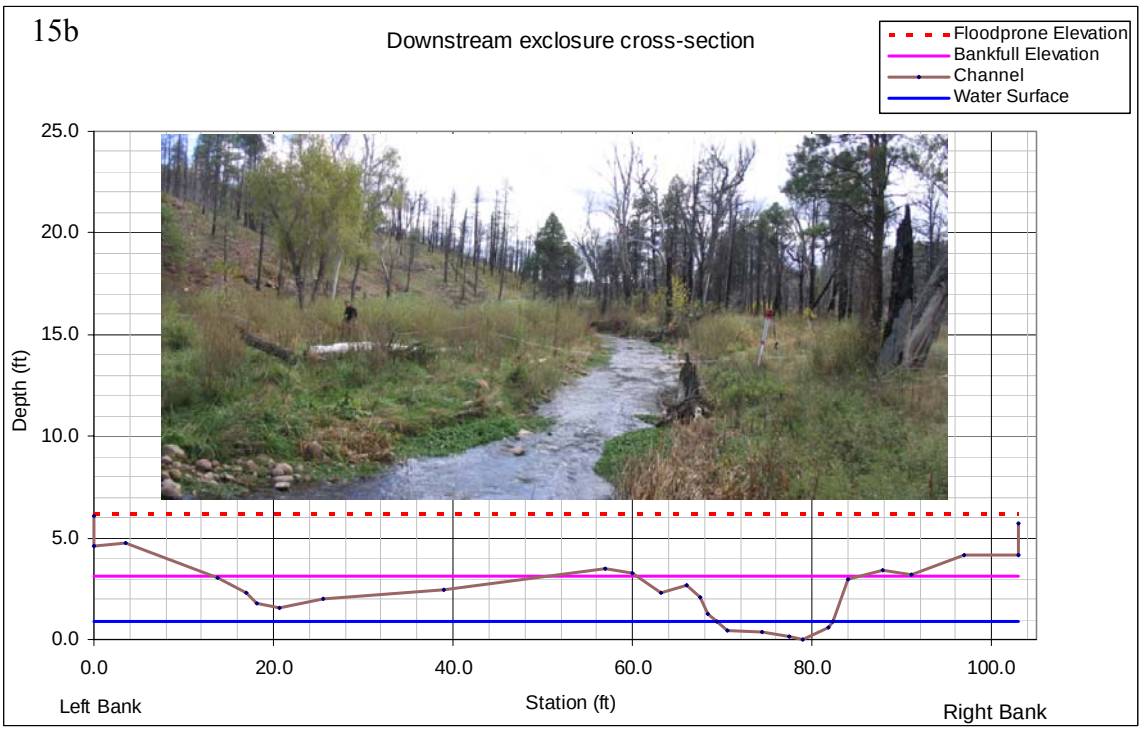


Table 9. Changes in vertical elevations (feet) of stream channel features measured by longitudinal profiles at four channel cross sections.

a. Above Exclosure - Elevation above water surface

Year	Terrace	Swale	Bar	Top of L Bank	Top of R bank
2005	5.57	3.52	5.12	3.74	3.62
2006	5.30	3.74	4.43	1.78	2.41
Difference	0.27	-0.22	0.70	1.96	1.22

b. Upstream inside exclosure - Elevation above water surface

Year	L upper terrace	L low terrace	L Greenline	R Greenline	Bar	Overflow Channel	R Terrace
2005	6.56	2.52	0.08	0.51	3.45	0.66	5.20
2006	6.71	2.81	0.87	2.29	3.62	1.14	5.09
Difference	-0.16	-0.29	-0.79	-1.78	-0.18	-0.49	0.12

c. Downsteam inside exclosure - Elevation above water surface

Year	L Terrace	overflow channel	L bar	R Terrace
2005	2.99	0.62	1.99	2.99
2006	3.16	0.51	1.41	2.73
Difference	-0.17	0.10	0.58	0.27

d. Below Exclosure - Elevation above water surface

Year	L Bank	point bar	R Bank	R Terrace
2005	1.70	0.05	1.37	5.37
2006	1.63	0.06	1.00	5.74
Difference	0.07	-0.01	0.36	-0.37

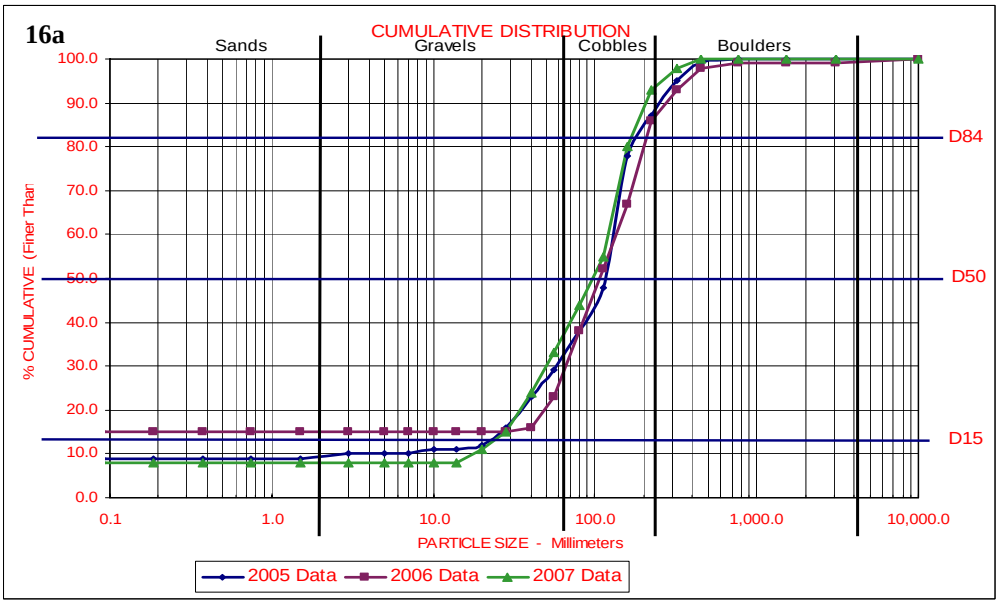
Table 10. Changes in substrate composition of stream channel bed and bank features measured at four channel cross sections.

% Particle Size Class	Year	Silt/Clay	Sand	Gravel	Cobble	Boulder	Bedrock
Above Exclosure	2005	9	0	20	58	13	0
	2006	15	0	8	63	13	1
	2007	8	0	25	60	7	0
Upper inside Exclosure	2005	0	2	16	68	14	0
	2006	10	0	15	63	12	0
	2007	12	0	12	68	8	0
Lower inside Exclosure	2005	0	3	35	57	5	0
	2006	10	0	13	74	3	0
	2007	9	1	25	62	3	0
Below Exclosure	2005	0	2	43	49	6	0
	2006	20	0	17	61	2	0
	2007	7	3	44	41	5	0

Channel Stability and Bank Stability.--Channel stability and bank erodibility ratings are based on ocular estimates of various rating factors which are scored on a rating sheet. Professional judgment about the various rating factors is necessary to score each factor. Both methods consequently involve a certain amount of subjectivity in the rating. Small changes in rating scores are probably not significant. The methods used were those presented in the Stream Reach Inventory and Channel Stability Evaluation Guide developed by Pfankuch (1975) and the Bank Erosion Hazard Rating Guide developed by Rosgen (1996).

Between 2005 and 2006 there appeared to be little change in the stream reach above the exclosure (Table 11 & 12). The change in bank erodibility class is based on a score change of only 1.5 points and should not be considered significant. There appeared to be some improvement in channel stability and bank erodibility conditions in the upper cross section within the exclosure. Scoring changes are based on an increase in root density, decrease in bank angle, and reduced evidence of scouring and deposition. The lower cross section within the exclosure had a slight improvement in scoring based on improvements in root density, surface bank protection, and reduced evidence of bank cutting. The cross section below the exclosure experienced a slight improvement in channel stability scoring based on small scoring changes in several rating factors. Small changes also occurred in the bank erodibility rating. These changes may be a result of the subjectivity inherent in the rating process rather than a reflection of changed conditions at the reach.

Figure 16. Pebble count data from above exclosure comparing 2005-2007 a) cumulative distribution and b) partical size classes.



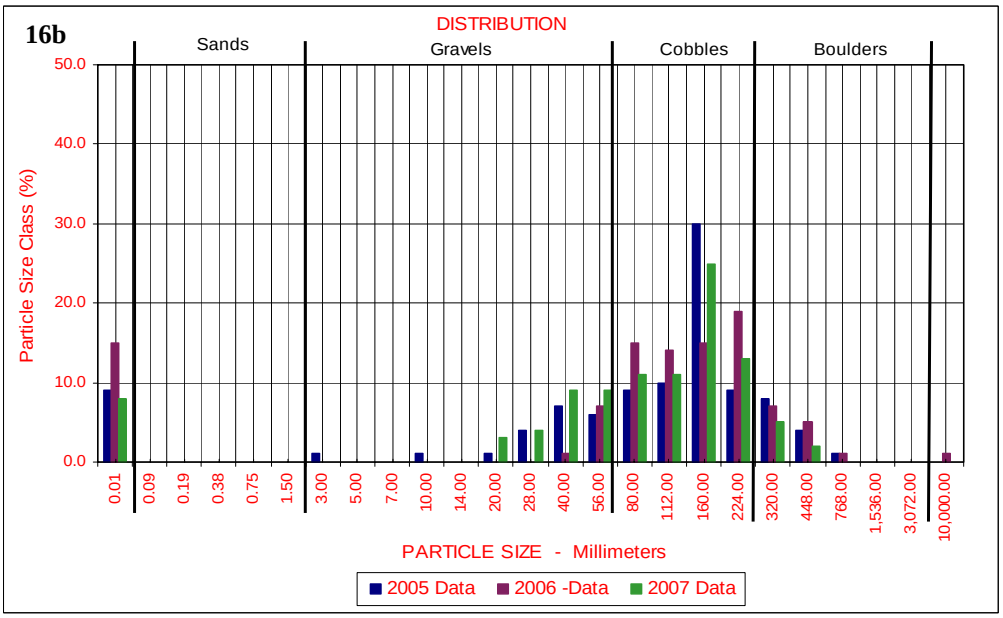
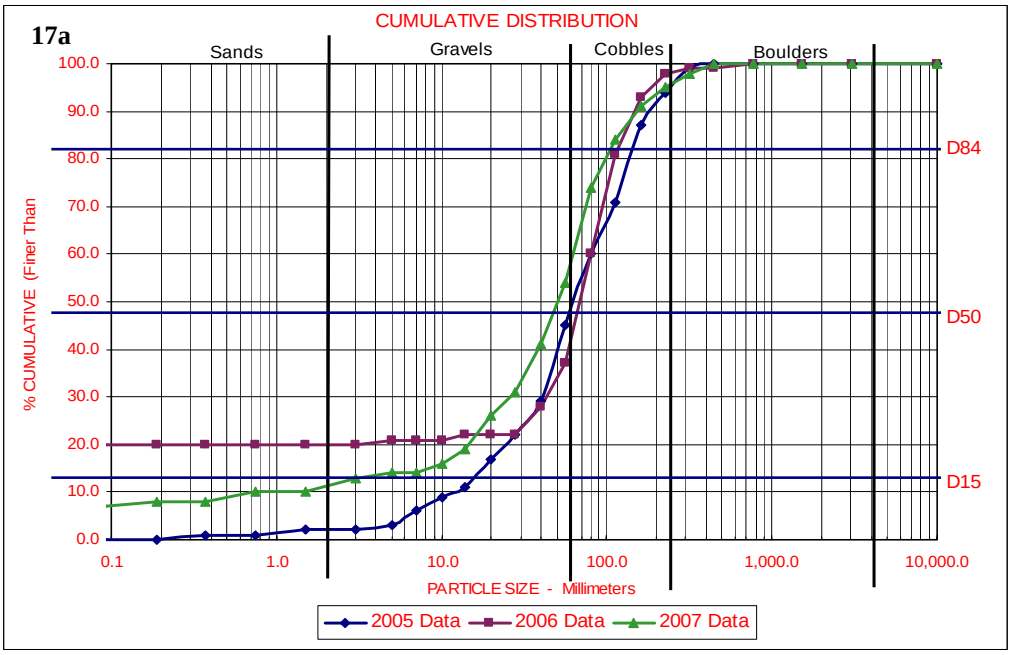


Figure 17. Pebble count data from below exclosure comparing 2005-2007 a) cumulative distribution and b) partical size classes.



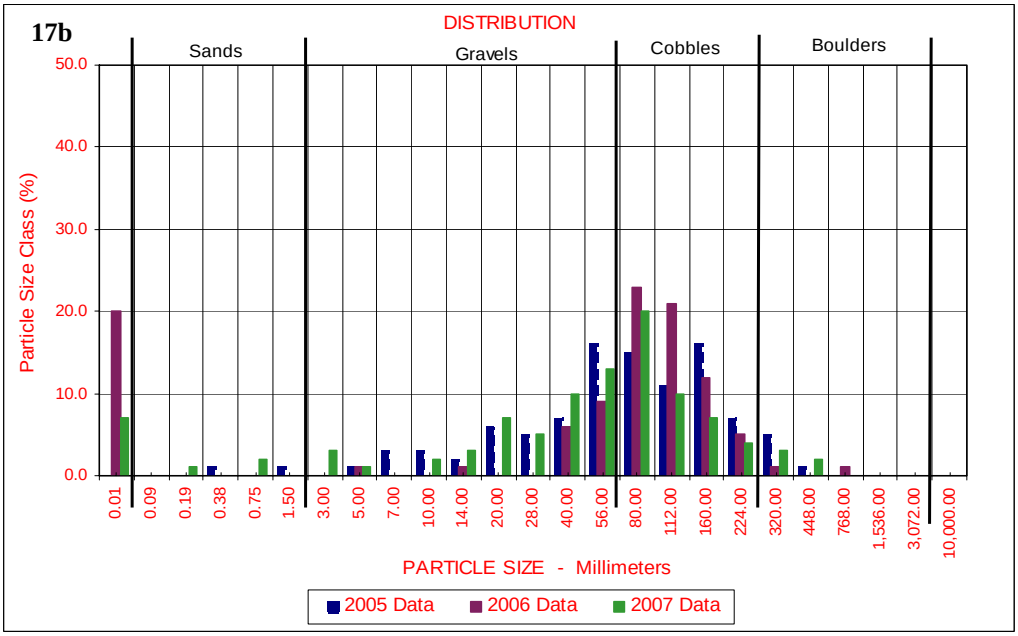
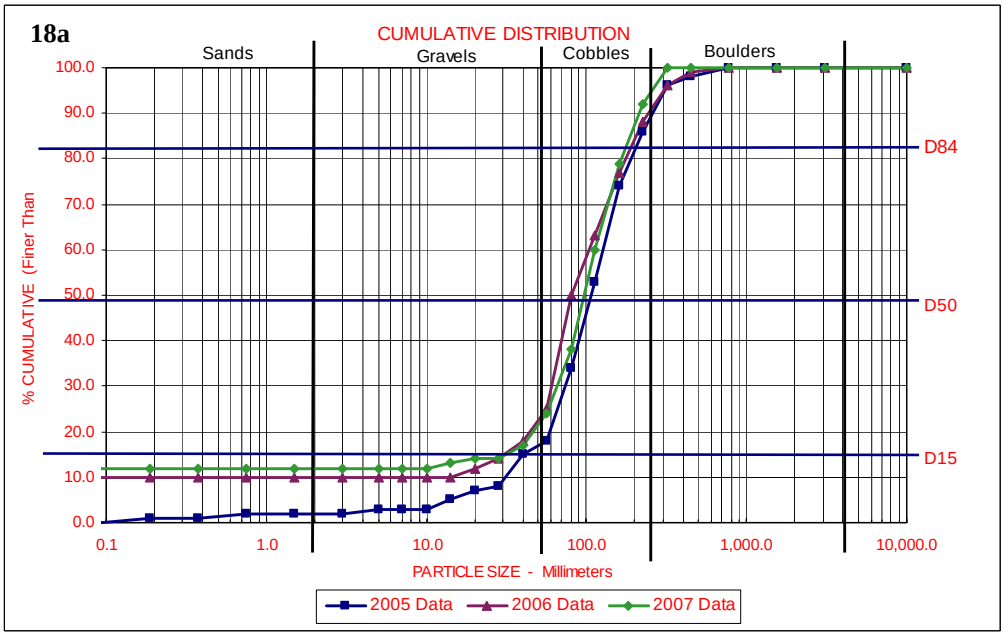


Figure 18a & b. Pebble count data from upstream in exclosure comparing 2005-2007 a) cumulative distribution and b) partical size classes.



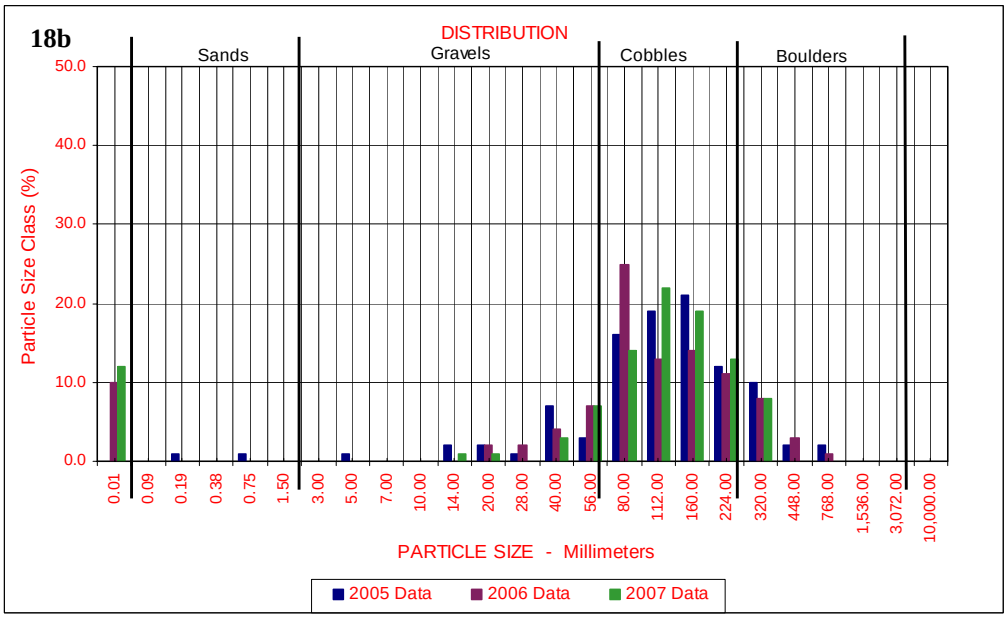
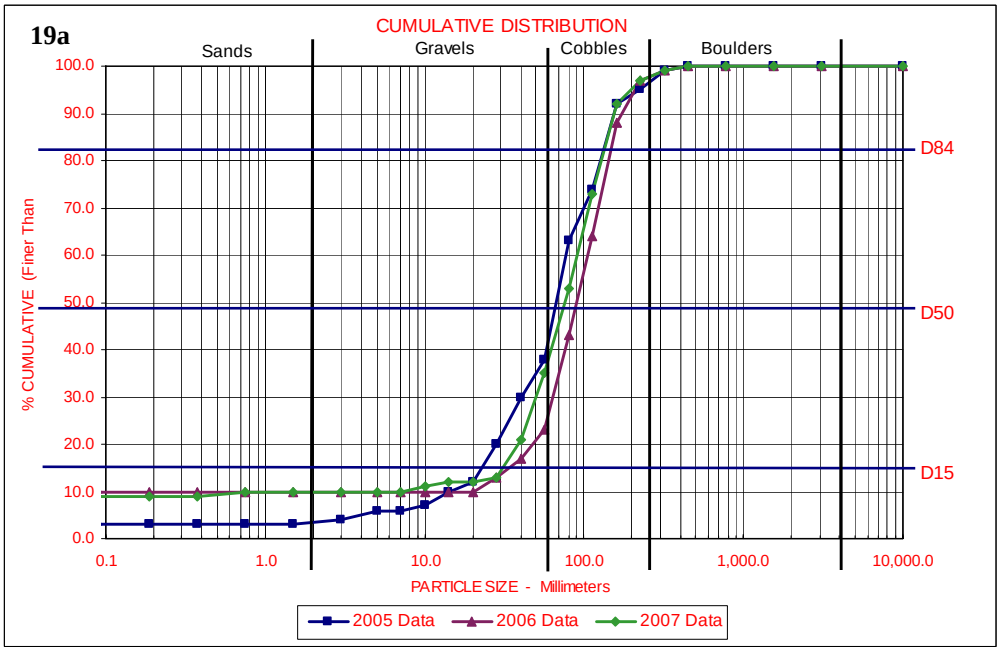


Figure 19. Pebble count data from downstream in exclosure comparing 2005-2007 a) cumulative distribution and b) particle size classes.



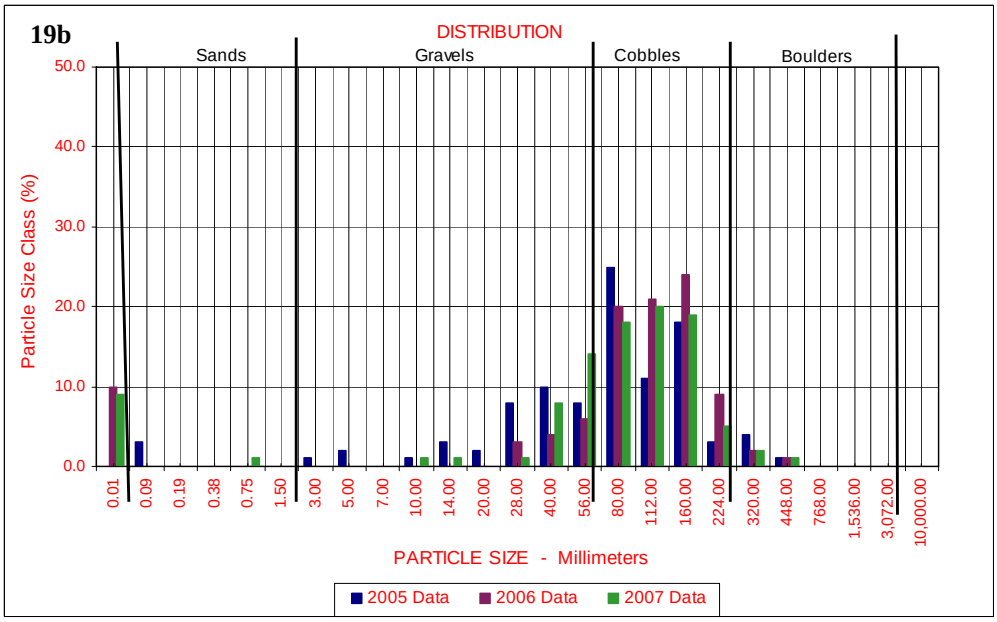


Table 11. Comparison of channel stability ratings at four channel cross sections between 2005-2007 (Pfankuch 1975). A lower stability score = increase in stability.

Cross Section ID	Score			Rating		
	2005	**2006**	**2008**	**2005**	**2006**	**2008**

Above Exclosure XS	81	80	83	Good	Good	Good
Upper within Exclosure XS	91	79	88	Poor	Poor	Poor
Lower within Exclosure XS	94	86	92	Fair	Fair	Fair
Below Exclosure XS	97	90	95	Fair	Fair	Fair

Table 12. Comparison of bank erodibility hazard rating at four channel cross sections between 2005-2007 (Rosgen 1996). A lower erodibility rating = a lower hazard.

Cross Section ID	Score			Rating		
	2005	**2006**	**2008**	**2005**	**2006**	**2008**
Above Exclosure XS	20	18.5	16.5	Moderate	Low	Low
Upper within Exclosure XS	20.2	16	19.5	Moderate	Low	Moderate
Lower within Exclosure XS	26.2	21	21.5	Moderate	Moderate	Moderate
Below Exclosure XS						
Left Bank	12.4	10	10.4	Low	Low	low
Right Bank	29	31.5	31.5	Moderate	High	High

Channel stability and bank erodibility ratings assessments were not repeated for 2007 concurrent with fall vegetation trend surveys and channel cross sections due to time constraints. A substantial flood occurred between the cross section surveys in November of 2007 and the stability assessments conducted in March of 2008. Flood events in other parts of the Tonto NF in late January of 2008 ranged between 10 and 25 year flood frequencies. Overbank flows were evident throughout Canyon Creek. Erosion of stream banks and deposition of bar materials were also evident throughout the reach of Canyon Creek within and outside of the exclosure. Erosion of stream banks resulted in widening of the channel at all monitoring sites. Following are a series of photographs (Photos series 10) that compare channel conditions fall of 2007 with conditions March 2008, to illustrate some of the flooding effects at the cross section inside of the exclosure. Additional photos are included in the 2007 project monitoring report. They show effects at the other cross sections (Warnecke 2007).

General visual observations of the flooding effects are that channel impacts were least evident at the site above the exclosure and similarly evident at the three lower sites. Raw cut banks were obvious at the three lower sites (river left at the upper site within the exclosure and river right at the two lower sites). The channel appears to have widened at all sites. Freshly deposited or exposed bedload material is evident at the three lower sites. The emergent vegetation that had trapped fine sediments within the limits of the low flow channel was scoured away by the flooding at all sites.

Photos Series 9a-f. Channel changes at cross section inside the exclosure (upper within); comparing fall 2007 to post-flooding winter of 2008.

Photo 9a. Looking upstream through cross section on Nov. 11, 2007.

Photo 9b. Looking upstream through cross section March 26, 2008.

Photo 9c. Looking downstream through cross section Nov. 28, 2007.

Photo 9d. Looking downstream through cross section March 26, 2008.

Photo 9e. Looking across through cross section Nov. 28, 2007.

Photo 9f. Looking across through cross section March 26, 2008.

Baseline Water Quality

Water quality parameters were measured at two locations, above the project area (NAD 27 12S 518548 3791787) and immediately below (NAD 27 12S 518651 3790912). Water samples were collected from the thalweg of the creek to measure total dissolved and total suspended solids. Conductivity, pH, temperature and turbidity were measured on site within the thalweg. Results are reported in Table 13.

Table 13. Baseline water quality measured fall of 2005.

Parameter	Sample Site	
	Above Exclosure	Below Exclosure
Solids, total dissolved	135 mg//	139 mg/l
Solids, total suspended	< 3.0 mg/l	<3.0 mg/l
Turbidity	0.81	0.63
Conductivity	182.1	273
Temperature	60 C	59 C
pH	8.63	8.98

Concurrent with this project, the Department's Region VI Fish Program had been monitoring stream temperature to track summer highs, a limiting factor on trout survival and habitat suitability. Temperature data loggers were installed in pools at several locations over the approximate 5 mile reach of Canyon Creek, from the headwater to the reservation boundary downstream of our project area. Monitoring data for 2007 indicated that summer temperatures peak in July and sometimes exceed the optimum range of thermal tolerance during daily fluctuations for brown and rainbow trout.. Temperatures also increased in a downstream gradient (Figure 20). These daily highs most likely limit trout distribution, creating competition for pockets of deeper water. Improvements in amount of riparian canopy cover are expected to decrease water temperatures and positively influence trout distribution. One data logger was installed within the exclosure reach (5A). Maximum daily temperatures during July decreased in 2007 compared to the 3 previous years (Figure 21). This may be a result of greater canopy cover along the greenline from floating vegetation such as watercress. Additional monitoring of temperature should demonstrate correlations between stream temperature and increasing canopy over time.

Photopoint Monitoring

Baseline photopoints were established in December 2005 post construction. Photopoints were replicated in October 2006 and 2007. Construction was completed after the end of the growing season and at a point where vegetation was already turning dormant. So therefore, the 2005 photographs appear somewhat more decadent than the 2006 and 2007 series that were taken when vegetation was still green and actively growing at the end of the growing season.

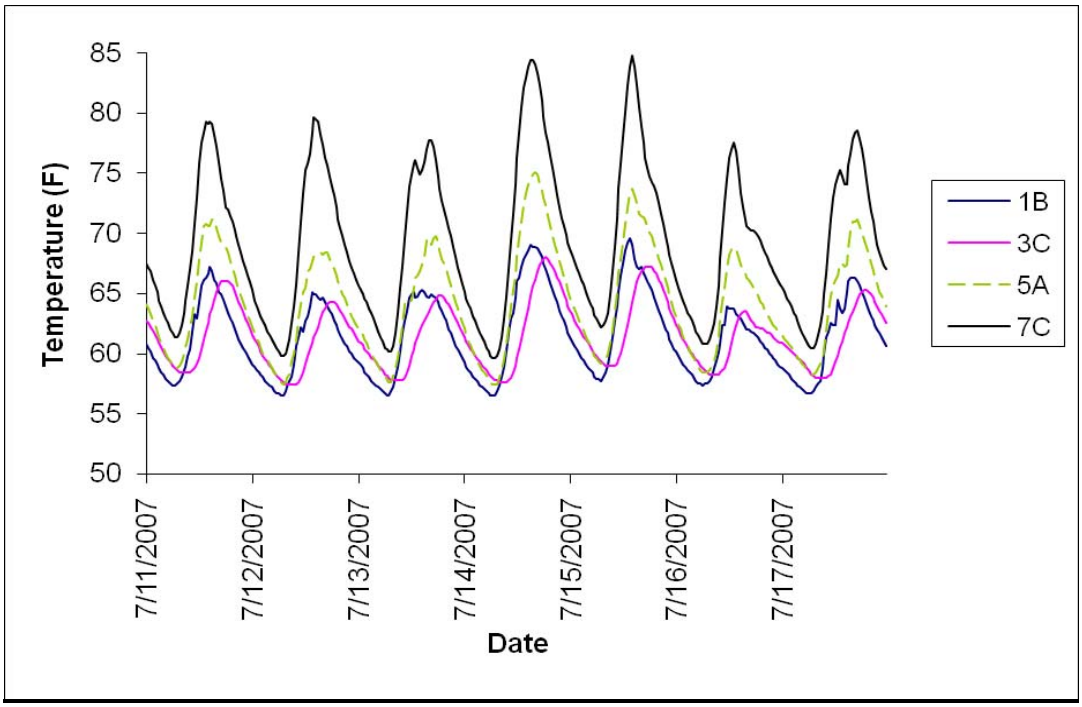


Figure 21. Maximum daily temperatures between July 11 and July 17, 2007 from 4 data loggers above (1B & 3C), within (5A) and below the exclosure (7C).

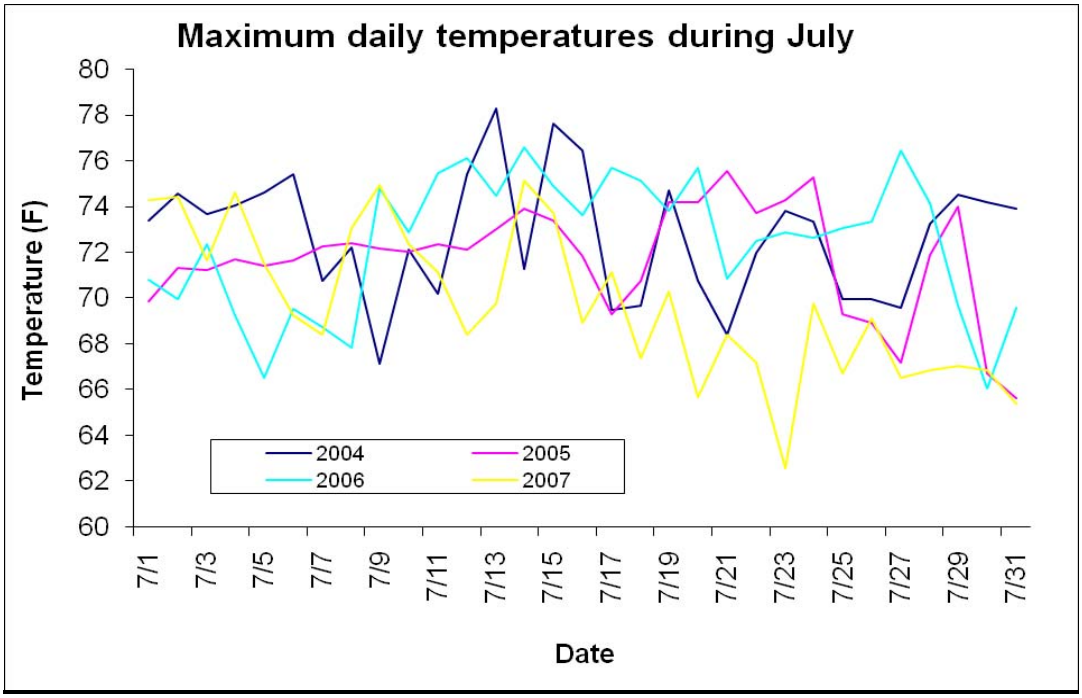


Figure 22. Comparison of July maximum daily temperatures between years, post-fire, at location 5A within the exclosure.

Overall, changes between 2005 and 2007 were very positive, and it appeared that vegetation had increased in density and structural diversity. Positive changes were apparent both inside

and outside the exclosure. However, changes inside the exclosure were more pronounced due to larger areas of colonization by woody species including, willow sp., narrowleaf cottonwood, Arizona alder, and box elder (*Acer negundo*). Different photopoints illustrate specific changes. For example, some illustrate changes in the density and size class of woody riparian species on the floodplain, or changes in the canopy cover of graminoid and forb species along the greenline, or a narrowing of the stream channel due to vegetation along the greenline. Table 14 summarizes which photopoints illustrate these different changes.

We found that alder saplings continued to increase in density and size inside the exclosure (Photos 11 & 12); however alders were rarely observed in reaches outside of the exclosure. In fact, concurrent with photopoint monitoring the Department conducted utilization monitoring to document the level of browsing by elk or deer on riparian woody species. We documented that between 20 and 60% of the leaders on riparian woody species, outside and upstream of the exclosure, were browsed depending on the season and year. This could be in part why species such as alder are rare outside the exclosure.

Photos 10 & 11. Looking at Arizona alder measured in 2006 (left) and 2007 (right). Alders were increasing in number (density) and size (height) during the monitoring period inside the exclosure.

There were no significant high flow events between fall of 2005 and 2007 that caused excessive scouring of stream banks or cobble bars within the floodplain, and the lack of disturbance likely contributed to the overall increase in canopy cover that our photographs document.

However, late December through March of 2008 there were several significant flood events that flowed above bankfull and onto the floodplain. Many old side channels were flowing and a significant amount of large woody debris, boulder, cobble and fine sediment was transported downstream and deposited in new areas. Stream banks were eroded and many cobble bars scoured of vegetation. There were a few significant channel changes. We expect that the next replication of photopoints fall of 2008 will illustrate some major changes between between 2007 and 2008.

Photographs are arranged by photopoint location and view, and presented in Appendix C. Mid-channel views (upstream and downstream) were added to several of the photopoints to more accurately document changes in stream channel widths in 2007 and will be replicated in the future. Photopoints are located in numerical order, beginning outside of the exclosure on the upstream end and proceeding downstream to just outside the exclosure. GPS locations for each photopoint monument stake are listed in Table 15.

Table 14. Summary of photopoints and views that illustrate changes in either woody species cover or herbaceous (graminoid and forb) cover along the greenline and floodplain.

Woody Cover	Herbaceous cover	
	Greenline	Floodplain
CC1 views 1 & 3	CC6 views 2 & 4	CC6 views 1&3
CC3 views 1 & 2	CC7 views 1, 2 & 4	CC7 view 2
CC4 views 1, 2 & 3	CC8 views 1,2 & 3	CC8 views 1,2 & 3
CC5 views 1,2 & 3	CC9 view 2	CC9 view 2
CC13 views 1 & 2		

Table 15. GPS locations of monument stakes for photopoints recorded as datum NAD27.

Photopoint #	Easting	Northing
CC1	518548	3791787
CC2	518590	3791749
CC3	518600	3791763
CC4	518628	3791659
CC5	518642	3791667
CC6	518634	3791426
CC7	518626	3791349
CC8	518652	3791238
CC9	518655	3791092
CC10	518677	3790941
CC11	518685	3790932
CC12	518651	3790912
CC13	518650	3790977

INFORMATION AND EDUCATION

Interpretive signs were developed and posted at 3 locations along Canyon Creek, above, below and adjacent to the project location. The signs were designed to illustrate the benefits that vegetation provides to the stability of the stream channel, water quality, and wildlife habitat. The illustration provides a simple compare and contrast of a stream with little vegetative cover to a stream with abundant vegetative cover (Photo 13). The sign highlights the partnership between government and non-governmental entities to fund, construct, and maintain the exclosure.

Photo 12. Onsite kiosk for Canyon Creek Riparian Restoration Project.

A web page was developed as part of the Department's website to highlight the Canyon Creek Riparian Restoration Project. The webpage expands on the information available at site kiosks and provides links to project partners and related websites. The primary components of the webpage include:

- Project overview
- Definition of "riparian"
- Purpose and need for restoration
- Canyon Creek background
- Fish management
- Wildlife
- OW Ranch history

- Project plans, accomplishments and events

MAINTENANCE

Volunteers were organized during one or two work days per year to deconstruct an old livestock fence that the exclosure replaced and to conduct periodic maintenance on the exclosure. In total 6 workdays, involving an average of 10-20 volunteers for each day, were conducted. In addition to these activities, maintenance was routinely conducted by Department staff on an as needed basis. The primary reasons for maintenance were fallen trees on the fence, flood damage or elk had pushed under. An 18" gap was left between the ground and the bottom of the exclosure fence to facilitate the movement of smaller wildlife including deer. We found that the area the exclosure was constructed in was used heavily as a movement corridor by elk. After construction was completed a significant amount of trailing around the outside perimeter of the exclosure became evident. We found that any areas where topography was not nearly level and the bottom fence gap exceeded18", elk pushed under. Over the past few years we have made several modifications to the exclosure fence to correct problems as they arise. This strategy has been successful and we will continue to monitor and modify as needed.

In 2006, the Department contracted to have fire killed trees felled around the perimeter of the exclosure. The contractors were successful in removing approximately 100 tree hazards to the exclosure fence. This work should have been done prior to the initial construction, however money and manpower was not available to do so.

The design of the fence segments that cross the creek, "watergaps", has proven to be extremely successful. Several high flow events have occurred, including the estimated 17 year event this past winter, and there have been no damages. The only maintenance has been to remove cobbles that had accumulated behind the fence and an occasional log jam. Although the design is expensive and technically more involved, it has proven to be worth the additional cost. In the past, watergaps were constructed with regular field fence and wired to break away in a high flow. The upstream watergaps for older exclosures on Canyon and Mule Creeks are a continual maintenance issue; with summer monsoon and spring snow melt flows leading to damage each year.

LONG-TERM PLANS

The Department and Forest will continue to conduct monitoring to measure vegetation trend and channel morphology. We will be adding belt transects to monitor changes in woody species density and size class now that we have detected enough individuals to begin sampling. The Department will continue to conduct photopoint monitoring, track stream temperature and monitor fish population trends through annual survey. Long-term monitoring data will be used to determine how long the exclosure will remain in place. The timing and decision will be based on a combination of factors including: the density and size class of facultative wetland and obligate woody species, the density of canopy cover along the stream banks, the amount of groundcover by live basal vegetation, changes in the width

and depth of the channel, and the biological response of fish populations to any improvements in stream habitat quality. A multidisciplinary group of Forest and Department specialists will be consulted for the decision making process. In conjunction with the future deconstruction of the elk exclosure, a new livestock exclosure (3-4 strand barbed wire) will be built in its place.

DISCUSSION

After 3 years of monitoring we have compiled a significant amount of information about Canyon Creek that underscores the high level of biodiversity and the dynamic nature of this riparian ecosystem. We believe that changes measured the past 3 years were more a reflection of the baseline condition, than any effects the riparian exclosure treatment may have had. Since we did not attempt to measure elk impacts to correlate with vegetation changes inside the exclosure versus outside the exclosure, we will depend on the results of long-term monitoring to evaluate our project success. Over time we expect measurable differences in total canopy cover for herbaceous and woody species, inside versus outside, as a result of the exclosure treatment. We are also interested in tracking ecological trends in the plant community; focusing on obligate and facultative wetland species, in addition to introduced or non-native species.

Many changes were detected between years in the amount of canopy cover, species composition, and ground cover. Small changes were detected in the substrate composition of the stream channel; however channel morphology did not change. More qualitative assessments on stream bank stability and erosion hazard indicated small changes between years, however those measures are subject to a certain level of observer bias. At this point in our monitoring we have not statistically tested for differences in the vegetation or the stream channel morphology that may be attributed to the elk-livestock exclosure. However, there were small changes that are meaningful to discuss.

By fall of 2007, total canopy cover had increased on the greenline feature from the 2005 baseline; but inside the exclosure increases were cumulative between years (51%, 69%, 98%) and outside they were variable (64%, 90%, 79%). Total canopy cover increases on the floodplain were also cumulative (67%, 72%, 85%) inside the exclosure and more variable (78%, 43%, 78%) outside the exclosure. Watercress dominated the greenline, more so inside the exclosure (78% of the composition in 2007 inside versus 49% outside), and contributed greatly to the narrowing of the non-vegetated stream width (greenline-to-greenline width) and the increase in canopy cover on the greenline between 2005 and 2007.

Canopy cover was primarily comprised of graminoid and forb species. However, we did begin to see riparian woody species recruit onto the floodplain and greenline by the end of the 3-year period. While the limited number of individuals captured in the Daubenmire plots did not indicate differences in recruitment, inside versus outside the exclosure, our photopoint monitoring documented significant changes in the amount of cover by riparian woody species inside the exclosure versus outside. Species with increases in density and

size class include: narrowleaf cottonwood, red and arroyo willows, and Arizona alder. Of those 4 species, the most preferred and palatable for elk are the willows followed by the alder. There appears to be very little browsing on narrowleaf by elk or deer (inside or outside the exclosure), and recruitment for this species is closely tied to periodic flood events to trigger recruitment on cobble bars and the floodplain. Two such events have occurred in the recent past; the post-fire flooding in 2002 and the estimated 17-year (magnitude) flood event of winter 2008. We expect to measure differences in woody species density over time within our monitoring reaches.

A third positive change that we measured relates to several variables. We found that percent ground cover of live basal vegetation and the percentage of silt on the floodplain increased between years slightly more inside versus outside the exclosure. In addition to that, total canopy cover on the floodplain increased more inside versus outside. Similarly, canopy cover on the greenline increased between years more consistently inside versus outside and the GGW width narrowed more inside the exclosure. All of these measures combined suggest a positive vegetative response to the exclosure. However, we can not say with statistical confidence that these small differences, inside the exclosure versus outside the exclosure, are the beginnings of a trend or simply a transitional baseline state.

The relationship between canopy cover, ground cover, and pebble count data can be meaningful and over time correlations may be developed. Previously we said the percentage of canopy cover, live basal vegetation and silt increased on the floodplain between years, slightly more inside versus outside the exclosure. The pebble count data characterizes the substrate in the stream channel, from wetted perimeter to wetted perimeter. Therefore, pebble count data includes portions of the greenline. Pebble count data indicated that the percentages of silt/clay increased inside and outside the exclosure between 2005 and 2006. However, the percentages decreased outside between 2006 and 2007, while they remained similar inside. The impression of the project hydrologist was that floating and emergent vegetation was trapping a substantial amount of silt/clay in the vegetation matrix and probably the reason for the increase in percentage of silt/clay inside the exclosure. In other words, when vegetation increases (canopy and ground cover) the amount of fine particles like silt increase, and the opposite may also be true. We speculate that vegetative changes inside the exclosure may have led to increased filtration and capture of fine sediments on stream banks and the floodplain, slightly more than outside the exclosure in 2007. The herbaceous component of the system appears to be most subject to change as a result of scouring floods and annual precipitation levels, apart from the relative impacts that grazing or trampling may have. Again, it will take more years of monitoring to correlate improvements in floodplain functions as a result of increased vegetative cover, and in response to the exclusion of elk and livestock from the riparian area.

Overall, species compositions were relatively similar inside versus outside the exclosure, and predominantly native species. Even though compositions were predominantly native, a greater proportion of the canopy cover was comprised of introduced species on the greenline versus the floodplains. The compositions on terraces, both inside and outside, tended to have more upland species as opposed to a combination of upland and facultative species found on

the floodplains that were of a similar elevation to the channel. As one would expect, the greenlines were dominated by wetland species. Watercress was far more dominant inside the exclosure, and was the primary reason for the differences in the GGW and the changes in species diversity along the greenline. Watercress was also the most dominant introduced species, however the functional niche (trapping sediments and floating cover) that watercress fills in the ecosystem is commonly perceived as beneficial despite the introduced status. That could also be said for tall fescue and red top, two other dominant introduced species.

There were 15 obligate wetland species recorded in our plots (only 1 introduced) that have a high potential to increase over time. Western water hemlock, an obligate wetland species with very limited distribution in Arizona, was found inside and outside the exclosure on the greenline. We found that wetland species comprised a greater percentage of the total canopy cover on the greenline outside of the exclosure. That changed in 2007, solely due to the increase in watercress inside the exclosure. However, the species diversity was equally represented by wetland obligate species inside versus outside the exclosure.

The diversity of wetland obligate graminoid and forb species was impressive and suggests that with time, the structure and diversity of the greenline could become quite complex. In fact, this may also be true for the diversity of the floodplain, equally represented by upland, facultative and wetland species. Species richness was higher than predicted and the relative richness of the area is likely attributed to perennial water, geography, environmental gradients, and the fluvial dynamics of the Canyon Creek ecosystem. In short, with protective measures in place to reduce grazing and browsing impacts, the diversity and abundance of vegetation is likely to increase with time. In the future, analysis of these changes should become statistically significant.

RECOMMENDATIONS

At this point in our project we cannot make conclusive statements on the success of the project or evaluate the costs/benefits of the elk-livestock exclosure. However, during our 3 years of project monitoring we believe we began to document positive changes in the plant community, more so inside the exclosure than outside. With additional years of monitoring data we will be able to statistically test whether those differences are significant. Our recommendations will instead focus on construction and maintenance issues and sampling designs for monitoring that address project objectives.

Part of our exclosure design included a 16-18” gap between the ground and the bottom of the elk-livestock exclosure fence in order to: a) facilitate the movement of small game and other wildlife and b) allow flood flows and debris to pass more easily through the fence and across the floodplain. We believe that the design addressed issues with flood flows very well. Although we had one incident where debris jams compromised the fence, over the 3 year period we avoided many other incidents. We also documented numerous deer and turkey moving in and out of the exclosure, therefore we believe the design facilitated wildlife movement. However, we have had to continuously monitor for locations where elk have

pushed under the fence. Most of the locations where this occurred were spots where the variability in topography led to a gap >18", however elk also had favored travel routes where they pushed under. In hindsight, we would recommend a gap closer to a 14-16" width and reinforcement of the bottom edge with a heavy gage smooth wire. This would be an adequate gap for larger wildlife such as deer, turkey and bear.

The second recommendation relates to the sampling design. We believe the limiting factor for detectecting more than a trace of woody species in our Daubenmire plots on the floodplain and greenline was in part a sampling shortfall. If woody species are increasing in abundance and size; more years of monitoring with our sampling design should be able to detect change. However, over the shorter 3-year monitoring period it may have been possible to detect changes if we had sampled more Daubenmire plots than we did. If time and manpower constraints allow, we recommend increasing the number of plots sampled on the greenline and floodplain. We also recommend extending the length of the perpendicular transects for a greater distance from the greenline across the floodplain. The floodplain on Canyon Creek is very wide with abandoned channels that are at similar elevations to the main channel and that retain water after high flow events. We believe the sampling design limited detection of important changes occurring beyond the 30 foot length.

We did not measure woody plant densities with the 100'x 6' belt transects because we did not detect enough woody plants in our Daubenmire plots to merit the time and effort. In hindsight, I would recommend including this method in a monitoring plan no matter what. Although detections may have been minimal, a thorough inventory of the belt transect may have found more woody plants than what was assumed present visually and in the Daubenmire plots. That information may have helped us to interpret the subtle changes we thought we were seeing on the ground. We would also recommend evaluating the appropriate belt width for the type of channel and valley bottom you are sampling. For a system like Canyon Creek with a wide floodplain, a wider belt width may improve the detection rates and provide more information about the broader area.

An alternative strategy to the changes in the monitoring methods previously discussed would be to add additional transects inside and outside the exclosure to increase the sample size and improve the chances of detecting changes across a broader context. The exclosure we constructed was ½ mile in length and 17 acres. Our monitoring design sampled only 300 feet of that length. Our photopoint monitoring detected major changes in other areas of the exclosure. Another paired set of monitoring reaches, inside and outside, would have also improved our sampling effort.

Our last recommendation relates to photopoints. In setting up photopoint locations, we focused primarily on changes along the stream banks and on the floodplain immediately adjacent to the channel. In hindsight, we should have established some photopoints from higher elevation vantage points to capture canopy cover changes across the valley bottom. By coincidence, another Forest monitoring effort established those views and they provide additional qualitative information on the changes that are occurring.

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APPENDIX A: PLANT SPECIES RECORDED IN DAUBENMIRE PLOTS ON THE FLOODPLAIN AND GREENLINE

Table 16. Plant species recorded in Daubenmire plots inside and outside exclosure on Canyon Creek, 2005-2007. Data for each species includes: % canopy cover on the greenline and/or floodplain by year, regional indicator category for species occurrence in a wetland versus a non-wetland, and the habit (characteristics and life form)[1].

SPECIES SURVEYED					% CANOPY COVER ON FLOODPLAIN						% CANOPY COVER ON GREENLINE					
FORBS					Inside Exclosure			Outside Exclosure			Inside Exclosure			Outside Exclosure		
Scientific Name	**Common Name**	**Family**	**R_Ind**	**Habit**	**2005**	**2006**	**2007**	**2005**	**2006**	**2007**	**2005**	**2006**	**2007**	**2005**	**2006**	**2007**
Acalypha neomexicana	spurge	Euphorbiaceae	UPL[1]	ANF						<1						
Achillea millefolium	yarrow	Asteraceae	FAC	PNF	<1	1	1	2	2	<1		<1		<1	<1	<1
Amaranthus powellii	amaranth	Amaranthaceae	UPL[1]	ANF	<1			1		1						
Ambrosia psilostachya	ragweed	Asteraceae	FAC	PNF	6	1	4	8	6	4	<1	<1	<1	<1	1	1
Aquilegia chrysantha	golden columbine	Rununculaceae	FACW	PNF								<1				
Artemisia ludoviciana ssp. sulcata	White sagebrush	Atsteraceae	UPL[1]	PHSN	<1		2	3								
Bahia dissecta	ragleaf bahia	Asteraceae	UPL[1]	ABPNF	<1				<1	<1						
Bidens leptocephala	fewflower beggertick	Asteraceae	FAC	PNF						1						
Chenopodium neomexicanum	goosefoot	Chenopodiaceae	UPL[1]	ANF						<1						
Cicuta douglasii	western water hemlock	Apiaceae	OBL	PNF	1								1			1
Cirsium arizonicum var. rothrockii	Arizona thistle	Asteraceae	UPL[1]	BPNF						<1						
Cirsium vulgare	bull thistle	Asteraceae	FACU	BIF	<1	<1	1	1	<1	1		1			1	
Comandra umbellata	bastard toadflax	Santalaceae	UPL[1]	PNF			<1									
Conyza canadensis	Canadian horseweed	Asteraceae	FACU	ANF			2		<1	2		<1				
Cosmos parviflorus	Southwestern cosmos	Asteraceae	FAC-	AIF						4						
Draba sp.		Brassicaceae	UPL[1]										<1			
Epilobium ciliatum	fringed willowherb	Onagraceae	FACW	PNF	<1	1	<1	<1		1	1	5	2	1	14	2
Equisetum arvensis	field horsetail	Equisetaceae	FACW-	PNH2	<1	<1		2	1	1	2	1	1	2	4	4
Equisetum laevigatum	smooth horsetail	Equisetaceae	FACW	PNH2	2	4	4	1		1	<1	5	<1	<1	1	<1
Erigeron flagellaris	trailing fleabane	Asteraceae	FAC-	BNF			1		<1	1						
Erigeron formosissimus	beautiful fleabane	Asteraceae	FAC	PNF	2			1						<1		
Erodium cicutarium	redstem stork's bill	Geraniaceae	UPL[1]	ABIF	<1	1	<1	3		3						
Euphorbia dentata	toothed spurge	Euphorbiaceae	UPL[1]	ANF			<1									
Galium mexicanum ssp. asperrimum	Mexican bedstraw	Rubiaceae	FAC	PNF	1	1						<1		<1		
Gaura hexandra ssp. gracilis	harlequinbush	Onagraceae	UPL[1]	ANF		1						<1				
Gaura mollis	velvetweed	Onagraceae	NI	ANF						<1						
Geranium caespitosum	geranium	Geraniaceae	UPL[1]	PNF	1	<1	1	1		<1		<1				
Geranium richardsonii	Richard's geranium	Geraniaceae	FAC	PNF		1	<1		<1	<1					1	<1
Geum triflorum	old man's whiskers	Rosaceae	FAC	PNF		<1										
Heterosperma pinnatum	wingpetal	Asteraceae	UPL[1]	ANF						<1						

1 The regional indicator categories and habit follow Reed (1988); in the case of "UPL[1]" there was no agreement for the regional ranking; therefore the national indicator "upland" was used. Definitions for indicators follow: OBL=obligate, FACW=facultative wetland, FAC=facultative, FACU=faculatative upland, NI=no information. Defininitions for habit follow: P=perennial, A=annual, B=biennial, N=native, I=introduced, F=forb, G=grass, GL=grasslike, V=vine, T=tree, H=partly woody, HS= half shrub, H2= horsetail, WV=woody vine, E=emergent, and Z=submerged.

SPECIES SURVEYED					% CANOPY COVER ON FLOODPLAIN						% CANOPY COVER ON GREENLINE					
FORBS					Inside Exclosure			Outside Exclosure			Inside Exclosure			Outside Exclosure		
Scientific Name	**Common Name**	**Family**	**R_Ind**	**Habit**	**2005**	**2006**	**2007**	**2005**	**2006**	**2007**	**2005**	**2006**	**2007**	**2005**	**2006**	**2007**
Heterotheca villosa var. pedunculata	hairy false goldenaster	Asteraceae	UPL[1]	PNF	2	1	<1	2	<1			2			1	<1
Lactuca ludoviciana	biennial lettuce	Asteraceae	UPL, FAC[1]	BPNF						<1						
Lactuca serriola	prickly lettuce	Asteraceae	FAC	ABIF			1					<1		<1		
Lemna sp.	duckweed	Lemanaceae	OBL	PNF												
Leucanthemum vulgare	Oxeye daisy	Asteraceae	UPL[1]	PIF	<1	1	1				<1					
Medicago lupulina	black medick	Fabaceae	FAC	AIF	1		1	4	3	<1	1	1		<1	1	<1
Melilotus officinale	yellow sweetclover	Fabaceae	FACU+	ABIF	2	2	<1	2	1	1	<1	<1	<1		1	<1
Mentha spicata	spearmint	Lamiaceae	FACW*	PIF								2		<1	1	
Mimulus guttatus	monkey flower	Scrophulariaceae	OBL	ANF							2		3	1		1
Nasturtium officinale	watercress	Brassicaceae	OBL	PIZEF			<1			<1	21	3	71	19	15	36
Oenothera elata spp. hirsutissima	primrose	Onagraceae	FACW	BPNF			<1			<1						
Oxalis stricta	woodsorrel	Oxalidaceae	UPL[1]	PNF			<1									
Plantago major	common plantain	Plantaginaceae	FACW	PIF	1	2	2	3	1	<1		<1		<1		
Polygonum convolvulus	black bindweed	Polygonaceae	FACU-	AIVF						<1						
Polygonum lapathifolium	curlytop knotweed	Polygonaceae	OBL	ANF		1		3			3	<1	<1	<1	4	<1
Potamogeton pusillus	small pondweed	Potamogetonaceae	OBL	PNZF									<1			
Potentilla norvegica	cinquefoil	Rosaceae	FAC	ABPNF						1						
Pseudognaphlium leucocephalum	white cudweed	Asteraceae	UPL[1]	ANF								<1				
Ratibida columnifera	upright praire coneflower	Asteraceae	UPL[1]	PNF	1		<1		1							
Rudbeckia laciniata	cutleaf coneflower	Asteraceae	FACW-	PNF			<1					2				
Rumex acetosella	common sheep sorrel	Polygonaceae	FACW	PIF			1	<1		<1			<1	1		<1
Rumex hymenosepalus	canaigre dock	Polygonaceae	UPL[1]	PNF						<1						
Rumex sp.		Polygonaceae	UPL[1]	F	<1						<1	<1				
Salvia reflexa	lanceleaf sage	Lamiaceae	UPL[1]	ANF						<1						
Saxafraga sp.		Saxifragaceae	UPL[1]	F		<1										
Securigera varia	crownvetch	Fabaceae	UPL[1]	PIV		1	11		1							2
Selaginella sp.	spikemoss	Selaginellaceae	UPL[1]	PNF				<1	1							
Sidalcea neomexicana	checker-mallow	Malvaceae	FACW	PNFH				<1								
Sisymbrium altissimum	tall tumblemustard	Brassicaceae	FAC	ABIF			<1	<1		1						
Solidago velutina	threenerve goldenrod	Asteraceae	UPL[1]	PNF				3	1					1	<1	
Solidago wrightii	Canada goldenrod	Asteraceae	FACU	PNF	2						<1					
Sonchus oleraceus	common sowthistle	Asteraceae	UPL	AIF			<1	1						<1		
Symphyotrichum falcatum var. commutatum	white praire aster	Asteraceae	UPL[1]	PNF			1									
Symphyotrichum lanceolatum ssp. hesperium	white panicle aster	Asteraceae	UPL[1]	PNF			<1			1		3				<1
Symphyotrichum sp.	aster	Asteraceae	UPL[1]	F		2										
Taraxicum officinale	dandylion	Asteraceae	FACU	PIF			<1		1	1	<1	<1	<1	<1	1	<1
Tragopogon dubius	yellow salsify	Asteraceae	UPL[1]	ABIF				1	<1							
Trifolium pratense	red clover	Fabaceae	NI	BPIF	1			<1		2		1		<1	<1	
Unk aquatic sp.				F		1										
Unknown Asteraceae				F				1								
Unknown mustard				F												<1

SPECIES SURVEYED					% CANOPY COVER ON FLOODPLAIN						% CANOPY COVER ON GREENLINE					
FORBS					Inside Exclosure			Outside Exclosure			Inside Exclosure			Outside Exclosure		
Scientific Name	**Common Name**	**Family**	**R_Ind**	**Habit**	**2005**	**2006**	**2007**	**2005**	**2006**	**2007**	**2005**	**2006**	**2007**	**2005**	**2006**	**2007**
Valeriana edulis	Tobacco root	Valerianaceae	FAC	PNF					<1	<1						
Verbascum thapsus	common mullein	Scrophulariaceae	UPL[1]	PIF	<1	2	1	<1		<1	2	<1				
Verbena macdougalii	MacDougal verbena	Verbenaceae	FACU	PNF		1						<1				
Veronica anagallis-aquatica	water speedwell	Scrophulariaceae	OBL	BPNEF							1	<1	3	1		<1
Vicia americana	American vetch	Fabaceae	NI	PNFV			<1	<1								
GRAMINOID																
Agropyron smithii	western wheatgrass	Poaceae	FAC-	PNG	3	5	1	8	5	1	<1					
Agrostis gigantea	red top	Poaceae	FACW+	PIG	4	7	4	3	3	8	3		4	5	15	6
Agrostis semiverticilata	water bentgrass	Poaceae	FACW+	PIG	<1									1		
Agrostis stolonifera	spreading bentgrass	Poaceae	FAC+,FACW[1]	PNG	1	<1					<1	11				
Bouteloua gracilis	blue grama grass	Poaceae	UPL	PNG	7	7	10	<1	1	2		2				
Bromus arvensis	soft brome	Poaceae	UPL	AIG			4									
Bromus carinatus	California brome	Poaceae	UPL	APIG			<1			<1					<1	
Bromus ciliatus	fringed brome	Poaceae	FAC	PNG	1		<1	<1		1						
Bromus inermis	smooth brome	Poaceae	UPL	PNG						1						
Bromus sp.		Poaceae	UPL[1]	G				1	5		<1					
Carex senta	swamp carex (rough carex)	Cyperaceae	OBL	PNGL												6
Carex sp.		Cyperaceae	OBL or FACW	GL							<1			<1		
Carex subfusca	brown sedge	Cyperaceae	FACU-	PNGL						1					6	
Cyperus esculentus	yellow nutsedge or chufa	Cyperaceae	FACW	PNGL							1	<1		16		
Dactylis glomerata	orchardgrass	Poaceae	FACU+	PIG	2	2		<1	3		<1				<1	
Eleocharis montevidensis	sand spikerush	Juncaceae	FACW	PNGL		2	1			2	1	1	4	<1	2	3
Elymus canadensis	Canada wildrye	Poaceae	FAC	PNG			<1					<1			1	
Elymus elymoides	squirrel tail	Poaceae	UPL	PNG						4				<1		<1
Elymus sp.		Poaceae		G	1									1		
Elymus trachycaulis	slender wheatgrass	Poaceae	FAC	PNG							<1	<1				
Eragrostis curvula	weeping lovegrass	Poaceae	UPL	PIG	<1			<1		2						
Eragrostis mexicana	Mexican lovegrass	Poaceae	FACU	ANG			<1	2		1						
Eragrostis sp.		Poaceae	FACU OR UPL	G						1				<1		
Juncus articus var. mexicanus	Arctic rush	Juncaceae	OBL	PNGL		1	<1					<1				
Juncus effusus	common rush (soft rush)	Juncaceae	OBL	PNEGL							1		<1	<1		
Juncus saximontanus	Rocky Mountain rush	Juncaceae	FACW	PNGL		<1	<1			1	<1	4	<1	<1	<1	<1
Juncus sp.		Juncaceae	OBL or FACW	GL			<1							1		<1
Lolium perenne ssp. multiflorum	Italian ryegrass	Poaceae	OBL	ABNF				<1		<1		2				
Muhlenbergia longiligula	longuetongue muhly	Poaceae	UPL[1]	PNG		<1										
Muhlenbergia rigens	deergrass	Poaceae	FACU*	PNG	<1	3	3	<1								
Muhlenbergia wrightii	spike muhly	Poaceae	FACU	PNG	1	3										
Panicum capillare	witchgrass	Poaceae	FAC	ANG						<1		<1				
Panicum obtusum	vine-mesquite	Poaceae	FAC	PNG						<1						
Poa compressa	Canada bluegrass	Poaceae	FAC	PIG						<1						
Poa pratensis	Kentucky bluegrass	Poaceae	FAC	PNG	2		2	1		2			<1			

SPECIES SURVEYED					% CANOPY COVER ON FLOODPLAIN						% CANOPY COVER ON GREENLINE					
GRAMINOID					Inside Exclosure			Outside Exclosure			Inside Exclosure			Outside Exclosure		
Scientific Name	**Common Name**	**Family**	**R_Ind**	**Habit**	**2005**	**2006**	**2007**	**2005**	**2006**	**2007**	**2005**	**2006**	**2007**	**2005**	**2006**	**2007**
Poa sp.		Poaceae		G							<1					
Schedonorus phoenix	tall fescue	Poaceae	FACW-	PIG	8	8	6	4	1	6	3	9	<1	3	8	1
Schoenoplectus tabernaemontani	softstem bulrush	Juncaceae	OBL	PNEGL			<1			<1		<1	<1		3	3
Scirpus americanus	American bulrush	Cyperaceae	OBL	PNEGL	1	1	1					<1	<1			<1
Scirpus microcarpus	panicled bulrush	Cyperaceae	OBL	PNGL		1				1	<1	<1	1	1	4	3
Setaria viridis	green bristlegrass	Poaceae	UPL[1]	AIG						<1						
Thinopyron intermedium	intermediate wheatgrass	Poaceae	UPL[1]	PIG					1							
Unknown grass				G				3			<1					
TREES, SHRUBS AND VINES																
Amorpha fruticosa	false indigo	Fabaceae	FACW+	NS	5		4	5		2	<1	<1			1	
Pinus ponderosa	Ponderosa pine	Pinaceae	UPL[1]	PNT					1							
Populus angustifolia	narrowlead cottonwood	Salicaceae	FACW	NT	1	1	1	1	<1	1	<1	<1		<1	1	1
Rosa woodsii	Wood's rose	Rosaceae	FACU	NS		<1										
Salix gooddingii	Goodding willow	Salicaceae	OBL	NT		1	1						<1			<1
Salix laevigata	red willow	Salicaceae	FACW+	NT		1										<1
Unk vine				V											<1	
Vitus arizonica	canyon grape	Vitaceae	FAC	NWVS						<1						

APPENDIX B. BOTANICAL INVENTORY COLLECTED FROM CANYON CREEK 2005-2008

Table 17. Botanical inventory collected from Canyon Creek 2005-2008.

Family	Scientific name	Voucher (x)
Aceraceae	Acer negunda	
Amaranthaceae	Amaranthus powellii	x
Apiaceae	Cicuta douglasii	x
Apocynaceae	Apocynum cannabinum	x
Asteraceae	Achillea millifolia	
Asteraceae	Ambrosia psylostachya	
Asteraceae	Antennaria sp.	
Asteraceae	Artemisia dracunculus	
Asteraceae	Artemisia ludoviciana ssp. sulcata	x
Asteraceae	Bahia dissecta	x
Asteraceae	Bidens leptocephala	x
Asteraceae	Bidens tenuisecta	x
Asteraceae	Cirsium arizonicum var. rothrockii	x
Asteraceae	Cirsium neomexicanum	
Asteraceae	Cirsium vulgare	x
Asteraceae	Cirsium wheeleri	x
Asteraceae	Conyza canadensis	
Asteraceae	Cosmos parviflorus	x
Asteraceae	Erigeron divergens	
Asteraceae	Erigeron flagellaris	
Asteraceae	Helianthus annuus	x
Asteraceae	Helianthus nuttallii	x
Asteraceae	Heliomeris multiflora var. nevadensis	x
Asteraceae	Heterotheca villosa var. pedunculata	x
Asteraceae	Lactuca serriola	x
Asteraceae	Leucanthemum vulgare	x
Asteraceae	Machaeranthera gracilis	
Asteraceae	Pseudognaphalium leucocephalum	x
Asteraceae	Ratibida columnifera	x
Asteraceae	Rudbeckia hirta	x

Asteraceae	Rudbeckia laciniata	
Asteraceae	Solidago velutina	x
Asteraceae	Solidago wrightii	
Asteraceae	Sonchus oleraceus	x
Asteraceae	Symphyotrichum falcatum var. commutatum	
Asteraceae	Symphyotrichum lanceolatum ssp. hesperium	x
Asteraceae	Taraxacum officinale	
Asteraceae	Tragopogon dubius	x
Betulaceae	Alnus obligifolia	
Boraginaceae	Lappula sp.	
Brassicaceae	Diplotaxis muralis	x
Brassicaceae	Draba sp.	
Brassicaceae	Lepidium campestre	x
Brassicaceae	Nasturtium officinale	x
Brassicaceae	Sisymbrium altissimum	x
Brassicaceae	Thlaspi montanum	
Cannabaceae	Humulus lupulus var. neomexicanus	x
Chenopodiaceae	Chenopodium neomexicanum	x
Clusiaceae	Hypericum formosum	x
Cucurbitaceae	Cucurbita foetidissima	x
Cucurbitaceae	Marah gilensis	x
Cupressaceae	Juniperus deppeana	
Cyperaceae	Carex meadii	x
Cyperaceae	Carex senta	x
Cyperaceae	Carex stipata	x
Cyperaceae	Carex subfusca	x
Cyperaceae	Cyperus esculentus	x
Cyperaceae	Eleocharis montevidensis	x
Cyperaceae	Schoenoplectus americanus	x
Cyperaceae	Schoenoplectus tabernaemontani	x
Cyperaceae	Scirpus microcarpus	x
Equisetaceae	Equisetum arvense	x
Equisetaceae	Equisetum laevigatum	
Euphorbiaceae	Chamaesyce sp.	
Euphorbiaceae	Euphorbia dentata	x
Euphorbiaceae	Euphorbia chamaesula	x
Fabaceae	Amorpha fruticosa	x

Fabaceae	Securigera varia	x
Fabaceae	Medicago lupulina	x
Fabaceae	Robinia neomexicana	x
Fabaceae	Melilotus officionalis	x
Fabaceae	Trifolium albopurpureum var. albopurpureum	
Fabaceae	Trifolium gracilentum	
Fabaceae	Trifolium pratense	x
Fabaceae	Vicia americana	x
Fagaceae	Quercus gambellii	
Gentianaceae	Gentianella amarella	x
Geraniaceae	Erodium cicutarium	
Geraniaceae	Geranium caespitosum var. eremophilum	
Geraniaceae	Geranium richardsonii	x
Grossulariaceae	Ribes sp.	
Hydrophyllaceae	Phacelia heterophylla	x
Iridaceae	Iris missouriensis	x
Iridaceae	Sisyrinchium demissum	x
Juglandaceae	Juglans major	x
Juncaceae	Juncus effusus var. solutus	x
Juncaceae	Juncus saximontanus	x
Lamiaceae	Dracocephalum parviflorum	
Lamiaceae	Mentha spicata	
Lamiaceae	Monarda pectinata	x
Lamiaceae	Nepeta cataria	x
Lamiaceae	Salvia reflexa	x
Liliaceae	Allium cernuum	
Linaceaea	Linum aristatum	x
Linaceaea	Linum lewisii	x
Linaceaea	Linum usitatissimum	x
Malvaceae	Malva neglecta	x
Malvaceae	Sidalcea neomexicana	x
Nyctaginaceae	Mirabilis sp.	
Onagraceae	Epilobium brachycarpum	
Onagraceae	Epilobium ciliatum	x
Onagraceae	Gaura hexandra ssp. gracilis	x
Onagraceae	Gaura mollis	x
Onagraceae	Oenothera elata ssp. hirsutissima	

Oxalidaceae	Oxalis stricta	
Pinaceae	Pinus ponderosa	
Plantaginaceae	Plantago major	
Poaceae	Agropyron desertorum	x
Poaceae	Agrostis gigantea	x
Poaceae	Agrostis stolonifera	x
Poaceae	Andropogon glomeratus	x
Poaceae	Blepharoneuron tricholepis	
Poaceae	Bouteloua curtipendula	
Poaceae	Bouteloua gracilis	x
Poaceae	Bromus arvensis	x
Poaceae	Bromus carinatus	x
Poaceae	Bromus ciliatus	
Poaceae	Bromus inermis	x
Poaceae	Bromus polyanthus	x
Poaceae	Dactylis glomerata	
Poaceae	Elymus canadensis	x
Poaceae	Elymus elymoides	
Poaceae	Elymus trachycaulus	x
Poaceae	Eragrostis curvula	
Poaceae	Eragrostis mexicana	x
Poaceae	Glyceria borealis	x
Poaceae	Glyceria striata	x
Poaceae	Hordeum vulgare	x
Poaceae	Koeleria macrantha	
Poaceae	Schedonorus phoenix	x
Poaceae	Lolium perenne ssp. multiflorum	x
Poaceae	Muhlenbergia fragilis	
Poaceae	Muhlenbergia longiligula	x
Poaceae	Muhlenbergia mexicana	x
Poaceae	Muhlenbergia rigens	x
Poaceae	Muhlenbergia wrightii	x
Poaceae	Panicum bulbosum	
Poaceae	Panicum capillare	x
Poaceae	Phleum pratense	x
Poaceae	Poa compressa	x
Poaceae	Polypogon viridis	

Poaceae	Setaria viridis	x
Poaceae	Sporobolus cryptandrus	
Polemoniaceae	Ipomopsis aggregata	
Polygonaceae	Polygonum convolvulus	x
Polygonaceae	Polygonum lapathifolium	x
Polygonaceae	Rumex acetosella	x
Polygonaceae	Rumex hymenosepalus	
Portulacaceae	Montia chamissoi	x
Potamogetonaceae	Potamogeton pusillus	x
Ranunculaceae	Aquilegia chrysantha	x
Ranunculaceae	Clematis ligusticifolia	x
Ranunculaceae	Delphinium geraniifolium	x
Ranunculaceae	Delphinium parishii	x
Ranunculaceae	Thalictrum fendleri	
Rosaceae	Agrimonia striata	x
Rosaceae	Potentilla hippiana	x
Rosaceae	Potentilla norvegica	x
Rosaceae	Potentilla thurberi	x
Rosaceae	Rosa woodsii	
Rubiaceae	Galium mexicanum ssp. asperrimum	x
Rubiaceae	Houstonia wrightii	x
Salicaceae	Populus angustifolia	x
Salicaceae	Salix gooddingii	
Salicaceae	Salix lasiolepis	x
Salicaceae	Salix lucida ssp. lasiandra	x
Santalaceae	Comandra umbellata	
Scrophulariaceae	Castilleja exserta	x
Scrophulariaceae	Mimulus guttatus	
Scrophulariaceae	Penstemon barbatus	x
Scrophulariaceae	Verbascum thapsis	x
Scrophulariaceae	Veronica anagallis-aquatica	x
Valerianaceae	Valeriana arizonica	x
Valerianaceae	Valeriana edulis	x
Verbenaceae	Verbena macdougalii	x
Violaceae	Viola nephrophylla	x
Vitaceae	Vitis arizonicus	

APPENDIX C: PHOTOPOINTS REPLICATED ALONG CANYON CREEK, FALL OF 2005, 2006 AND 2007

PHOTOPOINT- CC1

CC1 2005 View 1

CC1 2006 View 1

CC1 2007 View 1

View 1. Across - Looking across at right bank of channel; upstream and outside of exclosure. View shows floodplain and greenline of reach grazed by elk but not domestic ungulates. The height of riparian woody species has increased, nearly blocking the view of the exclosure fence in the background (see also View 3).

CC1 2005 View 2

CC1 2006 View 2

CC1 2007 View 1

View 2. Upstream - Looking upstream at right bank of channel; upstream and outside of exclosure. View shows floodplain and greenline of reach grazed by elk but not domestic ungulates. No significant changes between years.

CC1 2005 View 3

CC1 2006 View 3

CC1 2007 View 2

View 3- Downstream- Looking downstream towards exclosure.

View 3. Downstream - Looking downstream at right bank of channel; upstream and outside of exclosure. View shows floodplain and greenline of reach grazed by elk but not domestic ungulates. The height of

riparian woody species has increased, nearly blocking the view of the exclosure fence in the background (see also View 1).

CC1 2007 View 4

View 4. Mid-channel upstream (left) and downstream (right), upstream and outside of exclosure. View shows greenline of reach grazed by elk but not domestic ungulates.

PHOTOPOINT- CC2

CC2 2005 View 1

CC2 2006 View 1

CC2 2007 View 1

View 1. Looking just outside of exclosure at left bank of channel just outside of upper watergap. Views 1 & 2

compare fenceline constrasts over time, inside versus outside at the upper watergap. There were no significant changes between 2005 and 2007.

CC2 2005 View 2

CC2 2006 View 2

CC2 2007 View 2

View 2. Looking just inside of exclosure at the left bank of channel. Views 1 & 2 compare fenceline constrasts over time, inside versus outside at the upper watergap. There were no significant changes between 2005 and 2007.

PHOTOPOINT- CC3

CC3 2005 View 1

CC3 2006 view 1

CC3 2007 View 1

View 1. Looking just outside of exclosure at the right bank of channel. Views 1 & 2 compare fenceline constrasts over time, inside versus outside at the upper watergap. The height of riparian woody species has increased since fall of 2005.

CC3 2005 View 2

CC3 2006 View 2

CC3 2007 View 2

View 2. Looking just inside of exclosure at the right bank of channel. Views 1 & 2 compare fenceline constrasts over time, inside versus outside at the upper watergap. The height of riparian woody species has increased since fall of 2005.

PHOTOPOINT- CC4

CC4 2005 View 1

CC4 2006 View 1

CC4 2007 View 1

View 1. Across - To show changes on floodplain on left bank of channel inside exclosure. Woody species have increased in size and density at this location.

CC4 2005 View 2

CC4 2006 View 2

CC4 2007 View 2

View 2. Upstream – Looking at upstream left bank changes along the greenline and floodplain. The amount of watercress and woody vegetation increased dramatically at this location between 2006 and 2007. Photopoint 5 (CC5) documents the same location, but the opposite views, looking at the right bank.

CC4 2005 View 3

CC4 2006 View 3

CC4 2007 View 3

View 3. Downstream – Looking at downstream left bank changes along the greenline and floodplain. The amount of watercress along the greenline increased slightly, but woody species increased in size and density.

PHOTOPOINT- CC5

CC5 2005 View 1

CC5 2006 View 1

CC5 2007 View 1

View 1. Across- Looking at greenline changes along cutbank (right bank) of channel inside exclosure. Willow

densities and height have increased on the near bank to the point where photographs from the monument can no longer document change along the greenline and cutbank on the right bank of the channel.

CC5 2006 View 1a

CC5 2007 View 1a

View 1. Across - Alternate of View 1 taken 4 paces towards stream along 238 degree azimuth from monument to gain a clear view of greenline and cutbank on west side of channel. The far bank is starting to become vegetated but there are no significant changes between 2005 and 2007.

CC5 2005 View 2

CC5 2006 View 2

View 2. Upstream - Looking at greenline changes along cutbank (right bank) of channel. Willow densities

and height have increased on the near bank to the point where photographs from the monument can no longer document change along the greenline and cutbank on the right bank of the channel. This view was not replicated in 2007 and the alternate view 2a is substituted.

CC5 2006 View 2a

CC5 2007 View 2a

View 2a. Upstream - Alternate of View 2 taken 4 paces towards stream along 238 degree azimuth from monument to gain a clear view of greenline and cutbank on west side of channel. Note the willow in the foreground has grown significantly between 2005 and 2007.

CC5 2005 View 3

CC5 2006 View 3

CC5 2007 View 3

View 3. Downstream - Looking at greenline changes along on left and right banks of channel. Willow densities and height have increased on the near bank to the point where photographs from the monument can no longer document change along the greenline and floodplain on the left or right banks of the channel. This photo shows significant changes between 2005 and 2007.

CC5 2007 View 4

View 4. Mid-channel upstream (left) and downstream (right). View shows greenline of channel.

PHOTOPOINT- CC6

CC6 2005 View 1

CC6 2006 View 2

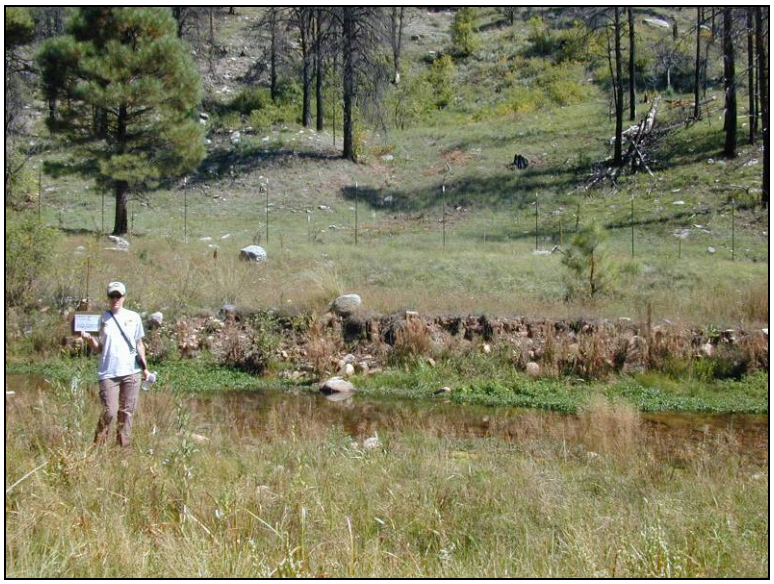
CC6 2007 View 1

View 1. Upstream - Looking upstream at changes on greenline and floodplain on left bank of channel. This site is located at the beginning of the vegetation trend monitoring reach inside the exclosure.

CC6 2005 View 3

CC6 2005 View 4

CC6 2007 View 2



View 2. Across – Looking across at changes on greenline and floodplain on left bank of channel. The amount of watercress increased between years along the greenline at this location. The grass and forb cover on the floodplain has also increased in the foreground.

CC6 2005 View 5

CC6 2005 View 6

CC6 2007 View 3

View 3. Downstream- Looking downstream at changes on greenline and floodplain on right and left bank of channel. Cover along the floodplain has increased and the cobble bar on the near side of the photo, visible in 2005, is no longer visible.

CC6 2007 View 4

View 4. Mid-channel upstream (left) and downstream (right). View shows greenline of channel. There was a 42% increase in canopy cover along the greenline between 2006 and 2007 along this reach.

PHOTOPOINT- CC7

CC7 2005 View 1

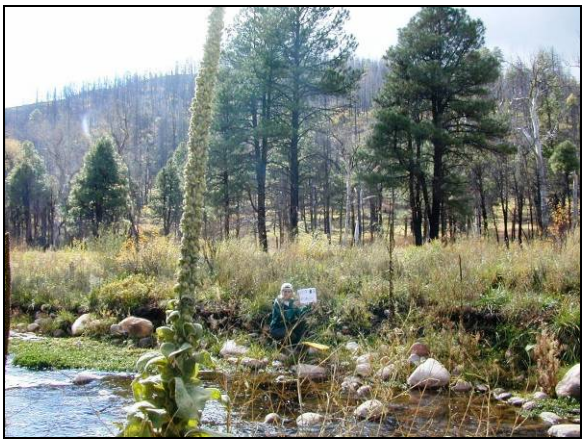
CC7 2006 View 1

CC7 2007 View 1

View 1. Upstream – Looking upstream and across at changes along greenline, floodplain and instream cover on right bank of channel.

CC7 2005 View 2

CC7 2006 View 2



CC7 2007 View 2

View 2. Across – Looking across at changes along greenline and floodplain on right bank of channel.

CC7 2005 View 3

CC7 2006 View 3

CC7 2007 View 3

View 3. Downstream – Looking downstream and across at changes along greenline and floodplain on right bank of channel. Vegetation on the greenline and floodplain increased between years.

CC7 2007 View 4

View 4. Mid-channel upstream (left) and downstream (right). View shows greenline of channel.

PHOTOPOINT- CC8

CC8 2005 View 1

CC8 2006 View 1

CC8 2007 View 1

View 1. Upstream- Looking upstream at changes on the floodplain (left bank-foreground) and on the 5 foot cutbank (right bank) across the channel. The side channel cobble bar was colonized predominantly by yellow sweet clover (*Melilotus officinale*). The false indigo *(Amorpha fructicosa)* has grown in height and width between years.

CC8 2005 View 2

CC8 2006 view 2

CC8 2007 View 2

View 2. Across – Looking upstream at changes on the floodplain (left bank-foreground) and on the 5 foot cutbank (right bank) across the channel. The willow in the foreground is beginning to block the view.

CC8 2005 View 3

CC8 2006 View 3

CC8 2007 View 3

View 3. Downstream - Looking downstream at changes on the floodplain (left bank-foreground) and on the 5 foot cutbank (right bank) across the channel. Significant changes in woody plant sizes and density.

CC8 2007 View 4

View 4. Mid-channel upstream (left) and downstream (right). View shows greenline of channel and floating vegetation across riffle (right).

PHOTOPOINT- CC9

CC9 2005 View 1

CC9 2006 View 1

CC9 2007 View 1

View 1. Upstream – Looking upstream at changes along greenline, floodplain on right bank. Note a rush or sedge plant has colonized a patch of watercress on the left bank. Also note the increase in cover on the right stream bank.

CC9 2005 View 2

CC9 2006 View 2

CC9 2007 View 2

View 1. Across – Looking across at changes along greenline and floodplain on left bank. Note the increase in cover on the right stream bank and greenline.

CC9 2005 View 3

CC9 2006 View 4

CC9 2007 View 3

View 3- Downstream- Looking downstream at changes along greenline and floodplain on left bank. Note the increase in cover on the left stream bank and greenline.

CC9 2007 View 4

View 4. Mid-channel upstream (left) and downstream (right). View shows greenline of channel.

PHOTOPOINT- CC10

CC10 2005 View 1

CC10 2006 View 1

CC10 2007 View 1

View 1. Across – Looking across at left bank of channel just inside exclosure at lower watergap. View 1 & 2 compare fenceline constrasts over time, inside versus outside at the lower watergap.

CC10 2005 View 2CC10 2006 View 2

CC10 2007 View 2

View 2. Across – Looking across at left bank of channel just outside of exclosure at lower watergap. View 1 & 2 compare fenceline constrasts over time, inside versus outside at the lower watergap.

PHOTOPOINT- CC11

CC11 2005 View 1

CC11 2006 View 1

CC11 2007 View 1

View 2. Across – Looking across at right bank of channel just inside of exclosure at lower watergap. View 1 & 2 compare fenceline constrasts over time, inside versus outside at the lower watergap.

CC11 2005 View 2

CC11 2006 View 2

CC11 2007 View 2

View 2. Across – Looking across at right bank of channel just outside of exclosure at lower watergap. View 1 & 2 compare fenceline constrasts over time, inside versus outside at the lower watergap.

CC11 2007 View 4

View 4. Mid-channel upstream (left) and downstream (right). View shows greenline of channel.

PHOTOPOINT- CC12

CC12 2005 View 1

CC12 2006 View 1

CC12 2007 View 1

View 1. Upstream - Looking upstream and across at left bank and changes along the greenline, floodplain and instream cover. This area is grazed by elk but not domestic livestock and downstream from exclosure. The density of watercress has increased mid-channel between 2005 and 2007 at this site.

CC12 2005 View 2

CC12 2006 View 2

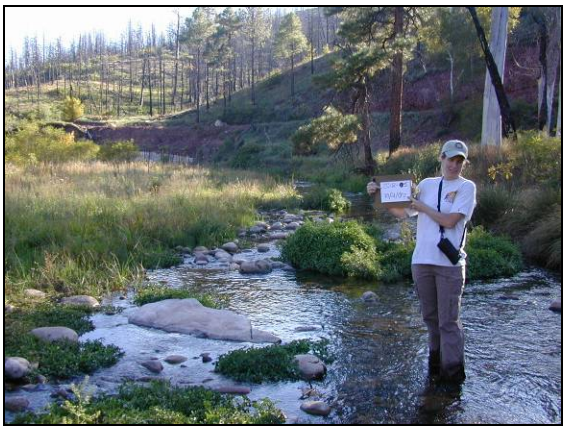
CC12 2007 View 2

View 2. Across - Looking across at left bank and changes along the greenline and floodplain. This area is grazed by elk but not domestic livestock and downstream from exclosure.

CC12 2005 View 3

CC12 2006 View 3

CC12 2007 View 3



View 3 & 4. Downstream - Looking downstream at left bank and changes along the greenline and floodplain. This area is grazed by elk but not domestic livestock and downstream from exclosure. The grass and forb cover on the opposite cobble bar (visible in 2005) has increased in density. There are no observed changes in cover as a result of woody species at this site.

CC12 2007 View 4

View 4. Mid-channel upstream (left) and downstream (View 3 downstream photo-previous photo). View shows greenline of channel.

PHOTOPOINT – CC13

CC13 2005 View 1

CC13 2006 View 1

CC13 2007 View 1

View 1. Narrowleaf cottonwood regeneration below cottonwoods killed in the fire inside exclosure on floodplain. The sapling cottonwoods measured 1.9 meters in 2005 and doubled in height by 2007. Photo is looking 340 degrees north from monument stake established as CC13. Monument is 4 degrees north and 31 yards from the SW corner of the exclosure near the cottonwood gallery.

CC13 2005 View 2

CC13 2006 View 2

CC 13 2007 View 2

View 2. Alternate view -Looking 52 degrees NE from CC 13 at an extension of the gallery and cottonwood regeneration.