Riparian Vegetation and Water Quality Monitoring:

Middle Fossil Creek Riparian Habitat Protection and Restoration Project

Final Report: Monitoring Data and Analysis, 2010-2014 (Task 4)

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Executive Summary

The objective of the Fossil Creek Riparian Vegetation, Water Quality and Visitor Use Monitoring Plan (NAU 2010) is to determine the effectiveness of the Middle Fossil Creek Riparian Habitat Protection and Restoration Project. This final report discusses the results of riparian vegetation and water quality monitoring conducted twice each year starting in 2010 (baseline monitoring) and for the following three and one-half years (2011, 2012, 2013, spring 2014). It also outlines the results of the recent spring 2014 monitoring effort.

The objective of the monitoring program was to measure the effectiveness of what came to be called the "interim measures" implemented by the U.S. Forest Service, Coconino National Forest as part of the Middle Fossil Creek Riparian Habitat Protection and Restoration Project funded by the Arizona Water Protection Fund (Grant No. 09-162WPF). These interim measures included capacity control techniques such as restrictions on camping in the riparian zone, trail renovation and establishment, and parking area delineations. Other interim measures included installation of temporary toilets and increased garbage cleanup efforts. Restoration efforts were implemented in a few areas of the middle reach of the creek including vegetative seeding and ripping (at sites Above Irving 1 and Mazatzal) as well as some bank stabilization (at Irving). The monitoring plan for the Middle Fossil Creek Riparian Habitat Protection and Restoration Project focused on indicators of structural and compositional components of the ecosystem where we anticipated to measure improvements in ecosystem health, including: riparian vegetation and disturbance factors, physical attributes of the stream channel and riparian corridor, and water quality.

Vegetation indicators were used to determine if a goal of vegetation recovery in former riparian camping zones (referred to as restoration transects) was being met. Vegetation recovery and tree seedling establishment is important for riparian bank stabilization and to prevent soil erosion.

By the end of the monitoring period, there were some signs of riparian vegetation recovery. Over the course of the monitoring program, the three direct vegetation indicators (grasses, herbaceous, and shrubs) exhibited increased overall mean coverage by as much as 38%. This increased coverage, however, occurred in both restoration and reference transects and was confined mostly to one year, 2011. This indicates favorable environmental conditions for plant growth at a landscape scale during that year. By comparison, vegetation indicators had increased

in restoration transects by 18%-21% relative to reference transects during the course of the study. This increase was statistically significant only during the last year of the study when compared to the first year of the study. However, these increases occurred only at a few sites (e.g. Above Irving 2 & Below Irving 1). Other sites, however, had decreases in vegetation coverage instead in reference transects relative to the restoration transects (e.g. Purple Mountain 1 & 2). The bare ground indicator showed similar results with a 10% decrease in coverage in restoration transects over the course of the study, but 6% increases in bare-ground coverage in reference transects. Soil compaction significantly decreased in 2014 in reference transects and has been slightly decreasing in restoration transects during the monitoring period. A concern throughout the monitoring period has been a lack of tree seedling establishment in restoration areas. Over the course of the monitoring there continued to be a 2-3 fold greater mean coverage of the vegetation indicators in reference transects compared to restoration transects. Therefore, while some of the former camping areas are demonstrating vegetation recovery, which is expected to continue, factors such as continued recreational disturbance or prevalent climate conditions may be hindering recovery in other areas.

Disturbance factor indicators related to recreational use closely mirrored visitation to the Middle reaches of the Creek during the years of the monitoring. The two response variables that were used as more direct indictors of recreational use were the percentage coverage of visible trampling and the percentage coverage of garbage. There was a large increase in the percentage coverage of trampling and garbage in 2011. These increases were a reflection of increases in recreational visitation at the Creek. The Forest Service estimated that there was a 23.7% increase in visitation in 2011 compared to 2010 (Rotert, 2013). These two indicators subsequently decreased slightly in restoration transects during the following years in 2012 and 2013. This also correlates with slightly decreased visitation (by automobile) in those years to the Middle reach of the Creek after the closure of the upper part of FR 708 from Strawberry, AZ. Trampling and garbage indicators did not change during the last few years of the study in restoration transects but there was a significant increase in garbage in reference transects. Some of the sites that continued to receive a large amount of trampling throughout the monitoring period include Above Irving 1, Fossil Creek Bridge, the Mazatzal site near the swimming hole, and Sally Mae. These four sites also have not demonstrated significant increases in vegetation recovery over the course of the study. Although it is speculative to conclude that recreational disturbance is preventing vegetation recovery in these areas, only the prevention of further disturbance would allow testing of this conclusion. Visitor demand and use is increasing over the entire Fossil Creek area despite a decrease in vehicle traffic (Rotert, 2013). Future recreational visitation levels will be dependent on decisions from the Forest Service regarding management details of the forthcoming Comprehensive River Management Plan.

Based on the data generated in this study, it is recommended that further actions be taken to try to reduce the continued disturbance to former camping areas where vegetation recovery has not occurred; these include Above Irving I, Fossil Creek Bridge, the Mazatzal site near the swimming hole, and Sally Mae. Positive results from Forest Service interim actions in the Mazatzal area (other than the former camping area by the swimming hole) such as seeding, erosion abatement, and trail delineation and reinforcement, have shown that restoration is possible (Rotert, 2013). It is recommended that such actions be considered for those areas mentioned in this study that are still experiencing problems with vegetation recovery. It is also recommended that management actions be taken to reduce general recreational impacts in the riparian zone based on the indications of deteriorating conditions in the reference transects. One of the more reliable methods of reducing recreational impacts would be reductions in visitation. This would reduce the proliferation and expansion of social trails and allow stabilization of banks and vegetation recovery in degraded areas of the stream channel. Increased efforts at trail delineation and confinement of recreational activity to select areas would also be beneficial for this goal. We also recommend continued monitoring to help determine if those mitigation practices are effective and are not being undermined by recreational impacts or low precipitation levels.

Stream channel attribute variables were measured between years for the detection of instability in the physical stream channel and for increases in sedimentation. Between 2013 and 2014, unlike previous years, there was an indication of a change in channel and bank stability measurements at one of the water quality sites, the Purple Mountain site. In 2014, this site had another increase in the percentage of fines and incurred the first statistically significant decrease in depth during the study and a significant increase in the width to depth ratio. This suggests that the channel is being filled in with sediment. High sedimentation values (which occurred both at the Bridge and the Purple mountain site between 2013 and 2014) can indicate problems with channel bank stabilization and erosion and can have potential impacts on the aquatic community.

During the study, there were continued observations of erosion in restoration transects after rain events where vegetation recovery has not occurred. Large floods in 2009 also caused significant damage to the stream channel.

The monitoring plan for this restoration project focuses on measuring indicators of ecosystem health, including disturbance factors and physical attributes of the stream channel and riparian corridor. Stream ecologists have long recognized the significant influence that surrounding lands have on the stream ecosystem (Allan and Castillo 2007). Rain and snow that fall within a watershed reach the stream by myriad flow paths, notably, surface and subsurface flows (Allan and Castillo 2007). Watersheds with adequate vegetation in relation to slope tend to decrease the energy of surface/overland flow of precipitation due to increased infiltration, and hence these watershed respond more slowly to sediment movement due to vegetation capture as compared to those with more anthropogenic and impervious surface cover (Wu et al. 2006).

In the case of multi-year monitoring, as was conducted in the Middle Reach of Fossil Creek, ecologists can gain insight into the year-to-year condition of specific monitoring sites with results that may point to larger causes of disturbance. As such, we believe that the increased sediment inputs measured in this study at the Purple Mountain site in 2013 and 2014 are indicative of changes in the larger landscape processes in the upper watershed of the Sally Mae Wash area rather than changes to the bank stability or width/depth ratios at the site itself (see pages 41-42 for details and further discussion). Management actions may be necessary to decrease sedimentation impacts to the channel. Such actions should include determination and identification of grazing impacts from livestock and roads and impacts from the destabilization of soil conditions in the upland areas of the watershed of Fossil Creek. The Forest Service could consider conducting sediment fingerprinting to determine the source of suspended sediment at the Purple Mountain site if there is uncertainty about origin (see Mukundan et al. 2010).

In 2013, for the first time since the 2010 summer recreation season, all three yearly monitoring sites exceeded EPA limits of fecal coliform bacteria in recreational water. This occurred during the August 2013 sampling date, and one site, Below Mid-falls, exceeded EPA limits in June 2013 as well. Fecal coliform bacteria were not monitoring by NAU in spring 2014. Improvements in fecal coliform levels during the 2011 and 2012 recreation seasons were attributed to the installation of temporary toilets. The return to greater levels of fecal coliform bacteria during summer of 2013 may be due to a combination of climactic factors and the continued popularity of Fossil Creek among recreation seekers. For 2013 in particular, a record-breaking precipitation during the month of July and increased sedimentation in the creek were followed by sediment disturbance by swimmers and hikers in August. It should also be noted that observances of discarded toilet tissue was common at some sites in 2013 and 2014 including the Bridge, Purple Mountain, and Sally Mae sites. These sites had temporary toilets in plain view, near parking areas and with associated signage. Since bacteria exceedances occurred despite the presence of temporary toilets, reductions in visitation may be needed to prevent problems in water quality. In addition, the effect of fecal coliform bacteria stored in sediments at Fossil Creek should be explored further as stored sediments may be a contributing source of these bacteria in the waters of Fossil Creek.

Introduction

The objective of the Fossil Creek Riparian Vegetation, Water Quality and Visitor Use Monitoring Plan (NAU 2010) is to determine the effectiveness of the Middle Fossil Creek Riparian Habitat Protection and Restoration Project. This final report discusses the results of riparian vegetation and water quality monitoring conducted over four and one-half years (spring 2010 – spring 2014). The riparian vegetation section of the Monitoring Plan takes a hybrid approach between predictive or stress-orientated monitoring and retrospective monitoring. Indicators were chosen from a conceptual model that are indicative and predictive of the anticipated changes in specific ecological conditions (and stressors) and then selected for measurement (Noon 2003).

Restoration Project Goals and Objectives

The Middle Fossil Creek Riparian Habitat Protection and Restoration project was developed by the U.S. Forest Service to implement specific, on-the-ground actions that reduce continued resource damage to riparian habitat and improve water quality. The main stressors to the health of the riparian zone and the stream channel in this 4.5 mile (7.2 km) reach are products of the continued disturbance to the riparian zone by recreational use. These stressors include denuded vegetation and compacted soil in the campsite areas located in the riparian zone and on riparian terraces, stream channel bank instability, erosion and sedimentation into the stream habitat, and increased contamination of water quality for safe recreational activities such as swimming.

Objectives of the restoration project are:

1) Protect and restore native riparian vegetation and habitat in the Middle Fossil Creek area;
2) Reduce soil sedimentation into Middle Fossil Creek resulting from recreational use in the riparian zone;
3) Minimize direct and indirect disturbance to aquatic and riparian obligate species and habitat;

The project focuses on restoring riparian habitat, and thereby reducing sediment and improving water quality through the removal of high-use dispersed campsites located within the riparian zone. Due to legislative and regulatory issues, the project was modified in 2009 after Fossil Creek was designated as a Wild and Scenic River. Camping within the riparian area of Fossil Creek was prohibited as of March 8, 2010, through the issuance of a Forest Closure Order and other non-permanent closure actions. Implemented actions include a prohibition of camping within ¼ mile of Fossil Creek between the old diversion dam (upstream of the Middle reach) and the bridge (within the Middle reach). Downstream of the bridge, camping is now prohibited within 100 feet of Fossil Creek. The Forest Service has implemented additional actions in a "phased" manner including ripping and seeding former campsites, erosion control and constructing vehicle barriers.

Monitoring Plan Goals and Objectives

The monitoring plan gives specific quantifiable measurements of indicator parameters to detect the progress toward the desired goals of the restoration. The sampling design uses two types of site locations to determine the effectiveness of the restoration actions: the sites in which the restoration actions (camping restrictions) have taken place (the restoration sites); and, the sites that act as references for obtaining restoration goals (the reference sites). The use of ten monitoring sites with each of both type site categories has provided spatial replication. Temporal replication was achieved by measuring the indicators twice a year starting in 2010 (baseline monitoring) and for the following three and one-half years (2011, 2012, 2013, spring 2014). Changes in the indicator parameters were tested using two statistical models: a paired BACI (Before-After-Control-Impact) statistical design model that compares the differences in an indicator response variable between restoration sites and reference sites over time; and a bioequivalence design that compares a mean ratio of a response variable between restoration and reference sites to determine the percentage of equality above a minimal threshold value based on management goals.

The monitoring plan operated under the assumption that recreational impacts in the Middle reach have currently pushed portions of the riparian and stream ecosystem into an unacceptable range of ecosystem stability. The plan outlines monitoring of structural and compositional components of the ecosystem where we anticipated measuring improvements in ecosystem health, including: riparian vegetation and disturbance factors, physical attributes of the stream channel and riparian corridor, and water quality. The degree to which the components and indicators are within an acceptable range of ecosystem health are judged by comparison to reference sites that are not impacted by heavier recreation. Periodic information on the status of the indicators provides managers with the information necessary to determine if future management actions are necessary for the goals of the restoration efforts.

Riparian vegetation is an important habitat and functional component of the riparian corridor ecosystem and also serves as an indirect link to the process of bank and soil integrity. The monitoring plan incorporates several riparian vegetation indicators, before and after campsites are closed, to document if and how this component improves over time. The amount of bare-ground at these sites, and other recreational use disturbance indicators, such as the percentage coverage of garbage, were monitored.

Physical conditions of the riparian corridor and stream channel were monitored over time to detect their responses to the implementation of the restoration actions. Improvements in the integrity of physical attributes of the riparian and stream channel are expected to reduce negative impacts on riparian re-establishment and habitat degradation of the benthic stream community. Such improvements could include: increased channel stability; reduced erosion; increased stream resilience to disturbance; reduced sedimentation in the stream habitat; and reduced substrate embeddedness of the stream bed. Decreases in these attributes could potentially indicate the need for management actions.

Water quality was monitored between 2010 (baseline data) and fall 2013 to detect potential physical and chemical stressors to biological systems and prevent harm to recreational visitors. Monitoring was expected to aid the detection of improvements from restoration and interim actions (such as decreased sedimentation impacts from erosion control or decreased bacteria levels from temporary toilet placement funded by an ADEQ grant and the Forest Service). Suites of water quality parameters were measured including dissolved oxygen, temperature, pH, conductivity, Total Dissolved Solids and levels Enterococci bacteria. The purpose of measuring these parameters was to detect unusual trends in water chemistry or increases in fecal coliform bacteria levels that are unsuitable for recreational use. Increases in conductivity, pH and Total Dissolved Solids measurements can be useful as an indicator of the effects of runoff from construction, agricultural practices, logging activities, sewage treatment plant discharges, and other sources (EPA 1997). Shifts in these parameters may indicate unusual stress to the aquatic environment. Enterococci levels are an indicator of whether waters are being contaminated by human waste.

Vegetation Monitoring Implementation

Ten sites were chosen for vegetation monitoring sites at Fossil Creek interspersed along the length of the Middle Reach based on the following requirements:

1) The sites were located either directly in the riparian zone at the edge of the creek or on the edge of the riparian terrace with direct disturbance leading down into the riparian zone and the edge of the creek.

2) The ten sites included those that had the greatest amount of disturbance in the Middle Reach due to human use such as camping and other recreational activities. Indications of disturbance included trampled vegetation, missing vegetation, bare ground, compacted soil, and areas of high erosion.

3) The degraded area of the site had to be large enough to accommodate at least one 15 meter long transect.

4) Each site needed an adjacent reference area transect of similar vegetation and topography.

Five of the restoration sites were located directly in the riparian zone, and five additional sites were located on a degraded riparian terrace with physical impacts occurring down into the riparian zone. The ten vegetation monitoring sites, with their designations, are shown in Figure 1.

Three sites were chosen for water quality monitoring for a gradient type of analysis. This was done to determine if water quality decreases along the length of the middle reach due to accumulated disturbance as a result of the close proximity of the creek to the road. One site was chosen approximately 1 kilometer upstream of the Above Irving 2 vegetation site monitoring site, north of the area where the road comes in to proximity with the creek. Another site was chosen in the middle of the reach, adjacent to the Fossil Creek vegetation monitoring site. The most downstream site was located at the Purple Mountain 2 vegetation monitoring just north of where the road leaves its close proximity to the Creek (Figure 1).

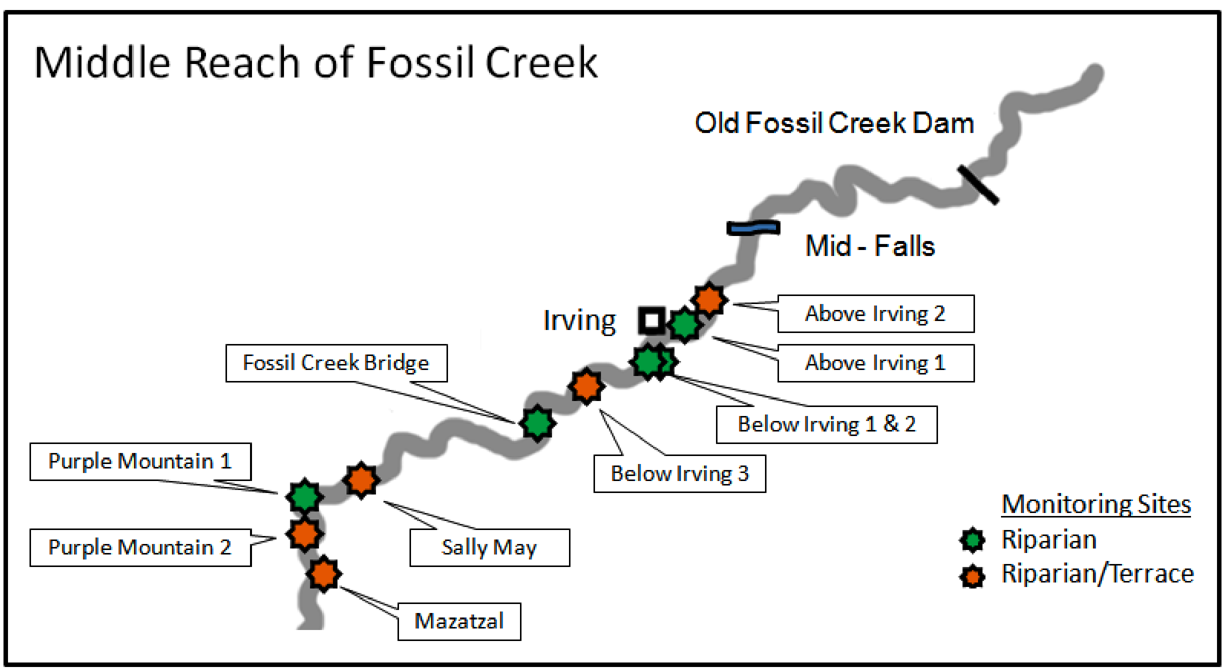

Figure 1: Vegetation monitoring site locations, Middle Fossil Creek

The monitoring design consisted of the establishment of two types of restoration treatment transects at each site in a statistical framework to determine the effectiveness of the restoration actions. Two transects were established with permanent markers at each site for each treatment. One treatment transect was placed in an area of the site that had been degraded from camping activities but where camping is no longer allowed (referred to hereafter as the restoration transects). The transects were placed in the site to incorporate areas that had obvious visible camping impacts (soil compaction, erosion, loss of vegetation) with a direct link into, and within, the riparian zone. The second treatment was the placement of a transect in a non-degraded area of the site to act as a reference for obtaining restoration goals (referred to hereafter as the reference transects). The reference transect was chosen for the least disturbance due to the stressors (recreational impacts) but also located in close proximity to the first to include the same physiographic features such as slope angle and substrate, similar solar angle, and the unique riparian area features of that site such as vegetation class and coverage. These sites were designated to serve as the desired target state and allow detection of the magnitude of the change in indicators in the desired direction. The GPS coordinates for each end of a transect were recorded and photo points were established to aid in transect identification at all ten sites. All transects were 15 meters total length and were therefore able to accommodate 7 nested plot quadrats.

The sampling periods outlined in the monitoring plan originally consisted of one year of baseline (2010) monitoring followed by three years (2011, 2012, and 2013) of follow-up post-restoration monitoring. In 2013, the Forest Service determined that an additional one-half year of vegetation monitoring in the spring of 2014 would be conducted as well. This report includes data for the 2010 baseline monitoring, and data for the years from 2011 to spring 2014. Baseline monitoring of vegetation transects and physical conditions of the stream channel occurred in May and September 2010. Post-restoration monitoring occurred in May and September 2011, June and October 2012, June and September 2013 and May/June 2014. The comparison of changes in indicator values using the reference treatments, baseline conditions (year 1), and future monitoring values, will allow detection of positive directional movement away from pre-restoration conditions. The monitoring plan also specified sampling for vegetation monitoring to take place twice a year, once in late spring and once in early autumn. The purpose of sampling both these two periods was to detect changes in indicator parameters due to impacts during the recreational season, and changes due to runoff, and to increase temporal replication.

Water quality indicators were also sampled during the same week as vegetation monitoring, in June and September 2013.

Indicator variables (measured environmental attributes), protocols, and procedures

The quantitative environmental attributes (indicators) were chosen to measure three majors areas related to the goals of the restoration project. These areas include 1) the recovery of the riparian (former campsite) areas, 2) improvements in stream channel attributes and bank stabilization, and 3) water quality. From the conceptual model, these attributes were chosen for their aggregated ability to detect the anticipated changes in specific ecological conditions and stressors due to the initiatives of the restoration action plan. These indicators and their associated measurements will allow a thorough and ecologically comprehensive evaluation of progress toward restoration goals. The monitoring program was designed to perform the initial sampling using the full suite of quantitative indicators. After the baseline assessment, the candidate list of indicators for future sampling may be modified and refined based on an analysis of the value and statistical power of the preliminary data from the full suite of indicators. All indicators and protocols outlined below (Table 1) were measured during the baseline monitoring in 2010.

A summary of the quantitative indicators for each area is as follows:

1) Riparian area vegetation and disturbance factors:

The re-establishment of the riparian vegetation was monitored to insure recovery of the ecological processes provided by reduced compaction and increased soil integrity, erosion control and bank stability for the stream channel, and increases in riparian vegetation and herbaceous cover. The indicators for vegetation recovery were plant community structure and composition measured by cover of grasses, herbaceous and shrub species; seedling density; tree stem density and basal area. The indicators for environmental attributes that were measured in conjunction with the vegetation transects were canopy closure, cover class categories for substrate, groundcover and disturbance, and soil compaction. The disturbance cover class category will be the indicator to monitor for the continued evidence of recreational impacts. Soil compaction will be the indicator for surface aggregate stability, which is positively related to soil's resistance to wind and water erosion. Table 1 summarizes the riparian area indicators with their associated measurements and measurement protocols.

Riparian area plant community structure and composition was measured using methods based on the Southern Colorado Plateau Network Riparian Monitoring Protocol (SCPN) of the National Park Service (Standard Operating Procedure #8, Nested Plot Sampling Methods). These SOPs are currently working drafts that have been implemented for several years. Finalization is scheduled to occur in the near future (pers. comm. Steve Monroe, National Park Service Southern Colorado Plateau Network). This method obtains frequency and cover estimates of herbaceous and shrub species within cover class categories and tree seedling density using nested plot sampling. The plots are evenly spaced along the transect with nesting of the 1 m^2, 5 m^2, and 10 m^2 plots at a given plot location (SOP #8, 2007). During the baseline monitoring, 7 nested plots were alternated along each 15-meter length transect. The nested plots will allow enough sub-samples and replication for statistical analysis.

	Indicator	**Measurements**	**Protocol**
Riparian Areas	Plant community structure and composition	Frequency and Cover of herbaceous and shrub species	SCPN Riparian Monitoring Protocol SOP #8
		Seedling density	
		Tree stem density and dbh	
	Environmental attributes	Canopy closure	SCPN SOP #8
		Cover class categories for substrate & groundcover	
	Disturbance	Cover class categories for disturbance	SCPN SOP #8
	Soil surface compaction	Soil compaction penetrometer	
Stream channel attributes	Stream channel integrity	Active & wetted channel width	SCPN Aquatic Macroinvertebrate Monitoring Protocol
		Channel depth	
		Water velocity	
	Stream channel sedimentation	particle size	SCPN SOP #5 & #6
		Stream bed embeddedness	

Bank stabilization	Bank vertical stability	Width/Depth Ratios	Channel Dimension Relations (AZDEQ, 2002)
Water quality	Water quality parameters	temperature	AZDEQ (2002)
		pH	
		total dissolved solids	
		Salinity	
		Specific conductivity	
		dissolved oxygen	
	Enterococcus faecalis	colony plate counts	Method 1600 (EPA 2002)

Table 1: Attribute Indicators with their associated measurements and measurement protocols.

The environmental attributes for the plots, which include canopy closure using a densitometer and cover class categories for substrate, groundcover and disturbance, were also measured using guidelines similar to Standard Operating Procedure #8 (SCPN, 2007). Substrate and ground cover measurements (such as particle size, bare ground coverage, leaf litter, woody material) are taken at the $1m^2$ size plot, while disturbance categories (such as trampling, camping, and flooding) are taken at the $10m^2$ plot. Densiometer readings were taken at three locations along of each transect at the beginning, middle, and end. Measurements of trees, including density and diameter breast height, were taken for any tree that occurred in the nested plots. Soil stability measurements of compaction were taken at 7 locations along the length of each transect using a penetrometer. Table 1 summarizes the riparian area indicators with their associated measurements and measurement protocols.

2) Stream channel attributes and bank stabilization:

For stream channel attributes, stream channel integrity will be determined through measurements of wetted channel width, active channel width, channel depth, and water velocity. Stream habitat structure will be measured by geomorphic channel unit (GCU) type, riparian canopy closure, pebble counts and substrate embeddedness. Indirect measurements of stream channel sedimentation were particle size (pebble counts) and embeddedness.

Measurements of bank stabilization parameters were used at the three stream water quality gradient sites to determine vertical stability of stream banks and the susceptibility of the stream banks to erosion due to the stressors caused by reduced vegetation and compaction from recreation. Vertical stability of the banks will be measured by the Channel Dimension Relations Using Width/Depth Ratios protocol. Table 2 summarizes the stream channel and bank stabilization indicators with their associated measurements and measurement protocols.

Standard Operating Procedure (SOP # 6) of the SCPN protocol was used for collecting physical habitat characterization of the stream channel and included sampling methods for measuring reach, transect, and point habitat along 7 transects within a 150 m reach of the stream. The large number of transects gives a large amount of replication. Physical measurements of bank and riparian features and in stream characteristics were made at each transect included wetted channel width, active channel width, depth, velocity, riparian canopy closure, pebble counts, (particle size) and substrate embeddedness.

3) Water quality monitoring:

Measurement of water quality parameters (temperature, pH, total dissolved solids, specific conductivity, salinity and dissolved oxygen) were taken in 2010-2012. In 2012, after data analysis, it was determined that there were highly skewed dissolved oxygen readings (probably from a malfunction) and therefore the data for that year was not used for further analysis. In 2013 there was total equipment failure of the Hydrolab water quality probes in the field and therefore data was unattainable. The purpose of measuring these parameters is the detection of unusual trends in water chemistry, and shifts in the parameters may indicate unusual stress to the aquatic environment.

The presence of Enterococci bacteria was also monitored. The installation of temporary toilets in 2009-2013 was a direct response over the concern of evidence of human wastes found around campsites in close proximity to Fossil Creek. Limited monitoring of Enterococci has taken place at Fossil Creek several times per year in 2008 and 2009 at the Bridge as well as behind the diversion dam by the NAU Department of Biological Sciences (Lambdin and Watwood 2009) The presence of Enterococci bacteria in water is an indication of fecal pollution of human and other warm-blooded animals and the possible presence of enteric pathogens (EPA 2002). Enterococci include *Streptococcus faecalis, Streptococcus faecium, Streptococcus avium*, and their variants (EPA 2002). Enterococci enter recreational waters from three primary sources:

sewage and storm water discharge; riverine discharge that contain sewage discharge; and, by other contamination, including excreta (WHO 1999).

The Enterococci method is designed to measure the bacteriological quality of recreation waters. The significance of finding Enterococci in recreational water samples is the direct relationship between the density of Enterococci in the water and swimming-associated gastroenteritis studies of marine and freshwater bathing beaches (as cited in EPA 2002). Sources of Enterococci in recreational waters worldwide include humans, horses, cows, dogs, chickens, beavers (WHO 1999) and some wild birds (Kuntz et al. 2004).

Table 1 summarizes indicators of water quality with their associated measurements and measurement protocols. Water quality monitoring will include measurements at each sampling event of temperature, pH, total dissolved solids, specific conductivity, salinity, and dissolved oxygen using Hydrolab environmental probes. Enterococci were monitored using EPA Method 1600 (EPA 2002). This method provides a direct count of Enterococci bacteria in water based on the growth of colonies on the surface of a membrane filter.

NAU collected Fossil Creek water and sediment samples over the 2010 – 2013 recreation season to determine fecal coliform counts as outlined in the Fossil Creek Vegetation and Water Quality Monitoring Plan (NAU 2010). Stream water and stream sediment samples were collected from three sites along Fossil Creek at various dates between June and September. From upstream to downstream, sample pool sites were identified at three locations: 1) approximately 0.5 km below mid-falls, 2) at the Bridge, and 3) at Purple Mountain. Five replicate samples of 30 mL stream water and 50-80 g stream sediment were collected from each site. Water and sediment samples were frozen with 15% glycerol to preserve fecal coliform cells until filtering and incubating on mEI media. We followed EPA protocol, including positive controls, to test for Enterococci in stream water samples. The EPA protocol was modified for stream sediment samples to include vortex mixing with 0.75% saline solution for 4 minutes prior to filtration. This additional step uses mechanical vibrating and mixing to remove Enterococci bacteria that are attached to sediment surfaces. After vortexing, stream sediment was rinsed through a coffee filter with 0.75% saline solution, and the rinse water was filtered and incubated on mEI media following EPA protocol for water samples. Water chemistry and velocity measurements were determined at each water quality site during each sampling period.

Vegetation and Disturbance Factor Monitoring Results

Background

This report encompasses 2010 - 2014 monitoring data. Two specific statistical models and tests were developed within the sampling design of the monitoring plan to incorporate the measurements of the indicators. Both the paired BACI (Before -After-Control-Impact- In- Pairs) statistical model and the bioequivalence statistical model were used to determine if restoration goals are being met. Both statistical models were used to answer four questions: 1) How different are the indicator conditions between the restoration and reference treatment? 2) Did the difference in indicator response variables change between years? 3) Are there some sites that are significantly variable in respect to the indicators? 4) Are the indicator response variables of the restoration areas near equivalency to reference conditions? The following paragraphs outline the sampling design and statistical analysis of the monitoring plan with a description of the methods used to answer the above questions. The equivalence model results are in the last paragraph of the results section for vegetation and disturbance factors.

Statistical Framework

The sampling design used two types of treatments, or transects, to determine the effectiveness of the restoration actions: the transects in which the restoration actions have taken place (the restoration sites); and, the transects that act as references for obtaining restoration goals (the reference sites). The use of 10 monitoring transects per treatment category gives spatial replication, and temporal replication will be done by measuring the indicators twice a year starting in 2010 (baseline monitoring) and for the following three and a half years (2011, 2012, 2013, & 2014). The percentage coverage of a response variable was converted to the midpoints of cover classes for each indicator. Changes in the indicator parameters were tested using two statistical models: a BACI (Before-After-Control-Impact) statistical design model; and a bioequivalence design that uses minimal threshold values for parameters based on management goals.

A paired BACI (Before -After-Control-Impact- In- Pairs) statistical model was used to determine if restoration sites were different in respect to chosen indicators before and after restoration by comparison to reference sites. This is done by subtracting the mean values of an indicator at a restoration site transect from the value at its associated and paired reference site transect. The statistical model is then used to determine if the mean differences between the two types of transects are significantly different from zero. The null hypothesis would be no difference in the indicator response variables between restoration and reference transects, which is the goal of the restoration program. The mean differences of the transects were then used to test for significant variation when comparing them between the Before and After periods (in this case between years) (Downes et al. 2002). The paired t-test is conservative compared to a simple t-test in that it does not ignore any correlations between the responses of the subjects. If the correlations were positive or negative (which would occur when the responses are measured over two different time periods) then the simple t-test could underestimate or overestimate the effect (SAS 2009). The paired t-test allows analysis for a significant variation in the difference between subjects (the means of the response variable) due to the treatment (the restoration) across time periods. All paired t-tests in this analysis were conducted using the means of a response variable calculated from the ten transects for either the restoration or reference sites for a given year. A second group of paired t-tests were also used to compare the mean differences between the spring and summer indicator.

The paired t-test was done in this analysis using the Matched Pairs platform in the SAS JMP 10.0 Statistical Program (SAS 2011). The main statistical test is for a significant mean difference between restoration and reference indicator response means. Even though it is expected there will be a significant mean difference for a given response variable at the beginning of this study, the goal of the restoration program is no mean difference between restoration and reference transects by the end of the study. The Matched Paired platform in the JMP program also has the added benefit of the capability to test if there is significant variation in the mean of the response variable between years. However, this is a test of variation in the overall mean of a response variable between years across all transects, not between the restoration and reference transects. A third test within the Matched Pairs platform (mean differences across groups) is a test for significant variation or change in the mean difference of a response variable between the reference and restoration transects across the years. The goal of the program is a change in a response variable in restoration transects relative to the reference transect. For example, if the overall mean coverage for grass increased equivalently at both the restoration and reference transects between 2010 and 2011 than there would not be a significant change in the mean difference between them across the two years. This could occur if there were favorable environmental conditions such as a moisture increase across the entire landscape and would not be due to an increase in grass coverage in the restoration transects relative to the reference transects. All three statistical tests were conducted to detect changes in the indicator response variables between: 1) 2013 and 2014; 2) between all four years of the study; and 3) between the spring (June) and summer (September) sampling periods (this test was conducted in all years except the last year, 2014).

An inferential problem with comparisons between restoration treatments and reference treatments in parametric hypothesis testing is that there will automatically be differences between the two treatments prior to restoration (Downes et al., 2002). Bioequivalence models use a ratio of the mean value of an indicator at a restoration site to a reference site. The null hypothesis would instead be that the restoration site is not bioequivalent to the reference site by incorporating a minimum percentage threshold of the ratio needed to become bioequivalent (Downes et al., 2002).

The results given in the next few sections are for some of the key attribute indicators. The vegetation indicator measurements are based on percent coverage and are expected to increase over time in the former campsite restoration transects. The indicator response variable measurements of the reference transect represent the desired goal of this increase in the statistical models. The key vegetation indicators are divided into the functional groups of total grass, total herbaceous, total shrub measurements, and the frequency of tree seedlings. Bare ground measurements provide a link between vegetation establishment and disturbance by recreational use. Other disturbance factors included the percentage coverage of trampling and the percentage coverage of garbage. Indicators of soil stability that will be presented in this analysis are measurements of soil compaction using penetrometer measurements. Graphs of a few key attribute indicators will follow the results text, while tables will give the results of the three groups of statistical tests. Additional graphs for all other response variables will be included in Appendix 1.

General Description of Riparian Vegetation Communities

Riparian vegetation is an important habitat and functional component of the riparian corridor ecosystem, and also serves as an indirect link to the process of bank and soil integrity. The recovery of the degraded vegetation communities in the former campsite areas is, therefore, a main component of the restoration and rehabilitation goals. The monitoring plan was designed to observe the recovery of those plant communities and monitor for potential continuous impacts from recreational use. The reference transects were placed adjacent to the restoration transects in the former campground areas in order to characterize the potential and desired recovery state of the vegetation communities of that site specific area. In general, there were two main types of vegetation communities based on their proximity to the wetted channel of the creek. Plant communities in the immediate vicinity of the wetted channel tended to exhibit the usual riparian floodplain community types with an overstory of deciduous trees and moisture preferring grasses, such as Bermuda and Johnson grass, and moisture tolerant herbaceous, including some semi-aquatic genera such as spikegrass or cattails (Table 2). The plant communities in the former camping areas that occurred on benches, or terraces, leading out of the immediate floodplain tended to have high desert community types with a Juniper and Mesquite overstory, or Soapberry, and had an understory of more drought tolerant grasses and herbaceous, including some succulents (Table 2). There was an equal representation of both community types which will allow a more generalized picture of potential conditions that could influence recovery of the desired vegetation types. Table 2 also provides observations of the amount of current recreational use that these sites are incurring.

Site	Terrace/ Floodplain	Current Usage	Vegetation community descriptors
Above Irving 2	Terrace	frequent trail	Walnut/Soapberry, grass herbaceous understory
Above Irving 1	Floodplain	day use	Sycamore/Willow, grass understory
Below Irving 1	Floodplain	day use	Fremont/Ash, grass and semi-aquatic herbaceous
Below Irving 2	Floodplain	limited	Fremont/Sycamore, Ash/willow, grass and semi-aquatic herbaceous
Below Irving 3	Terrace	day use	Juniper/Scrub Oak, succulent understory
Fossil Creek Bridge	Floodplain	frequent day use	Sycamore/Ash, grass and semi-aquatic herbaceous
Sally May	Terrace	camping /day use	Juniper/mesquite grass
Purple mountain 1	Floodplain	day use	Fremont/Sycamore, Alder/willow, grass understory
Purple mountain 2	Terrace	trail	Juniper/mesquite/Soapberry grass
Mazatzal	Terrace	camping /day use	Juniper/mesquite, grass and succulent understory

Table 2: Physiographic and vegetation community characteristics of monitoring sites with observed recreational use.

Results of Vegetation Indicator Measurements and Statistical Tests

The results of the statistical tests in the first column of tables 3 and 4 were used to confirm that the mean of the indicators were initially different between restoration and reference transects. As expected, there were significant mean differences (greater than zero) in the percentage coverage of vegetation indicator response variables between restoration and reference sites in 2014 and across the years of the study (Table 3 and 4, Figure 2). The three direct vegetation indicators (grasses, herbaceous, and shrubs) had a 2-3 fold greater mean coverage in reference transects compared to restoration transects since the beginning of the monitoring. The purpose of the statistical design was to determine if restoration goals were being met by detecting positive changes over time in the mean differences of the indicators between restoration and reference transects.

Between 2013 and 2014, the overall total mean percentage coverage of grasses, herbaceous, and shrubs did not significantly change (Table 2, Figure 2, and Figure 9 appendix). There were slight, but non-significant, increases in mean grass coverage in both restoration and reference transects. Restoration transects increased from 13.6% (±2.4) mean grass coverage to 17.9% (±2.9) and reference transects increased from 31.8% (±3.3) mean grass coverage to 37.1 % (±3.8) (Figure 2). There also was not a significant change in the difference of the means between restoration and reference transects from 2013 to 2014 indicating that the slight, but non-significant, increases in mean coverage of the indicators across the two years was consistent in both types of transect (p-0.841, Table 3, Figure 2). There also was not a significant change in the overall mean percentage coverage of herbaceous in 2013 compared to the year before (p-0.862, Figure 3). Similar to grasses, herbaceous coverage had slight but insignificant increases in both restoration transects (+0.6% mean coverage) and references transects (+0.35% mean coverage). There was no significant variation in the mean difference between restoration and reference transects (p-0.169, Table 2, Figure 2).

Response Variable	Test of Mean Difference between Restoration and Reference Transects	Test of Mean Difference between years (2013-2014)	Test of Mean between years (2013-2014)
Total Grass	<0.001*	0.841	0.189
Total Herb	0.009*	0.169	0.862
Total Shrub	0.008*	0.276	0.124
Seedlings	<0.001*	0.572	0.643
Canopy Coverage	<0.001*	0.839	0.915
Bare ground	<0.001*	0.967	0.606
Penetrometer	0.631	0.051*	0.009*
Trampling	<0.001*	0.520	0.374
Garbage	0.058~	0.265	0.306

Table 3: Statistical tests from 2013 to 2014 for the mean difference of indicator response variables between restoration and reference transects, variation in the mean difference between the years, and a test of variation in the overall means of the indicator response variable between years. An asterisk (*) indicates a significant statistical result at the 95% confidence level, and a ~ indicates marginally insignificant results.

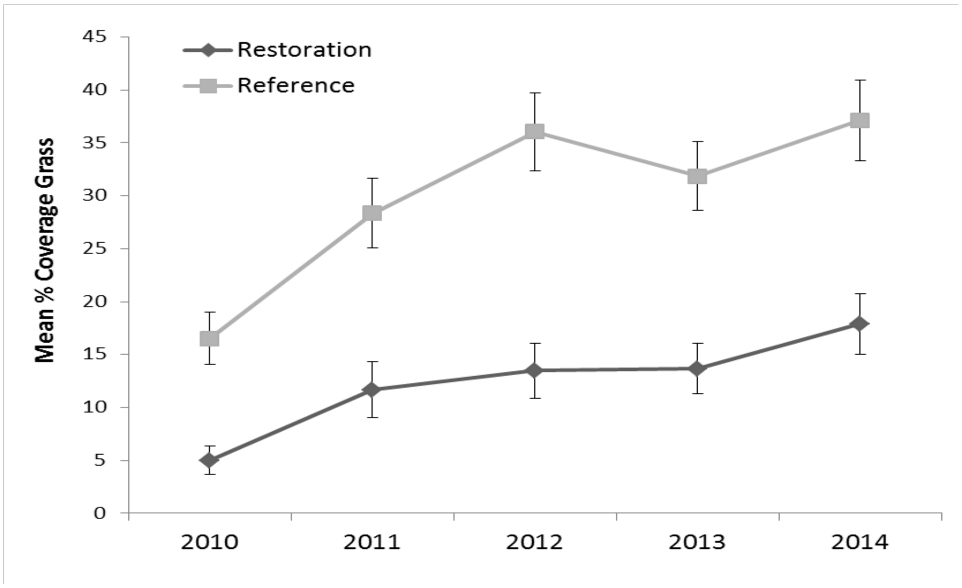

Figure 2: The mean percentage coverage of grass recorded for the reference transects and restoration transects from 2010 – 2014. Error bars are the standard error for the mean.

The 2014 results (similar to 2012 and 2013) are not as dramatic as 2011, when there was a general significant increase from the previous year in the overall means for the percentage coverage of grasses and herbaceous. For example, the mean coverage of grasses significantly increased in the restoration transects from a mean total of 5.01% (±1.31) in 2010 to 11.7% (±2.60) in 2011 (Figure 2). However, the overall mean coverage of the vegetative indicators has continued to have slight, incremental, increases over the years since 2011, which caused significant variation in the overall means among the years of the study for both (p-<0.001, Table 4, Figure 2). The mean coverage of grasses and herbaceous, but not shrubs, had significantly increased by 2014 when compared to 2010 in both restoration transects and reference transects (Figure 2 & 3). The mean coverage of grasses had increased in restoration transects by 12.8% by 2014 and increased in reference transects by 20.6%. The percentage coverage of herbaceous plants was also significantly increased in 2014 compared to 2010. Herbaceous coverage increased in restoration transects 2.9% by 2014 compared to 2010 and increased in reference transects by 3.1%. However, there was not a significant variation in the mean difference between restoration and reference transects among all years of the study (2010-2014) for either grass or herbs (p-0.265 and p-0.547, Table 4). This indicates that the increase in vegetation was consistent in both restoration and reference transects and suggests a general response to more favorable environmental conditions for growth at the landscape scale. The increased mean vegetation coverage has persisted in later years since 2011. However, it should be noted that there was a slight decrease in herbaceous coverage in reference transects in 2014.

Response Variable	Test of Mean Difference between Restoration and Reference Transects	Test of Mean Difference among years (2010-2014)	Test of Mean among years (2010-2014)
Total Grass	<0.001*	0.265	<0.001*
Total Herb	<0.001*	0.547	0.001*
Total Shrub	<0.001*	0.731	0.467
Seedlings	<0.001*	0.466	0.428
Canopy Coverage	<0.001*	0.346	0.147
Bare ground	<0.001*	0.023*	0.111
Penetrometer	0.038*	0.313	0.044*
Trampling	<0.001*	<0.001*	<0.001*
Garbage	<0.001*	0.678	0.002*

Table 4: Statistical tests across all five (2010 -2014) years for the mean difference of indicator response variables between restoration and reference transects, variation in the mean difference among years, and a test of variation in the overall means of the indicator response variable among years. An asterisk (*) indicates a significant statistical result at the 95% confidence level, and a ~ indicates marginally significant results.

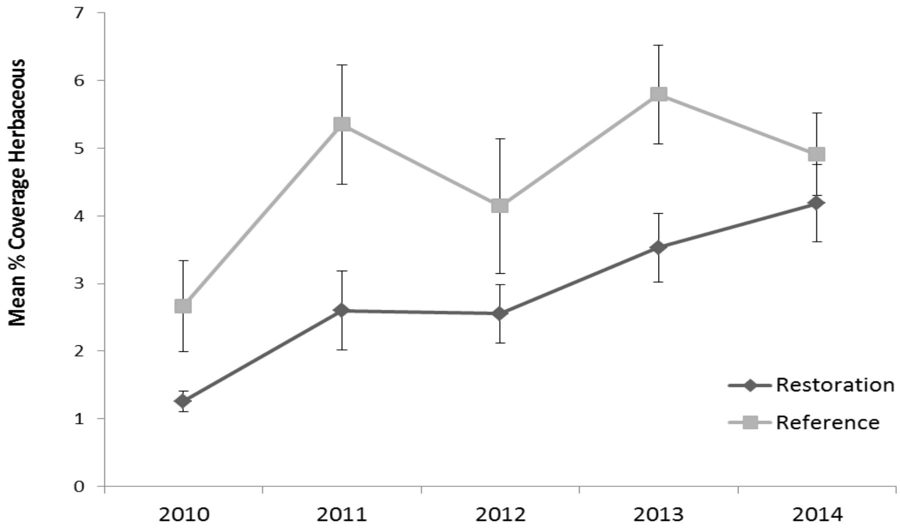

Figure 3: The mean percentage coverage of herbaceous plants recorded for the reference transects and restoration transects from 2010 – 2014. Error bars are the standard error for the mean.

Vegetation indicators were not measured at the end of the 2014 recreation season as funding allowed for only spring measurements. Across the years (from 2010 to 2013) there was not a significant change in the overall means of the indicators nor was there a change in the mean difference in indicators between restoration and reference transects. One exception was a slight increase in vegetation coverage in restoration transects (for both grasses and herbaceous but not shrubs) during the summer recreation season of 2011, but there were no significant changes during the recreation season of 2012 or 2013. Neither the overall mean of the percentage coverage of grass nor the percentage coverage of herbs changed over the recreational season of 2012 or 2013. The 2011 increases in restoration transects by the end of the summer may have been due to increased precipitation during that period compared to 2012 and 2013.

There are many factors that may affect tree seedling establishment in riparian areas, including hydrology and environmental factors, but the focus of this study was the possible link between seedling establishment success and the former use of the campsite areas in the riparian zone. There was neither significant variation in the overall mean of seedlings between 2013 and 2014 (p-0.643, Table 3) nor was there variation in the mean difference between restoration and reference transects (p-0.572, Table 3). Despite a small but insignificant increase in seedlings in reference areas in 2011 (Figure 3), there was not a significant variation in the overall mean number of seedlings among the years of the study (p-0.428, Table 4) nor was there a variation in the mean difference between restoration and reference transects among the years ($p<0.486$, Table 4, Figure 3). It should be noted that there was a number of sycamore tree seedlings at the Below Irving I restoration transect in 2011 that have since disappeared.

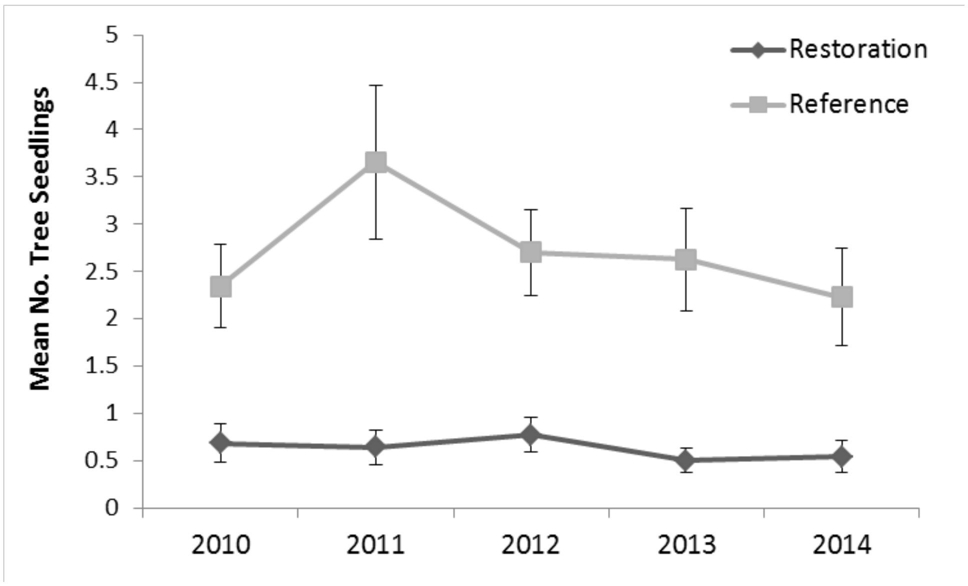

Figure 4: The mean frequency of tree seedlings recorded for the reference transects and restoration transects from 2010 – 2014. Error bars are standard error of the mean.

An aggregate indicator measurement of vegetation growth is the canopy cover measurements taken with a densitometer. These measurements were expected to have limited applicability in that they were expected to change very little over the short time span of the study. There was neither a significant variation in the overall mean canopy between 2013 and 2014 (p-0.915, Table 3) nor a significant variation in the mean difference between the two years (p-0.839, Table 3). Although there was a slight increase in the mean canopy coverage in reference transects in 2011 (Figure 13, appendix), there was not a significant change in the overall mean among the four years of the study (p-0.147, Table 4) or a significant variation in the mean difference between 2010 and 2014 (p-0.346, Table 4). The increase in canopy coverage of trees in 2011 was likely due to an increase in leaf production due to more moisture. Shrubs showed a similar slight increase in coverage in 2011.

The frequency of trees and measurements of their sizes in diameter breast height was recorded during 2014 similar to the previous years (2010-2013). In 2010, it was noted the reference transects had significantly more trees than the restoration transects (Chisquare-10.155, df 1, p-0.0004). In 2010, there were 26 trees total recorded in restoration transects and 65 trees (dbh >2.5 cm) recorded in reference transects. Except for seedling recruitment, yearly differences were not expected with the possible exception of damage during larger flood events. Although there was not any statistical change in the mean number of tree seedlings from both types of transects during the study (Table 3 and 4), there was an increase of 35 trees in reference transects due to recruitment from seedlings where they had grown to above 2.5 cm dbh. The mean number of seedlings had decreased in reference transects from 0.77 (±0.19) seedlings per transect in 2012 to 0.5 (±0.13) seedlings per transect in 2013. In contrast, only an increase of one tree had been recorded in reference transects in 2013. The number of trees did not change in 2014 due to a lack of change in the mean number of seedlings.

Results – Environmental Attributes and Disturbance Measurements

There has been a 4-fold greater percentage of bare ground in the restoration transects as compared to the reference transects since the beginning of the study (Figure 4). Similar to vegetation attributes, there was not a detectable variation in 2014 for the percentage of bare ground from the year before. This was indicated by a lack of change in the overall mean coverage of bare ground compared to the year before, (p-0.606, Table 3). The lack of variation in either transect also resulted in a lack of variation in the mean difference between the two types of transects (p-0.967, Table 3) from 2013 to 2014. By contrast, there was a significant mean difference between restoration and reference transects among years, over the course of the study (2010-2014) (p-0.023, Table 5). This difference was due to a significant decrease in the percentage of bare ground in restoration transects in 2011 and 2012, compared to 2010. The coverage of bare ground in restoration transects was 80.8% (±2.42) in 2010 and decreased to 59.1% (±4.4) by 2012. By 2014, however, the percentage of bare ground coverage in restoration transects had increased back to 69.7% (±3.4) (Figure 5). There was not a significant variation in the mean percentage coverage in reference transects over the course of the study which is also reflected in the lack of significant variation in the overall mean bare-ground coverage among years (p-0.111, Table 3).

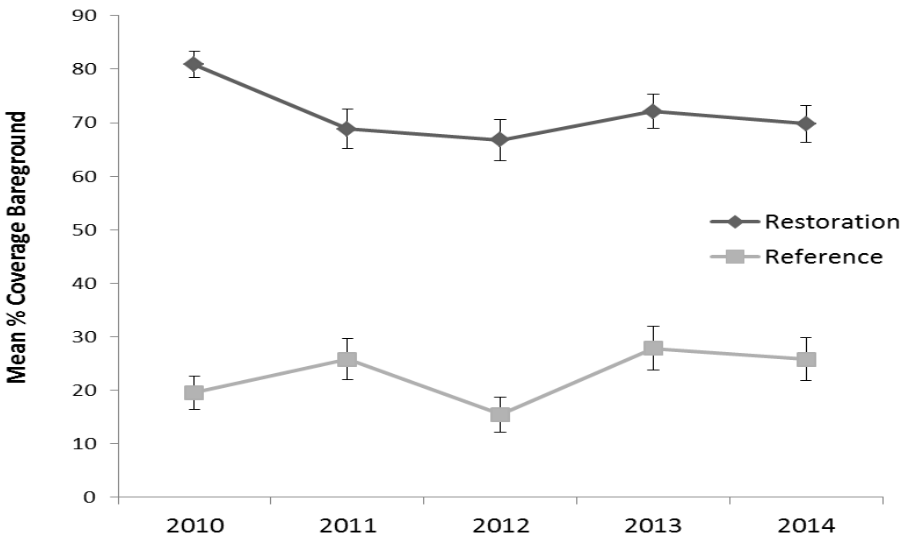

Figure 5: The mean percentage coverage of bare ground recorded for the reference transects and restoration transects from 2010 – 2014. Error bars are standard error of the mean.

Soil compaction measurements are one method of testing if soil contains an adequate amount of interstitial spaces and soil moisture to aid in vegetation establishment. Soil disturbance factors such as trampling may increase soil compaction. The penetrometer measurement approach used in this study provides quick and easy measurements but caution has to be used in interpretation of the results. Variation in measurements can occur due to site specific soil profiles, vegetation community characteristics, and microhabitat differences in moisture levels. The penetrometer used in this survey gives measurements in units of Kilograms/centimeter^2, ranging from 0 to a maximum of 5. During the last few years of the study, there had been slight and steady decreases in penetrometer readings in restoration transects (meaning compaction was increasing) with a slight increase in reference transects which resulted in no significant mean difference between the two transects in 2013 and throughout the study (p-0.313, Table 4). In contrast, soil compaction decreased significantly in reference transects between 2013 and 2014, with a corresponding marginally significant decrease in the overall mean (p-0.051, Table 3) and a significant mean difference between the two transect types in 2014 (p-0.009, Table 3). The overall mean decreased from 1.65 kg cm^{-2} in 2013 to 1.42

kg cm^{-2} in 2014 (Figure 12 appendix). Throughout the study, the overall mean has been significantly decreasing (p-0.044, Table 3), from an initial overall mean of 1.87 kg cm^{-2} in 2010, suggesting drier conditions in both types of transects. The variation in the means over the years may have been due to changes at a limited number of sites or may have resulted from similar decreased soil moisture conditions at the landscape scale across all sites.

The two response variables that were used as more direct indictors of recreational use were the percentage coverage of visible trampling and the percentage coverage of garbage. Generally, there has been a greater percentage coverage of both trampling and garbage in restoration transects relative to reference transects (Figure 5 and Figure 12 appendix). But, there was not a significant variation in the overall mean percentage coverage of trampling between 2013 and 2014 (p-0.372, Table 3) or a variation in the mean difference between restoration and reference transects between the two years (p-0.520, Table 3). This is in contrast to a large increase in the percentage coverage of trampling in 2011 compared to 2010, leading to a significant variation in the overall mean coverage of trampling among all four years (p-<0.001, Table 4, Figure 5). There also was a significant variation in the mean difference among the years (p-<0.001, Table 4). This difference was due to a large increase in trampling in restoration transects during 2011 relative to reference transects (Figure 5). The restoration transects had an average percentage coverage of trampling of 10.41% (±3.03) in 2010 and increased to 41.1% (±3.81) in 2011 (Figure 4). The increase in trampling was a reflection of increases in recreational visitation at the Creek. The Forest Service estimated that there was a 23.7% increase in visitation in 2011 compared to 2010 (Rotert, 2013). However, the mean coverage of trampling subsequently decreased in restoration transects during the following years, 2012 and 2014, to a mean of 21% (±2.41%) and 18.3% (±2.41%), respectively. This decrease also correlates with decreased visitation in 2012 and 2013 to the middle reach of the Creek due to the closure of the upper part of FR 708 from Strawberry, AZ to the Creek due to safety concerns, and the implementation of capacity closures on FR 708 via the Camp Verde side. Although there were slight increases in the estimated total amount of people visiting the creek in 2012 and 2013 (visitation was estimated at 85,486 in 2011, increasing to 90,396 in 2012, and slightly decreasing to 88,552 in 2013), the amount of motor vehicles entering the Fossil Creek area declined from 34,685 in 2011 to 22,764 by 2013 (Rotert, 2013). There were a couple of fire closures of the entire Fossil Creek area during the early months of the recreation season in 2012 and 2013.

Despite the closures, there was not a significant variation in the overall mean percentage coverage of trampling between the beginning and end of the recreation season of 2013 (p-0.103, Table 5) or a variation in the mean difference between restoration and reference transects (p-0.089, Table 5).

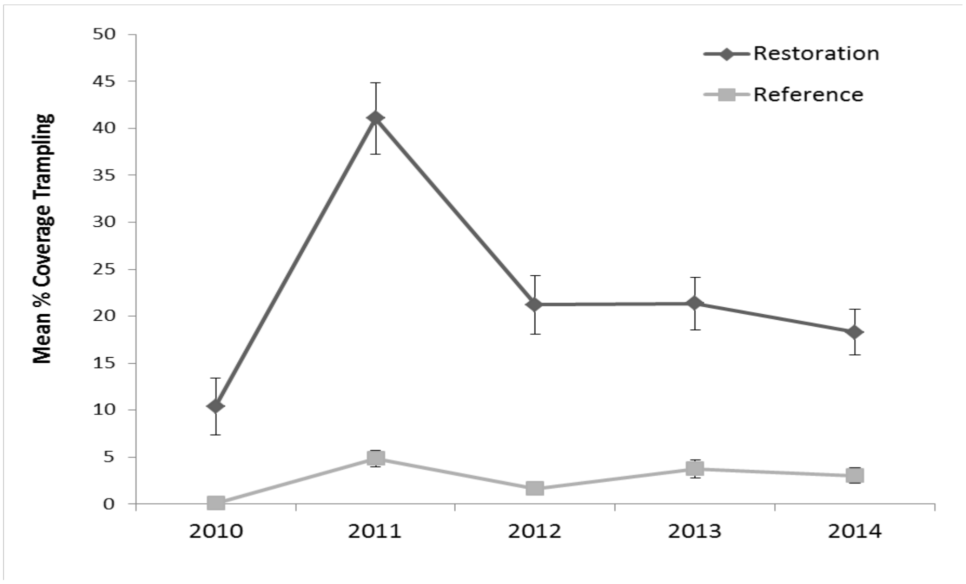

Figure 6: The mean percentage coverage of trampling recorded for the reference transects and restoration transects for from 2010 – 2014. Error bars are standard error of the mean.

Trampling continues to be an issue at four sites: the Bridge, Above Irving 1, Sally Mae, and Mazatzal. The restoration transects at these four sites had a significantly greater mean percentage coverage of trampling than the other six sites combined in 2012 ($p<0.001$, Figure 7). By 2014, one of these sites, Above Irving I had a significant decrease in trampling compared to 2012, while Sally Mae and Mazatzal had slight, but non-significant, decreases in trampling. Of those four sites, three of them (Above Irving 1, Sally Mae and Mazatzal) also had a bare ground percentage coverage in restoration transects around 80%, while the other sites range between 50% and 70%.

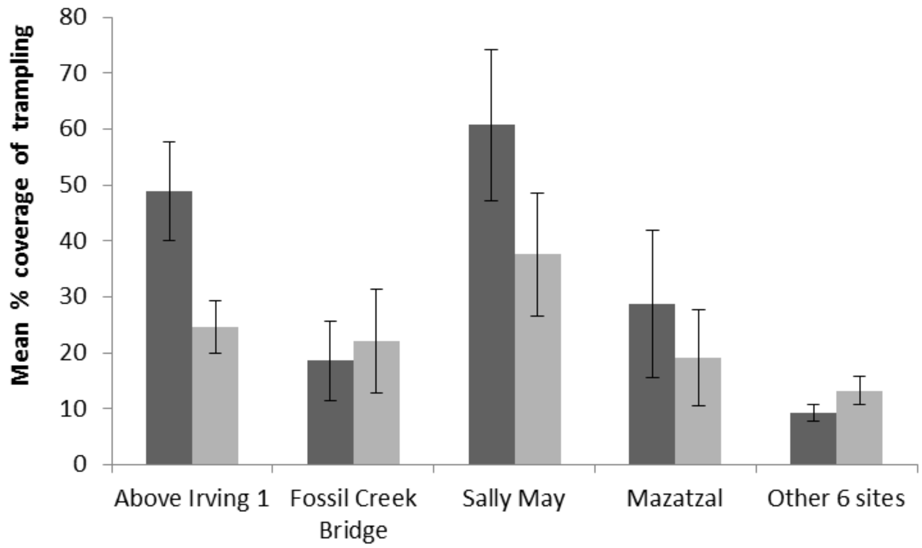

Figure 7: The mean percentage coverage of trampling recorded for each of the restoration transects in 2012 (darker bars) and 2014 (lighter bars) from the four sites with the greatest percentage coverage compared to the other six sites combined. Error bars are the calculated standard error of the mean.

The percentage coverage of garbage was recorded for all transects. It should be noted, however, that since many of these areas are patrolled and cleaned by the Forest Service, this measurement may not be a true reflection of current recreational impacts. Similar to trampling, there was not a significant variation in the overall mean percentage coverage of garbage between 2013 and 2014 (p-0.306, Table 3) or a variation in the mean difference between restoration and reference transects between the two years (p-0.265, Table 3). Over the course of the four years, however, there was a significant variation in the overall mean (p-0.002) due to an increase in the mean percentage of garbage in 2011 and an increase in garbage in reference transects in 2014, with no variation in the mean difference between restoration and reference transects (p-0.678, Table 4). This increase again correlates to the 25% increase in visitation in 2011 (USFS, 2011). There was not a change in the overall mean of garbage coverage during the recreational season of 2013 (p-0.490, Table 5) or a significant change in the mean difference (p-0.638, Table 5), again, probably due to Forest Service cleaning crews. It should be noted that despite the presence of portable toilets since 2010, toilet tissue continues to be recorded in some transects (for example Purple Mountain I and II, the Bridge site).

One more indicator measurement that was recorded was the evidence of recent erosion due to water runoff. Erosion from runoff was observed in restoration transects at most sites throughout the study. Comparison of the measurements for erosion between years was very inaccurate, however, so statistical analysis was conducted within years between seasons and between restoration and reference transects. For example, in 2012 there was a significant mean difference between restoration and reference transects due to evidence of greater runoff in restoration transects (p-0.038). In 2013, there was more erosional damage from runoff evident in September compared to June (p-<0.001), due to rain during the monsoon season. However there was not a significant variation in the mean difference between restoration and reference transects in 2013 (p-0.144). Seasonal analysis of erosional runoff was not conducted in 2014, but observations of erosion runoff damage was evident in restoration transects with little evidence in reference transects.

Results- Equivalency Ratios

The equivalency ratio is useful in evaluating the progress of an indicator toward the goals of the restoration. In this case, the goal of the restoration is increasing equality between the response variables of a given indicator in the restoration sites and the response variable in the reference sites. The equivalency model uses a calculated ratio of the mean value of a response variable at a restoration site to the mean value at the reference site. The null hypothesis would be that the restoration site is not equivalent to the reference site if the ratio is not reasonably close to unity (1.0). The target equivalent ratio would be at the discretion of mangers.

Equivalency ratios were calculated for the response variables listed in Table 6 for 2010-2014. For vegetation indicator response variables, the equivalence ratios in 2011 demonstrated an increase in the coverage of grass and shrubs in restoration transects relative to reference transects, with little change in herbaceous. However, as mentioned earlier, the mean of most of the response variables for vegetation increased in both the restoration and reference transects from 2010 to 2011, indicating a generally favorable environment. By 2014, despite a small decrease in 2012, grass mean coverage had increased in restoration transects to a new level at 48% of reference transects. Shrub coverage had a slight decrease in restoration transects in 2013 after but rose back to 2012 levels at 52% of reference transects. Herbaceous coverage also showed an increase in 2014 at 85% of reference transects.

Therefore, over the course of the monitoring program, mean grass and shrub coverage has increased by 18-24% in restoration transects relative to reference transects and herbaceous has increased by 18%. Although an increase in herbaceous coverage lagged behind that of grass and shrub coverage, the similar equivalency ratios between 2012 and 2013 demonstrate that vegetation coverage in the restoration transects is persisting after reestablishment and spread. Natural vegetation recruitment in the restoration transects is progressing during favorable environmental conditions but still may be limited by the disturbance legacies relative to the reference transects.

	Equivalency Ratios				
Response Variable	**2010**	**2011**	**2012**	**2013**	**2014**
Total Grass	0.30	0.41	0.37	0.43	0.48
Total Herb	0.47	0.48	0.61	0.61	0.85
Total Shrub	0.19	0.36	0.46	0.42	0.54
Seedlings	0.29	0.17	0.29	0.19	0.24
Bare ground	4.14	2.67	4.32	2.59	2.71
Penetratometer	1.24	1.25	1.05	0.92	1.16
Trampling	104.1	8.49	12.97	5.71	6.04
Garbage	17.85	2.28	1.86	2.46	1.18

Table 6: Equivalency ratios of the means of the indicator response variables between restoration and reference transects from 2010 to 2014. Equivalency is defined as being equal to 1.

Equivalency ratios for disturbance indicators related to recreation use remained relatively large (Table 6). While there has was a decrease in the percentage of bare ground in restoration transects in 2011 and a general overall decrease in trampling in 2012, equivalency ratios show that the percentage coverage of both indicator variables increased in restoration transects relative to reference transects in 2014. The percentage coverage of bare ground and the percentage coverage of trampling in restoration transects remain large relative to the reference transects (at 2.7 times and 6.0 times that of reference transects, Table 6). But if the overall decrease in trampling continues, then there may be reduced equivalency ratios in the future. The other disturbance factor, garbage, had remained virtually similar over the last three years, probably due to the persistent work of the Forest Service, but there was an increase of garbage in reference transects in 2014.

Vegetation and Disturbance Factor Results Analysis

The goal of the monitoring plan is to give specific quantifiable measurements of indicator parameters to detect the progress toward the desired goals of the restoration. Both the paired BACI (Before -After-Control-Impact- In- Pairs) statistical model and the equivalence statistical model were used to determine if restoration goals are being met. The main questions answered by the analyses include: 1) How different are the indicator response variables between the restoration and reference treatment? 2) Did the difference in indicator response variables change between years? 3) Are the indicator response variables of the restoration areas near equivalency to reference conditions?

It was expected that grasses and herbs would act as pioneering species and naturally move into the restoration areas and aid in recovery through the process of succession. The Forest Service did conduct some seeding and/or scarification at several of the sites early in the study (Janie Agaygos, pers. comm) but the dates and species seeded were not provided to NAU. Despite this direct action, overall results indicate that moisture was the driving force in grass and herb establishment during the length of the study. It should be noted that specific precipitation data for each restoration site were not measured and precipitation data cited here is from measurements in Payson.

Despite a small increase in herbaceous coverage in both restoration and reference transects, there was little statistical change in mean vegetation indicators from 2012 to 2013. By contrast, however, the overall mean percentage coverage of total grasses and total herbs has increased over the four years, particularly due to increases in 2011. This suggests that the increase in vegetation coverage occurred in both restoration and reference transects and is probably due to a general response to more favorable environmental conditions for growth in 2011. The increased mean vegetation coverage in restoration transects has also persisted in later years after establishment. These findings are in agreement with vegetation re-establishment in other formerly disturbed areas of the Creek. It has been found that interim management practices at Fossil Creek over the last few years, such as restricting vehicle access to denuded areas, has allowed vegetation recovery to happen relatively quickly (Rotert, 2014). Equivalence ratios also demonstrate an increase of 13-21% mean coverage of the vegetation indicators in restoration transects relative to reference transects over the course of the four years. However, there has not been a statistical change in the mean difference between transects in these indicators among the years due to fluctuations in reference transects. There have been some minor, but non-significant, decreases in vegetation coverage in reference transects after the 2011 increase. This illustrates that vegetation coverage in the restoration transects is persisting after establishment and spread, but vegetation coverage in general is sensitive to environmental fluctuation. The mean coverage of most of the vegetation indicator response variables measured in 2013 and 2014 continued to be at least two-fold to three-fold less in the restoration transects relative to reference transects. There has also been a 4-fold greater percentage of bare ground in the restoration transects as compared to the reference transects since the beginning of the study. Furthermore, tree seedlings that were present in reference areas at the beginning of the study have matured to adult size classes, but there has been a lack of tree seedling recruitment in restoration transects.

The general increase in 2011 in vegetation coverage correlates to more favorable environmental conditions such as near average rainfall during the previous year. In Payson, where 21.5 inches of precipitation is about average, the total precipitation in 2010 was near normal at 21.7 inches (NWS climate data). In 2011, precipitation in Payson was below average with a total of 16.8 inches and also again in 2012 with a total of 15.33 inches (NWS climate data). Therefore, vegetation successional recruitment appeared to occur after average yearly precipitation conditions, but not after years of lower precipitation. Furthermore, there has been a lack of immediate vegetation responses to summer monsoonal moisture which suggests that longer temporal trends in moisture levels are important. Some indicators such as bare ground have also increased by 2013, perhaps due to decreases in soil moisture as indicated by decreases in soil compaction in reference transects. The lack of a change in vegetation coverage under below average precipitation conditions demonstrates the ability for vegetation persistence once initial recruitment has occurred. But future recruitment may be slow if those conditions continue. In 2013, for example, yearly total precipitation for Payson was 10.71 inches.

During this study, disturbance legacies from recreational impacts were a concern for restoration areas, especially prior to 2012 and 2013. However, there has been decreased disturbance over the years due to management efforts and interim measures and the closure of Forest Road 708 west of Strawberry (USFS, 2011; Rotert, 2014). Disturbance factors seem to have become less of a deterrent to vegetation recovery compared to environmental conditions. For example, there was a statistical increase in the overall mean coverage of bare ground in 2013 but no variation in the mean difference between restoration and reference transects. The mean percentage of trampling and soil stability, on the other hand, were not statistically different from the previous year in either type of transect. Furthermore, there was not a statistical change in trampling over the summer recreation season, although there had been during the summer of 2012. Trampling of newly established grasses and herbs in restoration transects may have been minimized by lower visitation to the Middle reach of the Creek as a result of decreases in vehicle traffic and capacity closures, as well as the implementation of "interim measures." Therefore, the main deterrent to vegetation recovery may be the precipitation or moisture regime. However, trampling continues to be an issue at some sites (such as the Bridge, Above Irving II, and Sally Mae) where there have been visual observations of damage to vegetation. Overall, there has been a 4-fold greater percentage of bare ground in the restoration transects as compared to the reference transects since the beginning of the study. The Forest Service has also recorded small increases in the amount of denuded area in other parts of the Middle Reach of the Creek, such as the Tonto Bench and the Sally Mae swimming hole (Rotert, 2014). These areas are increasingly used for recreation as interim measures and capacity management have restricted access to other severely damaged areas (Rotert, 2014). Visitor demand and use is increasing over the entire Fossil Creek area despite a decrease in vehicle traffic (Rotert, 2013).

Given that most of the equivalency ratios of the response variables in this analysis are at most 50% of the reference, there is still the very real potential for decreases in improvement, especially if there are variations in climate (e.g. less precipitation), increases in trampling from recreation, and erosion or runoff in currently denuded areas. There is also a concern that the data shows decreases in reference areas of some indicators such as bare ground, tree seedlings and herbs. In 2011 and 2013 it was evident that disturbance factors were impacting the reference transects. Future monitoring will continue to be needed to assess how these factors respond to future disturbance levels and weather conditions.

Results-Water Quality, Water Chemistry and Physical Channel Attributes

Water Quality Sampling

Water Samples

Bacteria sampling from the three water quality sites was conducted for four years of the study (2010-2013). Bacteria sampling was not conducted in 2014 due to funding constraints but below is a recap of the results from 2013 and the previous years. Fecal coliform monitoring is commonly used as an indicator of water quality. Unlike general fecal coliform bacteria, Enterococci bacteria are a better indicator for human fecal contamination. The EPA limit for fecal coliform bacteria in recreational water (full body emersion) is 30 colonies per 100 mL water. For the first time since the 2010 summer recreation season, all three sites exceeded EPA limits for fecal coliform bacteria in recreational water during the August 2013 sampling date, and one site, Below Mid-falls, exceeded EPA limits for the June 2013 sampling date. For the June 2013 sampling date, fecal coliform levels were below EPA limits at the Fossil Creek Bridge and Purple Mountain sites, yet exceeded EPA limits at the Below Mid-falls site with an average of 37 colonies per 100 mL water for the (Figure 8). In August, all three sites exceeded EPA limits with averages ranging from 47 to 58 colonies per 100 mL water. These fecal coliform levels deviate from the 2011 and 2012 summer recreation seasons in which only one site exceeded EPA limits. Though the fecal coliform levels in stream sediment were not determined for 2013, previous monitoring indicate that these levels are much greater than the levels in the stream water. Though the EPA does not have limits for fecal coliform bacteria in stream sediment, NAU researchers suspect that waders and swimmers may disturb sediments in the streambed and suspend additional fecal coliform bacteria in the water column.

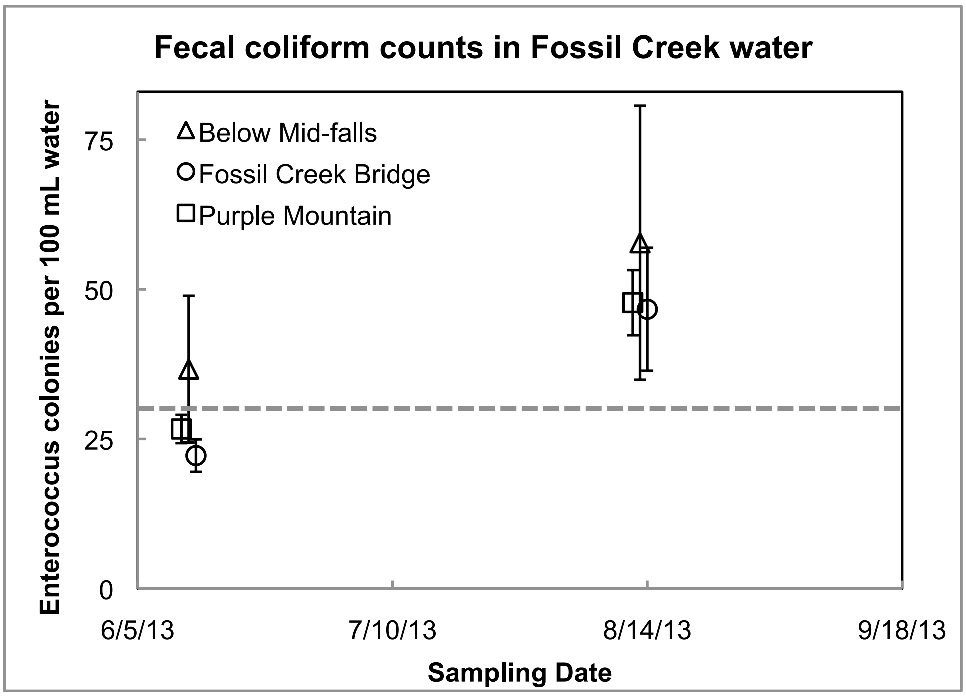

Figure 8. Average Enterococcus levels in Fossil Creek water collected at three sites during the 2013 summer recreation season. The EPA limit from fecal coliform levels in recreational water, 30 colonies per 100 mL water, is indicated by the dashed line.

Water Chemistry

Water chemistry data collected in 2014 (including temperature, pH, total dissolved solids, specific conductivity, salinity and dissolved oxygen) did not reveal any significant differences compared to 2010 and 2011. As mentioned previously, equipment malfunction and failure in the 2012 and 2013 summer recreation seasons resulted in no data for water chemistry parameters during the two previous years. Due to the consistent water chemistry and consistent flow of the springs, these variables are unlikely to change except for during a very large disturbance.

Instantaneous Flow Analysis

There have been 10 sampling events for water quality over the first four years of the project (2010-2013) with at least two sampling events per year. Although there has been significant variation in bacteria counts among sites and among years, there has not been significant variation that can be attributed to differences in the mean instantaneous flow. Data analysis conducted in 2013 showed that there was not a significant variation in mean flow across the three sampling sites (p-0.922) nor was there significant variation among years (p-0.386) or an interaction (0.981). However, there was significant variation in mean velocity among years and sites, although again there was not an interaction (p-0.948). It was expected that there would to be differences across the years in mean velocity among sites (p-0.004). The Purple Mountain site mean velocity was significantly greater at 0.18 m/s compared to mean velocities at the other two sites, Above Irving (0.15 m/s) and the Bridge (0.12 m/s).

Physical Stream Attributes

Stream channel attribute variables were measured to detect potential changes between years in the physical stream channel. Table 1 summarizes the stream channel, and bank stabilization indicators with their associated measurements and measurement protocols. An extreme change in these variables over a short amount of time could indicate stream bank or channel instability. The ratio of the riffle cross-section width/depth provides a measure of bank vertical stability and is obtained from riffle cross-section data. Increases in width/depth ratio are often associated with channel aggradations due to accelerated stream bank erosion, excess sediment deposition and channel widening, or can indicate channel incision (AZDEQ 2002). Channel substrate size and composition and the percentage of substrate embeddedness also provide a measurement of possible sedimentation patterns. The measurements conducted along 7 transects at each of the three monitoring sites include the following variables: instantaneous velocity, channel width and mean channel depth. Mean channel area, total flow, and the width/ depth ratio were calculated from those three variables (Table 7). A two-way analysis of variance statistical test was conducted to test for significant differences in the mean value of each of the response variables between years at each of the sites and between the years of 2013 and 2014. A separate analysis also tested for differences among all years of the study (2010-2014). Since channel stability response variables such as width, depth and the width/depth ratio were initially significantly different between sites, the main factors of interest in the analysis were year and the interaction between year and site. A significant interaction would indicate that a variable changed at a site between years. The substrate size and composition measurements included the median particle size, the percentage embeddedness, the percentage of travertine, and the percentage of fine particles (Table 7).

Indicator variable	Year	Above Irving	Bridge	Purple Mountain
Flow (m^3s^{-1})	2012	1.46	1.22	1.48
	2013	1.73	1.74	1.50
	2014	1.67	1.45	1.57
W/D Ratio	2012	19.9	30.3	18.0
	2013	16.0	26.3	16.9
	2014	19.3	24.7	25.9
Median particle size (mm)	2012	2500	96	1
	2013	2500	72	1
	2014	2500	72	1
% Fines	2012	19.5	31.5	59.7
	2013	33.9	27.4	58.4
	2014	24.0	27.4	65.7
% Embeddedness	2012	61.2	68.5	72.3
	2013	56.0	67.2	80.6
	2014	59.6	65.4	75.3

Table 7: Results of Stream channel indicator attributes and flow response variables between the three water quality sites for the years of 2012-2014.

This middle section of the creek that contains all three of the monitoring reaches was characterized by a relatively large mean width to depth ratios, due to mean depth ranges of 0.55 to 0.58 m (Table 7). The Bridge water monitoring reach had a greater mean width to depth ratio

(27.2) in 2013 since it was located downstream of a large pool, but Purple Mountain had a slightly greater width to depth ratio in 2014 (25.9). The Above Irving monitoring reach had the least width to depth ratio at 19.3. The Above Irving reach had a large percentage of bedrock substrate which tended to create a narrower channel and greater water velocities (around 0.35 m s^{-1} while the two downstream reaches have a mean of about 0.14 m s^{-1}). The banks of the Above Irving reach tended to have gradual slopes while the other two reaches had relatively steep slopes. There was no visible evidence of recent substantial bank erosion.

There were not any statistical differences from 2013-2014, nor were there any differences among the years of the study (2010-2014), for the indicator variables of mean velocity and mean flow. Among the years of the study (2010-2014) there were not statistical indications of a change in channel and bank stability measurements using year and site as the main factors. There also were not any statistical differences in channel width between 2013-2014.

However, there were statistical differences in depth and the width/depth ratio in 2014 compared to 2013. A significant interaction (p-0.002) indicated that a decrease in mean water depth between years (p-0.88) was due to a decrease in water depth at the Purple Mountain site from a mean of 0.61 m (±0.09) to a mean of 0.41 m (±0.04). The decrease in depth also caused a significant increase in the mean width/depth ratio at the Purple Mountain site (interaction p-0.053) between the two years (p-0.044) from 16.9 to 25.9. A post hoc one-way analysis of the width/depth ratio at the Purple Mountain site indicated that the width/depth ratio in 2014 (25.9) was significantly increased compared to all years of the study decrease as well (p-0.015).

The increase in the water depth at the Purple Mountain may also be related to a change in sedimentation between 2013 and 2014. The percentage of fine sediment in the stream channel at the Purple Mountain site increased between the two years from 58.4% to 65.7% (Table 7). These values were greater than the other two sites, Above Irving (24.0%) and the Bridge (27.4%), which stayed relatively similar between the two years (Table 7). Sedimentation is still lowest at the Above Irving site due to the prominence of bedrock and travertine in that area, but there was a slight increase in the mean percentage of embeddedness, which corresponds with the increase in the percentage of fines (59.6, Table 7). The Purple Mountain reach had the greatest mean percentage of embeddedness at 75.3%.

According to a USGS hydrograph of Fossil Creek there was a small flood (of about 600 cfs) during the spring of 2014 (Figure 14, appendix). It is unlikely that this small flood was a large enough event to contribute to the significant sedimentation that was observed in the channel at Purple Mountain. For example, in 2013 there were two floods in the spring of 2013 that had flows that peaked at about 700 cfs and 2000 cfs. Although the floods appeared to have increased the sediment input load into the channel that year, the increased sedimentation was not significant enough to cause an increase in the width to depth ratio. Therefore there were not any statistical changes in the width/depth ratio or other bank stability indicators between the years 2012 and 2013. However, between 2013 and 2014 there was an indication of a change in channel and bank stability measurements at the Purple Mountain site. In 2014, this site had another increase in the percentage of fines and incurred the first statistically significant decrease in depth during the study and a significant increase in the width to depth ratio. This suggests that the channel is being filled in with sediment. High sedimentation values (which occurred both at the Bridge and the Purple mountain site between 2013 and 2014) can indicate problems with channel bank stabilization and erosion and can have potential impacts on the aquatic community. The sediment inputs to the Purple Mountain site found in 2014, and perhaps throughout the monitoring period, may be due, instead, to larger landscape processes in the upper watershed of the Sally Mae wash area. The Sally Mae wash confluence is located just upstream of the Purple Mountain site.

It should be noted that these are high embeddedness readings that may have impacts on the aquatic benthic community (Waters 1995), especially at the Purple Mountain site. Without large scouring floods, the percentage of fine sediment will tend to accumulate. A recent study in Fossil Creek (Adams 2012) was conducted to compare the health of the aquatic benthic community with differences in the channel substrate characteristics between the lower, middle, and upper reaches of Fossil Creek. The study used a qualitative and quantitative inventory of emergent aquatic insects with an analysis of compositional and structural community metrics combined with an Arizona warm water Index of Biological Integrity. The channel characteristics of the lower Middle Reach of the creek that was intercepted by roads and ephemeral washes (the Purple Mountain site) had a greater percentage of fines and greater embeddeness values despite decreased travertine deposition. There were distinct differences in the aquatic insect community in the lower Middle reach compared to upper and lower reaches, resulting in less insect diversity, an indication of a relatively impaired health of the biotic community.

Summary and recommendations

Riparian Vegetation

For vegetation indicator variables (total grasses, herbaceous, and shrubs), there was neither a significant change in the overall mean coverage between 2013 and 2014 nor was there a significant mean difference between the two years indicating that this was a consistent result in both restoration and reference transects. However, there was a significant overall mean increase for both grasses and herbs in both types of transects in 2014 when compared to 2010. These increases followed and persisted after a general increase in 2011. This suggests that the increase in the mean coverage of vegetation in 2011 was related to landscape scale processes and was likely due to more favorable environmental growth conditions such as the near average total rainfall during the year before. These increases led to greater equivalency ratios for most vegetation indicators in 2014. However, a slight decrease of herbaceous coverage and an increase in bare ground for reference transects demonstrates the sensitivity of vegetation growth to environmental shifts. It is also a concern that tree seedlings have not become established in restoration transects during the course of this study. By contrast, the increases in vegetation that occurred in restoration transects in 2011 were still evident in 2014. This shows that natural vegetation recruitment in the restoration transects is progressing when environmental conditions are favorable and demonstrates the ability for vegetation establishment in those areas. These findings are in agreement with vegetation improvements in other formerly disturbed areas of the Creek that have been rehabilitated through interim management practices (Rotert, 2014). However, given that most of the equivalency ratios of the response variables in this analysis are around 50% of the reference, there is still a potential for either increases or decreases in improvement, especially if there are continued variations in climate leading to drier conditions. For example, the spring of 2014 was one of the driest on record for the southwestern United States and even though vegetation indicators did not decrease, soil moisture did for both types of transects. It will be important to continue to monitor the vegetation responses in coming years, especially given the potential local changes to weather patterns that may occur due to climate change.

While yearly precipitation and climate is an important factor for vegetation recovery, the disturbance created by trampling during recreational use was likely having large negative impacts. For instance, a decrease in soil compaction was observed in reference transects throughout the study and may be related to decreased precipitation levels, but trampling in reference transects also increased in later years. Even though the percentage coverage of trampling showed a general decrease in 2012 it has not changed levels in the years afterwards. The decrease in trampling in 2012 was likely due to management restrictions on visitation and recreational use after 2011 which benefitted the establishment of grasses and herbaceous. However, trampling continues to be an issue at some sites such as the Bridge, Above Irving 1, Sally Mae and Mazatzal. These four sites also have not demonstrated any increases in vegetation recovery over the course of the study. Although it is speculative to conclude that recreational disturbance is preventing vegetation recovery in these areas, only the prevention of further disturbance would allow testing of this conclusion. Visitor demand and use is increasing over the entire Fossil Creek area despite a decrease in vehicle traffic (Rotert, 2013). Future recreational visitation levels will be dependent on decisions from the Forest Service regarding management details of the forthcoming Comprehensive River Management Plan.

Based on the data generated in this study, it is recommended that further actions be taken to try to reduce the continued disturbance to former camping areas where vegetation recovery has not occurred such as Above Irving I, Fossil Creek Bridge, the Mazatzal site near the swimming hole, and Sally Mae. Positive results from Forest Service interim actions in 2012 in the Mazatzal area (other than the former camping area by the swimming hole) such as seeding, erosion abatement, and trail delineation and reinforcement, have shown that restoration is possible (Rotert, 2013). At another heavily trampled monitoring site, in the Above Irving 2 restoration transect, the Forest Service seeded the bare ground in the fall of 2011. While there were a few more sprouts evident in 2012 and again in 2013, the majority of the seeding was unsuccessful. The spring of 2012 may have been too dry for survival. It is recommended that such actions as occurred at the Mazatzal area be considered for those other areas mentioned in this study that are still experiencing problems with vegetation recovery. One of the more reliable methods of reducing recreational impacts would be reductions in visitation. This would reduce the proliferation and expansion of social trails and allow stabilization of banks and vegetation recovery in degraded areas of the stream channel. Increased efforts at trail delineation and confinement of recreational activity to select areas would also be beneficial for this goal. Again, we recommend continued monitoring to help determine if those mitigation practices are effective and are not being undermined by recreational impacts or low precipitation levels.

Water Quality

Bacteria sampling was not conducted in 2014. But in 2013, for the first time since the 2010 summer recreation season, all three sites monitored exceeded EPA limits for fecal coliform bacteria in recreational water during the August 2013 sampling date, and one site, Below Mid-falls, exceeded EPA limits for the June 2013 sampling date. Improvements in fecal coliform levels during the 2011 and 2012 recreation seasons were attributed to the installation of temporary toilets. The return to greater levels of fecal coliform bacteria during summer of 2013 may be due to a combination of climactic factors and the continued popularity of Fossil Creek among recreation seeker. For 2013 in particular, a record-breaking precipitation during the month of July and increased sedimentation in the creek were followed by sediment disturbance by swimmers and hikers in August. It should also be noted that observances of discarded toilet tissue was common at some sites in 2014 including the Bridge, Purple Mountain, and Sally Mae. These sites had temporary toilets in plain view near parking areas. Since bacteria exceedances occurred despite the presence of temporary toilets, reductions in visitation may be needed to prevent problems in water quality.

In addition, the effect of fecal coliform bacteria stored in sediments at Fossil Creek should be explored further. Sediments may be a contributing source of these bacteria in the water column. The identification of land-based *vs.* sediment-based sources of pathogens is important for the development of water protection plans (Wu et. al.2009). Multiple studies have identified high levels of indicator organisms in streambed sediments ranging from 10 to 10,000 times higher than concentrations in the overlying water column and field experiments have confirmed that bacteria associated with the stream sediments resuspend during high flows and contribute an additional bacteria load to the stream water column (cited in Pandey and Soupir, 2013). Studies conducted elsewhere in stream environments have shown that sediments can provide a yearround reservoir of fecal coliforms and E. coli. The University of California (2007) found through DNA fingerprinting that very few of the E. coli captured in the water column were identical to those isolates cultured from bottom sediments in an estuarine environment, indicating that bottom sediments may inadvertently be incorporated into the water column from wind or turbulence. This leads one to surmise that contaminate levels may be periodically high in Fossil Creek due to sediment disturbance caused by high flows and/or swimmers. If further investigation proves this to be the case, while still an issue for the health of swimmers, such high numbers may not indicate recent inflow of bacteria but rather the results of past contamination of sediments.

Stream channel attribute variables were measured between years for the detection of instability in the physical stream channel and for increases in sedimentation. Between 2013 and 2014, unlike previous years there was an indication of a change in channel and bank stability measurements at one of the water quality sites, the Purple Mountain site. This site, located downstream of the other two, has had the greatest percentage values of fines and emebeddedness throughout the study. In 2014, this site had an increase in the percentage of fines and incurred the first significant decrease in depth and a significant increase in the width to depth ratio. Since there was, however, not a significant change in channel width, this suggests that the channel is being filled in with sediment. It is unclear the degree to which bank erosion from restoration sites is contributing to stream sedimentation, and although it may be small relative to larger landscape processes, there was evidence of continued erosion in restoration transects over the course of the summer. These smaller areas of erosion will likely continue until there are substantial decreases in the amount of bare ground from vegetation re-establishment. The Forest Service has implemented soil erosion mitigation techniques at some riparian sites, which should prevent further degradation and aid recovery. But, the large amount of sediment inputs into the channel may be an additional concern worthy of investigation as it appears to be occurring due to processes in the larger watershed, particularly in the upland areas of Sally Mae wash. Since the sedimentation values have potential negative impacts on the aquatic community it is important that monitoring continue and the sources of sediment input be identified and reduced. The Forest Service could consider conducting sediment fingerprinting to determine the source of suspended sediment at the Purple Mountain site if there is uncertainty about origin (see Mukundan et al.

2010). Management actions may be necessary to decrease sedimentation impacts to the channel. Such actions should include determination and identification of grazing impacts from livestock and input from current road design as well as the destabilization of soil conditions in the upland areas of the watershed of Fossil Creek.

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Appendix 1

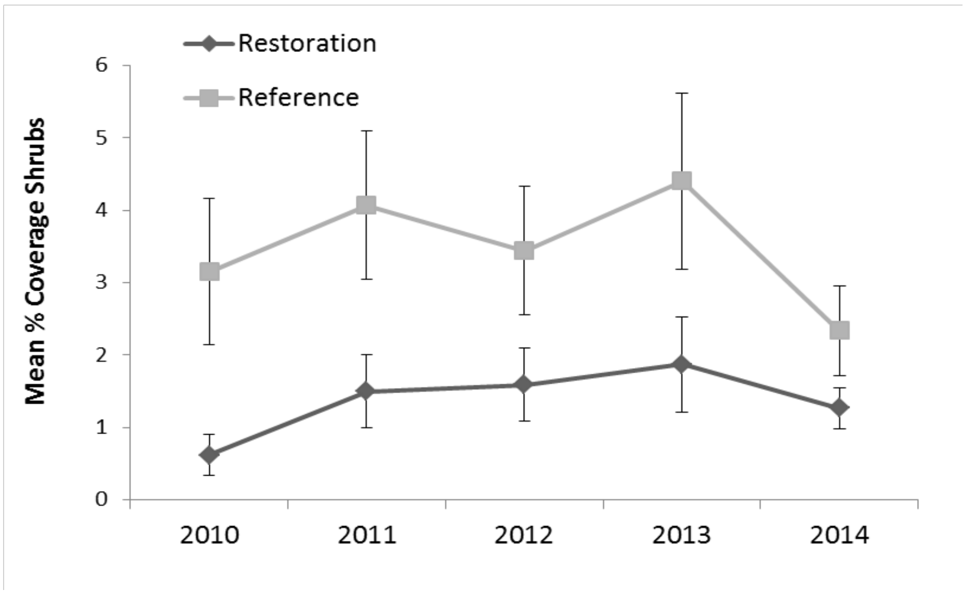

Figure 9: The average percentage coverage of shrubs for the reference transects and restoration transects from 2010 – 2014. Error bars are standard error of the mean.

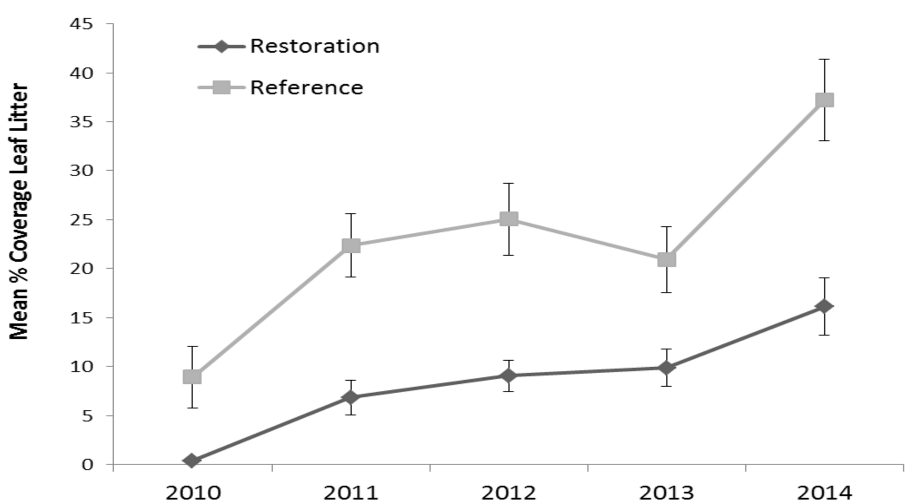

Figure 10: The mean percentage coverage of leaf litter for the reference transects and restoration transects from 2010 – 2014. Error bars are standard error of the mean.

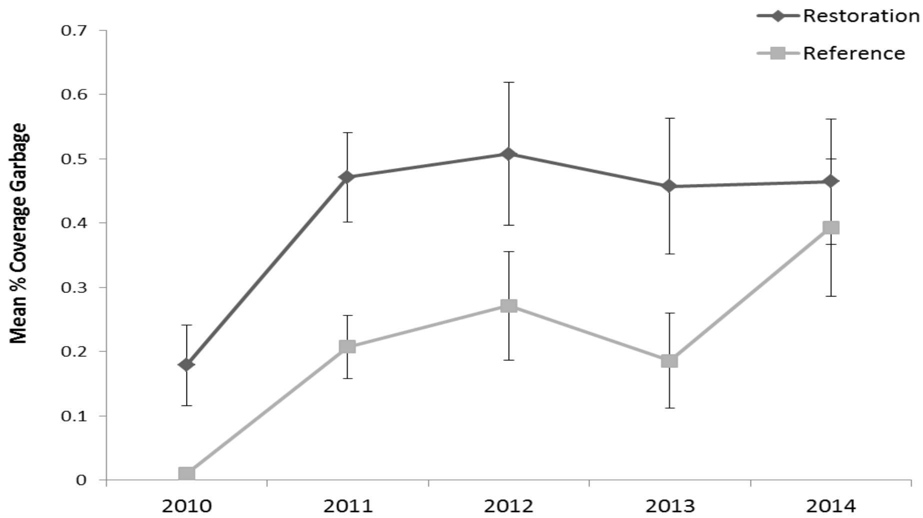

Figure 11: The mean percentage coverage of garbage for the reference transects and restoration transects from 2010 – 2014. Error bars are 95% standard error of the mean.

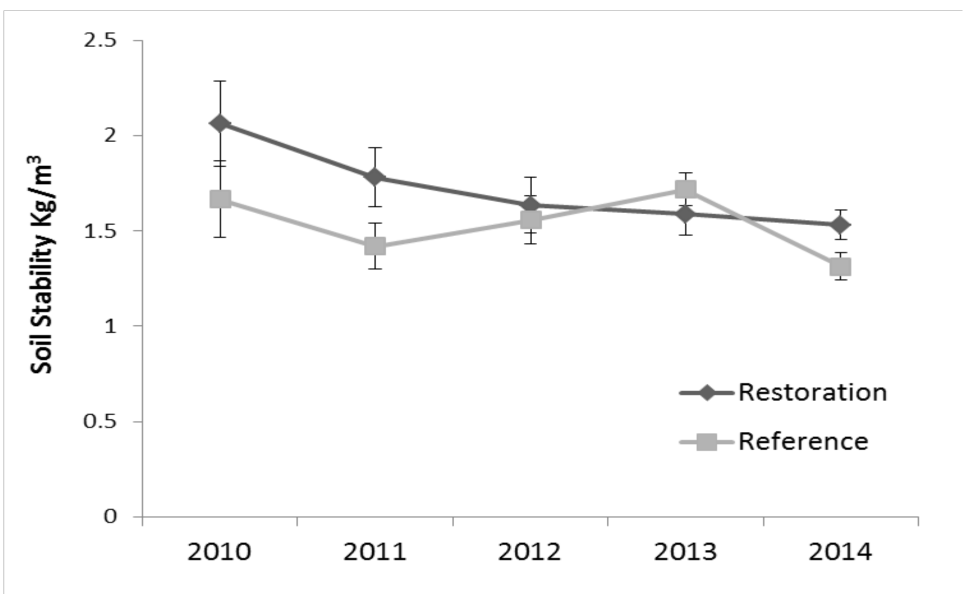

Figure 12: The mean penetrometer reading of soil stability for the reference transects and restoration transects from 2010 – 2014. Error bars are standard error of the mean.

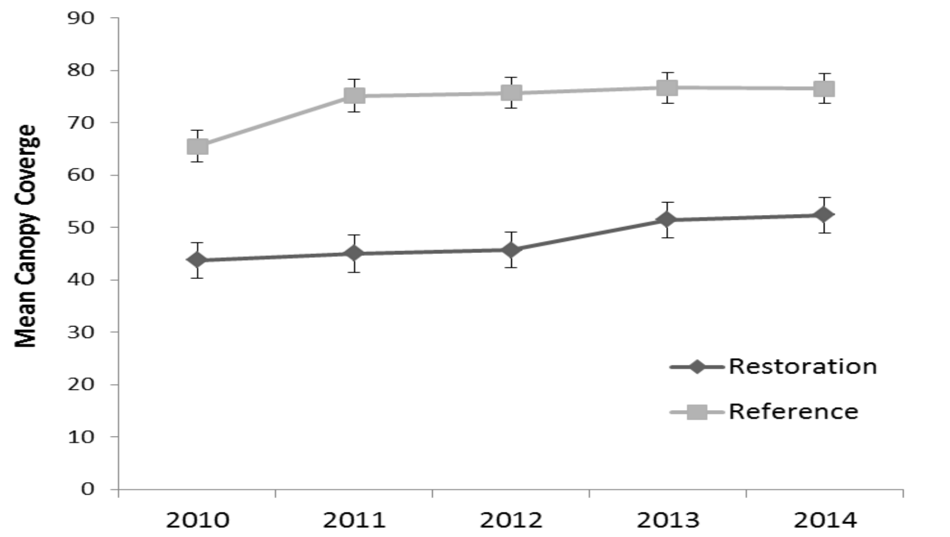

Figure 13: the mean densitometer reading of canopy coverage for the reference transects and restoration transects from 2010 – 2014. Error bars are standard error of the mean.

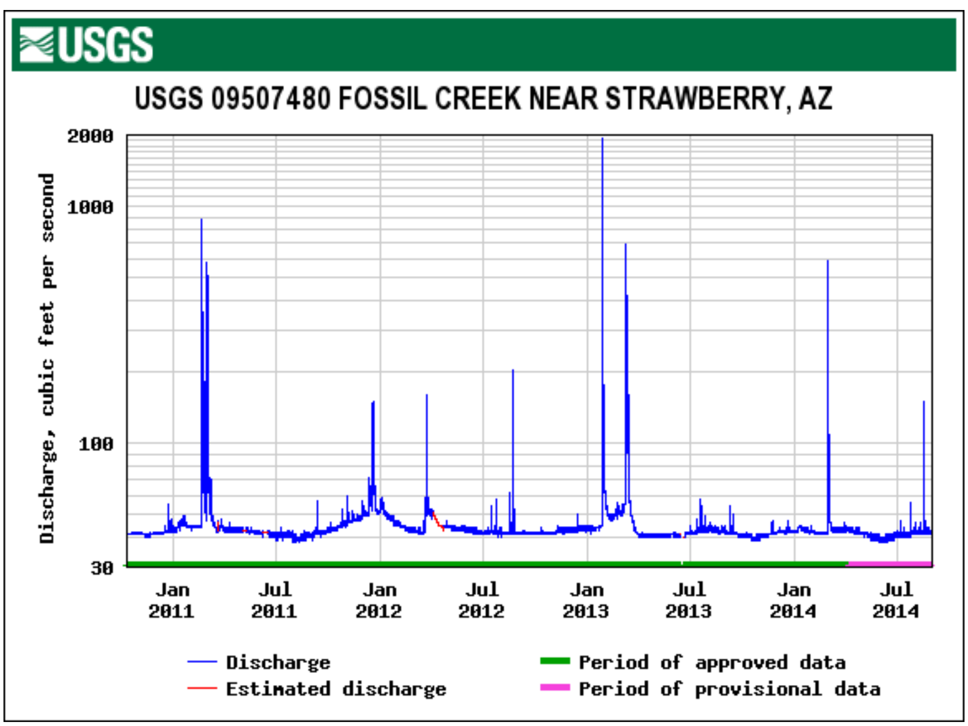

Figure 14: USGS hydrograph of Fossil creek from Jan 2011 to July 2014.