Nonpoint Source Program Effectiveness Assessment, 2008-2011

Final Report

New Mexico Environment Department, Surface Water Quality Bureau

Watershed Protection Section

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Cover Photo: Daniel Guevara searching for a thermograph in post-flood channel of San Antonio Creek on the Valles Caldera National Preserve

List of Acronyms

§319 – Section 319 of the Clean Water Act

ANCOVA – Analysis of Covariance

CWA – Clean Water Act

MAS – Monitoring and Assessment Section of the Surface Water Quality Bureau

SWQB - Surface Water Quality Bureau of the New Mexico Environment Department

TMDL – Total Maximum Daily Load

VCNP – Valles Caldera National Preserve

NIST – National Institute of Standards and Technology

NMED – New Mexico Environment Department

NTU – Nephelometeric Turbidity Unit

PQAPP – Project level Quality Assurance Project Plan

QAPP – Quality Assurance Project Plan

QA/QC – Quality Assurance/Quality Control

RERI – River Ecosystem Restoration Initiative of the NM Environment Department

SP-12 - EPA Success Story performance measure

TMDL – Total Maximum Daily Load

UDBA – Upstream/Downstream Before/After study design

WPS – Watershed Protection Section of the Surface Water Quality Bureau

WQ-10 - EPA Watershed Approach Success Story performance measure

Executive Summary

The Surface Water Quality Bureau (SWQB) of the New Mexico Environment Department (NMED) implements the Nonpoint Source Management Program, which coordinates multiple programs and funding sources to restore impaired streams and rivers in priority watersheds to meet water quality standards. Prior to 2008, stream restoration projects funded under this program were not required to include water quality monitoring, as implementation was the priority for limited resources. However, in 2008 the SWQB initiated an effectiveness monitoring program with the primary goal of evaluating the effects of stream restoration projects on water quality. Key objectives were to select practical methods and apply them to monitor water quality changes related to the new stream restoration projects, and to evaluate prior projects for nomination as success stories.

As a result, the water quality effects of new restoration projects are now determined using the upstream/downstream, before/after study design for statistical analysis. The SWQB has applied this approach on five projects: Rio de los Pinos, Bluewater Creek, San Antonio Creek, Comanche Creek, and Ponil Creek, all of which have §319 projects related to temperature impairments. Stream temperature was monitored each summer from 2009 to 2011, and an analysis of covariance was used to determine the effects of each project. Significant decreases in daily maximum stream temperature were detected on San Antonio and Comanche Creeks. An analysis of turbidity was also done for San Antonio Creek, but the results were inconclusive. The results for stream temperature on the remaining waters were also inconclusive, but at least two more years of additional monitoring will be conducted and will add strength to the analysis and better account for the lag time for vegetation growth.

In 2011, baseline data were collected on two new projects: Redondo Creek and Rito Peñas Negras. Redondo Creek was monitored cooperatively with the U.S. Forest Service, and Rito Peñas Negras with the University of New Mexico Water Resources Program. Effectiveness monitoring will continue on these project areas for at least five years to complete the statistical analysis.

Projects prior to 2008 did not have adequate baseline data for statistical analysis, but success could still be demonstrated on several projects using a weight of evidence approach relying on before and after photo documentation and post-project data supporting compliance with water quality standards and the removal of waters from the NM §303(d) impaired waters list. This approach was applied to projects on the Rio Cebolla in the Jemez Mountains, and the Lower Santa Fe River, and both projects passed a thorough EPA review and were recognized as official Nonpoint Source Success Stories. A highlight of the program in 2011 was the completion of the Santa Fe River Success Story, culminating with a site visit from Nancy Stoner, Acting Assistant Administrator for the EPA's Office of Water, to recognize the successful restoration project.

The experience gained through this project led to several recommendations for future monitoring, including reviewing changes to the NM §303(d) list for potential success stories, improving coordination with cooperators and staff in developing monitoring plans, continuing monitoring long enough to account for vegetative growth lag time, and prioritizing pre and post monitoring periods for efficiency. SWQB plans to implement these recommendations and continue the NPS Effectiveness Assessment as an ongoing element of the Nonpoint Source Management Program, in order to document success and to learn from watershed efforts that may not be as successful.

Background

The New Mexico Environment Department (NMED) Surface Water Quality Bureau (SWQB) coordinates and implements the Nonpoint Source Management Program in New Mexico. One of six main objectives of the program is to address water quality problems within priority watersheds, under a variety of programs and funding sources, to restore waters to meet their water quality standards. SWQB receives funding under §319 of the Clean Water Act to support both the coordination aspects of the Nonpoint Source Management Program and to support projects that directly improve water quality. SWQB is also responsible for managing the New Mexico Wetlands Program (funded under Section 104(b)(3) of the Clean Water Act) and the state-funded River Ecosystem Restoration Initiative. Both of these programs include water quality improvement among their goals, and are considered part of the Nonpoint Source Management Program. In addition, public land management agencies, private landowners, nonprofit organizations, and others seek to improve water quality through a variety of programs.

The Effectiveness Monitoring program has been developed to monitor the effects of these projects on water quality, document success stories, and provide the basis for delisting impaired waters when appropriate. This report summarizes the accomplishments of the first four years of this program.

Methods

Two primary approaches for determining the effectiveness of stream restoration projects were explored: the statistical analysis method and the weight of evidence approach. The statistical analysis method involves a more rigorous scientific process of developing a Project Quality Assurance Project Plan (PQAPP) and collecting data for statistical analysis. The weight of evidence method is an alternative approach primarily used with the older projects where adequate baseline data were not available for the statistical method. The EPA guidelines for success stories[1] allow for this weight of evidence approach when a trend of improvement can be shown, even if a statistical analysis is not possible.

[1]EPA Success Story Guidelines are available at the following two links:
http://www.epa.gov/owow/NPS/Success§319/pdf/storyformat0607.pdf
http://www.epa.gov/region9/water/watershed/docs/SP-12_Guidance_12-05-08.pdf

Statistical Approach

The most definitive method to determine the effects of a project on water quality is to collect and analyze adequate data to determine if there is a statistically significant difference. Several study designs are available for this purpose, but the study design selected as the most useful and practical for the SWQB Effectiveness Monitoring program was the Upstream and Downstream / Before and After Method (Spooner et al 1998). In this method, water quality parameters of interest are measured at locations immediately upstream and downstream of the project reach both before and after project implementation. Streamflow was included in the analysis as an explanatory variable when possible, but this was optional because this method accounts for explanatory variables such as climate and streamflow by incorporating paired data collected under the same climatic and hydrologic conditions. These explanatory variables are required for the more limited Before and After Method, in which the parameters are measured only at the downstream location. The paired watershed method would be the most definitive but the resources required are not practical for our program.

To apply the Upstream/Downstream Before/After method (UDBA) for stream temperature, thermographs are deployed upstream and downstream of a project reach and set to record hourly. The SWQB uses Onset Hobo V2 thermographs, which are small submersible temperature data loggers that can be downloaded underwater using the waterproof shuttle. Additional thermograph locations are added to account for tributary inputs or other factors that could have a significant effect on stream temperature within the project reach. The period of deployment is from late spring to early fall, since the parameter of interest is the summer daily maximum temperatures. The thermographs are deployed in shaded glide sections of streams using rebar stakes and zip ties (SWQB SOP 6.4).

For turbidity, multi-parameter sondes are deployed in accordance with the UDBA study design and set to record at hourly or shorter intervals. The SWQB uses both YSI and Hydrolab sondes, and sonde data provided by the Valles Caldera National Preserve were also collected with YSI sondes. The sondes are deployed from spring to fall, but sometimes for shorter periods than the thermographs as the sondes are much more expensive and in higher demand for other projects as well. The sondes are deployed in shaded and protected glide sections of streams, using a locking cable and protective covering (SWQB SOP 6.2.) The sondes are calibrated prior to deployment, and every two weeks during the deployment period.

Stream flow was also considered as an important factor affecting water quality. Higher flow may accompany higher sediment loads, or may dilute some pollutants. Higher flow may result in lower stream temperatures as more water is present to absorb incident radiation. Streamflow data are generally not available for specific project locations, and were not collected as part of this project. Often, a USGS gage is available in the vicinity of a project area, and records flow data that may be used to indicate hydrologic conditions in the larger watershed. Smaller scale hydrologic events within project areas may have little effect on flow at the gage sites, however.

Incorporation of flow as an explanatory variable for the UBDA analysis is optional, because with this study design paired data are collected under similar hydrologic conditions. Flow is accounted for by measuring stream temperature concurrently at both the upstream and downstream stations. This

analysis tests whether the relationship of the parameter at the two stations has changed, and describes the magnitude of the change. While flow varies over time, the effect is assumed to be the same at the two stations. A lag time may be required if the travel time between the two stations is significant relative to the sampling frequency (Grabow, Spooner et al. 1998).

For stream temperature and flow, the data were reduced from hourly to daily values to avoid autocorrelation. Although the SWQB uses temperature statistics such as the Maximum Weekly Average Temperature (MWAT), and the 4-hour maximum temperature that occurs for 3 consecutive days (4T3), to assess stream temperature relative to water quality standards, this analysis used daily maximum temperature during the summer as the most appropriate and practical statistic for detecting changes. Because the 4T3 and MWAT are calculated using data from multiple days, these statistics reduce the data more than is necessary to avoid autocorrelation.

Another component of effectiveness monitoring was to measure canopy cover before and after project implementation to document changes in percent shade. Percent cover was measured at Ponil and Bluewater Creeks. Ponil had more cooperator involvement and percent shade was measured at 30 sites which were randomly selected within the project reach using GIS. Using the EMAP protocol, densiometer readings were taken in a cross section at each site, with readings taken from the center of the stream looking up, down, and toward each bank, and also from the edge of water looking out towards each bank (Kaufmann 2000). For this method a convex densiometer is modified with tape in a v-shape to only include the 17 grid intersections facing forward from the observer (Figures 1, 2). These readings were used to calculate percent shade for the site, and they were repeated using the Global Positioning System (GPS) to locate the exact same sites in 2011 after the project was completed.

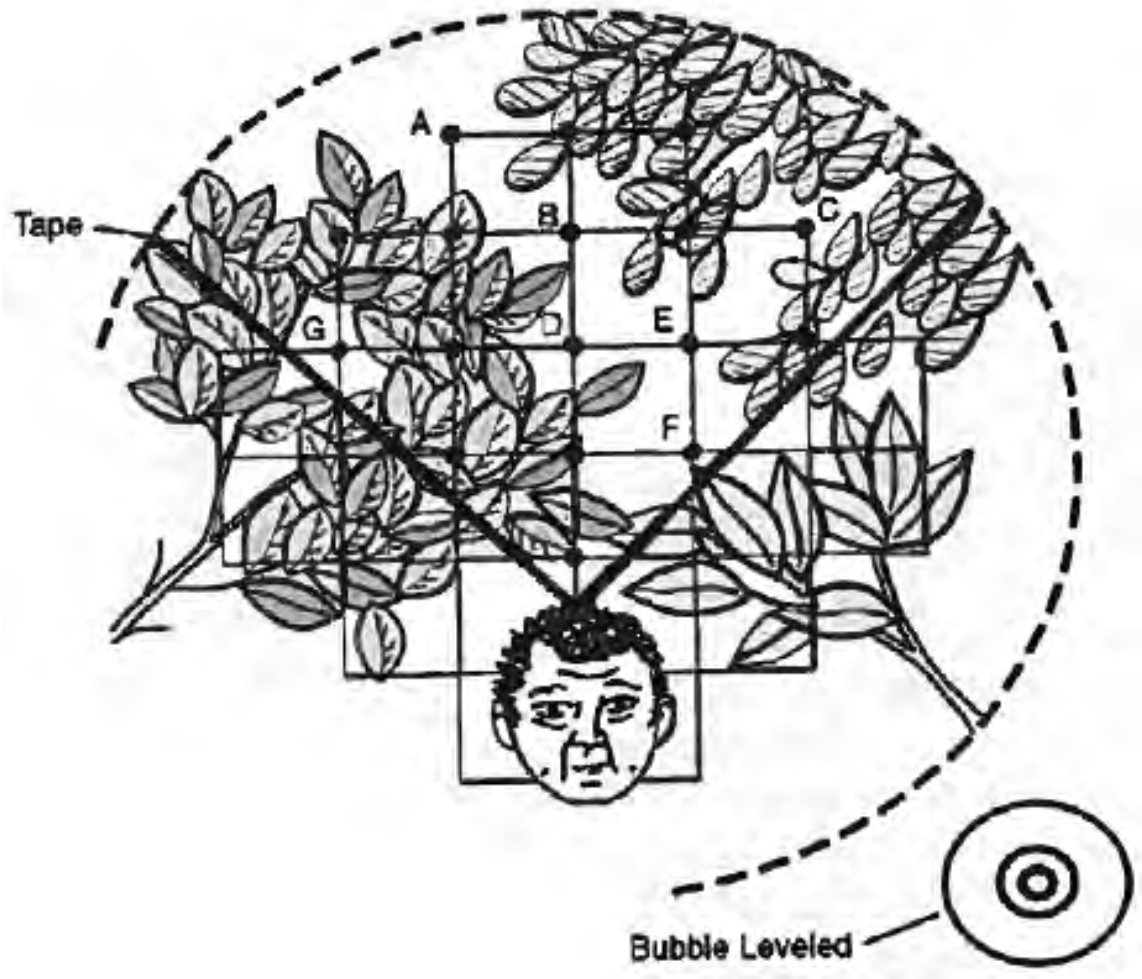


Figure 1: Modified Densiometer Method from EMAP Protocol

Figure 2: Densiometer modified in accordance with EMAP Protocol for canopy measurement

Weight-of-Evidence Approach

For projects that do not have adequate data for the statistical analysis, usually older §319 projects conducted prior to the emphasis on monitoring beginning in 2008, the weight of evidence approach was applied. With this approach the older successful projects could still be recognized for their benefits in spite of a lack of baseline water quality data. Part of this approach is to review the changes to the NM §303(d) list that occur every two years and identify where de-listings coincide with restoration projects, or other likely causes of water quality improvement. This was the case for the Rio Cebolla which was de-listed for sediment and the Lower Santa Fe River, which was de-listed for pH and sediment. Also, even if a full upstream/downstream before/after analysis is not possible, post-project data can be used to show an improvement relative to the water quality criteria, as was the case with dissolved oxygen for the Lower Santa Fe River. Additionally, photo monitoring can help make the case for project success when it is well documented and consistent in location. For example, the striking before and after photos of the riparian vegetation in the Lower Santa Fe River Preserve were very effective in illustrating the effects of the project.

Data Processing and Management

Effectiveness Monitoring data are collected and managed in accordance with the Quality Assurance Project Plan for the SWQB, and the more specific PQAPP for each project area. Thermographs are tested for accuracy once a year prior to deployment using an insulated room temperature water bath and a thermometer certified by the National Institute of Standards and Technology (NIST) (SWQB SOP 6.4). Sondes are calibrated prior to deployment, and at intervals of two to three weeks during deployment. The individual probes are inspected during calibration and maintained as necessary (SWQB SOP 6.3).

The time-series data from both the thermographs and sondes are downloaded and exported to an Excel spreadsheet format, and then imported into a template for data validation and verification developed by the Effectiveness Monitoring coordinator. This template uses graphs and conditional formatting with data bars to facilitate the data review process. A particularly useful feature of the template is that it highlights periods where the stream temperature increases more than three degrees Celsius in one hour, indicating that the flow decreased and the sensor was not submerged.

After review, the data are stored on the computer of the Effectiveness Monitoring Coordinator, and in the Archived Logger Data folder of the SWQB Public folder on the NMED network. The data are backed up weekly, and this system was tested in 2011 when the hard drive failed, and most of the data were successfully recovered, with the exception of some of the 2010 data for Bluewater Creek were stored under the program files directory and not backed up. Fortunately, the lost data were not critical for the analysis, as the 2011 data were better for post-treatment period. As a result, the backup system has been improved and all data are now covered.

There are plans to incorporate the thermograph and sonde data into the SWQB EDAS2 database. Initial testing of this procedure has begun and the data will soon be transferred to this database which will facilitate the eventual upload to STORET.

Data Analysis

Once the baseline and post-treatment data have been collected, verified, and validated, the Analysis of Covariance can be conducted. The first step is to reduce the data to a time interval of sufficient length to avoid problems with autocorrelation. Excel pivot tables are used to reduce the data from intervals of 15 minutes, 30 minutes, and one hour, to daily, weekly, and even individual storm periods in the case of turbidity. The next step is to use the data analysis tools in Excel to check that the data are normally distributed by plotting histograms and calculating skewness. If the skewness has an absolute value greater than 1.0, then a transformation is required. The most commonly used transformation is the logarithm with base 10, but the reciprocal transformation was also used with the turbidity data. If the transformation is not successful in producing the required normal distribution, then more advanced statistical methods are required, such as non-parametric analysis.

Once the data have been checked for autocorrelation and determined to have an acceptable skewness value, the regression analysis can be conducted. The data are formatted in Excel with the downstream site (dependent variable) in the first column, and the upstream site (independent variable) and the associated indicator and interaction terms, and explanatory variables such as stream flow, in adjacent columns. The analysis is an analysis of covariance (ANCOVA) that is combination of ANOVA and regression on the covariates. In this analysis, the covariates are stream temperature at the upstream and downstream locations (Grabow et al., 1998). The regression tool in Excel then provides the statistical output including p-values and coefficients that indicate the significance, magnitude, and direction of any effects attributable to the project (Table 2). If the confidence level is less than 95% for the p-value associated with the difference in slope between the calibration and treatment period lines, then the interaction term can be removed from the full model, and the analysis is repeated with the reduced model, in which the slopes of the two best-fit lines are assumed to be equal.

Included with the results of the ANCOVA are plots of the residuals, which are the difference between the measured values and the values predicted by the regression model. These residual plots are used to diagnose problems, as repeated patterns, mounding, or a funnel shape in these plots indicate problems with autocorrelation and other violations of the assumptions of the model. Once the residual plots are acceptable, the results can be plotted and interpreted in terms of project effectiveness, and the magnitude of change can be estimated using the coefficients generated by the model.

Results: Weight of Evidence Approach

At the beginning of1 the Effectiveness Monitoring Program in 2008, several pre-existing projects were selected for nomination as EPA Success Stories, including the Rio Cebolla downstream of Fenton Lake, and the Lower Santa Fe River, downstream of the Santa Fe Wastewater Treatment Plant, and Comanche Creek in the Valle Vidal.

Rio Cebolla

The Rio Cebolla in the Jemez Mountains of north-central New Mexico was found to be impaired by sediment during the 1998 water quality survey conducted by the Surface Water Quality Bureau (SWQB) of the New Mexico Environment Department (NMED). Subsequently a §319-funded program addressed the impacts to water quality from recreation, grazing, and roads (Figure 3). The program implemented by the Forest Service (USFS) was entitled "Respect the Rio," and it involved public outreach and fencing to manage livestock and recreational vehicles, as well as culvert replacement and road and trail drainage improvements. Ultimately it was successful in getting the Rio Cebolla removed from the list of impaired waters.

Rio Cebolla originates on the Santa Fe National Forest in the Jemez Mountains approximately 12 miles east of Cuba. It is a tributary to the Guadalupe and Jemez Rivers, and most of the watershed is on USFS land. As a result of the 1998-1999 SWQB monitoring in the Jemez River Basin, several exceedances of NM water quality standards for stream bottom deposits (SBD) were documented on the Rio Cebolla. The Rio Cebolla was analyzed as two separate segments: (1) from its confluence with Rio de las Vacas to Fenton Lake and (2) from the inflow to Fenton Lake to the headwaters. Rio Cebolla from Rio de las Vacas to Fenton Lake was listed for sediment in 1998, and found to be not supporting the designated use of high quality cold water fishery. A Total Maximum Daily Load (TMDL) for sediment was completed for the Rio Cebolla in 2004, and it indicated that the target load to meet standards would be 20% fines. The TMDL identifies potential sources as runoff from rangeland and roads.

The Respect the Rio Program (RtR) was initiated by the Santa Fe National Forest in 2001, following a previous §319 project specific to the Rio Cebolla in 1999. These projects were in line with the Watershed Restoration Action Strategy (WRAS) for the Jemez River Watershed. The goal of these projects was to reduce nonpoint source pollution to the Rio Cebolla and other streams on the Jemez and Cuba ranger districts. The RtR program has been conducted in three phases: phase I from 2001 to 2004, phase II from 2005 to 2008, and phase three from 2008 through the present. This program addressed three primary land use activities of concern: recreation, grazing, and roads.

A major impact to riparian conditions and water quality in this area comes from dispersed recreation, and a major component of this program was education and outreach aimed at the recreational users of this area. An aggressive outreach campaign was effective in increasing awareness and educating people on ways to protect the stream. In addition to education, recreational impacts were also addressed by closing off vehicular access to the stream banks by fencing and restoring closed areas.

Another component of the Respect the Rio program was to improve riparian conditions through better grazing management. An important change in management has been that now the livestock are transported more often by vehicles, whereas in previous years the permittees would drive the livestock through the watershed and riparian areas to the winter pastures. Grazing in riparian pastures is now limited to two weeks per year. Additionally, old fences were replaced as needed and upland stock tanks were constructed to relieve concentrated grazing in the riparian areas.

Impacts from roads were addressed by replacing culverts and improving road drainage. Two culverts on Forest Road 376 on the Rio Cebolla were replaced in order to improve floodplain function, reduce bank erosion, and improve fish passage. Selected road segments were improved with French drains using permeable material to facilitate seepage. Three French drains were constructed to reconnect an adjacent wet meadow with springs which had previously been intercepted by the road. These actions have considerably improved the stream conditions, as road impacts were a significant factor on the Rio Cebolla.

In 2008 the Rio Cebolla from Rio de las Vacas to Fenton Lake was declared to be fully supporting of all designated uses and it was removed from the NM 303(d) list of impaired waters. This de-listing was based on the water quality survey conducted in 2005, and use of a revised assessment protocol that includes biologic indicators in addition to the physical attributes.

The Santa Fe National Forest was awarded the §319 grants to conduct the program, but additional partners include New Mexico Trout, Habitat Stamp Program, New Mexico Game and Fish, Trout Unlimited, Backcountry Horsemen, individual permittees and landowners, Jemez Valley and Cuba schools, Boy and Girl Scouts of America, Student Conservation Association (SCA), and Forest Trust Youth Conservation Corps (YCC). The program was patterned after a similar USFS program in the Pacific Northwest.

The Rio Cebolla Project was officially recognized by EPA as an NPS Success Story in 2009, and is published on the Success Story website[2].

[2] The EPA website for the Rio Cebolla Success Story can be found at:
http://www.epa.gov/owow/NPS/success/state/nm_rio.htm

Figure 3: Erosion damage from off-road vehicle use in the Rio Cebolla watershed (Aug 2003).

Figure 4: Same location after treatment and fencing.

Santa Fe River

The lower Santa Fe River is a perennial reach of an otherwise intermittent channel, downstream of the city of Santa Fe. It is fed primarily by effluent from the Santa Fe Wastewater Treatment Plant. Prior to restoration, this reach was impacted by grazing and lacked a healthy riparian corridor, and it was included on the NM 303(d) list of impaired waters for sedimentation, dissolved oxygen, and pH. Starting in 2000, a local environmental group called the Forest Guardians (now the Wild Earth Guardians), collaborated with the city and county to protect and restore a two-mile reach using §319 funds. Restoration work included removal of exotic vegetation and planting of native vegetation, which included more than 5,000 cottonwoods and 15,000 willows. The work also included the removal of levees to allow high flows to reach the floodplain, the creation of wetlands, and outreach and education activities. Overall, the project has significantly improved the water quality and ecological health of the lower Santa Fe River. In 2010 it was de-listed for pH, chlorine, and sedimentation, and for dissolved oxygen in 2012.

In 2000, the Santa Fe River from Cochiti Reservoir upstream to the Santa Fe waste water treatment plant was impaired for stream bottom deposits, dissolved oxygen and pH. Subsequent TMDLs were written and approved by EPA for stream bottom deposits in March, 2000 and for dissolved oxygen and pH in January, 2001. Initial restoration efforts were funded through a Partners Grant from the U.S. Fish and Wildlife Service. In 2000, the Wild Earth Guardians received funding through a CWA §319(h) grant administered by NMED for the Santa Fe River Restoration Project and again in 2005 for the La Cieneguilla Open Spaces / Santa Fe River Restoration Project. The primary objectives of these projects were to improve the ecological condition of the riparian ecosystem and improve water quality in the Santa Fe River.

Restoration efforts on the Santa Fe River Preserve have improved water quality by establishing and protecting an abundant native riparian corridor (Figures 5-8). Restoration was conducted along a 1.5 mile reach of the river and included fencing to reduce the impacts from livestock grazing, prevent unauthorized motorized vehicle use within the riparian area, and to prevent illegal dumping along the river. The floodplain was restored by removing earthen berms and non-native plants, and planting native riparian vegetation including 5,000 cotton-wood poles, and 15,000 willow whips, as well as other shrubs, grasses and forbs. This created a buffer to filter stormwater, strengthened the streambank, and facilitated the formation of riparian wetlands, which reduced sediment loading and increased canopy cover. Increasing canopy cover and reducing available sunlight can have a direct impact on algal growth, and algae are known to be directly related to fluctuations in dissolved oxygen and pH in many aquatic ecosystems.

Figure 5: Santa Fe River below the Wastewater Treatment Plant Photo Point P– Before Restoration Project (1997).

Figure 6: Santa Fe River below the Wastewater Treatment Plant Photo Point P – After Restoration Project (2004)

Figure 7: Santa Fe River below the Wastewater Treatment Plant Photo Point G – Before Restoration Project (2000).

Figure 8: Santa Fe River below the Wastewater Treatment Plant Photo Point G – After Restoration Project (2004).

In 2002, 9 out of 11 grab samples exceeded the pH criterion (pH range from 6.6 to 9.0). In 2008, out of the 10 grab samples collected none exceeded the pH criterion. In addition, sondes deployed at both the station immediately below the Santa Fe waste water treatment plant in July 2005 and at the USGS gage above Cochiti Lake in October 2007 indicated full support for pH (minimum to maximum recorded pH values were 7.37 to 8.68 and 7.25 to 8.78, respectively). Therefore, pH was removed as a cause of impairment on the 2008-2010 NM §303(d) list. Furthermore, sedimentation/siltation was re-moved as a cause of impairment on the upstream reach which includes the Santa Fe River Preserve. Dissolved oxygen was removed as an impairment in the 2012-2014 NM §303(d) list based on data collected during the summer of 2010.

A highlight of the program in 2011 was the recognition of the Santa Fe River Success Story, culminating with a site visit from Nancy Stoner, Acting Assistant Administrator for the EPA's Office of Water, to recognize the successful restoration project (Figure 9). The Success Story is published on the EPA Success Story website.[3]

Figure 9: Dignitaries and cooperators gather at the Santa Fe River Preserve October 26th, 2011, in a ceremony to celebrate the official recognition of the EPA §319 Success Story. Included from left to right are Santa Fe Mayor David Coss, SWQB Chief James Bearzi, NMED Secretary David Martin, Acting Assistant Administrator for the EPA's Office of Water Nancy Stoner, EPA Region 6 Administrator Al Armendariz, and Santa Fe Indian School students.

[3] The EPA website for the Lower Santa Fe River Success Story can be found at: http://water.epa.gov/polwaste/nps/success319/nm_santafe.cfm

Results: Statistical Analyses

Using the Upstream and Downstream / Before and After method (UDBA), data were collected on five Waterbodies (Table 1).

Table 1: Effectiveness Monitoring Upstream/Downstream Before/After Stream Summary

Stream/River	Data Collection	Comment
Rio de los Pinos	Temperature	data collection 2009-2011
Bluewater Creek	Temperature	data collection 2009-2011; §319 Project completed 2010.
San Antonio Creek	Temperature, Turbidity	data collection 2009-2011; coordination with VCNP staff on sonde deployment.
Ponil Creek	Temperature, Canopy Density	data collection 2009-2011
Comanche Creek	Temperature	Post-Implementation monitoring

Comanche Creek

Comanche Creek is located in northern New Mexico, about 20 miles northeast of Taos. It is a perennial mountain stream that runs from its headwaters at an elevation of 10,400 feet to its mouth at 8,940 feet, where it flows to Rio Costilla which in turn is a tributary of the Rio Grande. The total area of the Comanche Creek watershed is approximately 43 square miles, all within the Valle Vidal Unit of the Carson National Forest.

There have been several §319 and RERI stream restoration projects on Comanche Creek as far back as 2000, with the goal of improving water quality for the native cutthroat trout fishery. The projects have included multiple grazing exclosures, in-stream structures such as post vanes and rock structures, channel re-alignment, culvert replacement, and vegetation planting.

Fortunately baseline thermograph data were collected by the Carson National Forest which enabled the statistical analysis. The ANCOVA results comparing 1999 with 2010 showed a mixed result: comparing the regression lines from pre- to post-project there was an increase in the y-intercept ($p<0.001$) but a decrease in the slope ($p<0.001$). This indicates that there have been greater reductions in daily maximum stream temperature at the higher temperature range, and the average difference was a decrease of 0.37°C from pre to post-project periods (Figure 10). Streamflow was found to not be a significant factor ($p=0.38$). These results indicate that although the projects have lowered stream temperature, it is not yet enough to consistently meet the criterion of 20° C for the high quality coldwater aquatic life use. Continued monitoring will be required to account for the lag time in vegetation growth.

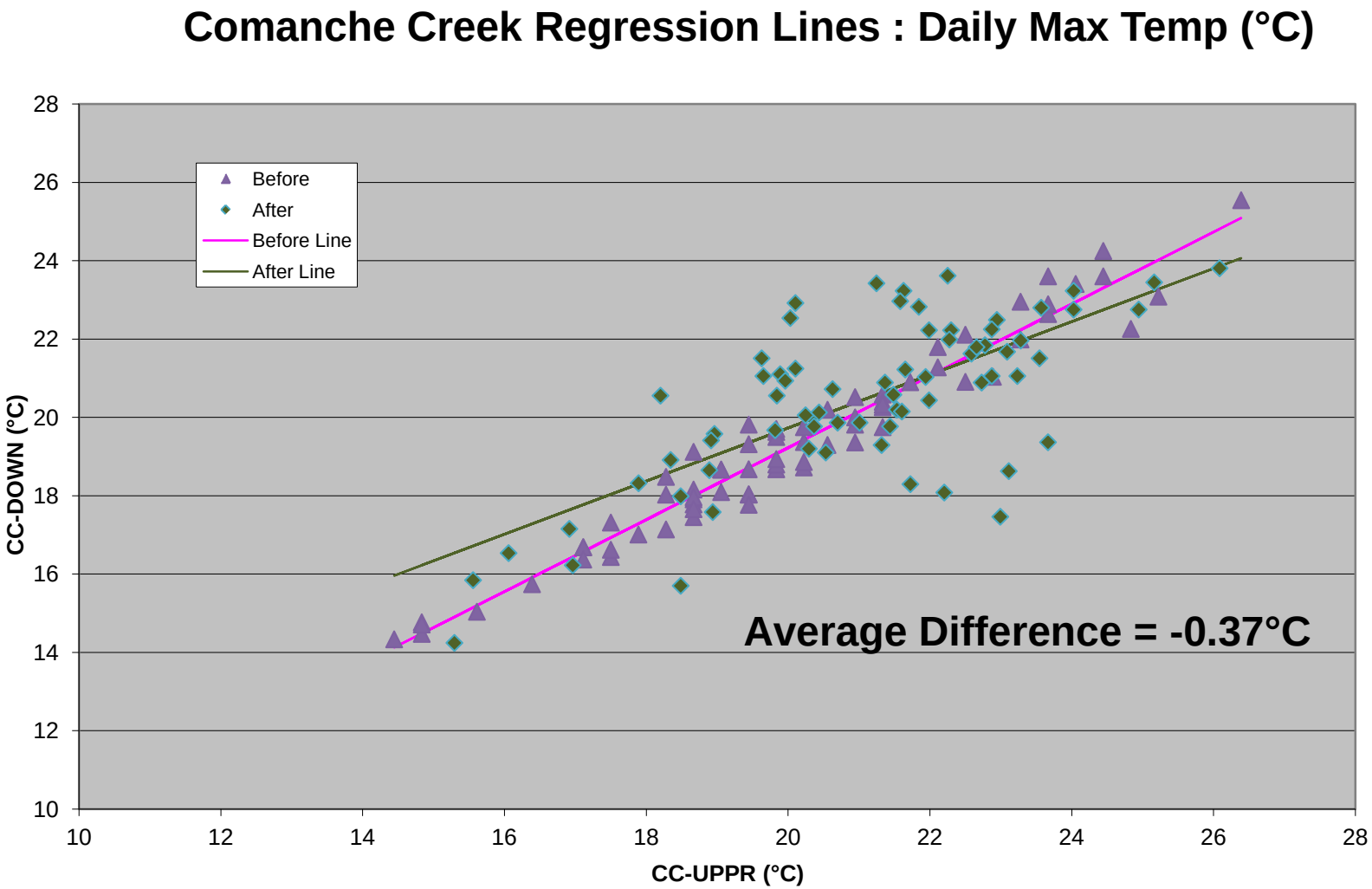


Figure 10: Regression Lines for Comanche Creek Before and After Stream Restoration Projects

San Antonio Creek

San Antonio Creek from its confluence with the East Fork Jemez River upstream to the Valles Caldera National Preserve (VCNP) boundary is listed as impaired by turbidity, temperature, and arsenic, and has total maximum daily loads (TMDLs) in place (NMED, 2010). From the VCNP boundary to its headwaters, San Antonio Creek is listed as impaired by temperature and has a total maximum daily load (NMED 2010).

Starting in 2009, a series of projects were implemented to improve water quality, wetlands, and riparian areas for ecological function. These projects were funded under the Wetlands Program, RERI, and §319 of the Clean Water Act. The projects generally have included grazing management to exclude both livestock and elk from riparian areas, planting of woody riparian vegetation, bank stabilization using post vanes, gully stabilization in tributaries, and drainage improvements on dirt roads.

Effectiveness Monitoring of these projects began in 2009, using the upstream/downstream, before/after study design, according to a quality assurance project plan (NMED 2010b). Additional sites were selected to bracket tributaries, including Rito de los Indios, an artesian well discharge, and the San Antonio warm spring (Figure 11). As documented in the PQAPP, more sites were added as new projects expanded the stream length that might be affected. The downstream station used for this analysis was at the VCO2 road crossing, which is downstream of most restoration activity, and upstream of the warm spring input. The preferred upstream station on San Antonio Creek (SA-INDI), located just upstream of the Rito de los Indios tributary was buried in sediment in 2011 as a result of flooding following the Las Conchas Fire, so the station just downstream of the Rito de los Indios (SA-XING) was used as the upstream station. Therefore possible effects on water quality of the RERI projects on the Rito de los Indios or downstream of the warm spring could not be detected using these two sites, but most of the work on the San Antonio could still be included.

An Analysis of Covariance was conducted on stream temperature data for San Antonio Creek to determine how stream temperature in 2011 compared with 2009. Under the full model, the y-intercept of the 2011 line (upstream vs. downstream) is significantly lower than the y-intercept of the 2009 line ($p=0.01$), but the slopes were not significantly different ($p=0.12$), leading to selection of the reduced model, in which the slopes of the two lines are assumed to be equal. In the reduced model, the difference in y-intercepts (-1.38, $p<0.001$) indicates that water temperature at the downstream station relative to the upstream station was 1.38 °C lower, on average, in 2011 than in 2009 (Figure 12).

Flow data from the gage operated by the VCNP staff on San Antonio Creek were not available for 2011 due to problems with the equipment, possibly due to post-fire flooding. Addition of flow data from the USGS gage on the main stem Jemez River to the full ANCOVA model indicated that flow is a useful predictor of temperature at the downstream station, with greater flows resulting in lower temperatures ($p<0.001$). The slopes of the 2009 and 2011 lines are once again not significantly different ($p=0.59$), leading to selection of a reduced model. In the reduced model that includes flow, the adjusted R^2 value is slightly improved, indicating that the model including flow may be preferred, and the difference in y-

intercepts (-1.57, $p<0.001$) indicates that water temperature at the downstream station relative to the upstream station was 1.57 °C lower, on average, in 2011 than in 2009.

The results for San Antonio Creek indicated that indeed there was a statistically significant difference due to the stream restoration projects. The p-values from the regression analysis indicate that there are statistically significant differences at greater than a 99% confidence level in the y-intercepts of the regression lines between the pre- and post-treatment periods. Furthermore, the fact that the β_2 coefficient is negative indicates that the y-intercept of the post-treatment regression line is lower than that of the pre-treatment line, and that there has been a reduction in stream temperature before and after the project (Figure 12). However, the reduction has not yet been sufficient to remove San Antonio Creek from the impaired waters list, as it still exceeds the 20°C criterion for high quality aquatic life use. Additional monitoring will be required to account for lag time and new projects.

Another notable event during 2011 was the Las Conchas Fire, which burned the headwaters of San Antonio Creek and multiple watersheds in the Jemez Mountains (Figures 13, 14). Large flooding events soon followed the fire during the summer monsoon rains, which carried large amounts of debris and ash from the burned areas. Surprisingly, the thermographs that were deployed in San Antonio creek were all recovered after the sites were accessible, and even the air thermograph that was attached to a partially-burned tree was recovered intact. These post-fire flows had at least short-term devastating effects on water quality and aquatic life. Valles Caldera Trust staff recorded ammonia concentrations high enough to kill fish, and documented a fish kill in San Antonio Creek. Although the San Antonio Creek channel and floodplain appear to have accommodated the high flows with little change to channel morphology or bank vegetation, the change that did occur may increase the difficulty of detecting project effects in the future.

In addition to the analysis of temperature, an ANCOVA was also conducted on turbidity data for San Antonio Creek comparing 2007 (before) to 2011 (after). The turbidity data were collected by the staff of the Valles Caldera National Preserve using YSI sondes at a station above the project area just upstream of the Rito de los Indios, and a station downstream of the project area at the western boundary of the preserve. While the upstream station is at a similar location to the upstream temperature station, the downstream sonde location is approximately four miles downstream of the downstream temperature station, and covers a larger project area.

For the analysis the turbidity data were reduced from 15 minute intervals to daily, weekly, and ultimately storm period values, which was tedious and time-consuming but necessary to remove autocorrelation. The turbidity analysis was also complicated because the data were not normally distributed, and the commonly used log transformation did not solve the problem. Other transformations were applied, but the one with the best results was taking the reciprocal of the dependent variable of downstream turbidity (1/Y). However, the ANCOVA results were still inconclusive as they did not show a significant relationship in turbidity between the upstream and downstream stations. Larger data sets and more advanced non-parametric statistical methods may be required to more definitively determine the effect of the projects on turbidity.

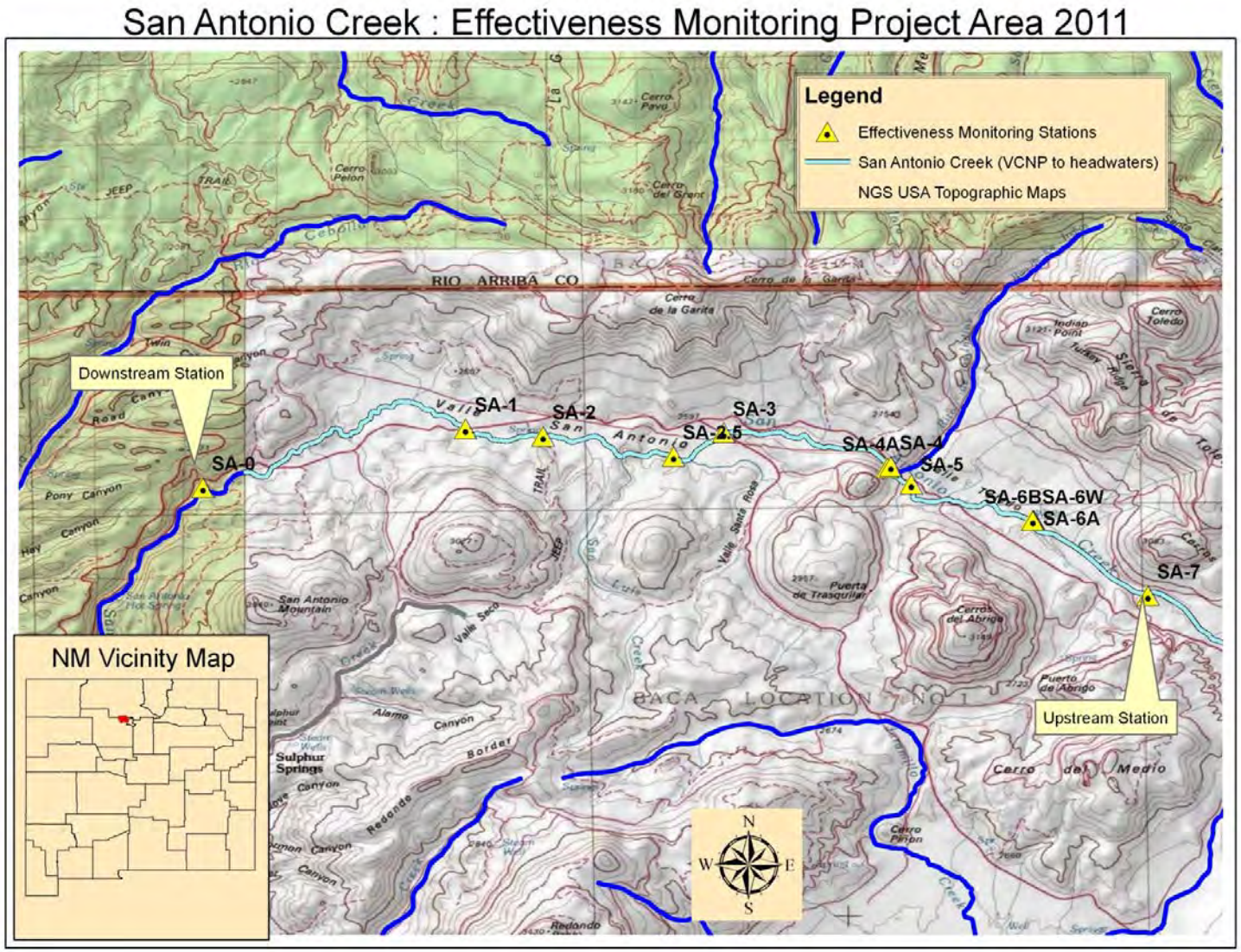


Figure 11: San Antonio Creek Study Area on the Valles Caldera National Preserve.

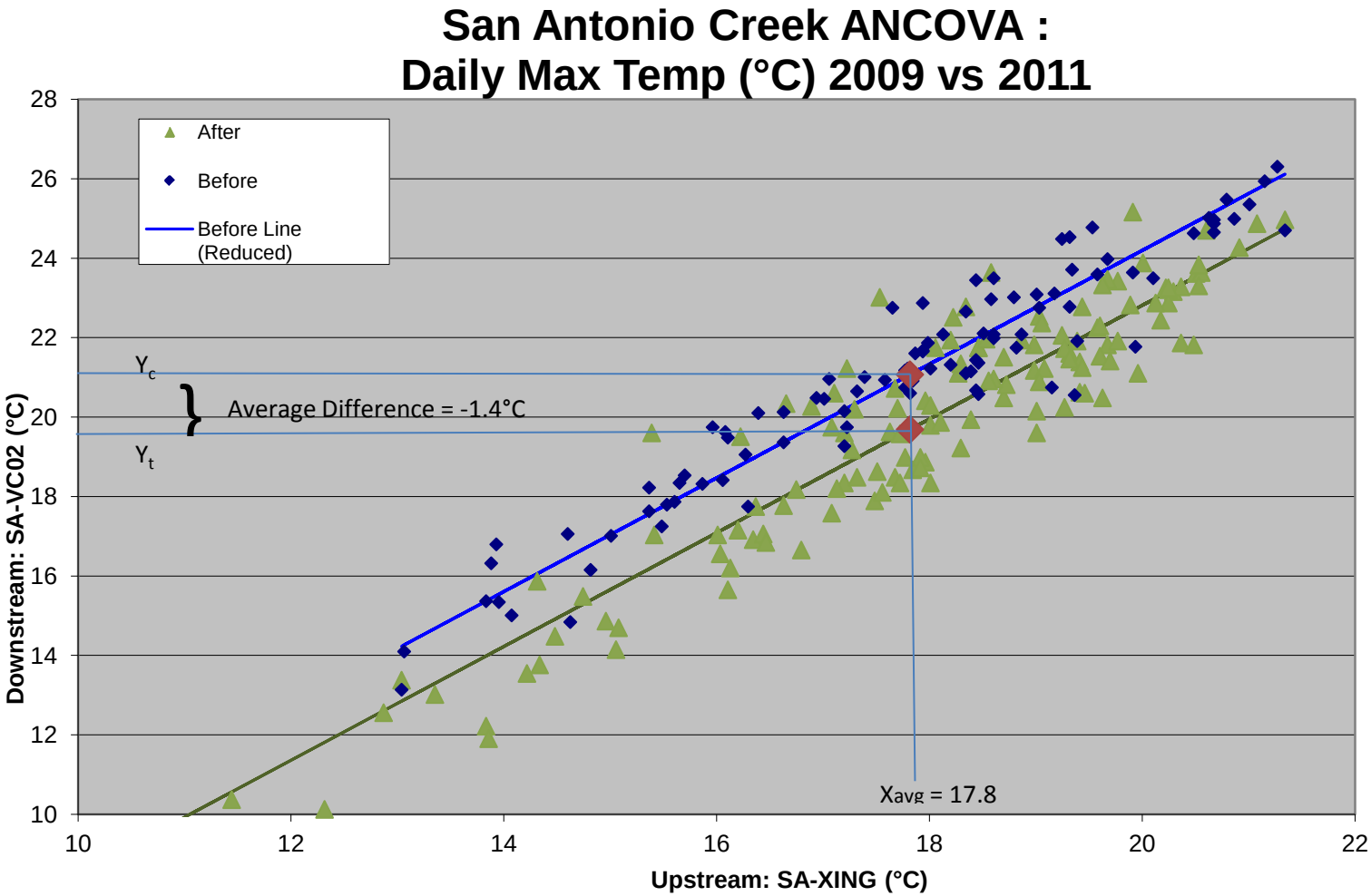


Figure 12: Regression Lines for San Antonio Creek Before and After Stream Restoration Projects

Figure 13: High intensity burn area from the Las Conchas Fire July 2011.

Figure 14: Runoff from the Las Conchas Fire burn area in July 2011

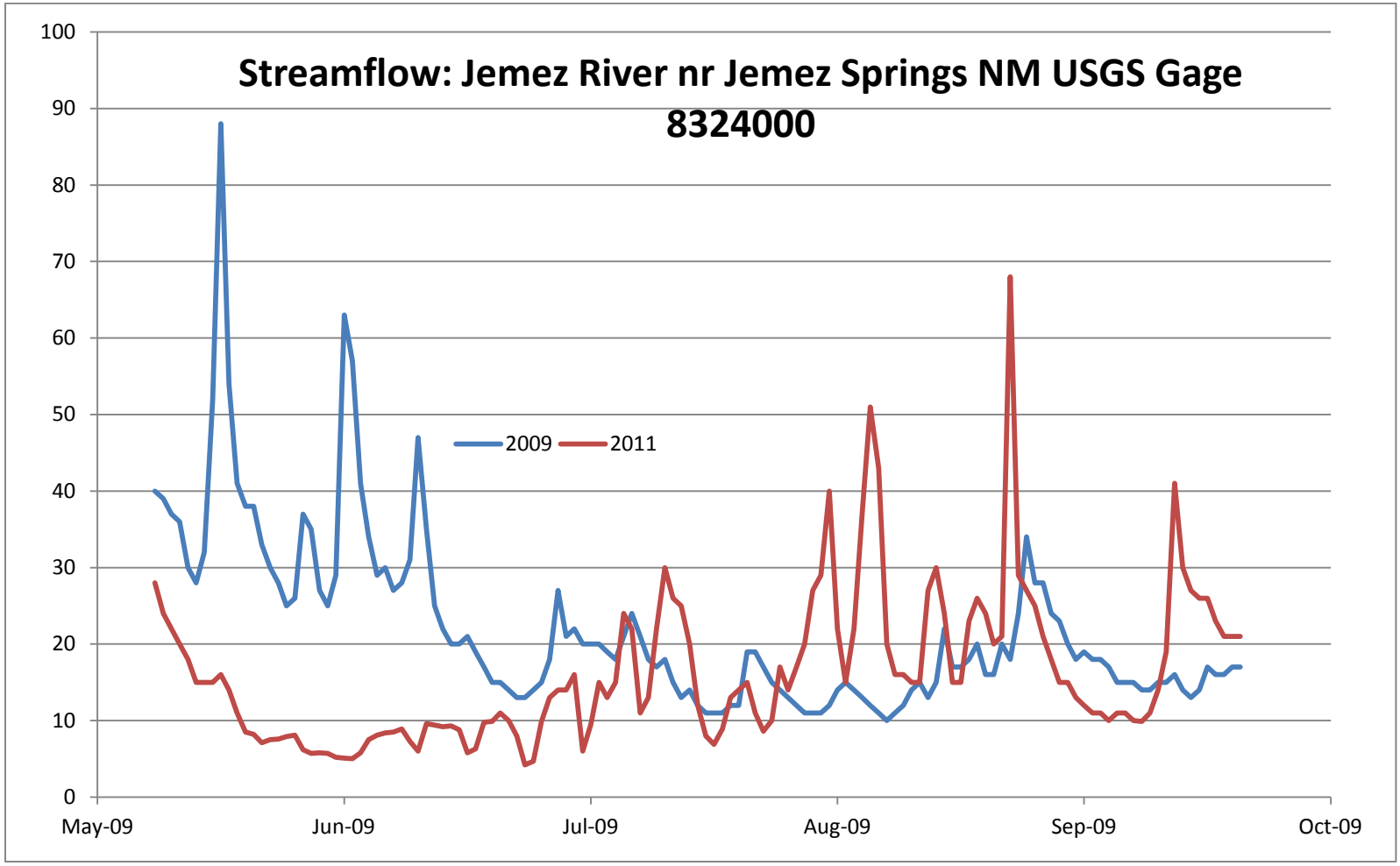


Figure 15: Hydrographs of Jemez gage applied to San Antonio Creek Analysis.

SUMMARY
OUTPUT

Regression Statistics	
Multiple R	0.949251896
R Square	0.901079163
Adjusted R Square	0.900199866
Standard Error	1.02990461
Observations	228

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	2173.960686	1086.980343	1024.773028	9.3299E-114
Residual	225	238.6582888	1.060703506		
Total	227	2412.618975			

		Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	β_o	-4.437859728	0.582181779	-7.622807663	6.88912E-13
X1	β_1	1.431698469	0.032248075	44.39640132	2.7203E-113
X2	β_2	-1.381968929	0.138393947	-9.985761364	1.13234E-19

Table 2: Excel Regression Analysis Output for San Antonio Creek

Rio de los Pinos

The Rio de los Pinos is a tributary of the upper Rio Grande that flows along the border between New Mexico and Colorado, and has been listed for temperature impairment. To address this impairment two §319 projects and an RERI project have been conducted. Effectiveness monitoring of stream temperature has continued from 2009 through 2011. Stream temperature exceeds the criterion of 20°C for the designated use of high quality coldwater aquatic life (Figure 16). Results of the analysis of covariance did not show a significant difference in the y-intercepts of the regression lines (p=0.13) and so were inconclusive (Figure 17). The analysis was hampered by missing baseline data that were lost due to a computer hard drive failure. Adding flow to the analysis improved the p-values but the results showed that there was a two-degree increase after the project. However, monitoring will continue for at least two more years and the additional data will add strength to the analysis and better account for possible lag time of the project effects.

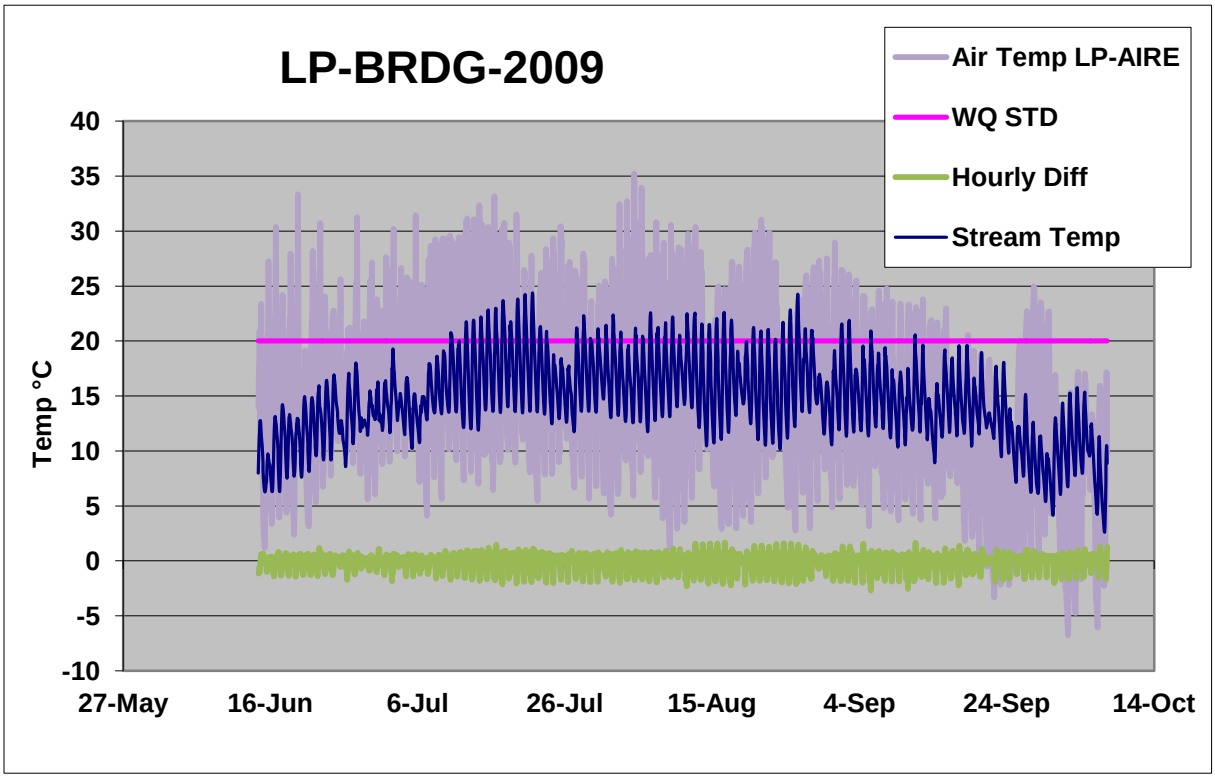


Figure 16: Hourly stream temperature for Rio de Los Pinos at upstream location.

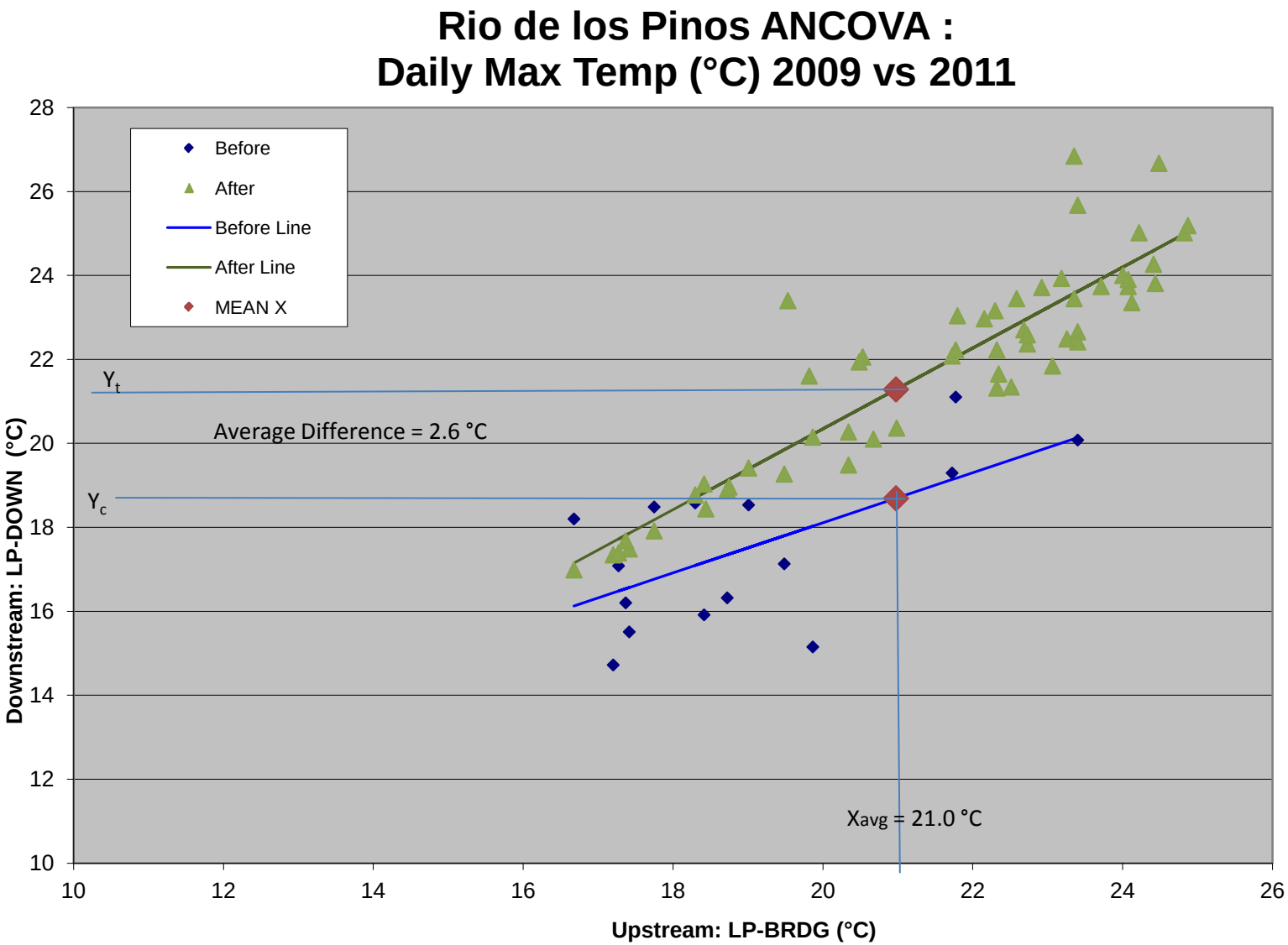


Figure 17: Regression Lines for Rio de los Pinos Before and After Stream Restoration Projects

Bluewater Creek

Effectiveness monitoring was conducted for the §319 project on Bluewater Creek just upstream of Bluewater Reservoir. The §319 project was conducted by the Wild Earth Guardians in cooperation with the New Mexico State Land Office, and includes grazing exclosures and planting of riparian vegetation, primarily willows and cottonwoods, to improve habitat and increase shading to address the temperature impairment. Baseline effectiveness monitoring data were collected in 2009, including stream temperature and canopy coverage. Monitoring continued in 2010 and 2011.

An ANCOVA was conducted to compare the upstream/downstream relationship between 2009 (before the project) and 2011 (after the project). Using the daily maximum temperatures, the results indicate a decrease in the y-intercept ($p=0.0$) and an increase in slope ($p=0.0$) of the pre and post-project regression lines, with an average decrease in stream temperature of 0.27 °C (Figure 18). However, the diagnostic plot of residuals over time indicates that autocorrelation may be an issue (Figure 19).

To eliminate the concern with autocorrelation, the stream temperature data was reduced further to weekly maximums. The ANCOVA results for the weekly data did not show a significant difference in either the y-intercept or the slope of the pre and post-project regression lines at the 95% confidence level ($\alpha= 0.05$).

Therefore, due to the autocorrelation problem the results for the project effects on stream temperature on Bluewater Creek are not yet conclusive. However, monitoring will continue for at least two more years and the additional data will add strength to the analysis and better account for the lag time of vegetation growth.

Another component of the effectiveness monitoring on Bluewater Creek was canopy coverage. An important finding was that in many cases the newly planted vegetation was just out of reach of the densiometer readings recorded following the EMAP protocol. This was due to the fact that planting occurred during the spring runoff when water level was high, which increased the distance of planting to the channel, and the densiometer readings were taken during low flow conditions which limited the range of the densiometer. However, the large amount of planted willows and cottonwoods are expected to continue to grow and multiply and have recruitment closer to the stream channel. Therefore canopy monitoring will continue for at least two more years to improve the assessment of changes in shading due to the project.

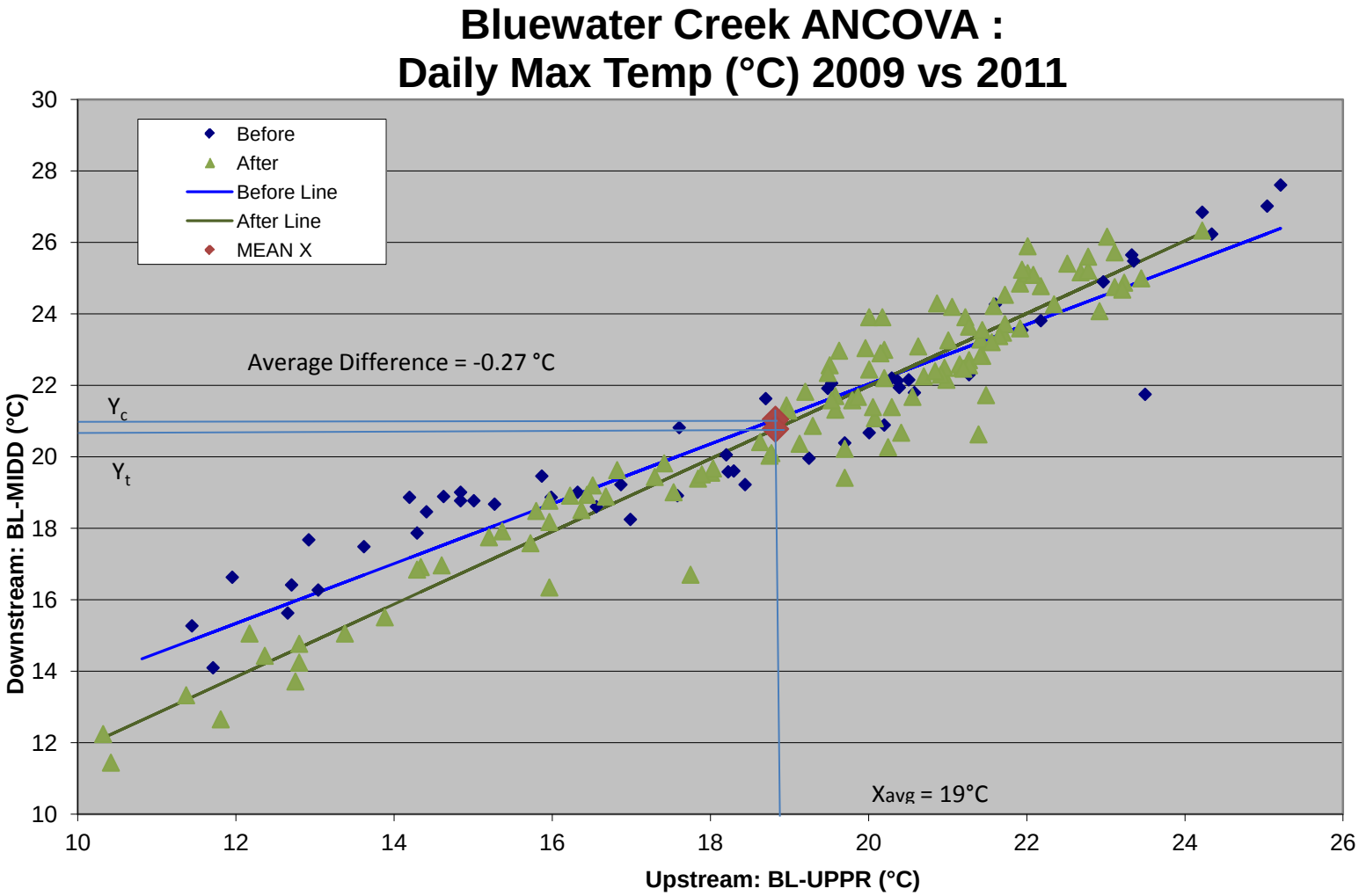


Figure 18: Regression Lines Bluewater Creek Before and After Stream Restoration Projects

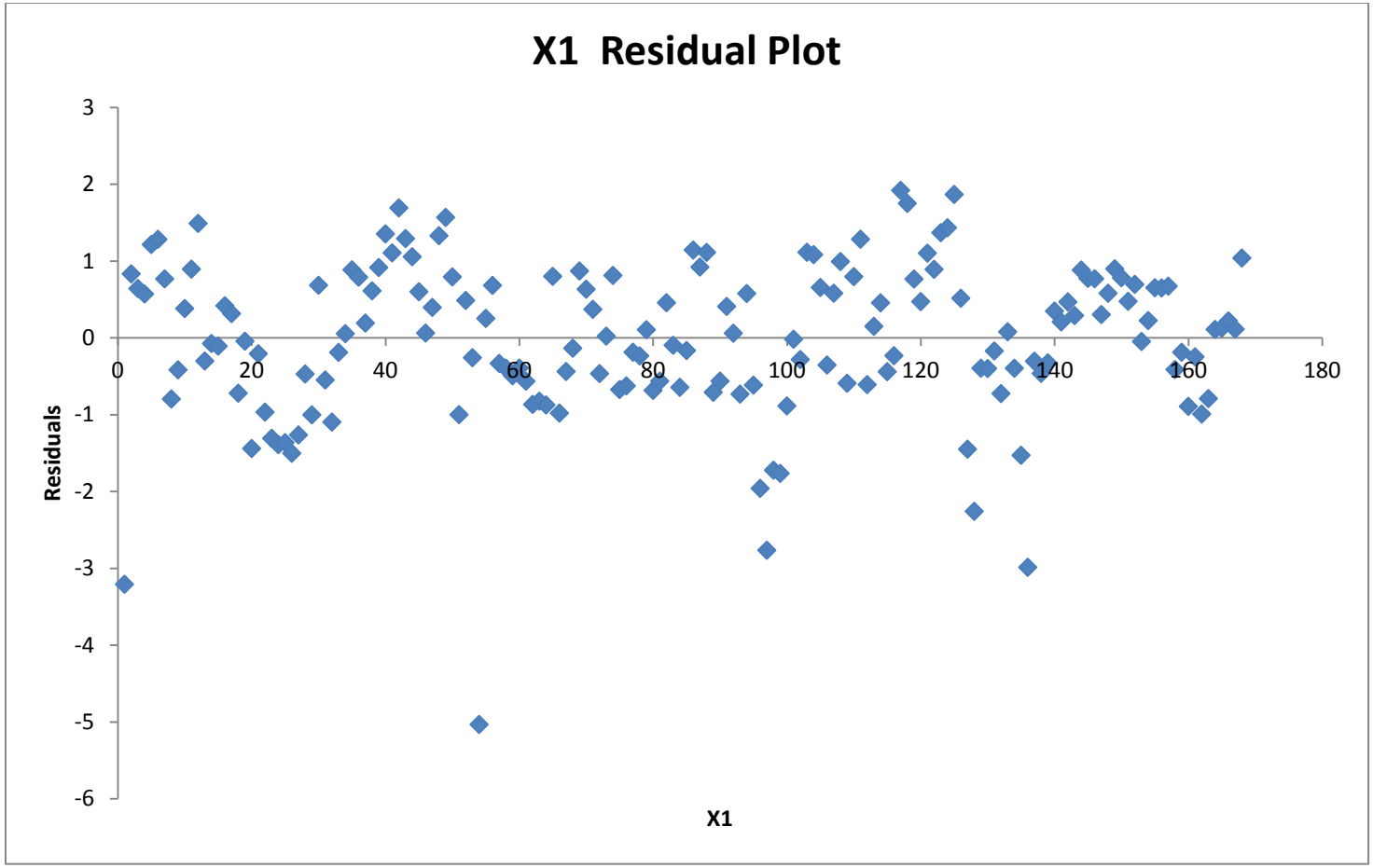


Figure 19: Regression Residual Plot over time for Bluewater Creek ANCOVA regression analysis, using daily maximum temperatures. Repeated patterns in the residuals indicate autocorrelation.

Ponil Creek

The project reach of Ponil Creek flows from its headwaters on the Valle Vidal Unit of the Carson National Forest, down through the Vermejo Park Ranch and the Elliot Barker State Wildlife Refuge, and onto the Philmont Boy Scout Ranch near Cimarron. This reach was listed for temperature in 2000 and a TMDL was completed in 2002. This area was heavily impacted by the Ponil Fire Complex of 2002, and much of the watershed was burned, in some areas all the way down to the edge of water on the stream. Since then grazing has been limited and restoration work has been conducted, and the riparian vegetation has recovered well in ten years. Restoration projects have included grazing exclosures, improvements to multiple road crossings, and the repair and rehabilitation of a major post-fire headcut.

Effectiveness monitoring on Ponil Creek included stream temperature and canopy coverage at multiple sites on Middle Ponil, South Ponil, and Greenwood Creek which is a tributary to the upper reach of the Middle Ponil. A complicating factor was that Middle Ponil Creek went dry for several long periods during the term of the study, especially in 2011 when it was dry most of the summer. Therefore, additional monitoring will be required to obtain a data set adequate for the statistical analysis of stream temperature.

Canopy coverage was an important element of effectiveness monitoring on Ponil Creek, and densiometer readings were taken at approximately forty randomly selected cross sections within the project reach. The results indicate that although there was a slight increase in percent cover in the upper reach, the lower reach showed a slight decrease, but neither was statistically significant using a paired sample t-test at the 0.05 significance level (Figure 22 and Table 3).

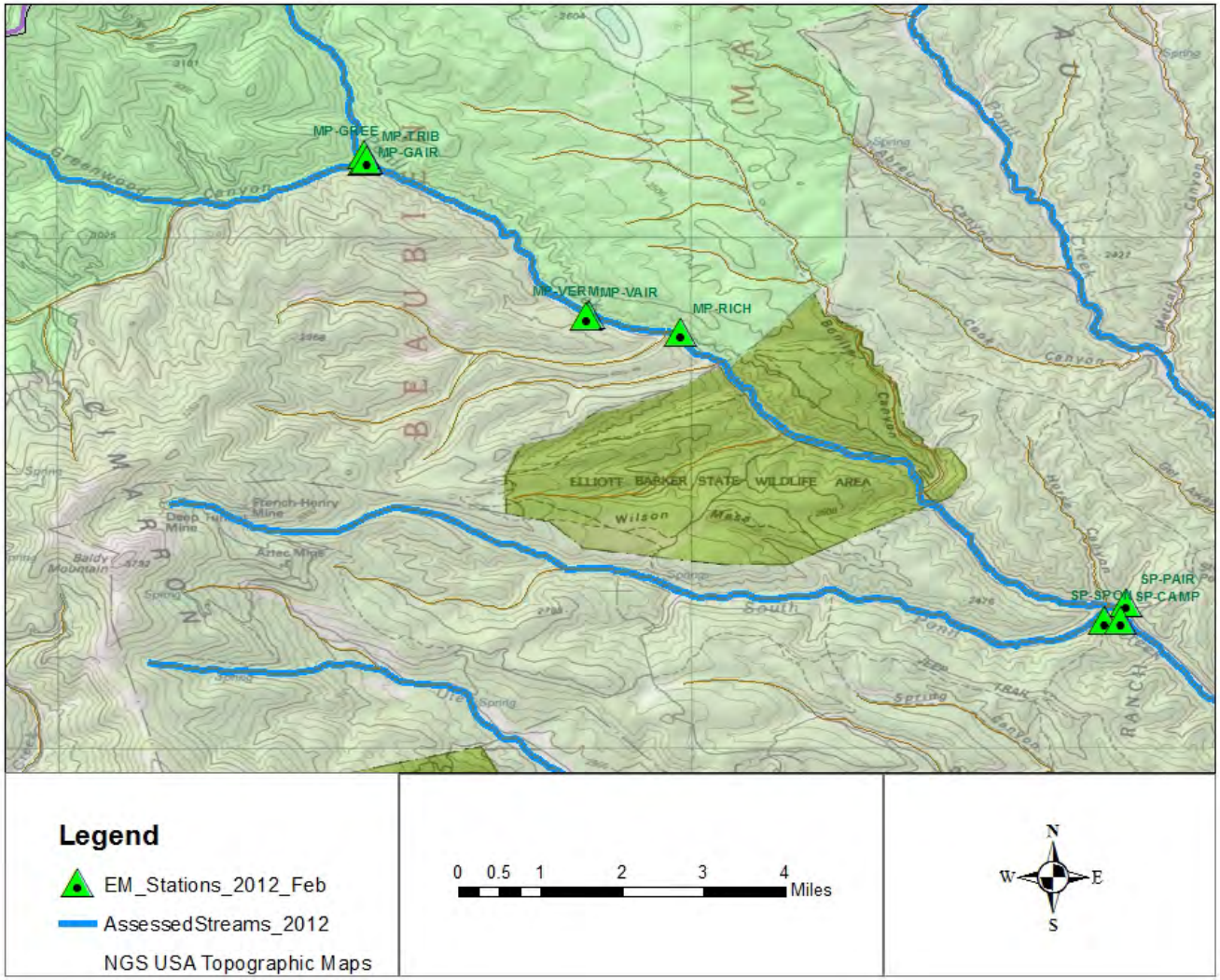
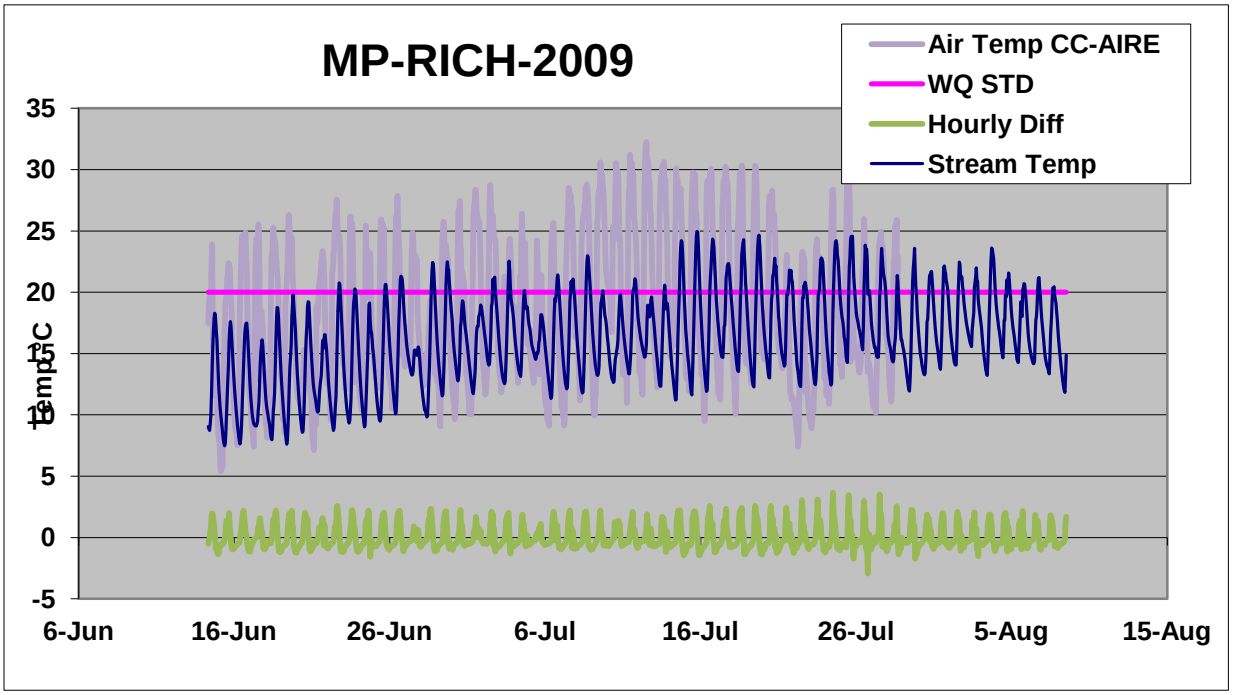


Figure 20: Ponil Creek Project area NE of Cimarron, NM



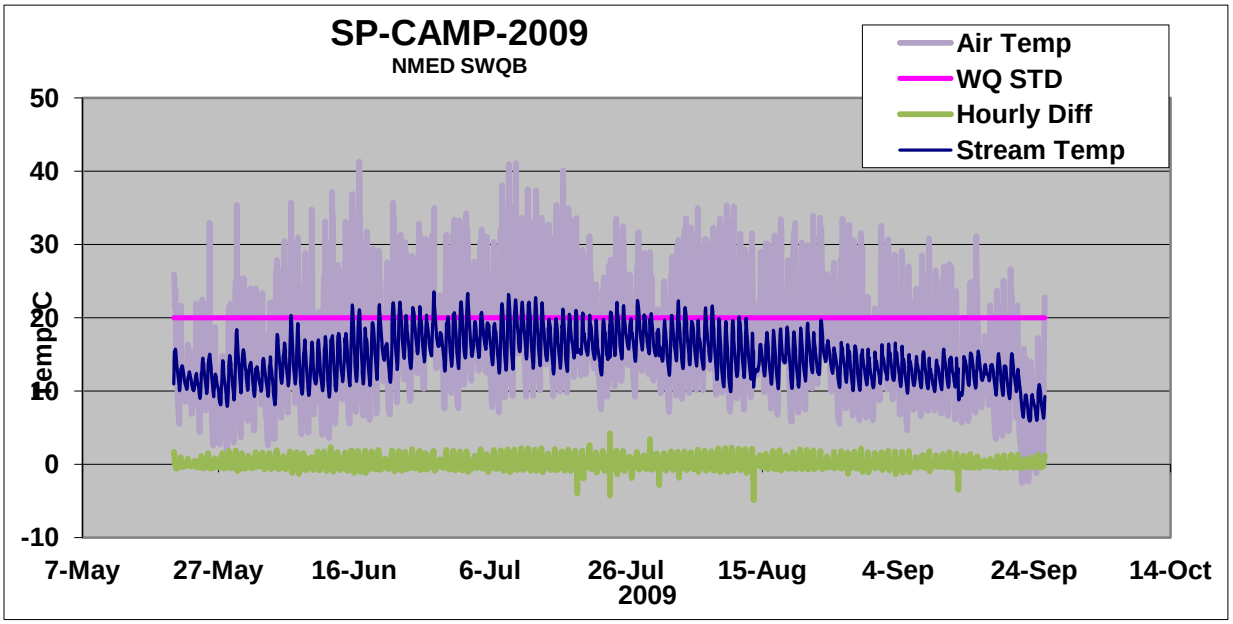


Figure 21: Stream and air temperatures for Middle Ponil at Rich Cabins (upstream) and South Ponil at Ponil Camp (downstream) for summer 2009.

	All Stations	Upper Reach	Lower Reach
2009	51%	48%	58%
2011	53%	54%	53%
p-value	0.26	0.07	0.29

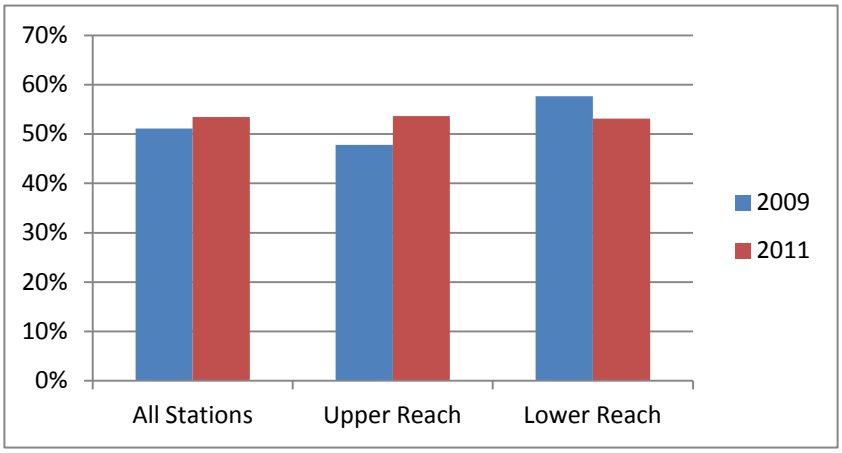


Table 3 and Figure 22: Percent Canopy Cover on Middle Ponil Creek between 2009 and 2011.

New Projects: Baseline Data and Initial Analysis

In 2011, baseline data collection was initiated for two new monitoring projects in the Jemez Mountains: Redondo Creek and Rito Peñas Negras. Both projects required time-consuming coordination with cooperators to complete project Quality Assurance Project Plans (QAPP). Thermographs were deployed in accordance with the QAPPs, which call for the upstream/downstream before/after study design. Monitoring for the Rito Peñas Negras is being conducted in conjunction with U. S. Forest Service, who collected the upstream thermograph data, and the University of New Mexico Water Resources Program, who completed a more thorough Water Resource Assessment[4].

[4] The assessment can be found online at:
http://www.unm.edu/~wrp/Rito%20Penas%20Negras%20Watershed%20Assessment.pdf

Recommendations

With the experience gained through this project, an important objective of this report is to develop recommendations for effectiveness monitoring and NPS project assessment for the future. These recommendations include:

- Continue to apply the UDBA monitoring approach.
- Review the biannual changes to the NM §303(d) list for possible weight of evidence success stories.
- Continue to monitor the FY08 temperature projects at least through 2013 to account for vegetation growth lag time.
- Incorporate SWQB Hydrolab sondes for turbidity and other field parameters.
- Explore methods of measuring flow and/or stage when gages are not available.
- Focus on true baseline and post implementation periods for efficiency, collecting fewer data in "middle years" if necessary.
- Develop longer-term data sets, in both pre-implementation and post-implementation periods, necessary for turbidity analysis of storm events. Long-term data collection is rarely practical without longer-term planning than typical in project implementation.
- Provide technical and financial assistance to local cooperators for effectiveness monitoring.
- Evaluate the use of alternative environmental indicators as a more practical parameter than water quality, such as canopy as an indicator of temperature.

Another lesson learned was the importance of having the cooperator, project officer, quality assurance officer, and effectiveness monitoring coordinator get together early in the process to develop the PQAPP. This was a challenging process during the first three years of effectiveness monitoring, but now that several PQAPPs have been completed there are templates available to facilitate future projects.

Another recommendation is to provide feedback to cooperators on methods, for example while taking densiometer readings on Bluewater Creek the observation was made that the planted willows and cottonwoods were just out of range, and planting them slightly closer to the bankfull water level if possible may have produced better results.

SWQB plans to implement these recommendations and continue the NPS Effectiveness Assessment as an ongoing element of the Nonpoint Source Management Program.

Appendix A: Summary of ANCOVA Results

Waterbody	Upstream	Downstream	Before	After	interval	stat	parameter	Model	Variable	skewness	Residuals	Autocorrelation	item	β	Coefficients	P-value	Confidence Level	comment
Bluewater Creek	BL-UPPR	BL-MIDD	2009	2011	daily	max	temp	Full	X	-0.62	ok	ok?	Intercept	β_o	5.30	0.00	100%	
									Y	-0.63			X1	β_1	0.84	0.00	100%	
													X2	β_2	-3.66	0.00	100%	
													X1*X2	β_3	0.18	0.00	100%	
																	Avg Difference =	-0.27 °C
Bluewater Creek	BL-UPPR	BL-MIDD	2009	2011	weekly	max	temp	Full	X				Intercept	β_o	5.77	0.00	100%	
									Y				X1	β_1	0.83	0.00	100%	
													X2	β_2	-3.55	0.09	91%	
													X1*X2	β_3	0.18	0.08	92%	
																	Avg Difference =	0.2 °C
Bluewater Creek	BL-UPPR	BL-MIDD	2009	2011	weekly	max	temp	Reduced	X				Intercept	β_o	3.17	0.00	100%	
									Y				X1	β_1	0.96	0.00	100%	
													X2	β_2	0.14	0.67	33%	
																	Avg Difference =	0.14°C
Comanche Creek	CC-UPPR	CC-DWN8	1999	2010	daily	max	temp	Full w Q	X	-0.21								
									Y	-0.24			Intercept	β_o	1.75	0.23	77%	
									Q	1.50			X1	β_1	0.91	0.00	100%	
									log Q	0.31			X2 Pre (0) Post (1)	β_2	4.84	0.01	99%	
													X1*X2	β_3	-0.23	0.00	100%	
													log Q cfs		-0.57	0.38	62%	
Comanche Creek	CC-UPPR	CC-DWN8	1999	2010	daily	max	temp	Full	X	-0.21	ok, slight mounding?	ok						
									Y	-0.24			Intercept	β_o	0.86	0.41	59%	
									Q	1.50			CC-UPPR (Site 3)	β_1	0.92	0.00	100%	
									log Q	0.31			X2 Pre (0) Post (1)	β_2	5.30	0.00	100%	
													X1*X2	β_3	-0.24	0.00	100%	
																	Avg Difference =	-0.4 °C
San Antonio Creek	SA-INDI	SA-VC02	2009	2011	daily	max	temp	Full	X				Intercept	β_o	-3.29	0.00	100%	
									Y				X1	β_1	1.37	0.00	100%	
													X2	β_2	-3.21	0.01	99%	
													X1*X2	β_3	0.10	0.12	88%	
San Antonio Creek	SA-INDI	SA-VC02	2009	2011	daily	max	temp	Reduced	X									
									Y				Intercept, β_o	β_o	-2.23	0.00	100%	
									Q				X1, β_1	β_1	1.41	0.00	100%	
									log Q				X2, β_2	β_2	-1.57	0.00	100%	
													log Q	β_3	-1.46	0.00	100%	
																	Avg Difference =	-1.4 °C
San Antonio Creek	SA-TOLE	SA-WEST	2007	2011	Storm	avg	turbidity	Reduced	X	1.13	OK							
									Y	3.09			Intercept	β_o	0.38	0.00	100%	
									log Y	1.62			X1	β_1	-5.70278E-05	0.86	14%	slope of calibration line not significant
									1/Y	0.58			X2	β_2	-0.336009596	0.02	98%	
													X1*X2	β_3	0.000432452	0.70	30%	
Rio de los Pinos	LP-BRDG	LP-DOWN	2009	2011	Daily	max	temp	Full	X	-0.19								2009 LP-DOWN limited to Jun 9 to Jul 6
									Y	-0.16			Intercept	β_o	6.17	0.04	96%	
													X1	β1	0.60	0.00	100%	
													X2	β2	-5.08	0.13	87%	
													X1*X2	β3	0.37	0.03	97%	
																	Avg Difference =	2.6 °C

Appendix B: Ponil Canopy Coverage Analysis

Station #	Sep 23 2009 % cover	Sep 23 2011 % cover
	2009	2011
11	0.64	0.92
12	0.88	0.82
13	0.58	0.71
14	0.29	0.41
15	0.52	0.41
16	0.71	0.50
17	0.87	0.23
18	0.32	0.30
19	0.55	0.63
20	0.40	0.38
21	0.39	0.25
22	0.64	0.76
23	0.63	0.81
24	0.59	0.75
25	0.22	0.32
26	0.38	0.63
27	0.54	0.59
28	0.17	0.40
29	0.32	0.29
30	0.31	0.42
31	0.23	0.34
32	0.33	0.76
33	0.87	0.89
34	0.42	0.27
35	0.30	0.29
36	0.30	0.14
37	0.77	0.54
38	0.80	0.79
39	0.80	0.72
40	0.53	0.75

step 1	null hypothesis: mean % cover is the same for 2009 and 2011
	alternative hypothesis: mean % cover is different between for 2009 and 2011
step 2:	alpha = 0.05
step 3:	the critical value
	t-Test: Paired Two Sample for Means

	2009	*2011*
Mean	0.510784	0.534641
Variance	0.046496	0.052518
Observations	30	30
Pearson Correlation	0.591666	
Hypothesized Mean Difference	0	
df	29	
t Stat	-0.64897	
P(T<=t) one-tail	0.260733	
t Critical one-tail	1.699127	
P(T<=t) two-tail	0.521465	
t Critical two-tail	2.04523	

step 5:	do not reject the null hypothesis
step 6:	The data do not provide sufficient evidence to conclude that mean % cover is different bewteen 2009 and 2011

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