Rio Grande Watershed
Emergency Action Coordination Team
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Rio Grande Water Quality Monitoring: The First Summer After the West Fork Complex Fire

Trout Creek debris flow

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Introduction

Purpose

The purpose of the work conducted over the 2014 summer was to monitor the water quality and stream ecosystem of the Rio Grande on behalf of the Rio Grande Watershed Emergency Action Coordination Team (RWEACT). The goal was to observe water quality effects from last year's West Fork Complex fire with the aim of mitigating impacts on the aquatic ecosystem and monitoring recovery time. The recent fire surrounded the Rio Grande, affecting water quality and habitat critical to insects and fish. Rio Grande water quality (above and below the burn) and in some of the effected tributaries has been monitored both daily in real time and bi-monthly with in situ tests. While aquatic macroinvertebrates and fish populations were sampled once, at the end of the summer. This work was a result of a cooperative effort between the Colorado School of Mines (CSM) Hogue Research group and RWEACT.

Background

The upper Rio Grande, located in Southwestern Colorado, was surrounded by the West Fork Complex fire during the summer of 2013. The West Fork Complex fire consumed 110,000 acres of forest in the state of Colorado, and was the second largest fire in Colorado's history. The complex of three fires were ignited naturally by lightning strikes and spread easily due to dry and windy conditions. The majority (88%) of the burn area was comprised of Engelmann spruce (*Picea engelmanii*) trees killed previously by Spruce Beetle (*Ips spp.*). Post-fire damage to the soils was of moderate to high severity in the majority of the area (60%).[1] Wildfires remove vegetation and alter sediment yield.[2] Sediment delivered to streams may alter insect habitat, fish spawning habitat and compromise water quality. The sediment can deteriorate the water quality altering pH and dissolved oxygen levels and bring heavy metals, and increased nutrient concentrations to the stream.

After a summer of monitoring, it is apparent that soils from severely burned hillsides with steep slopes have eroded. Soils became saturated during late summer monsoonal rain events which initiated the hillslope failure and resulted in discrete landslides.[2] Runoff from badly burned watersheds (Trout Creek and Hope Creek) where these landslides occurred carried loads of sediment that was delivered to the streams. The smaller headwater streams that meander through the burn area eventually feed into the Rio Grande where they transport sediment from the burn. Two fish kills were reported during the monsoon rain season, both occurred in tributaries to the Rio Grande; they were a result of discrete landslides delivering sediment to the river.

The goal of this work is to monitor the water quality in hopes of preventing future fish kills. Guided water releases from the Rio Grande Reservoir, as agreed upon in the Rio Grande Cooperative Agreement, may be used to dilute water quality problems mitigating impacts on the ecosystem. Monitoring the appropriate water quality parameters may reveal the moment water quality is deteriorated and releases could be utilized to improve water quality and ecosystem survival.

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[1] USDA-Forest Service Burned Area Report. FSH 2509.13. July 2013.
[2] Goode et al. (2012). Enhanced sediment delivery in a changing climate in semi-arid mountain basins. Geomorphology 139-140.

Methods

Study Area

Six sites along the Rio Grande were monitored from April through September. One site at Thirty Mile Campground is above the West Fork Complex burn area and is the control site to which burn impacted sites are compared. The other five sites along the Rio Grande are all in or downstream of the burn. In addition to the six sites on the Rio Grande, four headwater tributary streams have also been monitored. Two of the tributary streams are in the high severity burn area, Little Squaw and Trout Creek, while the other two tributaries are not burn impacted. Squaw creek is adjacent to Little Squaw but was not in the burn; Red Mountain creek is adjacent to Trout Creek and was also not in the burn.

River Discharge Monitoring

Each of the six sites studied on the Rio Grande was at a Colorado Division of Water Resources (CDWR) stream gaging station. Real time flow data is available at three of the sites while stream stage height in real time is available at the other three sites. The stage height data along with periodic stream gaging was used to build a rating curve to relate the stage height to discharge. This work was completed by the Colorado Division of Water Resources, all flow data and some of the water quality data can be seen on line at the Colorado Division of Water Resources website (http://www.dwr.state.co.us/SurfaceWater/data/).

Water Quality Monitoring

In order to monitor the water quality in real-time, six Hydrolab MS 5 sondes purchased by RWEACT were deployed at the six Rio Grande study sites (Figure 1). The sondes are a bundle of five probes set up to test, record, and transmit data every fifteen minutes. The Hydrolab MS 5 sondes have interchangeable probes. For this study the five probes on the sondes measured water temperature, pH, dissolved oxygen, conductivity (specific conductance), and total dissolved solids (TDS). Five of the sondes were wired into the CDWR gaging stations for both electrical power and transmission of the data over the internet. The sixth sonde, at Thirty Mile, was separated from the gaging station to gain the appropriate distance from the burn scar so as to function as a true control measuring water quality in the Rio upstream of the burn. Due to location the sonde at Thirty Mile was not connected to the CDWR website. The sondes were set-up in temporary shelters (PVC pipes) anchored to structures (a rock or a bridge) in order to be left out for the duration of spring and summer. The sondes were deployed in April, right as the ice in the river was melting and have been removed to prevent freezing. Every two weeks the sondes were checked and calibrated.

Figure 1. Hydrolab MS 5 multiprobe sonde. This is the sonde at the Marshall Park site on the Rio Grande.

A handheld Hydrolab, supplied by CSM Hogue research group, was also used at each site upon each visit. The handheld Hydrolab was equipped with a turbidity sensor, and was used to measure turbidity at each site periodically. Additionally, the handheld Hydrolab was used to monitor the tributary sites that were not equipped with one of the Hydrolab MS 5 sondes.

Total suspended solids (TSS) were tested at each of the 6 Rio Grande sites and at the tributary sites from July through September. TSS is a direct measure of the solids in the river water, which is what causes turbidity. The two measures, TSS and turbidity, are directly related. To quantify total suspended solids in a grab sample the EPA ESS Method 340.2: Total Suspended Solids, Mass Balance (Dried at 103-105EC)[3] was followed in a CSM Hogue research laboratory.

The concentration of nutrients, nitrite, nitrate, and phosphate (in the form of orthophosphate) were measured with a Hach DR900 colorimeter, supplied by CSM Hogue research group, monthly during site visits. Colorimetric methods are a way of testing nutrients in situ; preserving nutrient samples and transporting them to a laboratory can result in changing values that are different from true stream readings; in situ methods are preferred.

Concentrations of total and dissolved metals were measured twice, once during high flows in May and once during low flows in August. Samples were taken at each of the six Rio Grande sites and at two of the burn impacted tributaries. Samples were preserved with 1M nitric acid and kept refrigerated until analyzed with inductively coupled plasma (ICP) instrument in a CSM lab.

Macroinvertebrate Sampling

Aquatic macroinvertebrate populations were sampled at each of the six Rio Grande sites and the four tributary sites following the Colorado Department of Public Health and Environment (CDPHE) protocols outlined in Appendix D of the Aquatic Life Use and Attainment, Policy 10-1.[4] The method involved using a kick net over a one square meter area of the stream bottom and then picking through the material collected to remove and preserve aquatic insects for laboratory identification and analysis. Samples were preserved in 95% ethanol and delivered to the Laboratory where taxonomic identification and metric calculations will be performed. Specifically a multi metric index (MMI) for the macroinvertebrates will be calculated in the laboratory to compare to historic data obtained from the Colorado Department of Public Health and Environment.

Fish Population Sampling

The CSM Hogue Research team worked with Ben Feldt with Colorado Parks and Wildlife (CPW) to conduct fish population surveys on the Rio Grande and the South Fork of the Rio Grande on September 9-11, 2014. The CPW follows their own sampling protocols in order to compare with their historic data. The CPW, together with help from the CSM Hogue Research team conducted an electrofishing survey, where fish are stunned, removed, measured, and

[3] EPA: ESS Method 340.2: Total Suspended Solids, Mass Balance, Volatile Suspended Solids Volume 3, Chapter 2. (June, 1993)

[4] CDPHE: Water Quality Control Commission, Aquatic life use and attainment methodology to determine use and attainment in rivers and streams, Policy 10-1. (10/12/10)

marked before they are returned to the river. The same stretch of the river is then re-sampled two days later to get a population estimate based on the mark-recapture method.[5] The South Fork of the Rio was sampled by electrofishing following the depletion method.[5]

Results

Water Quality

Most of the water quality parameters observed in the mainstem of the Rio Grande were normal and in a healthy range for aquatic life, except turbidity and total suspended solids. The latter two parameters were elevated on the Rio Grande and the South Fork below where burned tributaries converged with the Rio. The tributaries that were burn affected and once surrounded by the West Fork Complex fire are experiencing more erosion. It appears that during the monsoon rain season the steep hill-slopes have slid and continue to erode with each rainstorm, contributing more suspended solids creating turbidity in the river.

The six Hydrolab MS 5 sondes that were deployed along the Rio and were taking continuous readings show a healthy river. From this data, the Rio appears to be a resilient river, thriving after a dramatic fire. The river flow, or discharge, follows the expected trend of a mountain river, where the majority of the discharge comes after the snowmelt in spring and the flows steadily decline throughout the summer (Figure 2). The stream temperatures, as recorded by the sondes, also show a normal river where the temperatures get warmer through the summer but do not exceed the threshold for aquatic life of 20˚C (Figure 3). The control site, Thirty Mile, does appear to be cooler than other stations, but it is also the furthest upstream and the most shaded site (Figure 4). The pH at each site was circumneutral (between 7-9) and appears to be unaffected by fire (Figure 5). Once again the control site appears lower, but that is likely due to probe abnormalities (Figure 6). Other sites show irregular pH's periodically, but again this is due to probe malfunctions and conditions around the probe. The dissolved oxygen (DO) concentrations at each of the six Hydrolab MS 5 sites all stayed within normal range, when they were functioning properly. Dramatic drops in the DO graph lines are due to mud accumulation and entrapment around the probes (Figures7 & 8). Conductivity and total dissolved solids are measures of dissolved materials in the water, including charged ions and organic constituents. The conductivity and total dissolved solids along the Rio were normal until a hillslope slide along Hope Creek occurred on July 9 that sent mud down the South Fork of the Rio and on to the Rio Grande at Del Norte around days 90-100 of the study (Figures 9-11). A fish kill on the South Fork of the Rio was reported at this same time and there was evidence of fish kills in the weeks that followed (Figure 14).

The most interesting and remarkable water quality signal was the elevated concentrations of total suspended solids and turbidity in burned tributary sites and Rio Grande below where these tributaries converge with the Rio (Figure12 & 13). The Rio Grande at Marshall Park is below the confluence with Trout Creek, another tributary that had a hillslope slide and subsequent debris flow and erosion after monsoon rains, this event happened on August 4. Several days of monsoon rains likely saturated the burned slopes and caused the steep slopes to move. The sediment inundated the creek with mud and choked fish, leading to a dramatic fish kill (Figure 14).

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[5] Ricker 1975 and Caughley 1977 as cited in Methods in Stream Ecology 2nd edition. (2007).

Nutrient concentrations, nitrate and phosphate at each station were normal all summer. Nitrite concentrations in Trout Creek, Box Canyon, and Marshall Park were higher after the early August monsoon rains (Figure 15). It is possible that nitrite is also a fire signal, as these sites were all fire impacted. However, these were single data points, more measurements need to be made to draw conclusions.

Total and dissolved metal concentrations were normal both during low flow and high flow time periods along the Rio and in the tributaries (Figure 16).

Macroinvertebrate and Fish Populations

Data from the macroinvertebrate sampling effort and the fish population sampling in the Rio Grande is still being processed. No conclusions can be made at this time.

The following graphs display water quality trends in the Rio Grande and its tributaries.

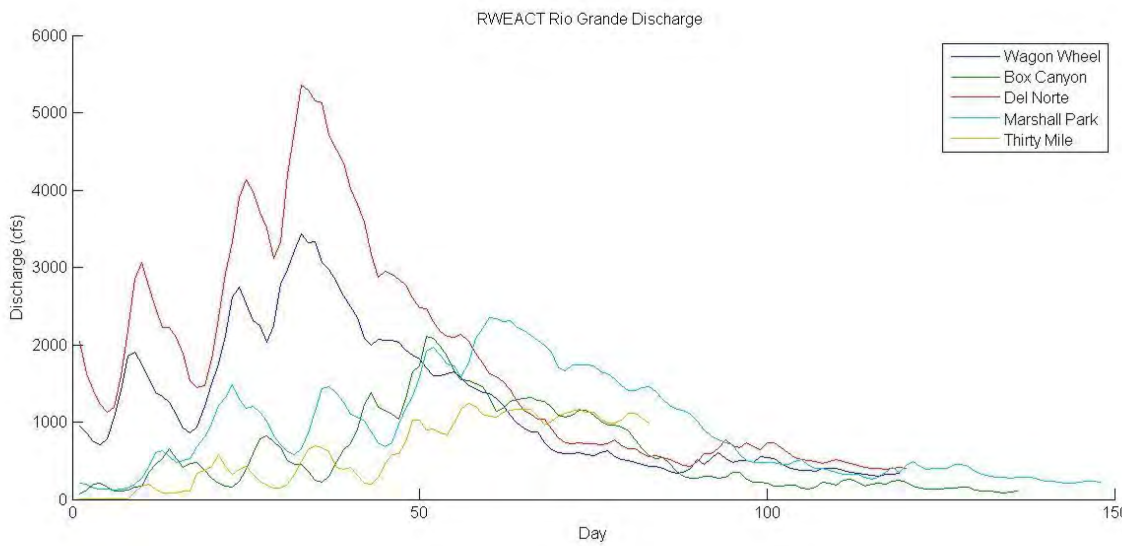

Figure 2. Stream discharge at each of the six RWEACT water quality monitoring sites along the Rio Grande. Day 0 was April 3, 2014, the first day that the Hydrolab MS 5 was deployed at each site, day 150 was August 31, 2014.

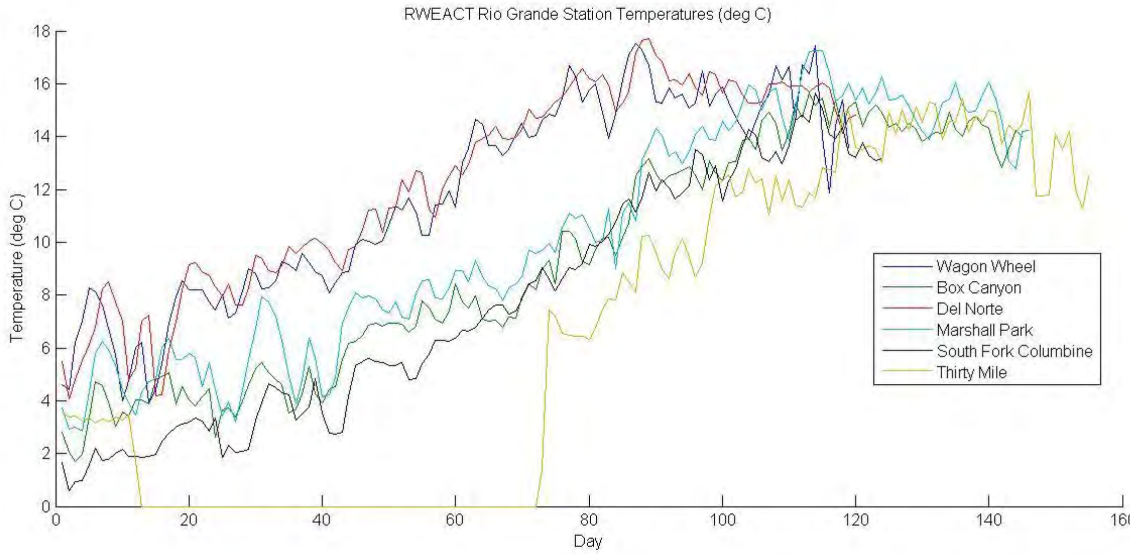

Figure 3. Stream temperature data from each of the six Rio Grande study sites from April 3- August 31, 2014.

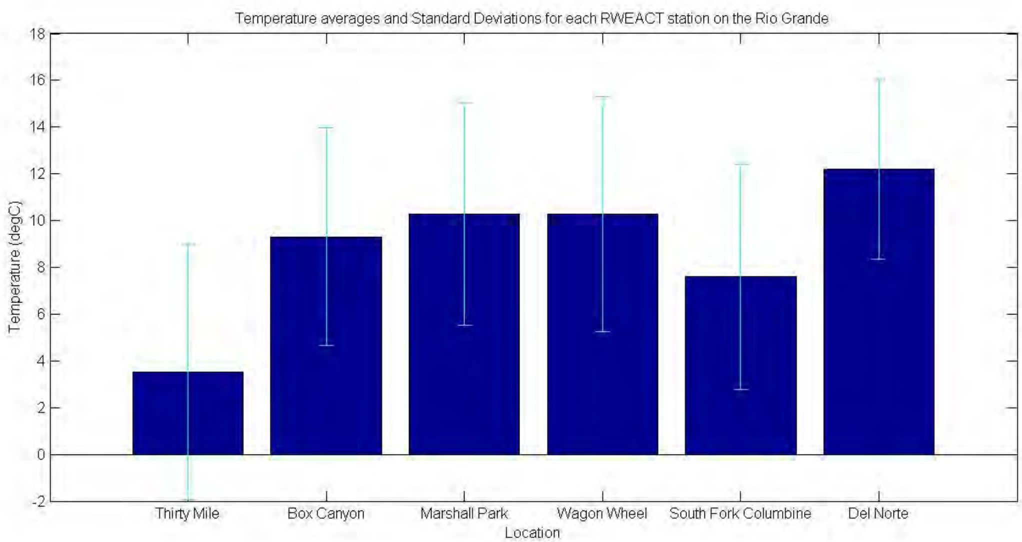

Figure 4. Stream temperature averages and standard deviations at each Rio Grande stations.

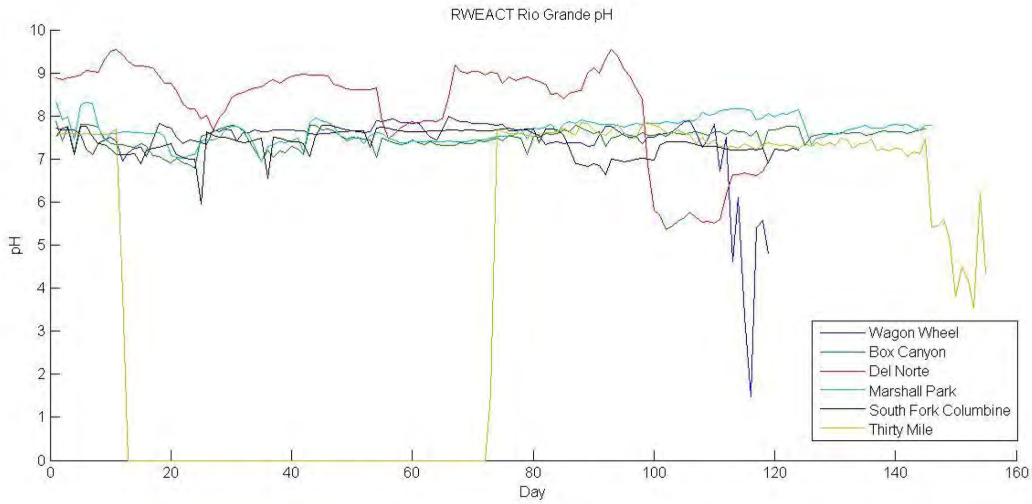

Figure 5. pH at each of the six Rio Grande study sites from April 3, 2014 to August 31, 2014. Anomalies in the pH data shown here were due to local conditions around the probe and are not true water quality abnormalities.

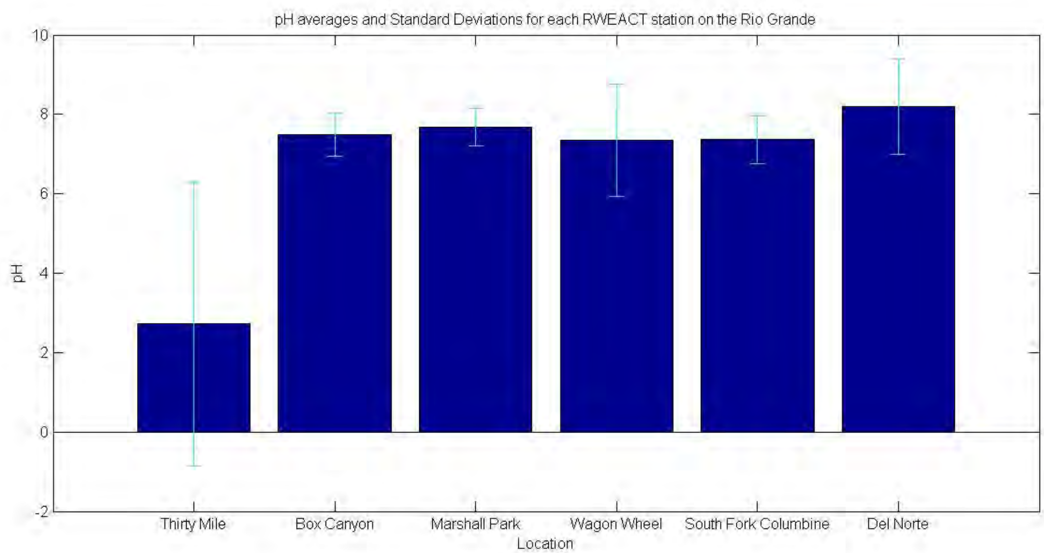

Figure 6. pH averages and standard deviations from Hydrolab MS 5 data at each site on the Rio Grande. Thirty mile pH is dramatically lower, but this is due to some probe malfunction.

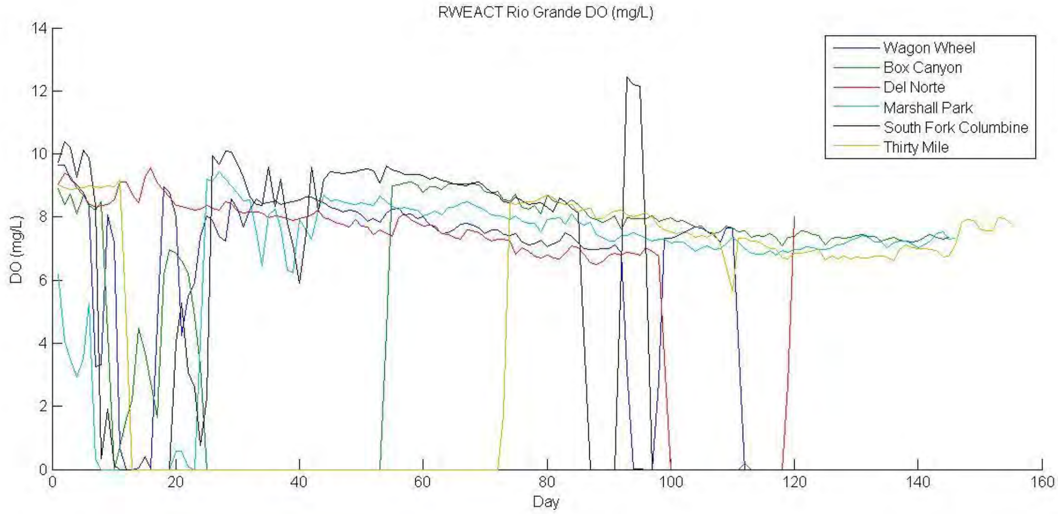

Figure 7. Dissolved oxygen concentrations at each of the six Rio Grande RWEACT water quality monitoring sites. Again, the dramatic drops in the dissolved oxygen in this figure have more to do with poor probe conditions than with water quality issues. When probes functioned properly, dissolved oxygen concentrations stayed within the normal range of 6-8 mg/L.

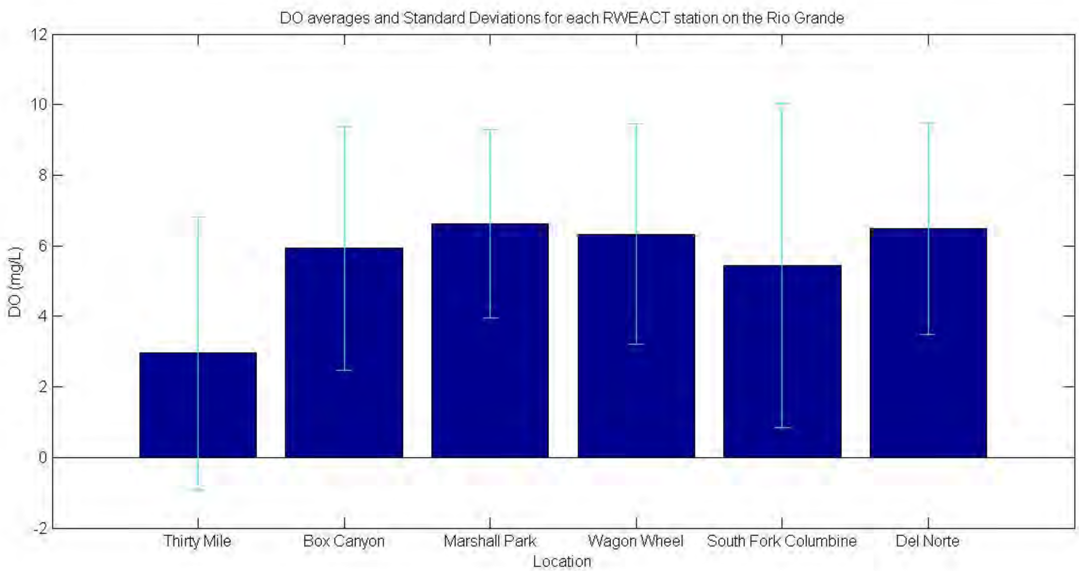

Figure 8. Dissolved oxygen averages and standard deviations at each of the Rio Grande sites.

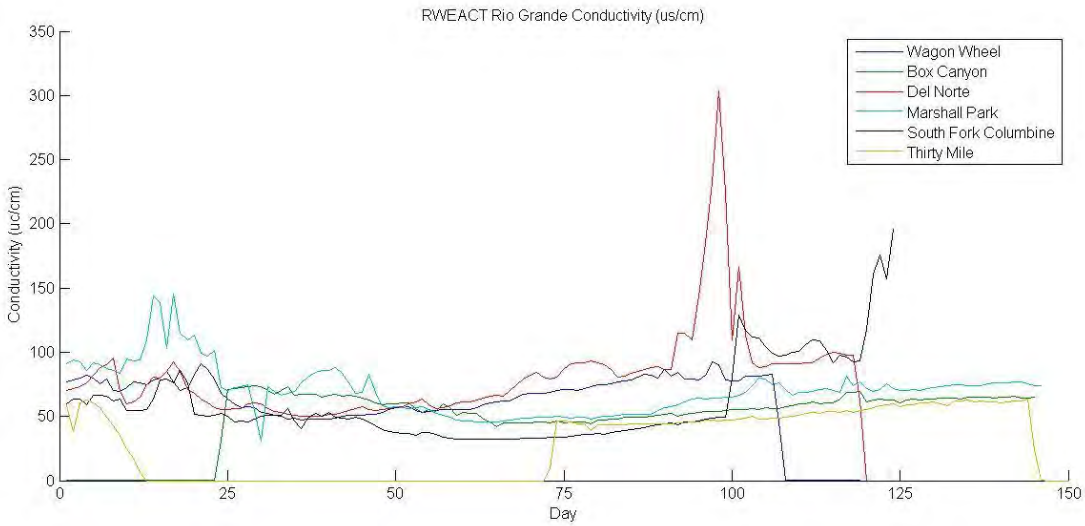

Figure 9. Conductivity values, in terms of specific conductance, at each of the six Rio Grande sites. Spikes in the conductivity correspond with a high mud flow event that took place on the S. Fork of the Rio on July 9. Here a spike in the conductivity at the S. Fork site was followed tw days later by a spike at the downstream, Del Norte site.

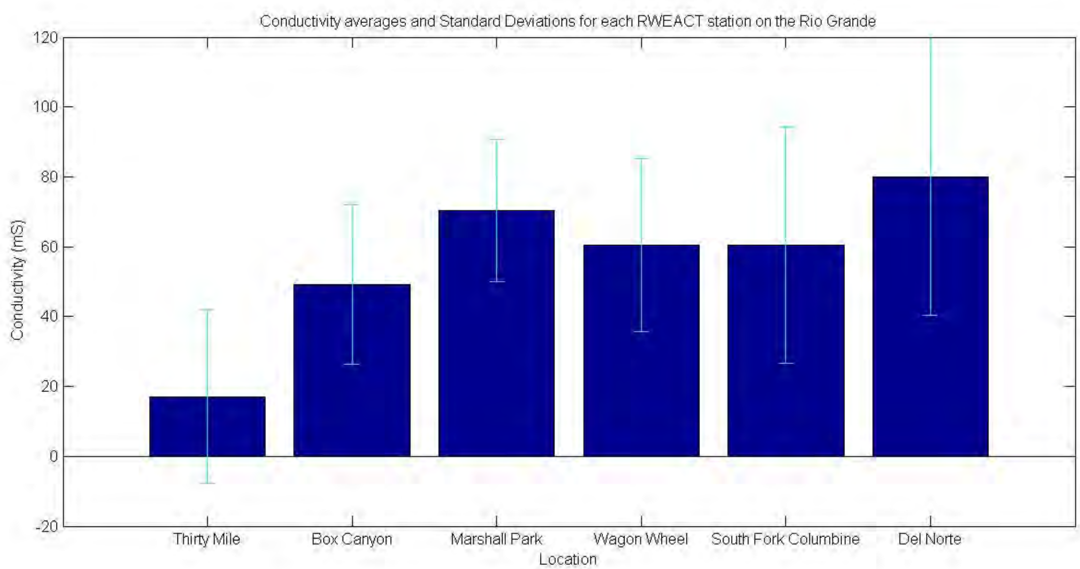

Figure 10. Conductivity averages and standard deviation at each Rio Grande sites.

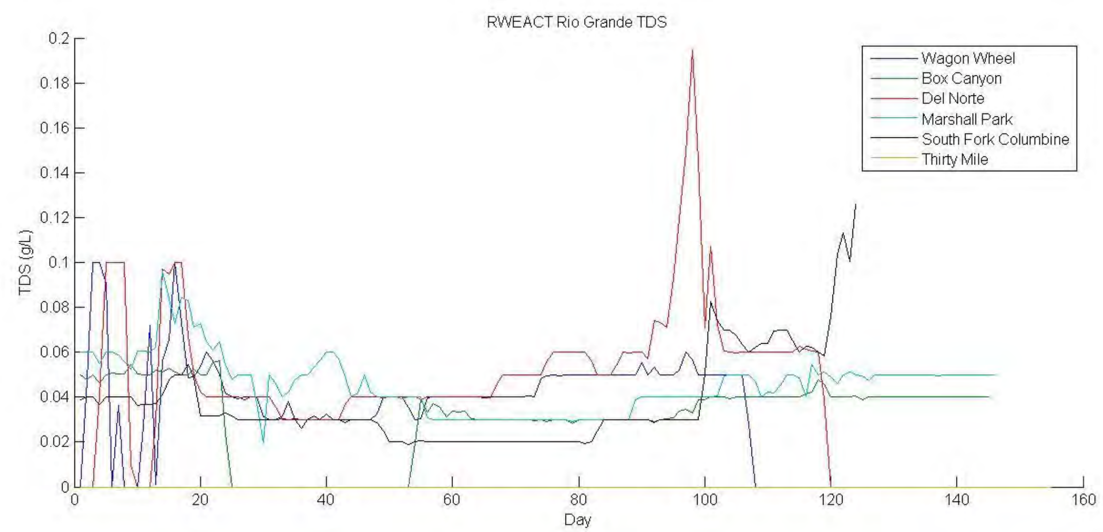

Figure 11. Total dissolved solids from each of the six Rio Grande RWEACT sites. Once again the early season data shows odd anomalies due to problems with the initial set-up of the probes where the later spikes that occurred on the S. Fork of the Rio followed by a spike at Del Norte are likely due to a landslide event occurring on Hope Creek before it merges with the S. Fork of the Rio Grande.

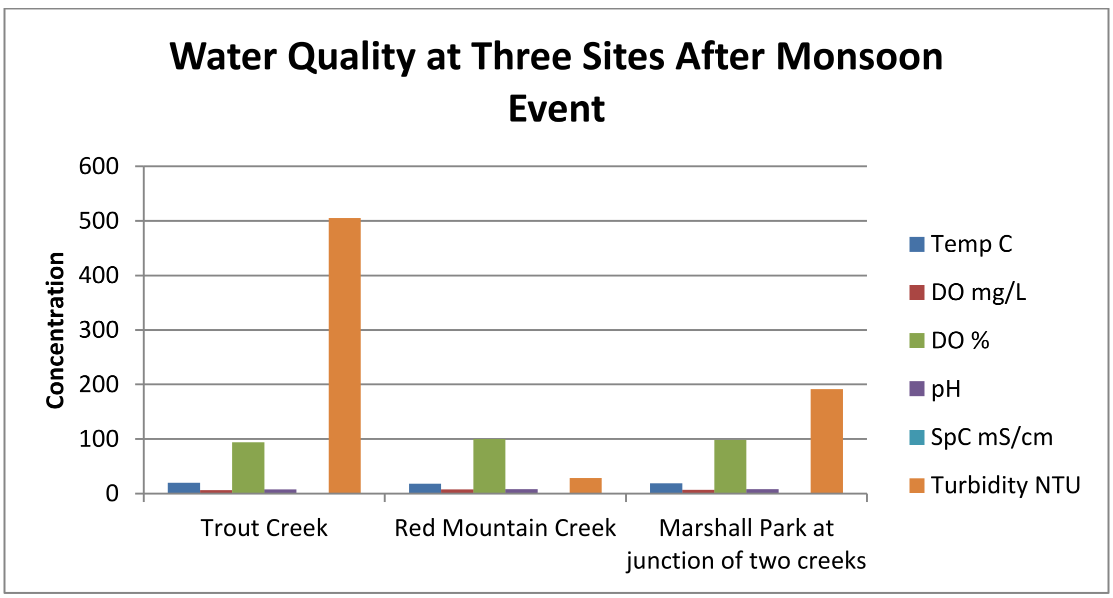

Figure 12. Data from the handheld Hydrolab multiprobe. This data was taken over a period of two weeks at a burn impacted tributary, Trout Creek, its neighboring yet not burned creek, Red Mountain Creek, and the location on the Rio below where the two merge with the Rio Grande at Marshall Park.

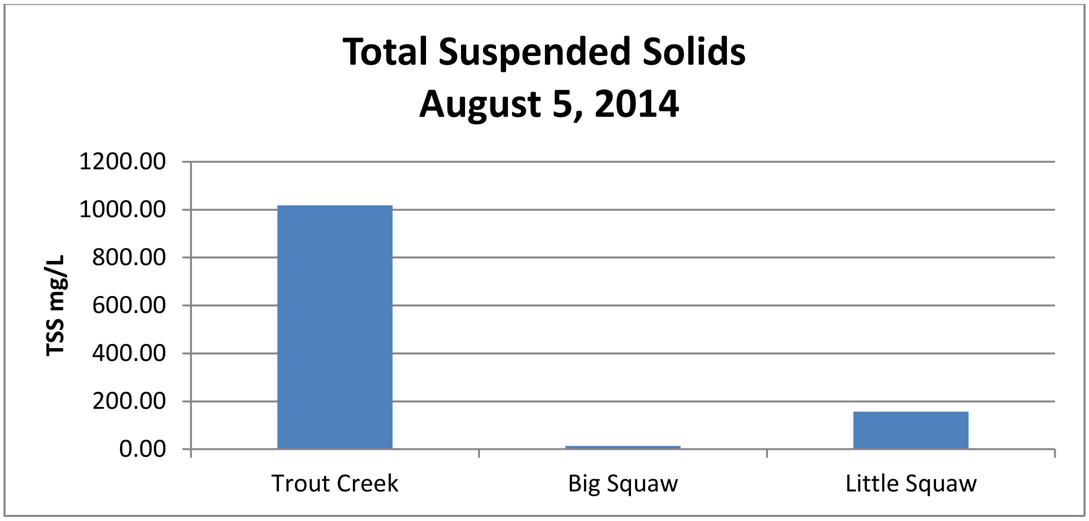

Figure 13. Total suspended solids at two burn impacted tributary headwater streams, Trout Creek and Little Squaw, and a normal un-burned stream, Squaw creek.

Figure 14. Hope Creek in the burn area on the top left with brown turbid water, ash and sediment deposit in the S. Fork top center (9/9/14), a fish kill on Trout Creek on the right (8/4/14), and a boulder in the debris flow on Trout Creek on the bottom center (9/20/14).

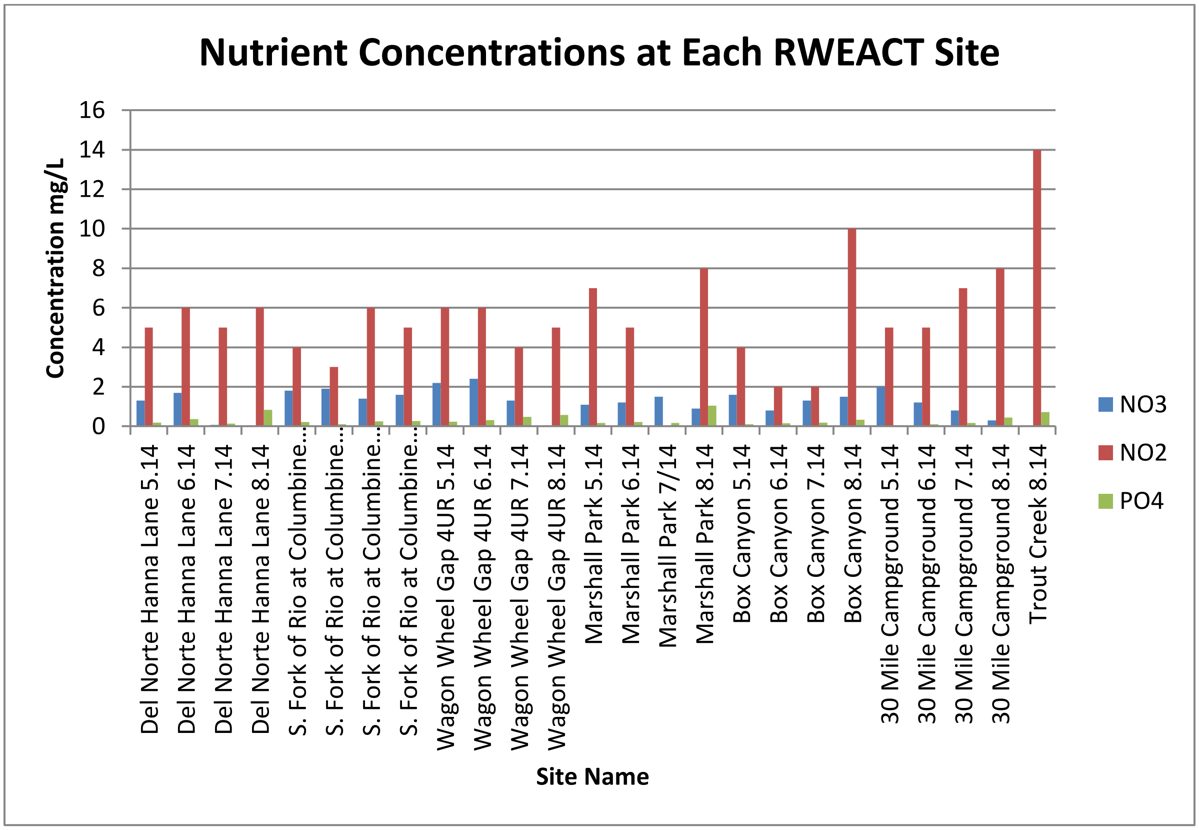

Figure 15. Monthly nutrient concentrations at each of the six Rio Grande RWEACT sites and burn impacted Trout Creek.

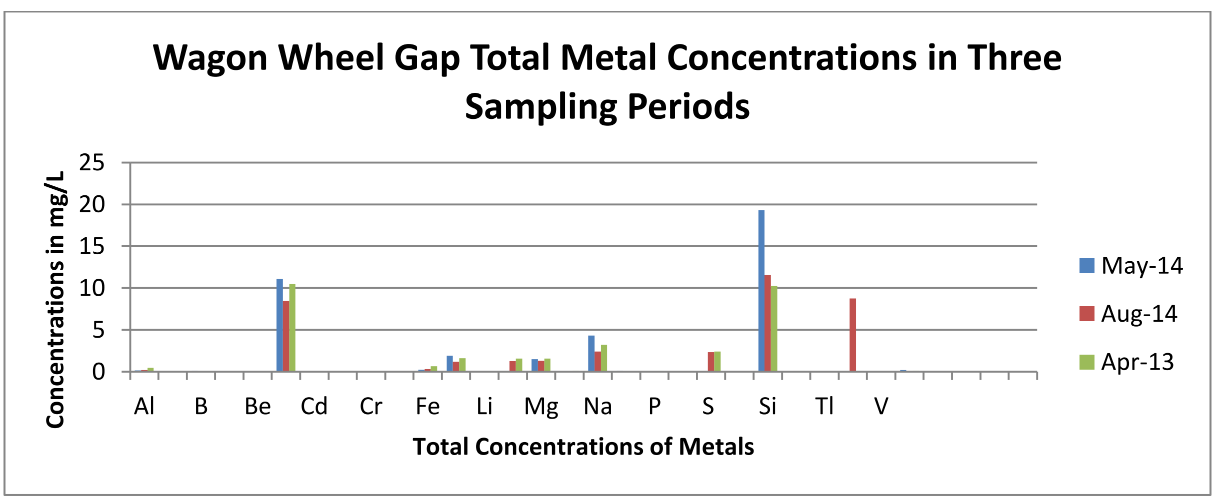

Figure 16. Total metal concentrations at the Wagon Wheel Gap site on the Rio Grande below the burn. Samples were taken before the burn in April 2013 by the Rio Grande Silver Corporation, and after the burn at both a high flow time, May 2014 and at a low flow time in August, 2014.

One goal of the study was to guide water releases from the Rio Grande Reservoir in order to mitigate impacts from the West Fork Complex fire. Using data from Table 1, the load duration curve in Figure 17, simple calculations could be made to dilute the total suspended solids. The load duration curve of total suspended solids is calculated with flow data, where any point above the red line could lead to chronic effects on fish populations and any point above the black line could cause a fish kill. Thirty two states have set water quality standards for turbidity, the total daily maximums vary with different states' goals and fisheries. A state with a turbidity standard that is trying to preserve a Rocky Mountain coldwater trout fishery and is most similar to Colorado is Idaho, their turbidity standard is 50 NTU instantaneous. Few states have a TSS standard because it is more difficult to measure in real time. The TSS standard for these select states ranges from 10-50 mg/L. The TSS total maximum daily load of 10 mg/L and 50 mg/L were used to create the two lines on the load duration curve in Figure 17. The relationship between turbidity and TSS at the tributary sites and the Rio is linear, although the data is limited at this point, this relationship has been proven by others.

Table 1. Discharge values at each station on the mainstem of the Rio Grande on August 5 at 8:00 am and total suspended solids values measured the same day.

8/5/2014	Thirty Mile	Box Canyon	Marshall Park	Wagon Wheel Gap	Del Norte
Discharge (cfs)	182	205	445	548	740
TSS (mg/L)	0.0	10.0	50.0	30.0	30.0

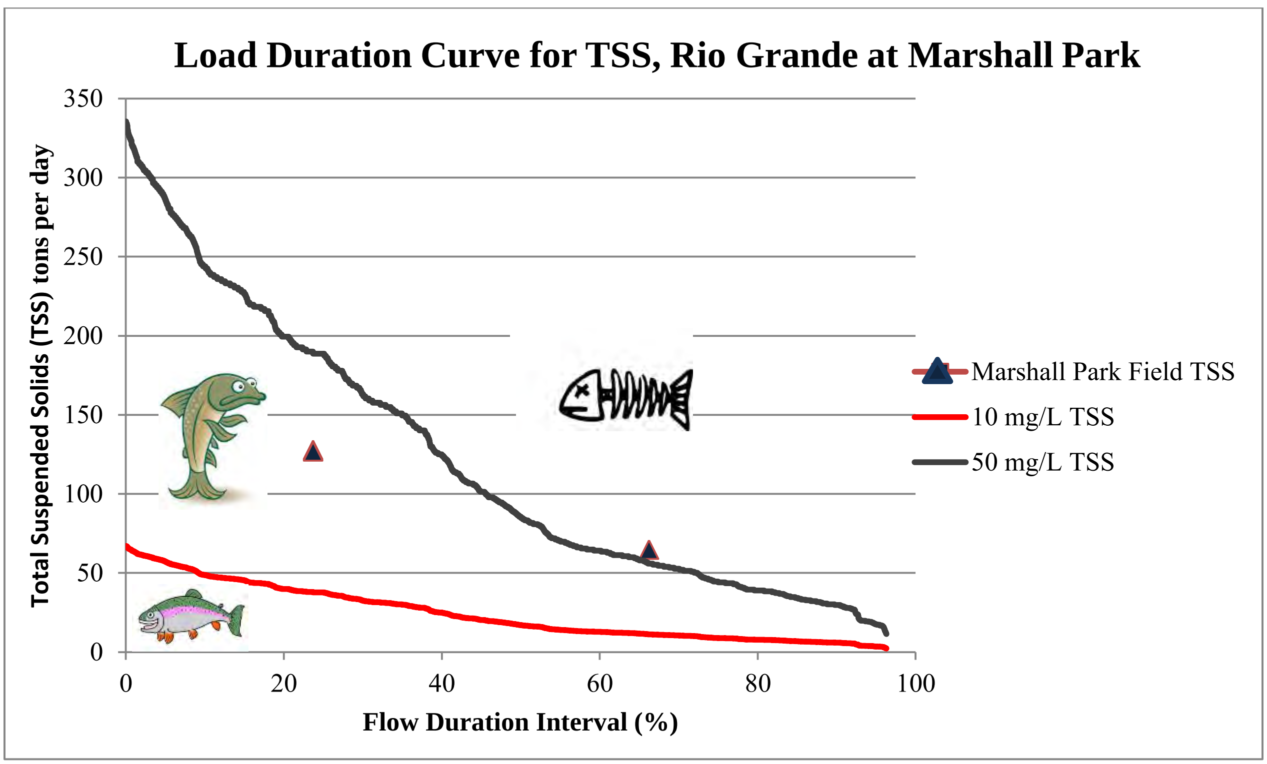

Figure 17. Load duration curves for total suspended solids in the Rio Grande at Marshall Park site. The lines illustrates the chronic limit of TSS for trout at 10 mg/L and the maximum acute limit at 50 mg/L multiplied by the flow. Point measurements taken for TSS in the field are plotted to show actual data.

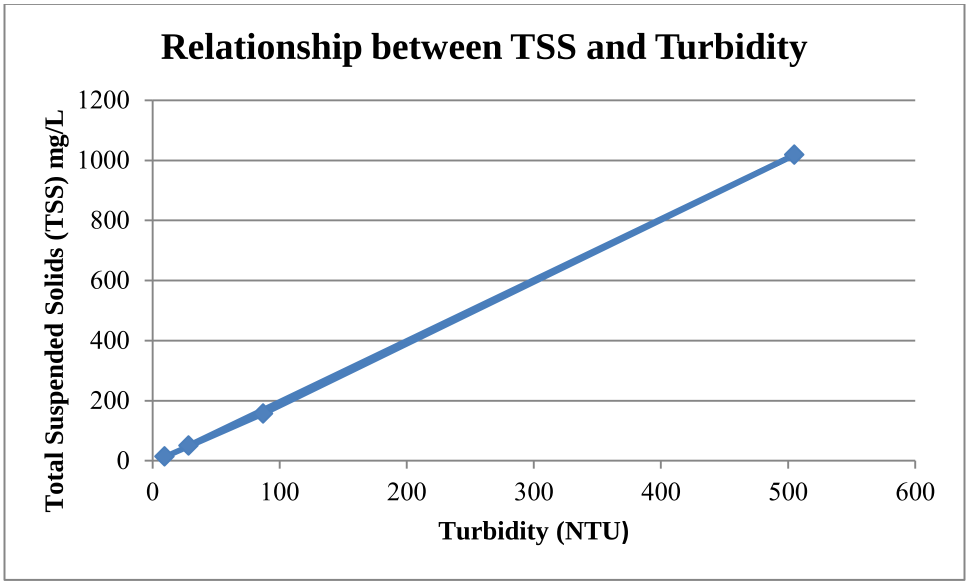

Figure 18. The relationship between total suspended solids and turbidity from data collected in August. More data will continue to be collected to build this relationship.

Key Findings

This was a successful first post- fire water quality monitoring program for RWEACT. There were some sites where the probes did not work properly and the set-ups could be improved to prevent mud from accumulating on the probe. The six Hydrolab MS 5 sondes did not pick up the most dramatic water quality fire signal, total suspended solids. Turbidity is correlated with total suspended solids, and can be used as a surrogate measurement. Turbidity appears to be the key fire signal that causes fish kills and should be monitored. Stream temperatures, oxygen concentrations, pH, conductivity, nutrients, and metal concentrations were all within the normal range. The total suspended solids and turbidity from the burned and eroding hillsides following rain are to blame for at least two large fish kills.

Recommendations for Future Work

Future water quality monitoring throughout the West Fork Complex burn area should continue until vegetation re-grows and hillsides are stable. The six Hydrolab MS 5 sondes could be retrofitted with turbidity sensors in order to monitor the most significant water quality signal. The study design with the six sondes along the mainstem of the Rio Grande covered a large area effectively but missed the activity and water quality problems in the severely burned tributaries. Up to four Hydrolab MS 5 sondes equipped with turbidity sensors could be added to monitor burn impacted tributaries, Little Squaw, Trout creek, and Hope creek, along with at least one control tributary, either Squaw or Red Mountain. These additional sondes would help give water managers warning when water quality events are happening.

- Cost: $2680 to retrofit each probe X 6 = $16,080
- Cost for new probes with battery pack: $8345 X 4 = $33,380
- Additional operation and maintenance fees for the sondes = $5,000

Leveraging

The Hogue Research group with Colorado School of Mines has been awarded a Joint Fire Science Program grant. This grant will help support the work on the West Fork Complex fire recovery. Ashley Rust and Terri Hogue, PhD, will collect, analyze and summarize data with the support of this grant. Ashley will receive a salary under this grant, $1,760 per month ($21,120/ 12 months) plus $18,000 in tuition and fees for a total of $39,000 support from the Joint Fire Science Program. Colorado School of Mines is also providing an undergraduate research assistant to help with the data analysis, the salary for this student is covered by CSM at $500 per month for 4 month, $2,000 total. The Joint Fire Science Program grant may not be used for equipment purchase or maintenance. The Hogue Research group is looking to partner with RWEACT and other supporters to continue this important water quality monitoring through the fire recovery.

Acknowledgements

I would like to thank RWEACT for the opportunity to be a part of the fire recovery. Heather Dutton, Travis Smith, and Tom Spezze have been excellent colleagues and mentors. I would like to also thank the Colorado Division of Water Resources and each of the employess that spent time helping me install the sondes. I want to thank Ben Feldt and the Colorado Parks and Wildlife for sharing their fish data and allowing me to participate in their electrofishing surveys, it was amazing. Terri and I would also like to thank Deputy Billy Fairchild for taking us on horseback to the witness the hill slide event at Trout Creek. I am grateful to be a part of this research and to have such an amazing dissertation project.