

**ROADWAY SOURCES OF MAGNESIUM CHLORIDE AND TOTAL SUSPENDED SOLIDS
AND THEIR EFFECT ON WATER QUALITY IN COAL CREEK IN 2009**



Prepared by:
The Coal Creek Watershed Coalition
PO Box 39
Crested Butte, CO 81224
www.coalcreek.org

Table of Contents	Page #
1. Overview	2
1.1 Chloride Standards	3
1.2 Magnesium Standards	4
1.3 Total Suspended Solids Standards	4
2. Materials and Methods	5
3. Results	9
3.1 Baseline Conditions	9
3.2 Rainfall Events	12
4. Discussion and Future Actions	15
5. Acknowledgements	16
6. Works Cited	17
7. Appendix of Tables	19

1. OVERVIEW

Dust from gravel and dirt roadways causes environmental impacts throughout the State of Colorado and the United States. Numerous methods have been employed to control dust generated by these roads to improve safety, driving visibility and the stability of the road materials.

Magnesium chloride ($MgCl_2$) is commonly used as a dust suppressant and has been associated with dehydration (chlorosis) of roadside plants. A study by Colorado State University (Goodrich, 2008) demonstrated that compounds in $MgCl_2$ can migrate from gravel road surfaces in Colorado into nearby creeks and streams. The study indicated concentrations in a stream vary based on the concentrations in the road surface and the distance from the road to the creek. Concentrations reported in the CSU study did not exceed standards established for the health of human or aquatic life.

In addition to chloride, total suspended solids (TSS) can be introduced into the creeks and tributaries from road surfaces. Studies have indicated that high levels of TSS may be “fatal to salmonids, while lower levels of suspended solids and turbidity may cause sublethal chronic effects such as loss or reduction of foraging capability, reduced growth, resistance to disease, and increased stress” (Bash). Gravel and sediment are detrimental to aquatic life, as they smother and fill voids in habitat. Gravel and sediment’s effect on the aquatic environment also provides habitat for *Tubifex tubifex*, an intermediate host for whirling disease.

The Coal Creek Watershed Coalition’s (CCWC) study was designed to ascertain the impacts of chloride and sediment releases from road surfaces and adjacent cut slopes along Kebler Pass Road to water quality in Coal Creek. The study’s three primary objectives aimed to:

- (1) Determine baseline conditions in Coal Creek in areas where magnesium chloride is not applied as a dust suppressant, using both chloride and total suspended solid measurements as indicators.
- (2) Determine what impacts to water quality are caused by Kebler Pass Road during baseline conditions and during rainfall events, using both chloride and total suspended solid measurements as indicators.
- (3) Use data generated from the study to determine Best Management Practices to reduce chloride or sediment loading to Coal Creek, in order to protect human and aquatic life uses.

The Coal Creek Watershed Coalition used funding from the State of Colorado’s Non-Point Source Program to purchase automated ISCO brand samplers to draw samples from the creek at specific intervals. Interns funded by the Thornton Endowment for Undergraduate Research at Western State College and the Volunteers in Service to America (VISTA) Summer Associate program helped collect and analyze water quality samples. The water quality data was coupled with rainfall data from four rain stations provided by the Colorado Division of Reclamation Mining and Safety.

1.1 CHLORIDE STANDARDS

Human Life

The Environmental Protection Agency (EPA) has established a secondary drinking water standard for chloride at 250 mg/L (U.S. Environmental Protection Agency). Secondary drinking water standards are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply. However, states may choose to adopt them as enforceable standards. The EPA's chloride standard has been adopted by the State of Colorado for domestic drinking water supplies.

Aquatic Life

The EPA established a Criteria Maximum Concentration (CMC) for chloride. The CMC is an estimate of the highest concentration of a chemical in surface water to which a freshwater aquatic community can be **briefly** exposed without resulting in an unacceptable effect. The CMC for chloride is 860 mg/L (U.S. Environmental Protection Agency). The Criterion Continuous Concentration (CCC) is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed **indefinitely** without resulting in an unacceptable effect. The CCC for chloride in freshwater is 230 mg/L. Because these aquatic life criteria are national guidelines, they are intended to be protective of the vast majority of the aquatic communities in the United States, but may not be protective of local species with higher sensitivities to a specific contaminant. It is difficult to determine the validity of these standards on a local level, due to different sensitivities of local fauna. The most relevant standards might come from research conducted by the Montana Department of Transportation (MDT) to determine the impacts from winter applications of deicers (Stimson, 2004).

In 1988, the EPA published the Ambient Water Quality Criteria for Chloride (U.S. Environmental Protection Agency). The EPA used 45 tests on various freshwater species to determine the acute effect level for chloride. The LC₅₀ value, the concentration at which mortality for test animals is 50 percent, was greater than 1,000 mg/L in 33 of 45 tests, and greater than 100 mg/L for 43 of 45 tests. Two tests for potassium chloride and calcium chloride tests on *Daphnia magna* had LC₅₀ values of 86 mg/L and 92 mg/L, respectively. The chronic effect level for sodium chloride was determined for rainbow trout (*Oncorhynchus mykiss*, 923 mg/l), fathead minnow (*Pimephales promelas*, 443 mg/L), and water fleas (*Daphnia magna*, 372 mg/L). Exposure studies conducted by Environment Canada and Health Canada summarized chloride toxicity thresholds (LC50 and EC50) of various aquatic organisms as ranging from 874 to 30,300 mg/L chloride, depending on exposure time (Environment Canada and Health Canada. Canadian Environmental Protection Act, 1999). A summary of additional standards for chloride are described in Table 1.

1.2 MAGNESIUM STANDARDS

Human Life

No standards for magnesium exist for drinking water uses in the State of Colorado. The EPA does not have criteria for magnesium concentration in freshwater. Human health risk criteria for magnesium in drinking water also do not exist. Magnesium and calcium are used in determining the hardness of water, though hard water is not a health hazard. The National Research Council National Academy of Sciences states that hard drinking water generally contributes a small amount toward total calcium and magnesium human dietary needs (National Research Council, 1980). The National Academy of Sciences also note that in some instances, where dissolved calcium and magnesium are very high, water could be a major contributor of calcium and magnesium to the diet. Researchers have studied water hardness and cardiovascular disease mortality. Such studies have been "epidemiological studies," which are statistical relationship studies. While some studies suggest a correlation between hard water and lower cardiovascular disease mortality, other studies do not suggest a correlation. The National Research Council states that results are inconclusive at this time, and recommends that further studies be conducted.

Aquatic Life

No standards exist for magnesium for aquatic life uses in the State of Colorado. The EPA does not have criteria for magnesium concentration in freshwater. Both Colorado and EPA use magnesium concentrations to develop toxicity standards for other contaminants. Studies determining aquatic life toxicity thresholds were not found.

1.3 TOTAL SUSPENDED SOLIDS STANDARDS

Human Life

No standards exist for total suspended solids (TSS) for domestic drinking water uses in the State of Colorado. In Regulation 31, the Water Quality Control Commission states: "The Commission recognizes that excessive salinity and suspended solids levels can be detrimental to the water use classifications. The Commission has established salinity standards for the Colorado River Basin...but has not established or assigned other standards for salinity or suspend solids control practices to be developed through....coordination with agricultural agencies, and further studies of existing water quality" (Colorado Department of Public Health and Environment Water Quality Control Commission, 1979).

Aquatic Life

The State of Utah uses 35 mg/L as a standard for cold water fisheries, and South Dakota uses 30 mg/L as its standard for cold water fisheries. Other states in the region use narrative standards based on cold water and warm water stream uses.

High TSS can block light from reaching submerged vegetation, reducing rates of photosynthesis and leading to lower dissolved oxygen concentrations in water bodies. High TSS can also cause an increase in light absorption, which in turn creates an increase in water temperatures. Decreases in water clarity caused by increased TSS concentrations can affect the ability of fish to see and catch food. Suspended sediments can also clog fish gills, reduce growth rates, decrease resistance to disease, and prevent egg and larval development. When suspended solids settle to the bottom of a water body, they can smother the eggs of fish and aquatic insects, as well as suffocate newly hatched insect larvae. Settling sediments can fill in spaces between rocks, which could have been used as homes by aquatic organisms. Excessive sedimentation (siltation) can fill in channels and increase overbank flooding, as well as fill in culverts and increase water-supply treatment costs. (Mark N. Landers, 2007)

2. MATERIALS AND METHODS

Study Area

Coal Creek's headwaters begin beneath the peaks of Mt. Ruby and Mt. Owen. The stream flows by the town of Irwin and passes three major hardrock mines (Forest Queen, Standard, Keystone) while also flowing parallel to Kebler Pass Road (Gunnison County Rd 12). As Coal Creek descends, it collects water from numerous tributaries before flowing through Crested Butte, a town that relies on Coal Creek for its main source of drinking water. Coal Creek is approximately nine miles long and drains about 15,600 acres (25mi²) before it merges with the Slate River. The Coal Creek watershed has a strong mining history, filled with extractions of coal, silver, lead, copper, zinc, and gold. Segments 11 and 12 of Coal Creek are listed as impaired by the State of Colorado, due to elevated levels of zinc and cadmium (Colorado Department of Public Health and Environment, Water Quality Control Commission, 1983). The riparian community along Coal Creek is dominated by Alder (*Alnus tenuifolia*) and Willow (*Salix* sp.) trees, while the uplands are dominated by Englemann Spruce (*Picea engelmannii*), Quaking Aspen (*Populus tremuloides*), and Douglas Fir (*Pseudotsuga menziesii*). Fall's aspen colors and big game hunting are probably the largest sources of tourism in the watershed during the fall. Although in-depth biological surveys of the drainage are lacking, the habitat is appropriate for many state or federally listed species, including Bald Eagles, Peregrine Falcons, Southwestern Willow Flycatchers, Wolverines, Northern Leopard Frogs, Cutthroat Trout, Lynx, and the Boreal Toad (Joseph N. Ryan, 2009).

Kebler Pass Road (County Road 12) is closed to vehicular traffic during the winter months, due to extreme snowfall and avalanche danger. However, it remains open to cross-country skiers and snowmobilers. Therefore, we can conclude that any effects from MgCl₂ on the Coal Creek watershed are from summer dust suppression treatments, since no winter treatments are applied.

In June of 2009, Gunnison County applied 33,360 gallons of MgCl₂ along approximately 5 miles stretch of Kebler Pass Road within the Coal Creek Watershed. The stretch of treated road started at the top of Kebler Pass (partially outside the watershed) and ended at a maintained gravel section near the Keystone Mine. This equates to approximately 0.058 gallons/ft² of MgCl₂ that were applied

along this stretch of roadway, close to the target of 0.05 gallons/ft² the County aims to use.

Gunnison County Public Works and their contractors prepared Kebler Pass Road for MgCl₂ during the week of June 23rd. Typically, grading the road and saturating it with water precede the application of magnesium chloride. A contractor with specialized equipment designed to deliver MgCl₂ within twelve inches of the road surface applied MgCl₂ to Kebler Pass Road, likely on June 25th (personal communication with Marlene Crosby and field observations from Steve Bogott). The road was only treated with MgCl₂ once this summer, although parts of the road were graded and watered later in the summer to regain the binding abilities of the previously applied solution. The date of the second operation is unknown. The need for this late-summer re-grade could be related to the drier summer season that occurred during 2009.

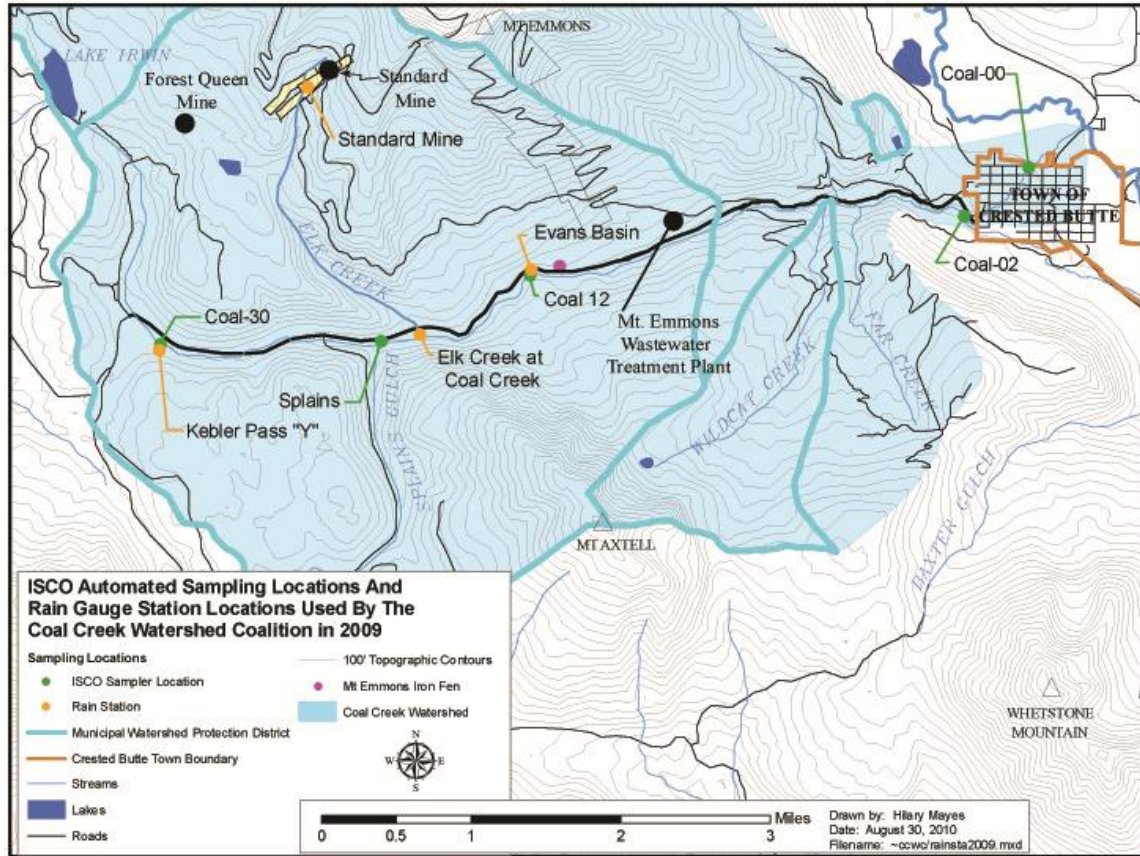
Gunnison County provided the annual application rates for Kebler Pass Road (including sections on each side of the Ohio Creek pass) from 1999 to 2009. Annual applications varied from a low of 119,840 gallons (1999) to a high of 211,618 gallons in the severe drought year of 2002. Gunnison County provides road preparation, which includes grading and saturating the road surface with water, prior to the MgCl₂ applications. (Crosby, 2009)

Water Sampling

Water sampling was completed using five ISCO 6700 automatic field samplers (ISCO) that were programmed to take 500 ml samples on a variety of schedules, dependent upon need and weather conditions. Most samples were taken on a rolling twelve-hour program. Although the five samplers were programmed mainly on twelve-hour programs, they were still able to collect water on a secondary program; for our project, this meant they would sample high flow events caused by rainfall measured by a stream level rise of 0.3 inches. Twenty of the sampler's twenty-four 1000 ml bottles were used for the hourly programs, while the four remaining bottles were dedicated to high flow events. Although none of our five samplers ever sampled a high flow event (the spike associated with rain events was overestimated), we now know the proper trigger range for future sampling to be 0.05 inches or less. After field sampling was complete, the individual bottles were collected and split in two individual 250 ml bottles. One bottle underwent chloride analysis and the other was tested for Total Suspended Solids (TSS). Bottles were stored in a refrigerator at the Crested Butte Wastewater Treatment Plant until they could either be run for TSS in Crested Butte or chloride analysis at Western State College of Colorado, Gunnison, Colorado.

Sampling Sites

Locations for ISCO samplers and rainfall stations are shown in the image below.



Irwin (Coal-30) identifies a sampling site in Coal Creek where the stream runs parallel to the road that leads to the town site of Irwin. This site was chosen as the control site since the private road does not have localized $MgCl_2$ application during the summer, and Coal Creek is at least 100 meters from the road at this sample site.

Study Sites:

Splains lies above the confluence of Splains Gulch with Coal Creek. The sample site lies 10 meters down slope of Kebler Pass Road, but many sections of the creek upstream of this station lie much closer to the Road.

Coal-12 is in Evans Basin, downstream of the Splains ISCO site by approximately 2 miles, and sits less than 200 feet upstream of the culvert outfall for the Mt. Emmons Iron Fen.

Coal-02 is located just upstream of the town of Crested Butte. An access drive immediately preceding the start of Kebler Pass Road leads to the sampling site.

Coal-00 is the most downstream site and is located below the Butte Avenue bridge on the northern edge of the Town of Crested Butte. Coal-00 provides samples from Coal Creek prior to its confluence with Slate River.

Rain Gauges

Four Onset/Hoboware data-logging rain gauges were placed throughout Coal Creek Watershed to record localized rainfall. Rain station “Kebler Pass ‘Y’/Iwrin Forks” was placed a quarter mile below the first ‘Y’ at the top of Kebler Pass Road, where the road splits towards the Lake Irwin/Irwin Townsite. The second rain gauge, “Elk at Coal Creek”, was placed near the confluence of Elk and Coal Creek, close to the CCWC’s water sampling location Coal-20. The third rain gauge, “Evans Basin,” was further downstream, in Evan’s Basin near the Coal-12 water sampling site. The final rain gauge, “Standard Mine,” was placed at the Standard Mine Superfund site, near the Level 1 adit. These Hoboware data-logging rain gauges measure the exact time of each rain event in increments of 0.01 inches, and also continually measure temperature every 15 seconds. The rain gauge readouts were examined for rainfall events and compared with sampling events to see if rain and $MgCl_2$ applications correlated with Chloride concentrations and TSS in the creek.

Chloride Analysis

A Chloride Ion-Selective Electrode was utilized to measure chloride concentrations. Chloride Ion-Selective Electrodes are membrane electrodes that measure the passage of ions through the membrane. The comparison of these rates to the reference electrode estimate chloride concentrations in milligrams per liter (mg/L).

Samples were placed in a hot water bath and warmed to a temperature of 25°C. For each sample, 2mL of ionic strength adjuster were added to 100 mL aliquot from each sample to create a uniform background ionic strength, improving accuracy. The probe was calibrated using four standards (1, 5, 10, and 100 mg/L) each day and also once every hour while sample analysis was occurring. The average reading from three voltage readings from the lowest standard (1.1 mg/L) was used to determine the detection limit. Three voltage readings from each field sample were recorded and an average was calculated based on the three readings. Chloride concentrations were determined using a regression analysis of the average voltage readings for the two or three standards that most closely fit the regression analysis slope (Steven Bogott, 2010).

Total Suspended Solids

Two hundred and fifty milliliters (mL) from samples captured with the ISCO samplers were used to quantify the TSS of Coal Creek. Samples were measured by running the collected water through a

1.00 micron nucleopore filter. The filter was evaporated at between 103 and 105 degrees Celsius (C) for one hour. After this, the filters were cooled in a dessicator for 20 minutes, and their total load was weighed. The calculation of total suspended solids is derived by using the following formula:

$$\text{Milligrams of total suspended solids per liter} = \frac{(A-B) \times 1000}{\text{liters of sample volume.}}$$

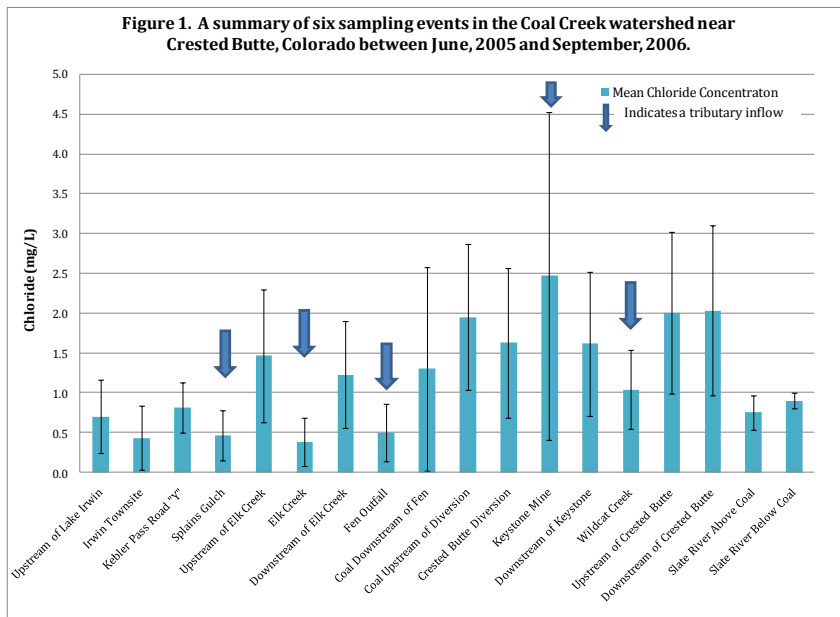
A = filter weight + sediments

B = filter weight before sediments

3. RESULTS

3.1 Baseline Conditions

3.1.1 Chloride



In general, background concentrations of chloride in Colorado streams during non-rainfall conditions (referred to as baseline conditions in this report) are expected to be less than 5.0 mg/L, depending on the geology of the area (Goodrich, 2008). In areas where human inputs have altered stream chemistry, concentrations have been measured at up to 400 mg/L.¹ The EPA's Screening Level Ecological Risk

Assessment (SLERA) for the Standard Mine uses Splains Gulch as a reference site, with 0.63 mg/L as a background for the watershed. MgCl₂ is not applied along the Forest Service road providing access into Splain's Gulch.

Since the release of the SLERA in 2006, new samples have been added to the dataset for Splains Gulch, generating an average of 0.329 mg/L for this site. This average is based on three detections of chloride and four non-detections throughout all of the data available through September, 2007. The method detection limit reported by the lab was no higher than 0.2 mg/L through 2007. Since 2007, the method detection limit has increased to 2 mg/L. Using this increased detection limit, no detections were returned for samples from Splain's Gulch.

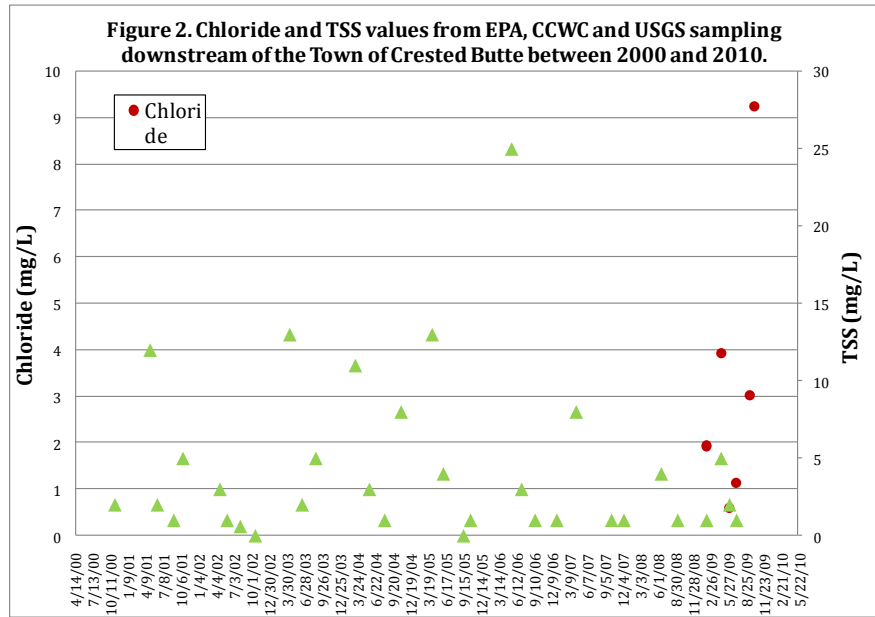
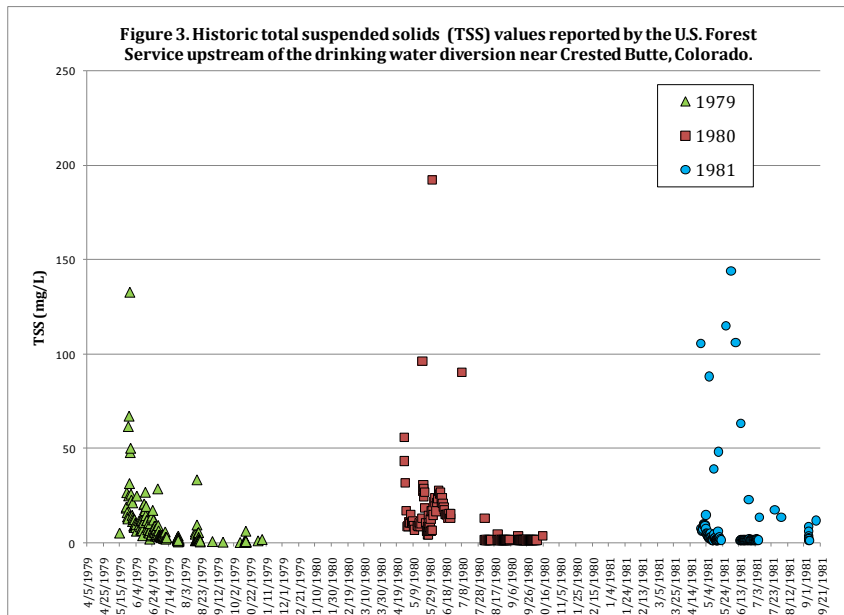


Figure 1 presents mean chloride values (standard deviation bars shown) from six sampling events during 2005 and 2006. These six events had the most comprehensive basin-wide data from the last five years; this data was also analyzed using detection limits of 0.2 mg/L or lower. There is a trend for the chloride concentrations to decrease from upstream to downstream sections of the stream, with the range increasing no more than 2 mg/L over the entire reach of Coal Creek. Tributaries to Coal Creek are not a significant source of chloride in Coal Creek. Higher concentrations of chloride in Coal Creek may be influenced in some way by natural loading, but this relationship is poorly understood. A summary of the EPA and CCWC data available since 2005 is found in Table 1.



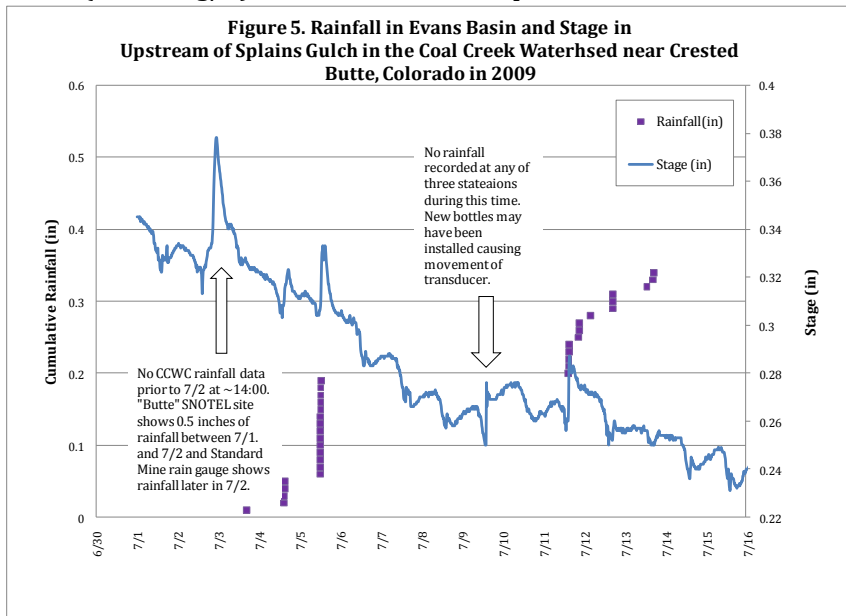
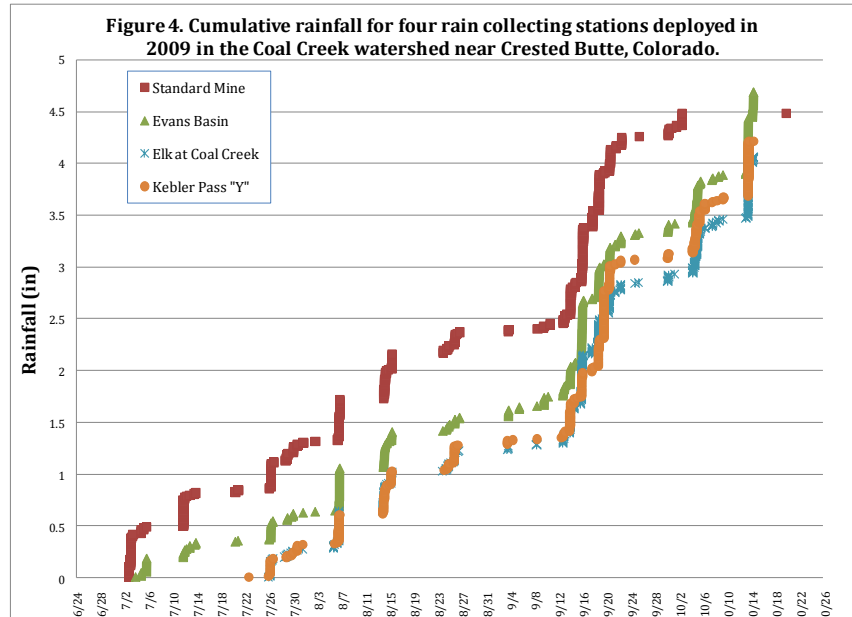
Historic data for the Coal Creek Watershed has also been gathered from the United States Geological Survey water monitoring and gauging station, near the confluence with the Slate River, since 2000. Seasonal peaks for TSS typically occur in March, April, and May (Figure 2). The chloride data from the USGS site is limited to six samples from 2009. Chloride values were

reported at two sites in 1977 with results (0.2, 0.4 mg/L) much lower than values reported during sampling conducted from 2005-2009. The 1977 samples pre-date the first regular $MgCl_2$ applications that occurred around 1995.

On September 17, 2007, the EPA collected grab samples both before and after a storm event of 1.4 inches of rainfall (SNOTEL, 'Butte' site). Samples collected during storm conditions had a

chloride concentration of 7.3 and 8.9 mg/L at sites just upstream and just downstream of the confluence of Elk and Coal Creeks, compared to a sample with values of 2.2 and 2.8 mg/L collected under normal conditions two days earlier, on September 16th. A grab sample from the roadside ditch on June 25th at 15:10 returned a value of greater than 100 mg/L, a value within the upper limit of the detection range of the probe used. The actual value for this sample could not be determined.

In late June and early July of 2009, the CCWC collected 36 chloride samples downstream of the Townsite of Irwin and just downstream of the Forest Queen Mine (Coal-30). Only two samples returned detectable levels of chloride (1.4, 1.5 mg/L), which were both just above the detection limit (1.031 mg/L) for this batch of samples.



3.1.2 Total Suspended Solids

Figure 2 presents data from the USGS station downstream of the Town of Crested Butte. Historic data from the United States Forest Service (USFS) was collected in the watershed between 1979 and 1982. Figure 3 presents data from upstream of the Crested Butte Intake (Coal-10) collected by the USFS with automated samplers. Note the

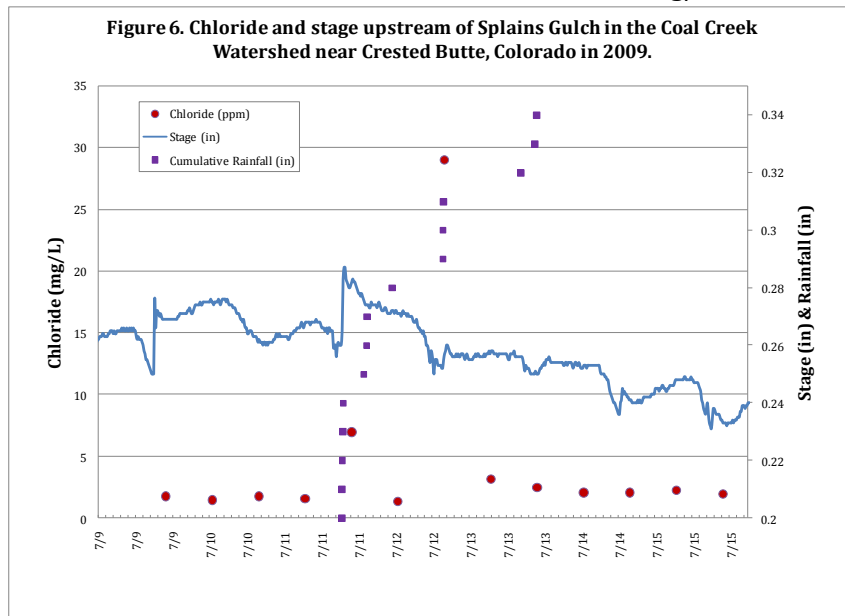
seasonal outliers in TSS data exceeding 50 mg/L during high flows. The USFS also collected water samples at two other sites on Coal Creek; this data is presented in Table 2. There is no consistent trend in loading rates from these three sites on Coal Creek.

Sediments loading from tributaries did not entirely explain sediment loading in Coal Creek (Table 1) during the USFS sampling. Sediment loading rates in Coal Creek are thought to be controlled by several factors, including tributary and non-tributary sources. However, loading from Splains Gulch and Elk Creek were not always accounted for at the “Coal Creek Below Elk Creek” sample location, indicating either a deposition of sediment in the creek or an additional source of sediment loading during these sampling events. Due to problems with analytical results from 2009, the CCWC was unable to document TSS baseline conditions.

3.2 TSS and Chloride Concentrations During Rainfall Events

Figure 2 presents historic TSS and chloride data from the USFS station downstream of the Town of Crested Butte. The USFS collected this historic data about the watershed between 1979 and 1982. TSS data from the USGS station did not correlate with chloride values.

The EPA did not analyze water samples for TSS from 2005 to 2009. In 2005, the EPA collected two samples from site Coal-25 near the USFS “Irwin Fork of Coal Creek” site, but downstream of Kebler Pass Road. Two samples were collected approximately 15 minutes apart; during baseline conditions, the chloride value was measured as 0.3 mg/L and after the rainfall event 15 minutes



later, a value 5.6 mg/L was reported. The EPA also collected two samples at the Coal Creek site downstream of the Town of Crested Butte (Coal-00). A sample collected on September 26, 2005 returned a chloride concentration of 2.4 (mg/L), compared to the sample collected after rainfall on September 28, 2005, which had a concentration of 10.8 mg/L.

A comparison of EPA data from sampling events during documented rain events is presented in Table 4. Samples from 2007 and 2009 were noted as “storm” (2007) events in the SCRIBE database or with the phrase “rained significantly” in field notes (2009). For sites in Coal Creek, there is an observable increase in chloride concentrations between baseline and rainfall conditions (Table 4). Of all the data reported in Table 1, the maximum reported value (11.2 mg/L) occurred during September of 2007 at the Crested Butte Diversion.

Rainfall and Stage Relationships

Four rainfall stations were deployed in the watershed in 2009. The cumulative rainfall for each station is shown in Figure 4. The Standard Mine and Evans Basin units were installed on July 2, 2009, and the other two stations were installed on July 22, 2009. All stations were removed on or near October 13, 2009.

The cumulative rainfall was recorded at four stations: the Evans Basin (4.69 inches), Standard Mine (4.48 inches), Kebler Pass Y (4.21 inches), and Elk at Coal Creek (4.06 inches) locations. Rainfall events at the four stations visually correlate with each other, but over time the measurement intervals at each rain station shift due to the start and end times of the rain event. For example, when a rain event ends at one station at 10:00 the station resumes a normal reporting interval of 7 minutes, in this case at 10:07. During the same storm event another station might report the last rainfall measurement at 10:02 and therefore the next reporting would occur 7 minutes later at 10:09. Over time these gaps in reporting times are enough to make statistical analysis impractical for the purposes of this study.

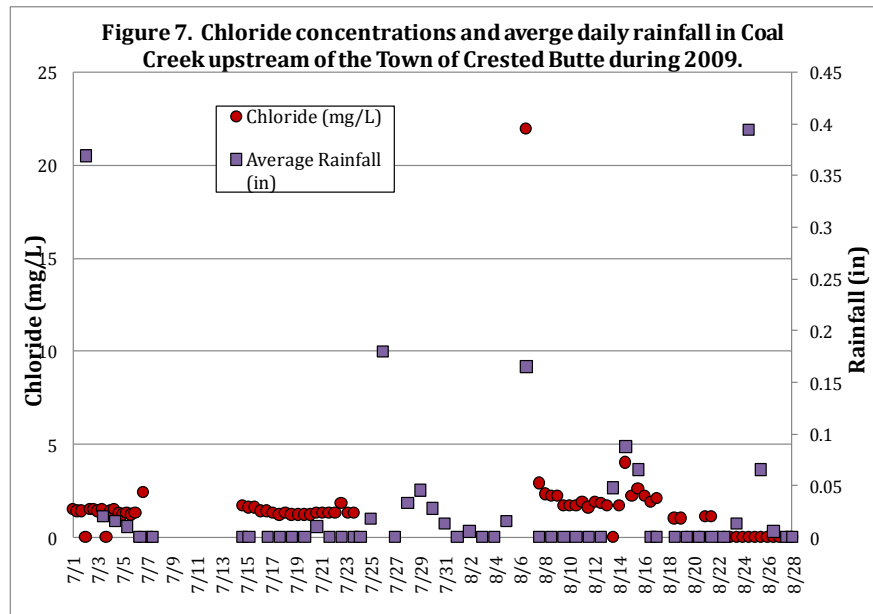
The 2009, CCWC study recorded stage using ISCO samplers at five locations in the watershed. One ISCO unit was installed in Coal Creek, upstream of Splain's Gulch. A rain gauge was installed more than one mile downstream, near the confluence of Elk and Coal Creeks, making a comparison of the stage and rainfall data from these two units difficult with the limited data available. Though directly comparing the data between this rain gauge and ISCO unit was difficult, the effect on stage from nearby rainfall events can be extrapolated (Figure 5). In general, rain events measured during 2009 caused a much smaller increase in stage than anticipated (Table 5).

An increase in chloride concentrations associated with these rainfall events seems more delayed than the pulse in stage levels associated with rainfall events. For instance, the peak chloride value (29 mg/L) recorded during an extended rainfall that occurred on July 11th and 12th was measured over 20 hours after the start of the precipitation (Figure 6). However, chloride levels do not consistently correspond with rainfall events at other sites (Figures 7 & 8) and chloride concentrations in specific sites in Coal Creek do not relate in a linear fashion to rainfall. Concentrations in the stream may therefore be controlled by a variety of other factors, such as evapotranspiration rates after rainfall events, soil and road moisture content prior to the rainfall event, and vegetative cover in areas adjacent to the sampler and/or rain station. The analysis and investigation of these variables was outside the scope of purpose of this study.

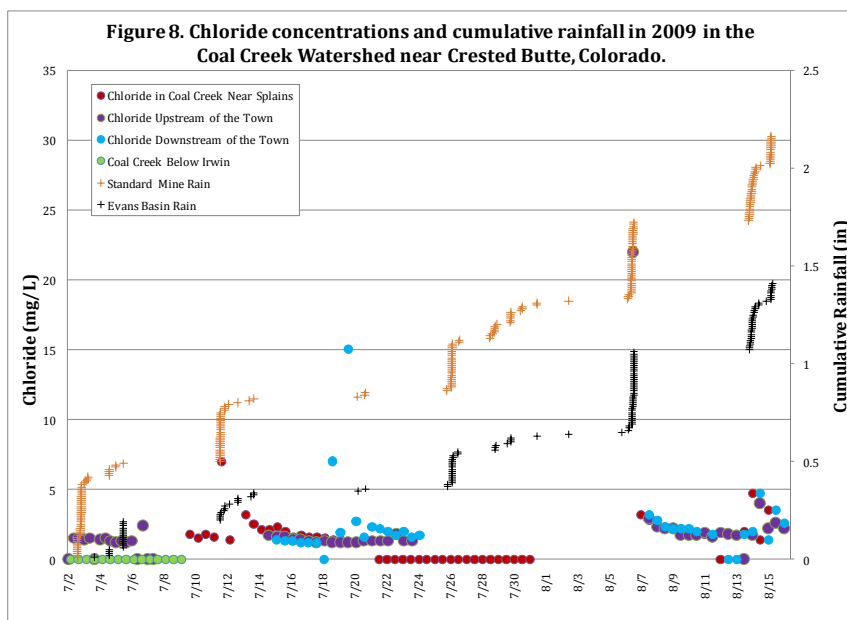
Comparing Data from Different Sites

On August 19, 2009 velocity was measured at four sites. Between 21 and 23 measurements were taken per site, for a total of 86 velocity measurements in Coal Creek, beginning just upstream of Crested Butte (Coal-02) and ending upstream of the fen (Coal-12). The average velocity of Coal Creek was 0.41 feet/second (ft/s). Using this data and the distance of 4.51 creek miles (~23,812

feet) between the sampler upstream of Town and the sampler in Coal Creek near Splains Gulch, we can estimate that surface water in Coal Creek will take 16.32 hours flow between these sites. However, the limited amount of stage data from upstream samplers and high level of variability in flow measurements at each site and between sites makes it difficult to compare data from different sampling locations. Additionally, the velocity of waters in Coal Creek can be expected to vary dramatically between seasons.



In addition, rainfall data did not always correlate well between rain stations. Rainfall recorded at the Kebler Pass Road Y (Y) started on August 13, 2009 at 20:37 and triggered the rain station at Elk Creek at 20:38 and the station at Evans Basin at 21:39. An increase in Coal Creek's stage at the ISCO station upstream of the Town began at approximately 22:45, less than two hours later. This suggests two possibilities: (1) the transport time of rainfall entering Coal Creek at upstream locations is either much shorter than predictions made using stream velocity, or (2) a rainfall event moved west to east in the watershed, and reached Coal Creek in areas close to Town prior to the flush of materials from higher elevations in the watershed. The short time interval between the start of rainfall at the Y and Elk Creek stations indicate either a fast moving storm or a possible near-simultaneous release of precipitation from the same at two locations. However, this



phenomenon is not confirmed since the precipitation was not recorded until one hour later at the more easterly, but similarly spaced, rain station in Evans Basin. In general, with the existing data gaps in stage readings both from the sampling intervals and equipment issues, as well as the distances between rain stations, it is difficult to determine when pulses of stormwater might arrive at

sampling points downstream. Determining when pulses arrive at each station was not a specific objective of the study, but could be incorporated into future studies. The speed of storms passing through the watershed as well as the magnitude of rainfall events are significant factors to consider when making attempts to pair data.

4. DISCUSSION AND FUTURE ACTIONS

Historic data and data from the 2009 study indicate chloride concentrations are well below the ranges considered to be deleterious to aquatic life. However, there is limited research on supporting the use of these thresholds for aquatic life in Rocky Mountain watersheds. Lack of continuous water quality monitoring in this study allows for the possibility that chloride spikes during, or directly after, precipitation events or early spring snowmelt events were not captured during this study.

Though chloride concentrations downstream of the Town of Crested Butte remain low, there is a trend for concentrations at downstream locations in Coal Creek to be higher than upstream locations, indicating some chloride loading to Coal Creek. This study did not explore ways to discern contributions from natural and anthropogenic sources.

Alternatives to MgCl₂

Several companies have developed alternatives to chloride based dust suppressants⁶. Over the years, Gunnison County has evaluated the alternatives to MgCl₂, but has not found any clear and convincing evidence that there is a better alternative. A number of years ago, Rocky Mountain Biological Lab (RMBL) studied the impacts of MgCl₂ in comparison to calcium chloride and requested the County use MgCl₂ rather than calcium chloride compounds on Gothic Road through the areas where RMBL conducts research. RMBL's studies indicated that the magnesium chloride stayed in place better than the calcium chloride, which seemed to leach off the road more easily⁷.

The incompatibility of adding new compounds to gravel roads previously treated with other compounds is another obstacle to changing products. In one case, an alternative specified for use on roads previously treated with MgCl₂ was applied to a road in Castle Mountain, and during a drenching summer rain the road became impassable; the road required re-blading. The County tried a blend of MgCl₂ and a lignin product on Kebler, but it was not any more effective than the MgCl₂ alone. Counties that have tried the lignin by itself say that it creates a sticky, slick surface (they compared it to driving through honey) and noted that the smell was unappealing even in the blend.

At the request of a Forest Service engineer, the Gunnison County Road and Bridge Department tried an acid-based product on Spring Creek Road. The product had a terrible odor, required the person adding it to wear protective equipment, and did not successfully control dust. Other alternatives have also been explored, but cost is a prohibitive factor in considering new products unless evidence shows that these products will persist for 3-4 years (Crosby, 2009).

Several alternatives to using MgCl₂ as a dust suppressant have been explored by other municipalities in Colorado. Douglas County Public Works tried two alternative mixes on a limited basis in 2009. These products, Durablend & X-hesion, are environmentally preferable to the magnesium chloride and lignin sulfonate blend; however, the County used X-hesion twice on gravel roads with very poor results⁶. Though the product has been used in other areas outside of Douglas County with success, X-hesion was used 2-3 years ago by Douglas County and did not work for their applications; it necessitated the re-gravelling of the road. Durablend held up well but tends to clump up when it gets wet and also tends to track. In general, it seems to hold up better than the magnesium chloride and lignin blend, and Douglas County will test this product on a few more roads in 2010 (Teague, 2009). Larimer County has completed some extensive testing and plans to release their findings in June of 2010.

Future Actions

Based on the findings from this study, the CCWC plans to collect additional field data to validate the chloride values seen in the watershed. Due to concerns with the results from the TSS analyses performed in 2009, additional field data will be collected to develop an understanding of the sedimentation in the watershed. The CCWC will also begin to document chloride in all seasons, including the rising concentrations seen typically in early spring.

Best management practices (BMPs) will be implemented along Kebler Pass Road to reduce sediment and chloride transport. In 2009, the CCWC installed a series of rock check dams within a reinforced vegetative swale. This BMP will be assessed to determine sediment capture efficiency. Additional BMPs, including revegetation and erosion control measures, were also implemented. These strategies will also be assessed and implemented in appropriate areas of the watershed. The CCWC will continue to work with Gunnison County Public Works to implement these BMPs and to follow efforts related to addressing contaminants of this nature in other parts of Colorado.

5. ACKNOWLEDGEMENTS

The Coal Creek Watershed Coalition would like to thank the following people, entities, and organizations for their assistance with this program:

Special thanks go out to all of the volunteer board members and advisory committee members of the Coal Creek Watershed Coalition and the organizations, agencies, businesses, and municipalities they represent. Their individual commitment to the efforts of the CCWC and their dedication to the restoration of the Coal Creek Watershed are critical to the organization's success. The 2009 Board of Directors deserves additional thanks for their tireless efforts.

Additional thanks go to the following member of the CCWC's Technical Committee for their review of this report: Wendy Brown, Amy Weinfurter, Tara Tafi, Rosemary Carroll, Dr. Kevin Alexander, Scottie Willey, and Anthony Poponi. Anthony Poponi and Amy Weinfurter served as the primary

authors and editors of this report and received additional assistance Dr. Alexander's detailed reviews. Marlene Crosby of Gunnison County Public Works provided information on the County's history of magnesium chloride use. Steve Bogott, a Western State College intern and Summer Associate, was the primary data collector and analyzed hundreds of samples and was assisted by Ross Metler who also served as a Summer Associate. Western State College's Thorton Foundation provided research funding for a portion of Mr. Bogott's research. Dr. Dale Orth of Western State College provided invaluable assistance in determining the appropriate equipment and methods for this study. Funding for the CCWC comes largely from the State of Colorado's Non-Point Source Program, Town of Crested Butte, Upper Gunnison River Water Conservancy District, Gunnison County, and the Colorado Healthy Rivers Fund. The Town of Crested Butte provides office and meeting spaces, fiscal and administrative services, reporting services for the CCWC's Non-Point Source Program grant, as well as project oversight. Special thanks to Rodney Due and the Public Works Department at the Town of Crested Butte. The U.S. Environmental Protection Agency generously donates water sample laboratory analysis services and assists in water sampling training and field measurements.

6. WORKS CITED

Bash, J. B. (n.d.). *Effects of Turbidity and Suspended Solids on Salmonids*. Retrieved March 1, 2010, from <http://water.washington.edu/Outreach/Publications/>

Colorado Department of Public Health and Environment Water Quality Control Commission. (1979, May 22). *Regulation 31: The Basic Standards and Methodologies for Surface Water (5CCR 1002-31)*. Retrieved March 1, 2010, from Water Quality Control Commission Regulations: <http://www.cdphe.state.co.us/regulations/wqccr>

Colorado Department of Public Health and Environment, Water Quality Control Commission. (1983, January 10). *Regulation 35. Classification and Numeric Standards for Gunnison and Lower Dolores River Basins*. Retrieved January 15, 2010, from Water Quality Control Commission Regulations: <http://www.cdphe.state.co.us/regulations/wqccregs/100235wqccgunnisonlowerdoloresriverbasinnew.pdf>

Crosby, M. (2009, December 28). Public Works Director, Gunnison County, Colorado. (A. Poponi, Interviewer)

Environment Canada and Health Canada. Canadian Environmental Protection Act. (1999). Retrieved 1 2010, March, from Priority Substances List Assessment Report: Road salts: http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/psl2-lsp2/road_salt_sels_voirie/road_salt_sels_voi

Goodrich, B. K. (2008). Environmental Effects of Magnesium Chloride Dust Suppression Products on Roadside Trees, Soils and Streams. *Arboriculture and Urban Forestry* , Volume 34(4):252-259.

Joseph N. Ryan, H. B. (2009). *Sources of Metal Contamination in the Coal Creek Watershed, Crested Butte, Gunnison County, Colorado: Part III. Early Spring Flow, April 2007*. Boulder, Colorado.

Ken Skorseth & Ali A. Selim, P. P. (2000). *Gravel Roads Maintenance and Design Manual (Chapter 4)*. U.S. Department of Transportation, Federal Highway Administration.

Mark N. Landers, P. D. (2007). *Watershed Effects on Streamflow Quantity and Quality in Six Watersheds of Gwinnett County, Georgia*. Reston, Virginia: United State Geological Survey.

National Research Council. (1980). *Drinking Water and Health (Volume 3)*. Washington, D.C.: National Academy Press.

Stimson, E. (2004, December 27). Memo to Dan, Maintenance Division, Montana Department of Transportation.

Teague, R. (2009, April 7). *Memo to Douglas County, Colorado*. Retrieved March 1, 2010, from Douglas County:
http://www.douglas.co.us/meetingsandagendas/business/documents/BM_04_07_2009_Item_e_2009_Dust_Suppression_Bid006-09.pdf

U.S. Environmental Protection Agency. (n.d.). *Drinking Water Contaminants*. Retrieved April 5, 2010, from Ground Water and Drinking Water: <http://www.epa.gov/safewater/contaminants/index.html>

U.S. Environmental Protection Agency. (n.d.). *National Recommended Water Quality Criteria*. Retrieved March 1, 2010, from Water Science:
<http://www.epa.gov/waterscience/criteria/wqctable/>

7. APPENDIX OF TABLES

Table 1 – Summary of available standards for chloride			
	Chronic (mg/L)	Acute (mg/L)	Notes
Iowa Department of Natural resources	320	638	For coldwater designated waters.
Environmental Protection Agency National Recommended Water Quality Criteria	230	860	Aquatic Life Standards: CMC and CCC from the 304(a) list of non-priority pollutants
Environment Canada	5% of organism affected at levels above 210. 10% of all organisms affected at levels above 240.		
Colorado State Extension	Below 70: Generally safe for all plants. 70-140: Sensitive plants show injury. 141-350: Moderately tolerant plants show injury. Above 350: Can cause severe problems		For water to be used in irrigation
Colorado Department of Public Health and Environment – Water Quality Control Commission	250		Regulation 31 – for domestic water supplies only. No aquatic life standards exist for chloride.
Birge et. al - University of Kentucky Study	<p>In each 30 consecutive days:</p> <p>a. The average concentration of chloride should not exceed 600 mg/l;</p> <p>b. The maximum concentrations should not exceed 1200 mg/l; and</p> <p>c. The concentration may be between 600 mg/l and 1200 mg/l for up to 48 hours.</p>		Used to develop the EPA criterion referenced above.

Table 3. A summary of sediment loading at select sites in the Coal Creek Watershed. Units = pounds/day

Date	Irwin Fork of Coal Creek	Splains Gulch and Elk Creek	Coal Creek Below Elk Creek	Difference
6/21/1979	356	127	1426	943
6/28/1979	3570	436	3824	-182
7/25/1979	65	43	183	76
9/7/1979	17	4	54	33
7/8/1980	60	69	224	94
8/5/1980	87	3	1016	926
8/20/1980	2	105	27	-80
9/15/1980	1	112	25	-89
10/15/1980	0	1267	39	-1228
4/27/1981	452	550	884	-118
5/7/1981	228	451	733	54
5/28/1981	2271	40	8058	5747
6/25/1981	97	48	279	133
7/27/1981	206	11	70	-146
9/16/1981	7	3	39	29

Table 4. September chloride values for baseline conditions (2005, 2006) and during rainfall events (2007,2009).

Site Name	Baseline Conditions		Rainfall Events	
	2005, 2006		2007, 2009	
	Average	Standard Deviation	Average	Standard Deviation
Kebler Pass Road "Y"	0.7	0.5	5.4	2.2
Splains Gulch	0.4	0.5	1.0	1.4
Upstream of Elk Creek	2.3	0.9	5.8	4.4
Elk Creek	0.3	0.3	1.0	1.4
Downstream of Elk Creek	1.9	0.7	4.9	3.4
Coal Upstream of Diversion	2.6	*	6.6	2.8
Crested Butte Diversion	2.6	0.8	8.2	4.2

* - Standard deviation cannot be calculated because only one sample is available for these dates

Table 5. Stage and rainfall data from Coal Creek in the July of 2009 at the "Coal Creek Above Splains" ISCO site and the "Elk and Coal Creek Confluence" rain station.

Date	Rainfall Inches/Hour	Stage Increase Inches
7/4/2009	0.089	0.016
7/5/2009	0.181	0.027
7/11/2009	0.012	0.031