Water Quality Assessment from Data Collected at River Watch Sites in the Uncompahgre Basin

Compiled by Arlen Huggins, Uncompahgre Watershed Partnership (UWP) Board Member

1. Brief Description of River Watch

***From the River Watch website**: River Watch is a statewide volunteer water quality monitoring program operated by Colorado Parks and Wildlife (CPW). Our mission is to work with voluntary stewards to monitor water quality and other indicators of watershed health and utilize this high-quality data to educate citizens and inform decision makers about the condition of Colorado's waters. This program is unique in its statewide focus and frequency of data collection.*

Since 1989 River Watch has had two primary goals: 1) Provide a hands-on real science experience learning the value and function of Colorado's River and water ecosystems, and 2) Generate quality aquatic habitat data over space and time for use in the Clean Water Act, Colorado Parks and Wildlife, watershed, local and other decision making processes.

River Watch is primarily funded by CPW through a mix of federal funds and Colorado Lottery funds. CPW contracts every five years with a non-profit partner to help provide professional staff to support volunteers, diversity in funding, size, and program areas. (In 2019 CPW negotiated with a new "partner", but a delay in setting up a new contract resulted in missing at least one month of metals sampling on the Uncompahgre, and the fall low-flow nutrients sampling.)

River Watch has an annual cycle that works around the school and state fiscal calendar. All volunteers are required to attend one of our four-day training events, offered in late summer or mid-fall, switching east and west slope central locations when possible.

As a baseline engagement, all groups sample and analyze all stations monthly for temperature, dissolved oxygen, alkalinity, and hardness. Also, total and dissolved metals are collected monthly and analyzed at CPW laboratories for 13 metals (Al, As, Ca, Cd, Cu, Fe, K, Mg, Mn, Na, Pb, Se, and Zn). High-flow and low-flow nutrient samples (total nitrogen, ammonia, nitrate/nitrite, total phosphorus, chloride, sulfate, and total suspended solids) are collected and analyzed at CPW laboratories. Fall macroinvertebrate samples are collected with a physical habitat assessment (not currently done on the Upper Uncompahgre). Samples are sent to a certified taxonomist for identification and subsequent calculation of biotic indices that imply the health of the aquatic habitat. All data are entered into the River Watch database.

The Uncompahgre Watershed Partnership (UWP) has participated with volunteers in the CPW River Watch project since 2013. However, other River Watch volunteers have collected water quality samples from

Project Name	Organization	Station Name	Station Number	Water Body ID	River	Latitude	Longitude	Elevation (ft)
River Watch	Ethan Funk	Idarado Compliance	3580	COGUUN06B	Red Mtn Creek	37.9382	-107.6729	10320
River Watch	Ethan Funk	Abv Unc Conf	3188	COGUUN06B	Red Mtn Creek	37.9667	-107.6604	9600
River Watch	Ethan Funk	Abv Red Mtn Conf	3582	COGUUN03A	Uncompahgre	37.9883	-107.6496	8797
River Watch	Ethan Funk	Above Hydo Dam	4135	COGUUN03A	Uncompahgre	38.0103	-107.6496	8160
River Watch	Ethan Funk	Camp Bird Rd	4134	COGUUN09	Canyon Creek	38.0022	-107.694	8514
River Watch	Ethan Funk	USGS Gauge	3586	COGUUN03B	Uncompahgre	38.0359	-107.6789	7631
River Watch	UWP	Potters Ranch	392	COGUUN03C	Uncompahgre	38.11909	-107.73316	7020
River Watch	UWP	Ridgway Town	402	COGUUN03C	Uncompahgre	38.1571	-107.754	6973
River Watch	UWP	CR24	395	COGUUN03C	Uncompahgre	38.184	-107.7461	6887
River Watch	UWP	Below Ridgway Res	393	COGUUN03E	Uncompahgre	38.24422	-107.76328	6980
River Watch	UWP	Abv Confluence Unc	347	COGUUN11	Cow Creek	38.25225	-107.7651	6605
River Watch	UWP	CR24 blw Pleasant V Cr	336	COGUUN11	Dallas Creek	38.1722	-107.7956	7146

Table 1. River Watch sites on the Uncompahgre currently sampled by Ridgway and Ouray volunteers. Water quality analyses in Section 3 use data from sites shaded in blue.

the Uncompahgre and its tributaries since as early as 1999. UWP volunteers collect samples as noted above, except dissolved oxygen and macroinvertebrates are not currently sampled.

2. Ouray County River Watch Sampling Locations and Impaired Waters in the Uncompahgre Basin

River Watch volunteers from Ouray and Ridgway currently sample at seven Uncompahgre River sites and an additional five sites on tributary creeks. The sites are listed in Table 1 and shown on the map in Figure 1. The river sites extend from site 3582 just above the Uncompahgre confluence with Red Mountain Creek down to site 393 about a half mile below the outlet of Ridgway Reservoir. The sites used in subsequent water quality analyses are shaded blue in Table 1.

The Clean Water Act (CWA) requires a state to produce a list (303(d) list) of impaired waters in the state.

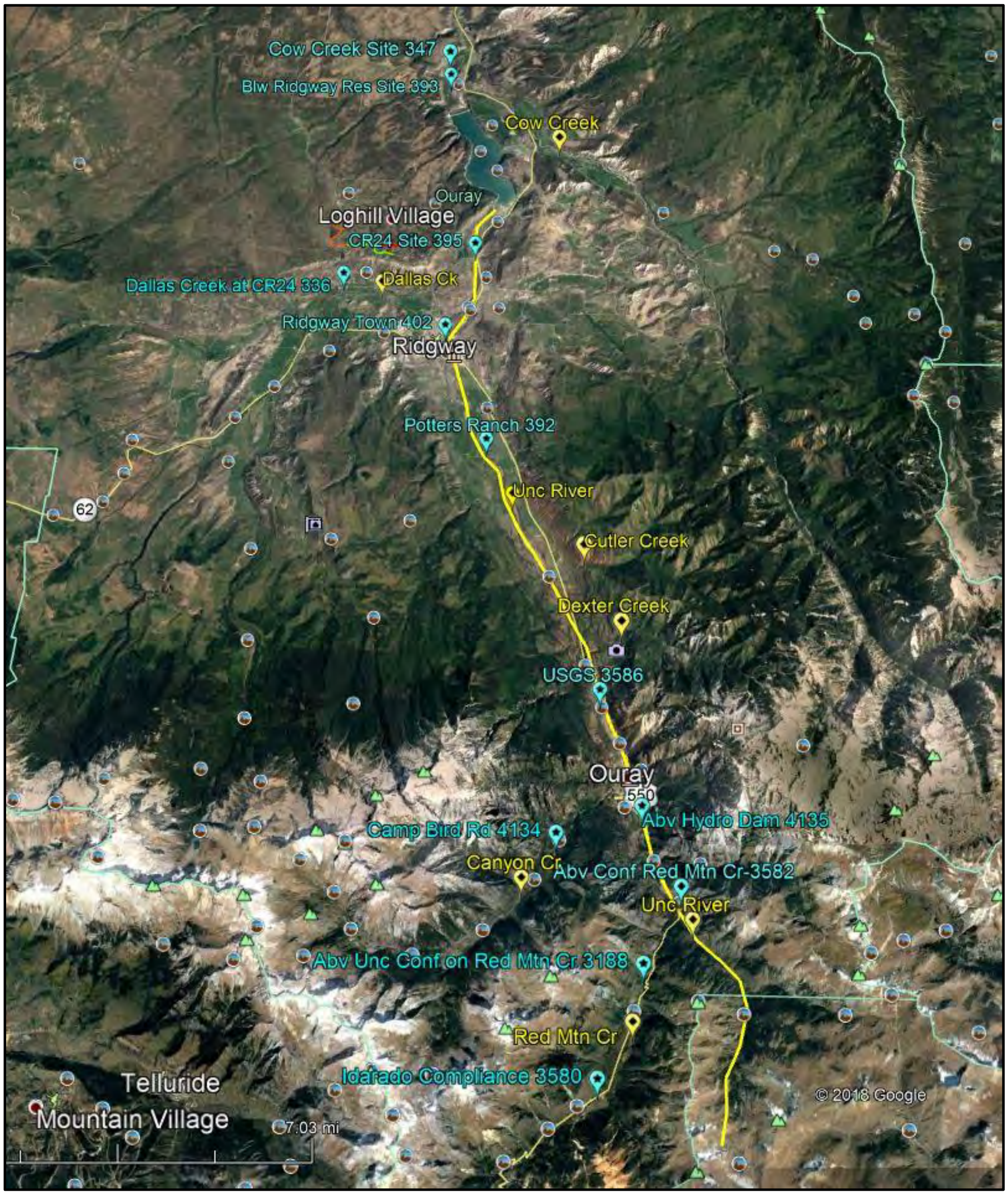

Figure 1. Map of a portion of the Uncompahgre Basin with Ouray County River Watch water quality sampling sites shown in blue. The Uncompahgre River from its headwaters to Ridgway Reservoir is shown by the yellow line.

Once listed as impaired a Total Maximum Daily Load (TMDL) is determined for each impaired water body every 10 years. A TMDL is the maximum pollutant load that a water body can assimilate and still attain water quality standards. The Uncompahgre River Watershed Plan (2018) provides a list of impaired waters in the Uncompahgre Basin, as well as a list of river segments for which TMDLs have been completed (as of 2010 and 2011). Once TMDLs have been approved for specific parameters for a river segment, the segment can be removed from the 303(d) list. Relative to Aquatic Life Use, segments COGUUN02, -03A, -03B and -03C (see Table 1) are listed as impaired for pH and zinc, and segment -06 is on the impaired list for silver and zinc. Segment -09 (Canyon Creek) is also impaired for zinc.

Regarding 2010 and 2011 TMDLs, segment COGUUN02, the upper Uncompahgre ending at site 3582, has approved TMDLs for cadmium, copper, and zinc. The mainstem of the Uncompahgre River in segment COGUUN03 has approved TMDLs for cadmium, copper, and iron. Except for silver, River Watch data provide a continuous record of the metal concentrations in all the impaired segments.

The Water Quality Control Commission (WQCC) is responsible for adopting water quality standards in Colorado. The WQCC has adopted a set of numeric Table Value Standards (TVS) meant to protect the designated use of a water body and at least 95% of the aquatic life present in a stream segment. The TVS for metals like cadmium, copper, lead, zinc, and others are regression equations based on water hardness. A complete set of standard tables is available in Regulation No. 31, The Basic Standards and Methodologies for Surface Water, Colorado Department of Public Health and Environment (CDPHE), WQCC. The following sections provide a review of River Watch data from site 3188 on Red Mountain Creek down to site 393 on the Uncompahgre below Ridgway Reservoir. Although the River Watch data are not used here for a formal standards assessment, the TVS for aquatic life are shown for reference on many of the plots to indicate where and when TVS have been exceeded**.**

3. Analysis of Water Quality Data from Eight Uncompahgre River Watch Sites

Water quality data from eight of the River Watch sites listed in Table 1 were downloaded from the River Watch database. The sites, from highest to lowest elevation, were 3188 on Red Mountain (RM) Creek; and 3582, 4135, 3586, 392, 395 and 393 on the Uncompahgre River. Site 3134 on Canyon Creek above Ouray was also used in the analysis. The sites had differing periods of record, but the 12-year period from 2007 through 2018 was selected as being nearly consistent over all sites except 3188, which had data only from 2010 through 2018. Several analyses were performed for each site, including time series analysis for the entire period, regression analysis for various pairs of parameters, and a determination of averages and medians of all parameters by month. The monthly medians and averages were compiled from samples collected on any date in a given month. The spread in sampling dates, as well as annual variation in runoff over the twelve-year period, led to considerable variation in average values, however distinct trends were still obvious. In addition, some sites had relatively few samples in winter months due to access issues. After considering the implications of using averages or medians on relatively small data sets, the monthly median value was chosen to show the trends in water quality parameters.

This report begins with a look at the monthly parameter medians along the length of the river, sometimes referred to as a longitudinal display. At the three highest sites data were often not available for all months during winter, so here only June and November medians were used to compare parameter values during relatively high flow (June) and relatively low flow (November). For all parameters, the sites have been ordered in subsequent figures in the same way, with the first site being **Abv RM Conf** (3582), on the Uncompahgre River just above its confluence with RM Creek. The RM Creek site **Abv Unc Conf** (3188) is shown next, then the **Abv Hydro Dam** site (4135) followed by the **Campbird Rd** site (4134) on Canyon Creek. The remaining four Uncompahgre River sites are shown to the right of (below) **Campbird Rd**. This order was used to illustrate the influence of RM Creek and Canyon Creek on nearly all water quality parameters. All longitudinal bar graphs show the relative locations where RM Creek and Canyon Creek enter the river.

Appendix A contains similar bar graph plots for two sampling periods in 2014, however these plots begin at the Uncompahgre River headwaters at Lake Como (Figure 1) and include eight sampling sites on the Upper Uncompahgre above **Abv RM Conf**. As in the figures below the longitudinal displays end at **Blw Ridgway Res**.

Streamflow medians, or estimated averages in three cases, for June and November are shown in Figure 2. Flows for a single relatively high-flow year (2015) are also shown to illustrate a year with a large departure from the medians. In 2015 **CR24** had a peak flow of ≈870 cfs compared to the **CR24** median peak of only 440 cfs. USGS stream gauges are collocated with River Watch sampling sites at **USGS Gauge**, **CR24**, and **Blw Ridgway**

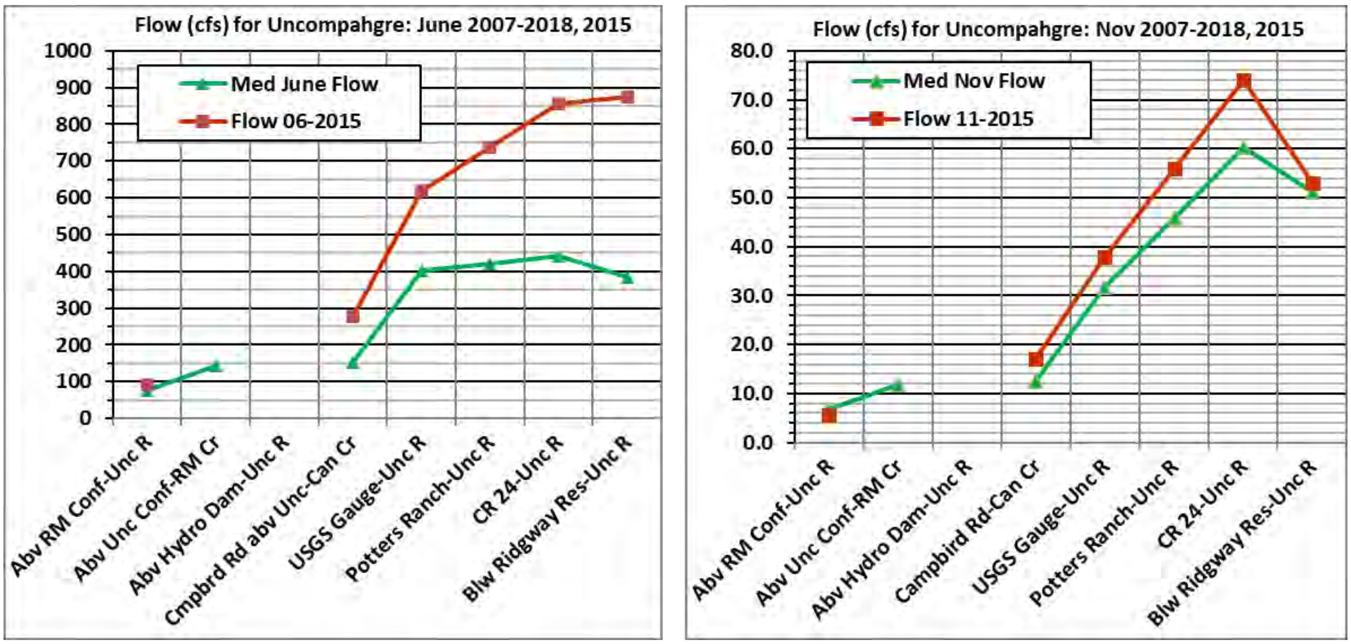

*Figure 2. Streamflow at River Watch sampling sites for June (left panel) and November (right panel). Flow at **Abv RM Conf**, **Abv Unc Conf**, and **Campbird Rd** are estimated monthly averages from the USGS StreamStat program. **Potters Ranch** is also an estimate. Other sites show median USGS measurements at River Watch sampling times. Also shown are the flows in June and November 2015, a relatively high runoff year.*

Res. The monthly <u>average</u> flows at **Abv RM Conf, Abv Unc Conf** and **Campbird Rd** were estimated using the area-based USGS StreamStats program. Flow at **Potters Ranch** was estimated simply as the midpoint between the flow at **USGS Gauge** and flow at **CR24**. Flow data in Figure 2 show the obvious increases in flow downstream to CR24, with the increase of median or average June flow being considerably less than the increase in a high runoff year like 2015, when irrigation diversions would have had less of an impact on total streamflow. Comparing the medians and 2015 case, streamflow increases in November, were similar since irrigation diversions would have ceased for the season. Streamflow below Ridgway Reservoir is regulated and can at times be higher or lower than the flow coming into the reservoir near **CR24**. The June flow medians indicate that the typical reservoir release was about 370 cfs, while in 2015 the release rate was about 500 cfs higher, likely to keep the reservoir at or below its prescribed maximum level. In November both the median and 2015 releases were dropped to near 50 cfs.

A. pH Measurements

The pH of water is a measure of its acidity and is measured on a logarithmic scale from 0 to 14. Water

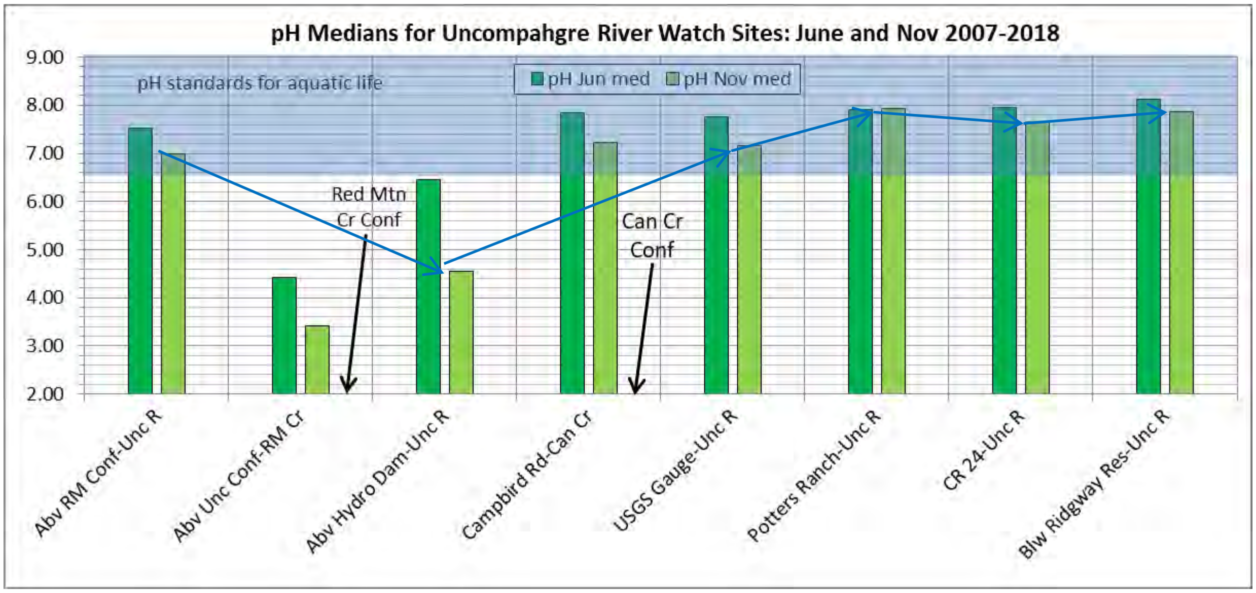

Figure 3. pH medians for June and November for the eight River Watch sites indicated on the horizontal axis. See locations in Figure 1. The relative locations where Red Mountain (RM) Creek and Canyon Creek enter the Uncompahgre are shown by the black arrows. The blue arrows show the continuum of sites on the Uncompahgre River. The pH standards range for cold water Aquatic Life use is shown by the blue shading.

with a pH of 7 is neutral, with values < 7 being acidic and values > 7 being basic. River Watch monitors pH because aquatic organisms are quite sensitive to pH levels that are above or below the “normal” range of a water body. Aquatic species are adapted to a range of pH from 6.5 to 8.0. The basic standard pH range for cold water is 6.5 to 9.0, which applies to most streams in the Upper Uncompahgre that are rated for Aquatic Use.

Figure 3 is a graph of pH medians at eight River Watch sites, determined from samples collected in June and November for the years 2007 through 2018. The blue arrows show the river continuum by connecting November medians for only the six sites on the river itself. All sites except the RM Creek site and the first site below the confluence (**Abv Hydro Dam**) had pH values within the 6.5 – 9.0 pH aquatic life standard range for cold water. The two sites with pH outside the standard range are in river sections listed as impaired for pH. The pH medians at **Abv RM Conf** were both within the standard range, however Figure A1 in Appendix A shows several sites in Poughkeepsie Gulch just below Lake Como had pH values as low as 4 in samples collected in July and September of 2014. The 2014 data show pH increased gradually to the standard range as the river descended to **Abv RM Conf**.

The low pH of RM Creek at **Abv Unc Conf** is due to acidic water from runoff over exposed rock or waste piles containing minerals like iron pyrite, and from water draining from mines or mine tailings into RM Creek. Following the river path from left to right, the influence of RM Creek on the Uncompahgre is evidenced by the pH drop from above the confluence (**Abv Unc Conf**) to below it (**Abv Hydro Dam**). At high-flow the pH median dropped by about 1.0 (10x more acidic), and at low-flow the median dropped by about 2.4 (250x more acidic). The median pH then increased from **Abv Hydro Dam** to **USGS Gauge**, due to the influx of higher pH water from streams such as Canyon Creek. Below **USGS Gauge** pH increased to **Potters Ranch** and then was relatively constant down to the last site below Ridgway Reservoir.

Differences between high-flow (June) pH medians and low-flow (November) medians were greatest at the RM Creek site and the first site below it at **Abv Hydro Dam**. At **Abv Hydro Dam** the low-flow pH median was about 60 times more acidic than the high-flow median, since at low-flow acidic water is not diluted by snowmelt runoff. The next section shows that there is no alkalinity to buffer the acid in RM Creek, so lower flow leads directly to greater acid concentration and markedly lower pH. Below **Abv Hydro Dam** the pH median increased down to **Potters Ranch**, by about 1.4 (25x more basic) in high-flow and by 3.2 (1600x more basic) in low-flow. This change to more basic pH water is due to the influx of water from streams with greater alkalinity (see Section B), and runoff from soils that are more alkaline in nature. The small differences in pH, between low-flow and high-flow, at the lower three sites in Figure 3 are also indicative of the higher alkalinity in this section of the river, and its ability to buffer inputs of acidic or basic water.

B. Alkalinity Measurements

Alkalinity represents the concentrations of carbonates and bicarbonates in water. It is measured as the

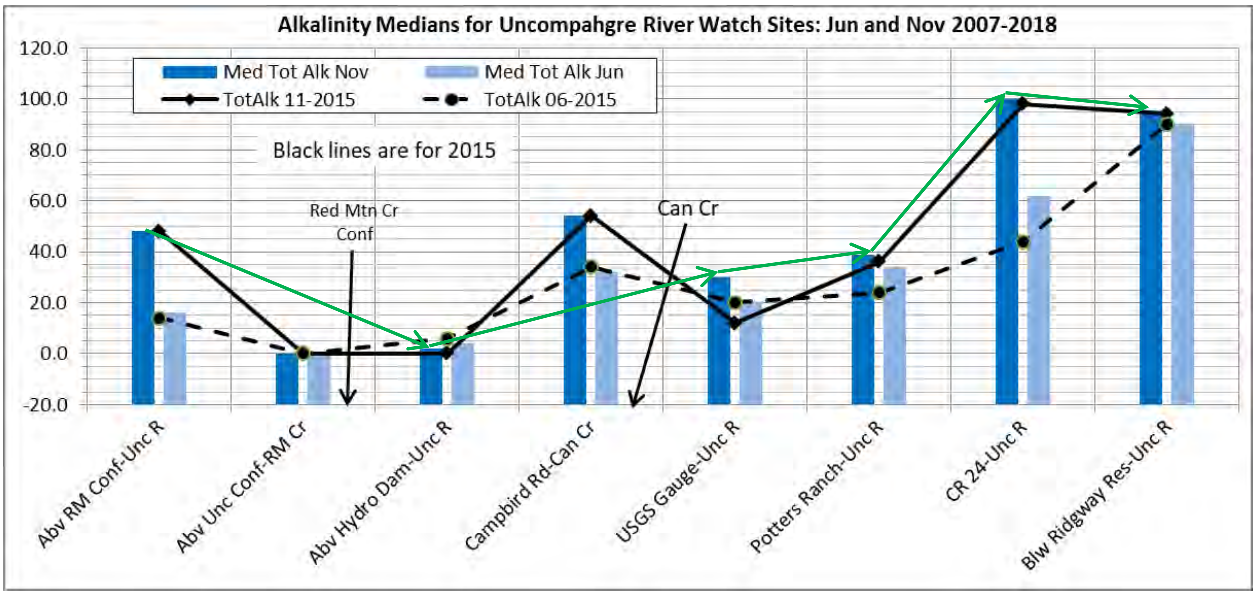

Figure 4. Alkalinity medians for June and November for the eight River Watch sites indicated on the horizontal axis. See locations in Figure 1. The relative locations where RM Creek and Canyon Creek enter the Uncompahgre are shown by the black arrows. Also shown are the alkalinity values in June and November (dashed and solid lines) for the high runoff year of 2015. Green arrows show the river continuum on November median bars.

concentration of calcium carbonate ($CaCO_3$) in mg/liter. Alkalinity increases in water flowing over limestone (composed of $CaCO_3$), which is generally absent in the Uncompahgre high country, but present in the lower parts of the basin. Alkalinity can also increase as return flow from flood irrigation enters the river. Irrigation diversions on the Uncompahgre become common below the town of Ouray and River Watch site **USGS Gauge**. So, alkalinity in the Uncompahgre should increase in the downstream direction.

Looking first at the longitudinal trend in Figure 4 at June high-flow (light blue bars), alkalinity medians first decrease between **Abv RM Conf** and **Abv Hydro Dam** after the zero-alkalinity water from RM Creek enters the river. Alkalinity medians then increase steadily from **Abv Hydro Dam** to **Potters Ranch**, and then increase more abruptly below **Potters Ranch**. The initial steady increase is mainly due to the higher alkalinity of streams like Canyon Creek entering the river, while the more rapid increase below **Potters Ranch** in June can be attributed to a change in the composition of the streambed, in addition to runoff from agricultural land and return flow from irrigation. Note that the trends in high-flow medians and the June 2015 alkalinity values (dashed line) are similar, indicating the alkaline composition of the Uncompahgre is consistent year to year.

For the low-flow trend analysis the green arrows in Figure 4 show changes along the river path at only the sites on the river itself. The longitudinal trend in alkalinity at low-flow (dark blue bars in Figure 4) has a pattern like high-flow, but with a couple of exaggerated differences at **Abv RM Conf** (larger decrease to downstream site) and **CR24** (larger increase from upstream site).

Note that at low-flow the median trend and the 2015 trend (solid line) are remarkably similar. At **Abv RM Conf** and **Campbird Rd** the higher November medians, compared to June, are likely due to higher concentrations of carbonates and bi-carbonates with less water in the river. On the river below **Abv Hydro Dam** this same rather large June to November difference is mainly apparent only at **CR24**. It is harder to explain this large increase in alkalinity in November when irrigation return flow should be minimal. It does suggest some other source of calcium carbonate is entering the river, possibly subsurface flow, between **Potters Ranch** and **CR24**.

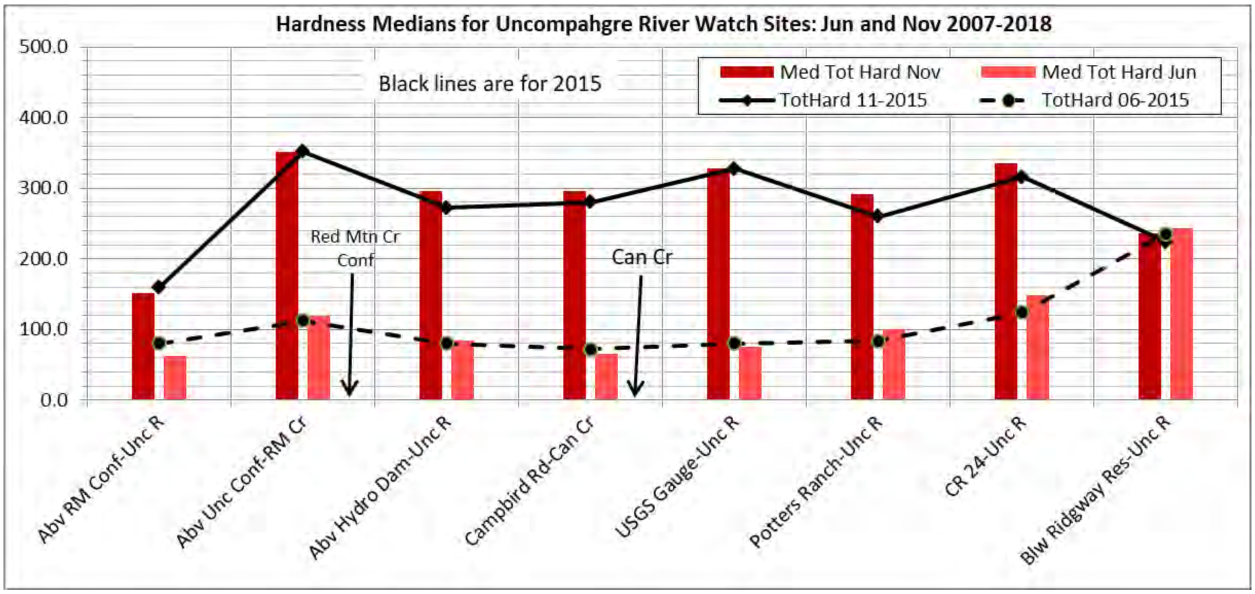

Figure 5. Hardness medians for June and November for the eight River Watch sites indicated on the horizontal axis. See locations in Figure 1. The relative locations where RM Creek and Canyon Creek enter the Uncompahgre are shown by the black arrows. Also shown are the hardness values in June and November (dashed and solid lines) for the high runoff year of 2015.

Finally, as with pH the large volume of water in Ridgway Reservoir moderates the various chemical inputs, leading to relatively constant alkalinity in the water at **Blw Ridgway Res**.

C. Hardness Measurements

Water hardness is a measure of calcium (Ca) and magnesium (Mg) polyvalent cations (ions with a positive charge greater than +1). It has been shown that fish residing in high hardness waters can withstand higher concentrations of metals than fish residing in low hardness water with the same metals' concentrations. One toxic effect of metal ions is thought to be due to their attachment to the gill sites of fish, and that magnesium and calcium ions, which are non-toxic, might "out compete" the metal ions on fish gills. Amphibians and macroinvertebrates can also be intolerant to various concentrations of metals. [See Woodling (2012), and Mize and Deacon (2002) for discussions of the effects of metals on fish and macroinvertebrates.] The effect of water hardness is reflected in the TVS (see Section 2) for each metal. These TVS are displayed with metals bar graphs in subsequent sections.

Figure 5 shows the June and November hardness medians for the eight River Watch sites, together with data from 2015 as a single year comparison. In contrast to alkalinity, there is a large difference in hardness between high and low flow at all sites except **Blw Ridgway Res**. High flow medians fall into the moderately hard (60-120) to hard (120-180) ranges, while all low flow medians below **Abv RM Conf** are considered very hard

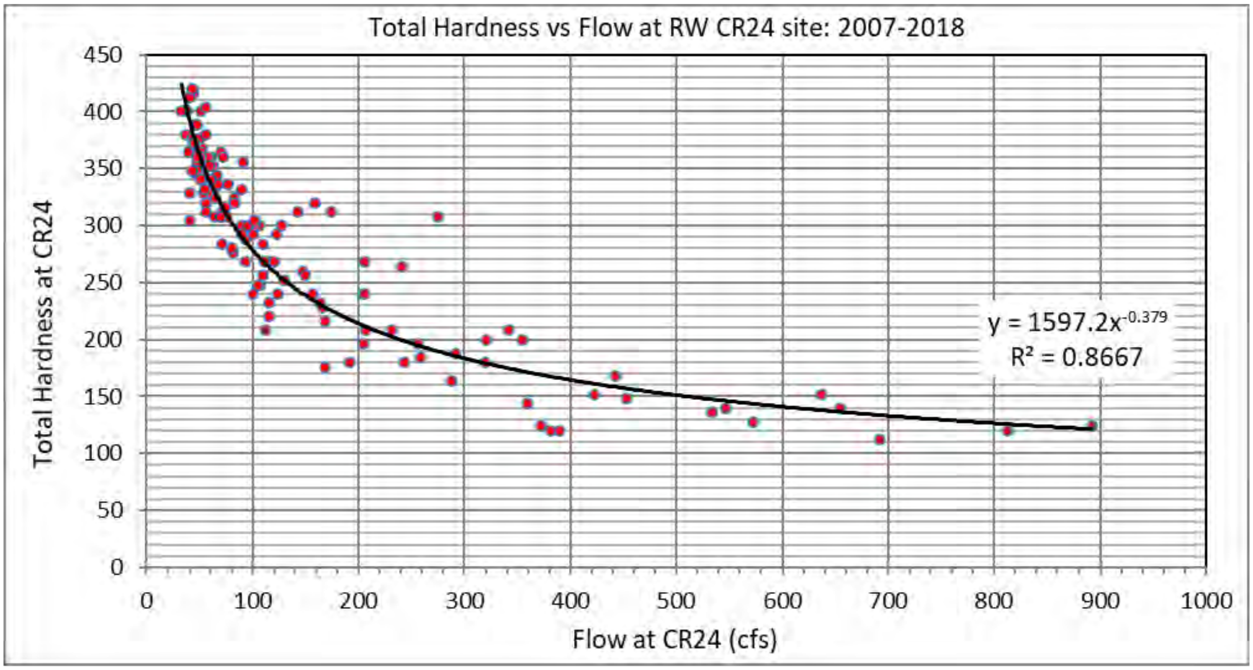

Figure 6. Scatter plot of water hardness versus flow for the ***CR24*** *River Watch site. Data include all samples from 2007-2018. The black line is a best fit power curve with its equation and correlation coefficient shown in the box.*

(>180). This flow dependence is reasonable since the concentrations of calcium and magnesium should increase with less water in the river.

The longitudinal trend at high flow in Figure 5 shows increasing hardness values from **USGS Gauge** down to **Blw Ridgway Res**, and this trend is reflected in both the medians and the June 2015 data. The hardness at **Blw Ridgway Res** seems to be unaffected by flow as values are nearly constant under both flow conditions, resulting in an increase in June and a decrease in November. Since hardness is a ratio of mass to volume, the fact that both flow (Figure 2) and hardness increase between **USGS Gauge** and **CR24** indicates calcium and magnesium are being added to the river over this section of the Uncompahgre.

The longitudinal low-flow trend in November is more erratic but is also quite similar in the medians compared to 2015 data. Figure 2 shows median flow steadily increasing from upstream to downstream in November, so the up-and-down pattern in hardness should be due to increases or decreases in the mass of calcium and magnesium entering the river between the sampling sites. It is obvious that water exiting Ridgway Reservoir is not affected by seasonal variations in upstream flow.

The relationship between flow and hardness at a specific sampling site is seen more clearly in Figure 6 where all hardness and flow data from **CR24** appear in a scatter plot, together with a best fit power curve. The R-squared value of 0.87 indicates that nearly 90% of the variation in hardness can be explained by stream flow at this sampling site. A similar analysis of hardness and flow at the **USGS Gauge** site below Ouray returned a best-fit equation of: $y = 1716.2x^{0.489}$ and an R^2 of 0.90.

D. Metals Measurements

Acidic water, like that observed in RM Creek and the Upper Uncompahgre (Appendix A, Figure A1), can dissolve metal compounds producing metals that are harmful to aquatic life. Woodling (2012) cites numerous studies on toxicity of metals to fish and Mize and Deacon (2002) report on the effects of metals on macroinvertebrate populations in the Upper Uncompahgre. River Watch monitors the concentrations of 13 potentially harmful metals. The analysis results for several of the more problematic metals relative to water quality are presented here. These include metals on the WQCC 303(d) impairment list and the Monitoring and Evaluation (M&E) list, such as manganese (Mn), cadmium (Cd), copper (Cu), lead (Pb), iron (Fe), aluminum (Al), and zinc (Zn). All these metals except manganese and aluminum are on the impaired list for Aquatic Life on several segments in the Uncompahgre River Watershed. Manganese is on the 303(d) list for Water Supply. For each metal, the 12-year median concentration will be compared to aquatic life TVS computed from coincidentally measured

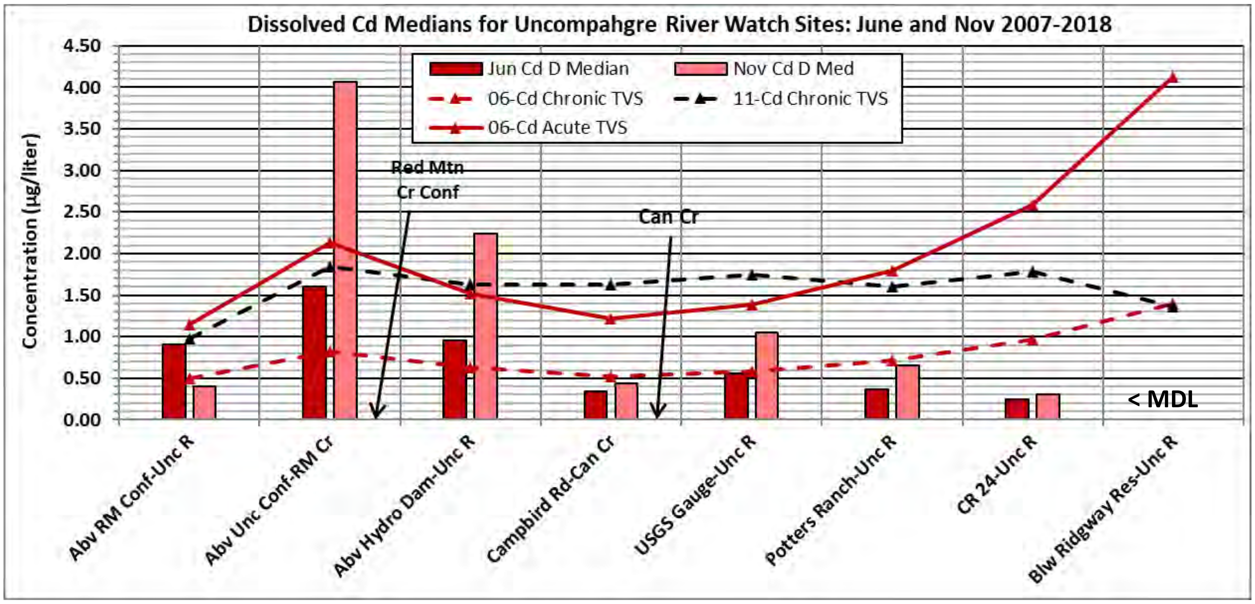

*Figure 7. Dissolved cadmium (Cd) medians for June (red bars) and November (pink bars) for the eight River Watch sites indicated on the horizontal axis. See locations in Figure 1. The relative locations where RM Creek and Canyon Creek enter the Uncompahgre are shown by the black arrows. Also shown are chronic (dashed lines) and acute (solid line) Table Value Standards for Cd. Medians at **Blw Ridgway Res** were below the Method Detection Level (MDL) of 0.18 µg/liter for cadmium.*

water hardness. Although Uncompahgre streams are not listed as impaired for aluminum, the WQCC has adopted standards for aluminum and results to follow show aluminum concentrations at times exceed TVS for aquatic life.

Cadmium: Dissolved cadmium concentration medians for June and November, for the eight River Watch sites, are shown in Figure 7. Also shown are chronic and acute aquatic life TVS computed from the median hardness at each site. Except for **Abv RM Conf**, all sites above Ridgway Reservoir show higher median concentrations during November low flow. For the sites on the river the longitudinal trend from **Abv Hydro Dam** down to **CR24** shows consistently decreasing concentrations in both June and November. This suggests the main source of cadmium is RM Creek since the concentration at **Abv RM Conf** is relatively low. The steady downstream decrease is due to dilution by other streams, like Canyon Creek, below RM Creek. Cadmium concentrations were generally below the Method Detection Level (MDL) of 0.18 µg/liter at **Blw Ridgway Res**, so no median value is shown in Figure 7.

Because TMDLs for Cd, Cu and Zn were completed for segment COGUUN02 (the Upper Uncompahgre down to **Abv RM Conf**) in 2010, the segment is not listed as impaired for these metals. However, Figure A4 in Appendix A shows cadmium concentrations below Lake Como in July and September 2014 were as high as 10 µg/liter, well above acute and chronic TVS. These high concentrations correspond to the low pH values (Figure

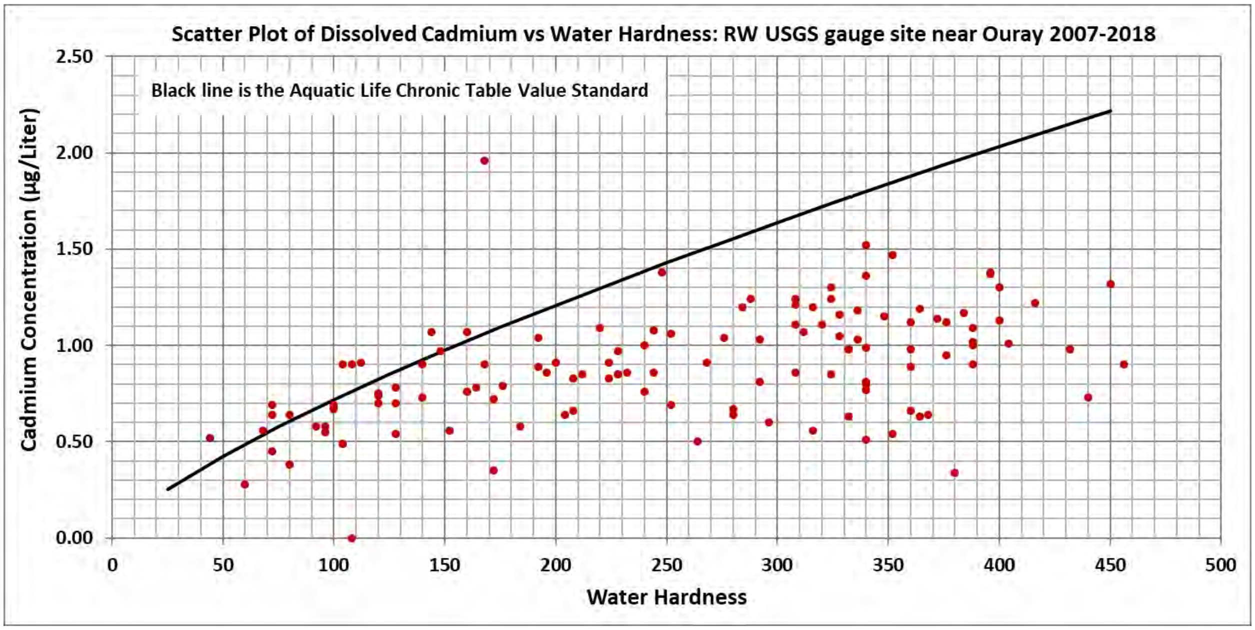

*Figure 8. Scatter plot of dissolved Cd concentration versus water hardness for the **USGS Gauge** site. The chronic TVS curve for Cd is shown by the black line.*

A2) observed in the same section of the river. Figure A4 shows cadmium concentrations decreased down to **Abv RM Conf**, but the median concentration in Figure 7 indicates that the June samples were still about 1.8 times the chronic TVS.

The lower portion of the Uncompahgre, section COGUUN03, is also not listed as impaired for cadmium (approved 2010 TMDL), but the chronic TVS was exceeded by the median down to **Abv Hydro Dam** in June, and down to **USGS Gauge** in November. The **Abv Hydro Dam** site had a November median value about 1.4 times the chronic TVS. The acute TVS was only exceeded by the median at the RM Creek site **Abv Unc Conf**. The entire cadmium data set (all months 2007-2018) for **USGS Gauge** is shown in the scatter plot in Figure 8. Cadmium concentration is plotted versus measured hardness, together with the chronic TVS curve. The TVS was only ex-

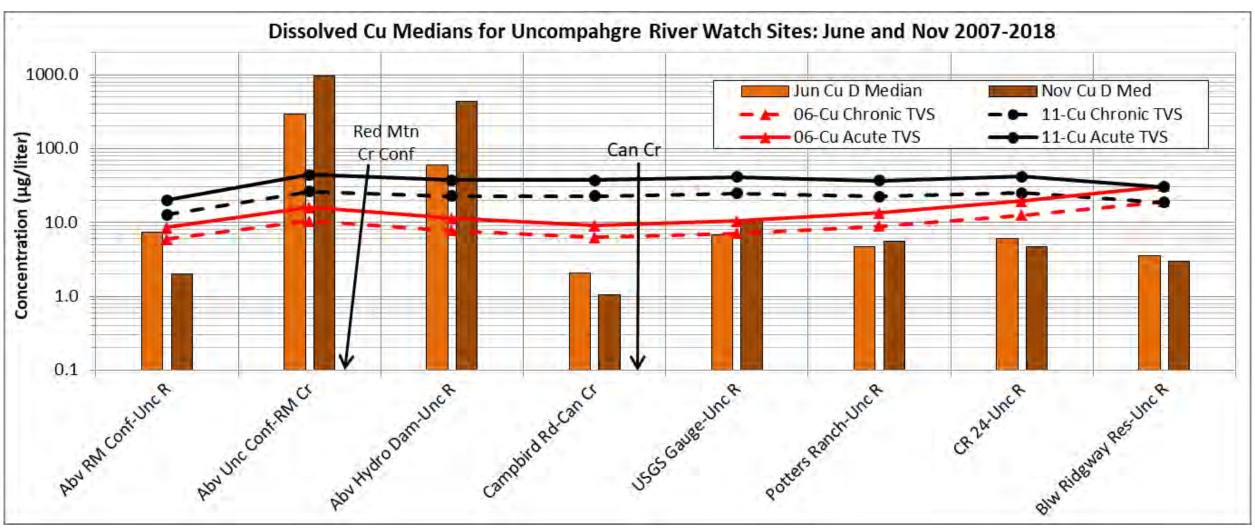

Figure 9. Dissolved copper (Cu) medians for June (tan bars) and November (brown bars) for the eight River Watch sites indicated on the horizontal axis. See locations in Figure 1. The relative locations where RM Creek and Canyon Creek enter the Uncompahgre are shown by the black arrows. Also shown are chronic (dashed lines) and acute (solid lines) Table Value Standards for Cd in June (red) and November (black).

ceeded at hardness values below about 160, which corresponds to higher streamflow.

Copper: Dissolved copper concentration medians for June and November are shown in Figure 9. The longitudinal trend for copper shows a large drop in concentration from **Abv Hydro Dam** to **USGS Gauge** (factor of 10 decrease in June and factor of 40 decrease in November), and then smaller decreases down to **Blw Ridgway Res**. The June to November concentration differences were largest at the three highest sites, and relatively small at the four lowest sites. The June median at **Abv RM Conf** also exceeded the chronic TVS and, as with

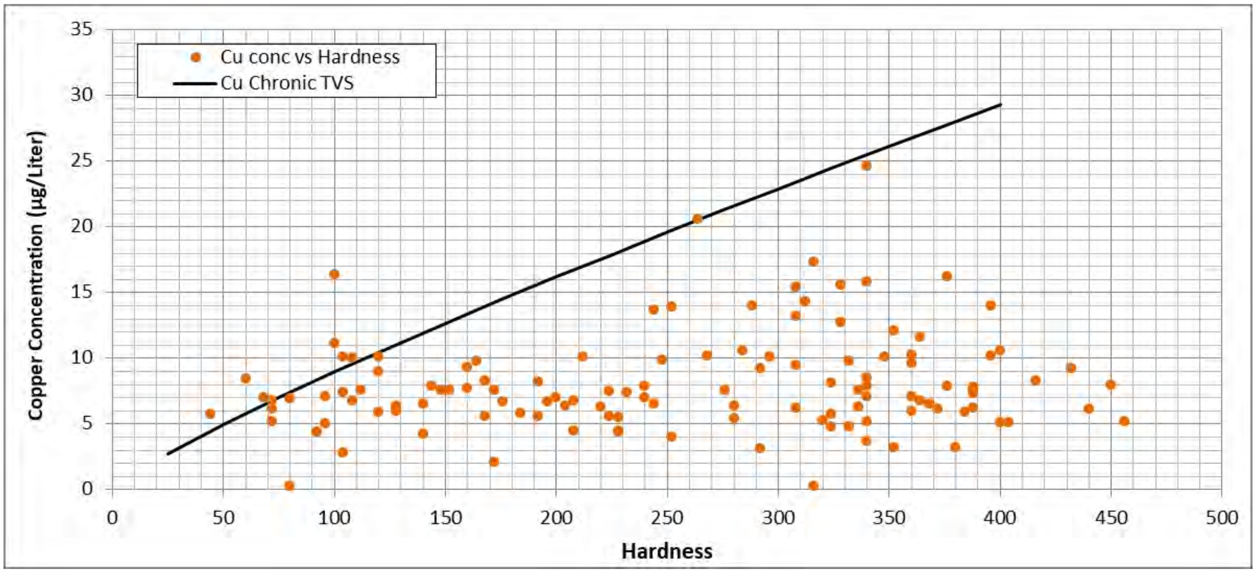

*Figure 10. Scatter plot of dissolved Cu concentration versus water hardness for the **USGS Gauge** site. The data include all samples obtained from 2007 through 2018. The chronic TVS curve for Cu is shown by the black line.*

cadmium, the June median was greater than the November median. Like cadmium the copper concentrations immediately below Lake Como (Figure A5) were very high (> 30 µg/liter) in 2014, but dropped to near the chronic TVS as the river descended to **Abv RM Conf**.

The overall trend was for copper concentration to decrease with distance from the main sources in RM

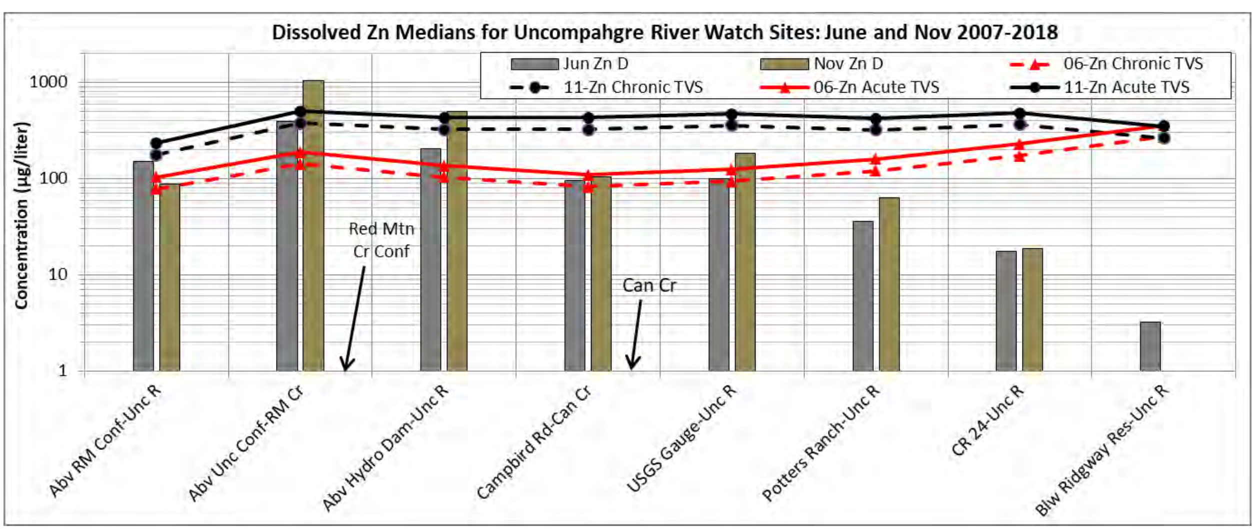

Figure 11. Dissolved zinc (Zn) medians for June (gray bars) and November (olive bars) for the eight River Watch sites indicated on the horizontal axis. See locations in Figure 1. The relative locations where RM Creek and Canyon Creek enter the Uncompahgre are shown by the black arrows. Also shown are chronic (dashed lines) and acute (solid lines) Table Value Standards for Zn in June (red) and November (black).

Creek and the highest sections of the Uncompahgre. The impact of RM Creek, as with cadmium, was diluted below **Abv Hydro Dam** by low copper concentration water from Canyon Creek and other streams, such that neither chronic nor acute TVS was exceeded by the medians at the four lowest Uncompahgre sites. Note that copper is not on the impaired list for these sections of the Uncompahgre since TMDLs for copper were approved in 2010. The entire copper data set (all months 2007-2018) for the **USGS Gauge** site is shown in the scatter plot in Figure 10. Like cadmium very few copper concentrations exceeded the chronic TVS curve over the 12 years of data, and those that did corresponded to the lower hardness values (< 120).

Zinc: Dissolved zinc concentration medians for June and November are shown in Figure 11. Figure A6 also shows zinc concentrations from Lake Como down to **Abv RM Conf** in 2014. The July and September 2014 concentrations were extremely high (≥ 1000 µg/liter) just below Lake Como, well above chronic and acute TVS, then decreased markedly down to **Abv RM Conf** where they were slightly greater than the chronic TVS. The medians at **Abv RM Conf** in Figure 11 were at or slightly below the chronic TVS.

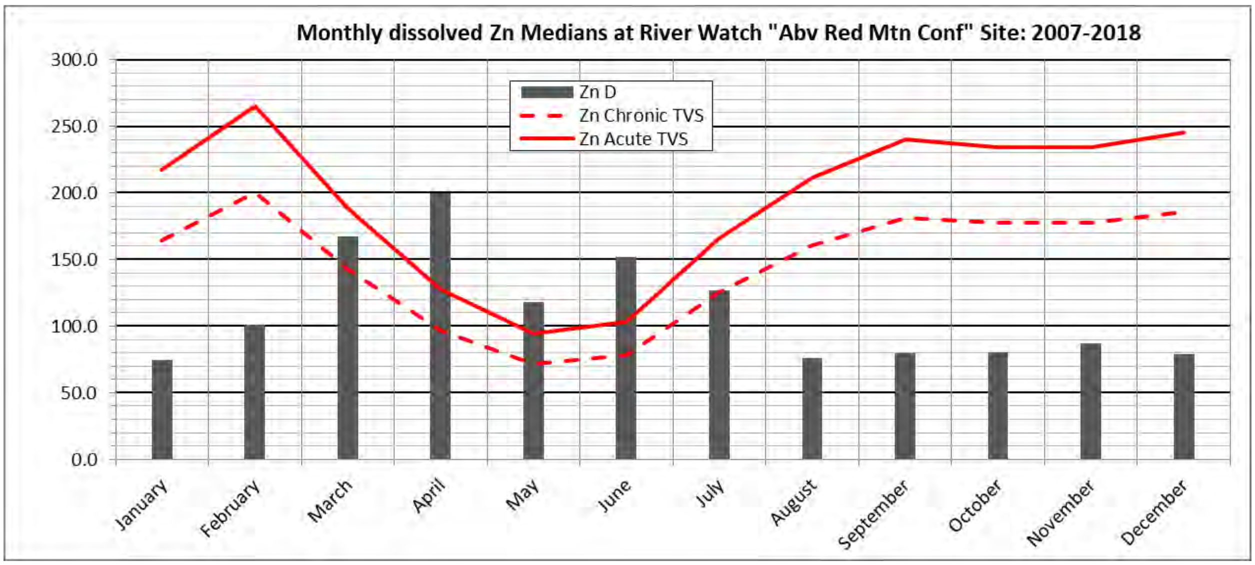

*Figure 12. Median zinc concentrations at **Abv Red Mtn Conf** site, plotted by month for years from 2007 through 2018. Red lines show chronic (dashed) and acute (solid) TVS values.*

The Uncompahgre below the RM Creek confluence is on the 303(d) list of impaired waters for zinc, as are portions of RM Creek and Canyon Creek. As with cadmium and copper the increase in zinc from **Abv RM Conf** to **Abv Hydro Dam** came from the high zinc concentration of RM Creek entering the river. Median zinc concentrations at **Abv Hydro Dam** exceeded chronic and acute TVS in both June and November and the June Canyon Creek (**Campbird Rd**) median was about equal to the June chronic TVS. The monthly medians for 12 years of data from **Campbird Rd** (not shown here) indicated that the chronic TVS for zinc was only exceeded in May and June, due to very low hardness values in these higher flow months. Figure 11 shows that zinc concentration medians in both months declined steadily below **Abv Hydro Dam** but were still greater than chronic TVS at **USGS Gauge**. Below **USGS Gauge** the medians dropped below chronic and acute TVS at the three lowest sites.

At **Abv RM Conf**, as with cadmium and copper, zinc had the opposite trend, compared to all other sites, with a lower concentration in November than in June. The median concentrations at **Abv RM Conf**, by month in Figure 12, show that the higher zinc concentrations began in March, peaked in April, and tapered off after July as flow from snowmelt significantly decreased. This pattern suggests that zinc begins entering the upper Uncompahge at the start of snowmelt and might have a relatively high concentration because flow is still relatively low.

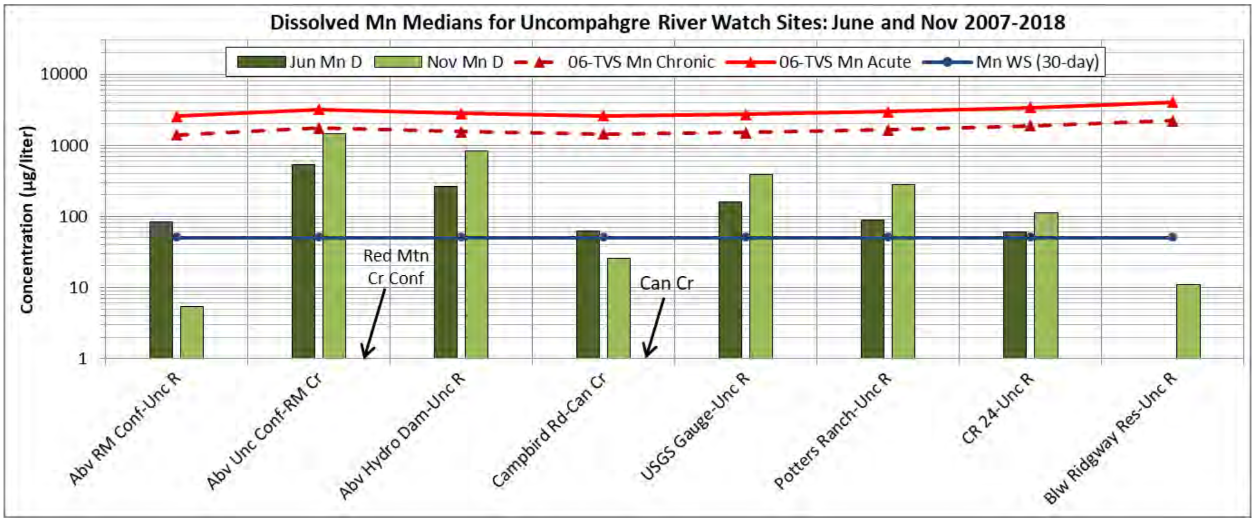

Figure 13. Dissolved manganese medians for June (dark green bars) and November (light green bars) for the eight River Watch sites indicated on the horizontal axis. See locations in Figure 1. The relative locations where RM Creek and Canyon Creek enter the Uncompahgre are shown by the black arrows. Also shown are chronic (dashed lines) and acute (solid lines) Table Value Standards for Aquatic Life in June. The blue line is the Mn standard for Water Supply.

Concentrations then drop in late spring when peak flow is reached. Median concentrations in March through June all exceeded chronic and acute TVS. Note that the highest monthly medians occur in March and April and not June, as indicated in Figure 11. The higher concentrations at high flow suggest that zinc is mainly deposited into the river in enough mass by snowmelt and its runoff to keep concentrations relatively high. This source of zinc during snowmelt is apparently lost in fall and winter where Figures 11 and 12 indicate the lowest concentrations of zinc occur.

Manganese: Upper and lower sections of the Uncompahgre (COGUUN02 and COGUUN03) are on the 303(d) list of impaired streams for manganese, but for Water Supply use, not Aquatic Life use. The EPA standard for manganese is a secondary one, not health-related but more cosmetic in nature (e.g., staining, discoloration, etc.). Dissolved manganese concentration medians for June and November are shown in Figure 13. The June and November differences are like other metals; markedly higher in November compared to June. And as with other metals, the difference is reversed at **Abv RM Conf**. The declining trend in concentration below the RM Creek confluence is also like metals previously discussed. None of the sites reached median concentrations that exceeded chronic or acute TVS for Aquatic Life. However, the water supply standard of 50 µg/liter was exceeded at all sites except **Abv RM Conf** and **Campbird Rd** in November and **Blw Ridgway Res** in June and November.

Lead: The final dissolved metal to be considered is lead. It appears on the 303(d) list for Monitoring and Evaluation (M&E) for the section of the Uncompahgre ending at **Abv RM Conf** (COGUUN02). Lead is on the impaired list of several tributaries of RM Creek and the Uncompahgre but is not listed on the Uncompahgre section below **Abv RM Conf** where the remaining five River Watch sites are located.

Figure 14 shows the median lead concentrations at the eight River Watch sites. Only three medians were greater than 4 µg/liter, and these three higher values were from RM Creek (**Abv Unc Conf**) and **Abv Hydro Dam** below the confluence with RM Creek. These three medians were also the only concentrations that exceeded either the chronic or acute TVS for Aquatic Life. Most lead concentrations at the other six sites were below the lead MDL of 2.4 µg/liter, and therefore the medians, as shown in Figure 14 were also below the MDL.

Iron: Iron, probably the metal for which Red Mountain and RM Creek is most known, is also harmful to aquatic life. At total concentrations above 1000 µg/liter iron precipitates may cover spawning habitat (and eggs),

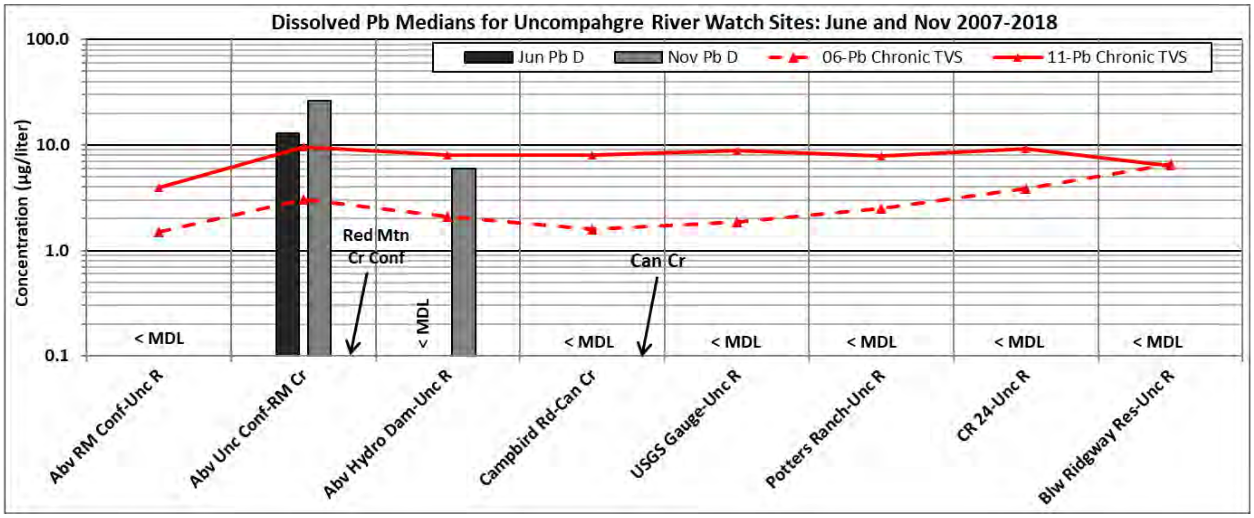

Figure 14. Dissolved lead medians for June (dark gray bars) and November (light gray bars) for the eight River Watch sites indicated on the horizontal axis. See locations in Figure 1. The relative locations where RM Creek and Canyon Creek enter the Uncompahgre are shown by the black arrows. Also shown are the chronic TVS (dashed line) for June and the chronic TVS (solid line) for November.

as well as macroinvertebrate habitat. Iron precipitate is visible on rocks and soil lining the banks of the Uncompahgre at least as far down as **Potters Ranch**. Higher iron concentrations can also impair breathing in fish. For segments of the Uncompahgre represented by the eight River Watch sites there are four different site-specific iron standards (see WQCC Regulation 35). Iron is also found on a 2010 TMDL list for the Uncompahgre from RM Creek to Montrose (COGUUN03); a reason for it not appearing on the 303(d) impaired list. Segment COGUUN03 includes five of the River Watch sites considered here.

Figure 15 displays the median total iron concentrations together with the iron data from June 2015 (a high runoff year). Data from 2014 in Figure 6A show no iron concentrations between Lake Como and **Abv RM**

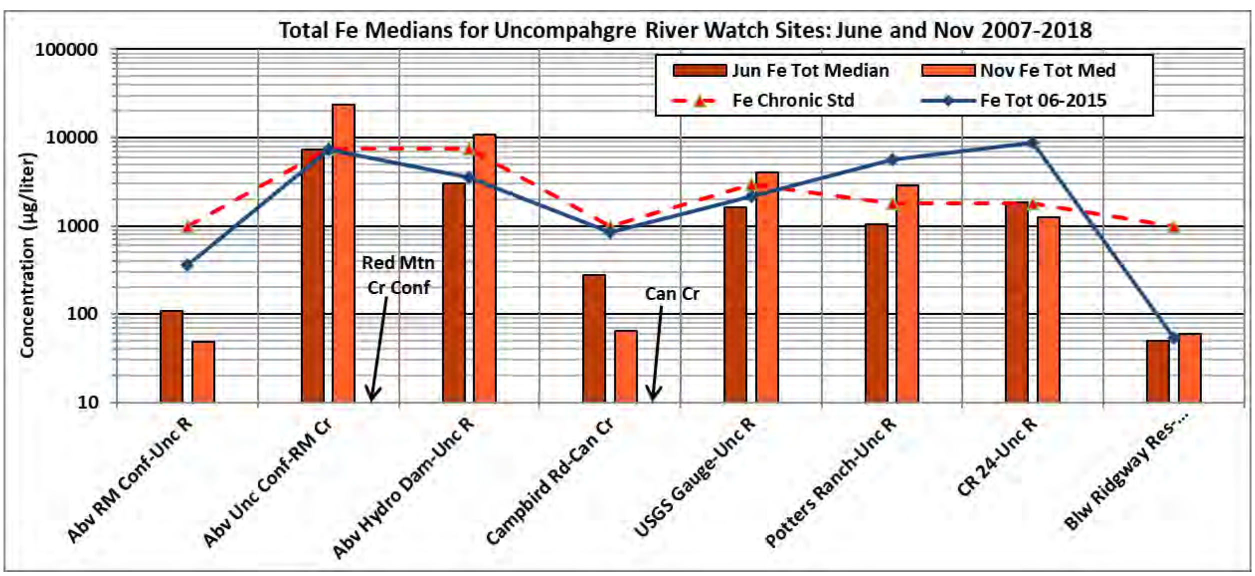

Figure 15. Total iron concentration medians for June (brown bars) and November (orange bars) for the eight River Watch sites indicated on the horizontal axis. See locations in Figure 1. The blue line shows total iron concentration in June 2015. The relative locations where RM Creek and Canyon Creek enter the Uncompahgre are shown by the black arrows. The dashed red line shows the site-specific iron standards for Aquatic Life.

Conf exceeded the Aquatic Life standard of 1000 µg/liter. **Abv RM Conf, Campbird Rd** and the site below the reservoir (**Blw Ridgway Res**) had median concentrations well below their site-specific standard of 1000 µg/liter in June and November. Of the other five sites two, **Abv Unc Conf** and **CR24**, exceeded their site-specific standards in June, and all except **CR24** exceeded the standards in November. As with all the dissolved metals, RM Creek also had the highest total iron concentration in June and November. In contrast, the **Abv RM Conf** median indicates that only a minor part of the iron in the Uncompahgre above the RM Creek confluence comes from the Upper Uncompahgre. This site as well as the Canyon Creek site again show a June median greater than November. The June to November differences from **Abv Unc Conf** to **USGS Gauge** are like several of the dissolved metals, and the decreasing concentration trend from upstream to downstream in November is also like the dissolved metals. The sharp drop below the reservoir indicates much of the total iron settles out in the calm waters of the lake.

The June medians show an interesting increase below **USGS Gauge**. This concentration increase, not seen in the dissolved metals, suggests iron is being added to this section of the river in amounts sufficient to overcome the dilution caused by an increase in flow. Figure 15 shows that this same pattern is present, and more pronounced, in June 2015 data. The higher and more turbulent June flow could be resuspending iron from the streambed, as well as removing iron sediment from rocks and shoreline soil as they become submerged. At low flow yellow to reddish brown sediment is clearly visible on rocks lining the shore between **USGS Gauge** and **Potters Ranch**. The November trend does not show the same increase below **USGS Gauge**, but by this time the water level would have dropped and become less turbulent, and suspended iron particles would have settled onto the rocks and shoreline. Both **USGS Gauge** and **CR24** show a weak but positive correlation between total iron concentration and flow, while dissolved metals like cadmium either show no correlation, or a weak negative correlation.

<u>Aluminum</u>: Aluminum at certain concentrations has been shown to have harmful effects on aquatic life. Woodling (2012) points out the complex nature of aluminum toxicity on several species of fish. Toxicity was

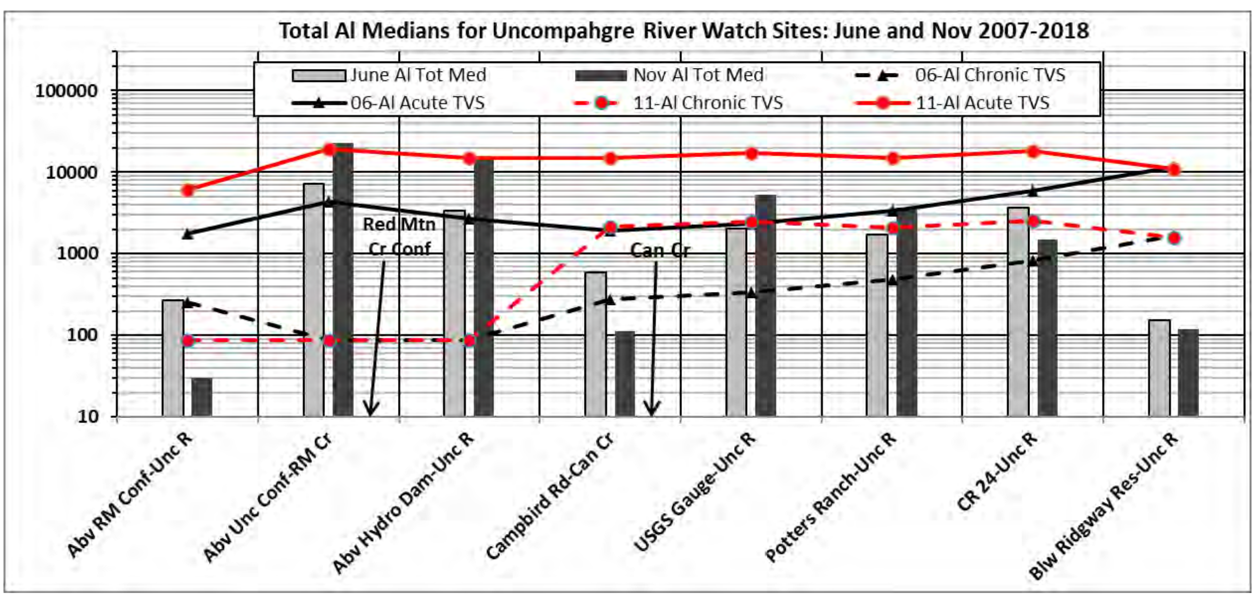

Figure 16. Total aluminum concentration medians for June (light gray bars) and November (dark gray bars) for the eight River Watch sites indicated on the horizontal axis. The relative locations where RM Creek and Canyon Creek enter the Uncompahgre are shown by the black arrows. Dashed lines show the chronic standards for Aquatic Life for June (black) and November (red). Solid lines show the acute TVS for June (black) and November (red).

found to vary with pH level and to have both direct and indirect toxic effects. As with iron, aluminum is not included on the 303(d) list for any segments of the Uncompahgre. Aluminum standards (WQCC Regulation 31) have been adopted for Aquatic Life but have not been applied to any Uncompahgre River segment by Regulation 35. The adopted standards are pH dependent, with different standards applied to water above and below a pH of 7. Although the adopted standards have not been applied to the Uncompahgre, they are compared for reference in Figure 16 to aluminum median values and in Figure A9 to aluminum concentrations measured in July and September 2014.

On the Upper Uncompahgre below Lake Como Figure A9 shows the higher aluminum concentrations were at sites between Lake Como and the confluence with Mineral Creek (Figure A1), all exceeding chronic standards in both July and September. Concentrations declined down to the confluence with RM Creek, but exceeded chronic standards (either high or low pH version) at **Abv RM Conf**. The two Michael Breen mine sites were the only ones where aluminum concentrations were below the chronic standard, and this was due to the higher pH TVS being applicable.

The median concentrations of aluminum for the eight River Watch sites are shown in Figure 16. The longitudinal trends for both June and November are remarkably like those of iron in Figure 15. Similarities include the higher June medians (compared to November) at **Abv RM Conf**, **Campbird Rd** and **CR24**; and the increase in the June median between **USGS Gauge** and **CR24**. Some specific differences are seen at **Abv RM Conf** and **Campbird Rd** where aluminum median concentrations for June exceeded the chronic TVS.

The June median concentrations of aluminum exceeded chronic standards at every site except **Blw Ridgway Res**. The acute TVS for June were exceeded at **Abv Unc Conf** and **Abv Hydro Dam**, again showing the negative impact of contaminated runoff from RM creek. November chronic TVS values were exceeded at the RM Creek site and the first three downstream river sites. As in June the November acute TVS was exceeded by the aluminum medians at **Abv Unc Conf** and **Abv Hydro Dam**.

4. Metal Loading Above and Below Ridgway Reservoir

Ridgway Reservoir functions as a metals' sink for the Uncompahgre River. Woodling (2012) used River Watch and USGS streamflow data from 2002 to 2007 to estimate that 90% of the annual metals load (~ 1.4 million pounds) from the Uncompahgre was trapped in Ridgway Reservoir. Here River Watch and streamflow data from 2003-2018 are used to make similar estimates. Three River Watch sites with collocated USGS stream gauges were used for the calculations: the **USGS Gauge** below Ouray, the **CR24** site below Ridgway, and the **Blw Ridgway Res** site. In addition, the USGS StreamStat program was used to estimate monthly average streamflow at **Abv Unc Conf**. The streamflow estimates combined with River Watch metals data for **Abv Unc Conf** were used to estimate the metal loads entering the Uncompahgre River from Red Mountain Creek.

At each site a metal load in pounds per unit of time can be found by multiplying the metal concentration from River Watch data by the streamflow from the USGS stream gauge, and then multiplying this product by a factor to arrive at the desired units, like pounds per day or pounds per month. A 16-year River Watch data set like the 12-year data set used in Section 3 provided monthly averages of metals' concentrations at each site except **Abv Unc Conf** which only had nine years of data from 2010-2018. A streamflow average can be found using the streamflow recorded at each River Watch sampling event. However, these instantaneous readings taken over a wide variety of times during a month can differ markedly from the monthly average streamflow compiled from all stream gauge readings. So, for a monthly load calculation each average metal concentration was taken from the River Watch data set and the corresponding streamflow average was taken from a table of monthly averages of USGS data for the period from 2003-2018, or from StreamStat results in the case of **Abv Unc Conf**.

One other adjustment was made for aluminum and iron concentrations since River Watch data showed significant correlations between concentration and flow for these two metals at **CR24** and **USGS Gauge**. At **CR24** both iron and aluminum were positively correlated with streamflow, while at the **USGS Gauge** site both metals were negatively correlated with streamflow.

The linear regression equations were as follows:

At USGS	Fe conc = -5.8983 x streamflow + 4630.9	$R^2 = 0.323$	$P < 0.054$
	Al conc = -8.3015 x streamflow + 5254.3	$R^2 = 0.611$	$P < 0.003$
At CR24	Fe conc = 3.1728 x streamflow + 1698.8	$R^2 = 0.298$	$P < 0.067$
	Al conc = 7.1194 x streamflow + 1470.3	$R^2 = 0.462$	$P < 0.016$

R^2 *is a statistical measure of how close the data are to the fitted regression line; 1 a perfect fit and 0 no-fit.*

The level of statistical significance is often expressed as a ***p-value*** *between 0 and 1. The smaller the* ***p-value****, the stronger the evidence that you should reject the null hypothesis (no correlation between the variables). A* ***p-value*** *less than 0.05 (typically ≤ 0.05) is statistically significant.*

Strictly speaking only P-values of 0.05 or less are considered significant, but the two regressions with P-values slightly greater than 0.05 were also used here. For the iron and aluminum load calculations the average monthly concentrations computed from these linear regressions were used in place of the averages determined from River Watch data for each month. None of the other metal concentrations were significantly correlated with streamflow, so the River Watch monthly averages were used for load calculations of cadmium, copper, lead, manganese, and zinc.

Examples of iron and aluminum monthly load averages for sites **CR24** and **Blw Ridgway Res** are shown in Figures 17 and 18. The decreases in loads below the reservoir are obvious where peak loads at **CR24** were roughly 35-38 times peak loads at **Blw Ridgway Res**. It is interesting to note that the three peak load months (June, July, and August) below the reservoir were shifted one to two months later compared to peak load months above the reservoir (May and June). This is likely due to higher controlled releases from the reservoir during the summer irrigation season.

The average annual loads of iron and aluminum above and below Ridgway Reservoir are shown in Figure 19, and Table 2 provides the calculated loads for seven metals. Annual loads above and below the reservoir were obviously dominated by iron and aluminum, and their estimates are the most robust since concentrations were all well above detectable levels and monthly averages were based on relatively large sample sizes. Loads for metals like lead, particularly below the reservoir, have a larger uncertainty because monthly averages were based on smaller sample sizes due to many concentrations being below Method Detection Levels (MDLs).

The annual load results in Figure 19 indicate that the region between **Abv Unc Conf** and **USGS Gauge** is a sink for both iron and aluminum. However, the region between **USGS Gauge** and **CR24** appears to be an additional source for both iron and aluminum. These load results are reasonable considering both streamflow (Figure 2) and iron and aluminum median concentrations (Figures 15 and 16) increased in June between **USGS Gauge** and **CR24**. Woodling (2012), based on data from 2002 to 2007, found the river section between **USGS Gauge** and **CR24** was a source for aluminum, but the same region was an iron sink. The difference in results might be due to either flow or iron concentration differences between the two periods analyzed.

Table 2 indicates that annually aluminum and iron are the only metal loads that increase below the **USGS Gauge** site. In terms of the percentage of metals retained in Ridgway Reservoir the current study produced results like Woodling (2012) for five of the same six metals analyzed. The current study found a lower percentage of cadmium was retained. Table 2 also reveals that 95% of metals entering the reservoir are retained there.

The actual load estimates differed markedly between the current study and Woodling (2012). Table 2

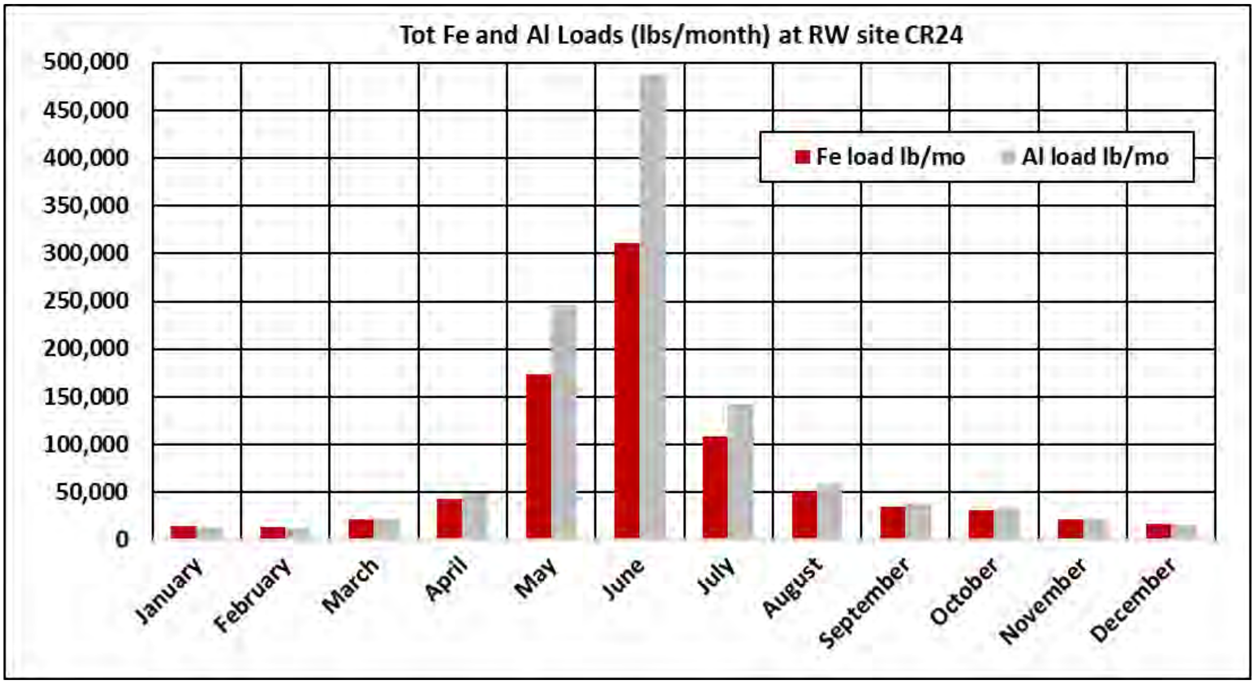

*Figure 17. Iron and aluminum monthly load averages at River Watch site **CR24**. Averages were computed over the period from 2003 to 2018.*

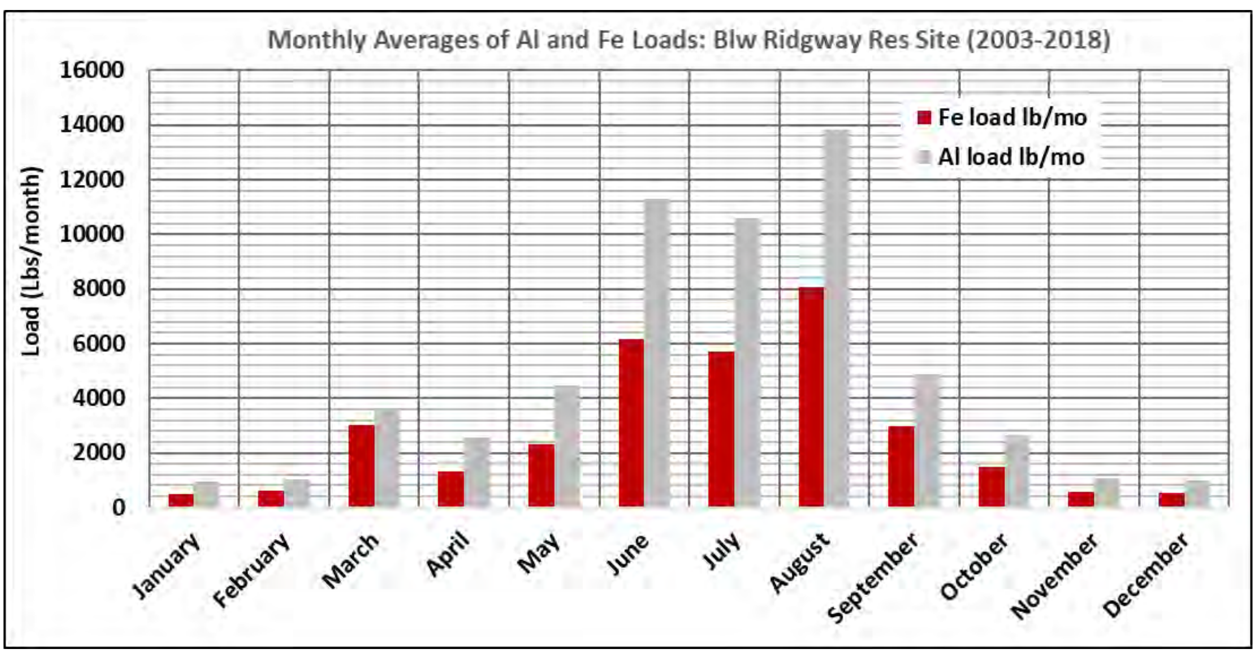

*Figure 18. Iron and aluminum monthly load averages at River Watch site **Blw Ridgway Res**. Averages were computed over the period from 2003 to 2018.*

shows approximately 2.1 million pounds for the total annual load entering the reservoir at **CR24**, while the Woodling (2012) total was about 3 million pounds. The load computations for the period 2002-2007 were re-done in an attempt to duplicate Woodling's totals. The result was an annual load total estimate of 1,923,342 pounds, well below 3 million but quite close to the CR24 total in Table 2 (~8% lower), indicating the load estimates from the current study are reasonable.

5. Summary of Results

Three data sets were used for analyses presented in Sections 3 and 4. First, water quality data from eight River Watch sites in the Uncompahgre River Basin were analyzed over the 12 years from 2007 through 2018. Second, annual metal load estimates in Section 4 were made from River Watch data for the 16 years from 2003 through 2018. Finally, water quality data from special samples collected in 2014 on the Upper Uncompahgre from Lake Como down to the Uncompahgre-Red Mtn Creek confluence were combined with River Watch data below the confluence. Longitudinal displays of the 2014 data appear in Appendix A.

For the 12-year data set the Uncompahgre River sites ranged in location from a point just above the Un-

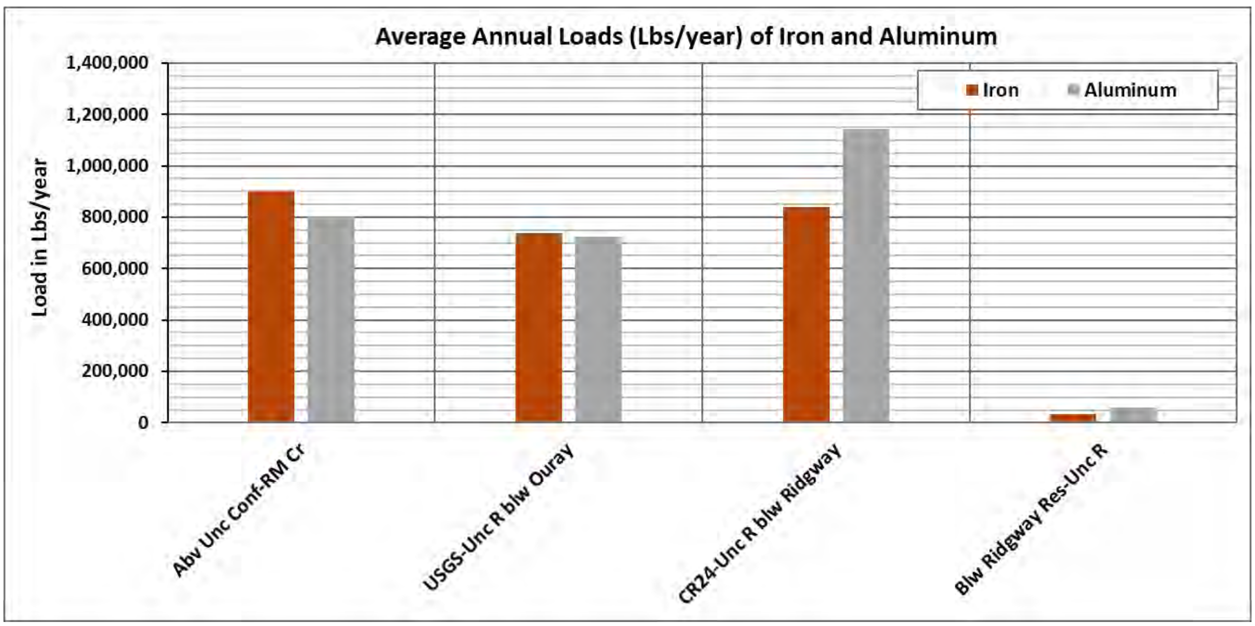

*Figure 19. Bar graph showing the average annual loads of iron and aluminum above (**Abv Unc Conf**, **USGS** and **CR24** sites) and below (**Blw Ridgway Res** site) Ridgway Reservoir. Averages were computed from River Watch monthly concentration averages, or from concentration-flow regression equations, and USGS monthly average stream data or estimates.*

Table 2. Annual metal loads (Lbs) at four River Watch sites. All loads were computed using total concentrations. Data were from 2003-2018 except for Abv Unc Conf where data was from 2010-2018. The Percent Retained results come from comparison of CR24 with Blw Ridgway Res load totals.

River Watch Sampling Site	Iron	Aluminum	Cadmium	Copper	Lead	Manganese	Zinc	Totals
Abv Unc Conf-RM Cr	901,954	803,305	207	38,166	1,911	66,790	49,292	1,861,624
USGS-Unc R blw Ouray	739,735	723,312	447	26,009	3,938	78,798	56,161	1,628,399
CR24-Unc R blw Ridgway	840,189	1,143,039	185	12,940	4,772	63,557	29,798	2,094,479
Blw Ridgway Res-Unc R	33,266	57,873	43	1,796	438	8,578	3,079	105,074
Percent Retained in Reservoir	96.0%	94.9%	76.9%	86.1%	90.8%	86.5%	89.7%	95.0%
Percent from Woodling (2012)	96.0%	94.0%	92.0%	89.0%	92.0%	-	89.0%	

compahgre confluence with Red Mtn Creek to a point about a half mile below the outlet of Ridgway Reservoir, about 23 miles. Two sites were on tributary creeks: one on Red Mtn Creek above the Uncompahgre confluence and one on Canyon Creek above its confluence with the Uncompahgre. The sites ranged in altitude from 9600 ft at the Red Mtn Creek site to 6980 ft at the site below the reservoir. Over this longitudinal section the river streambed changes from a steep narrow gorge lined with large rock and boulders to a flatter, wider stream with a mixture of gravel and finer soil, some deposited from agricultural land. The upper regions of the basin's streams contain drainage from many mines and mine tailings that impact the water quality of the river.

For the first two data sets River Watch data were first compiled for each site over the 12-year or 16-year periods. From the entire database for each site monthly averages and medians of all River Watch water quality parameters were determined. Since averages of relatively small sample sizes are influenced more by extreme values, the monthly median values were chosen to show trends in water quality parameters. (Averages were used for load estimates in Section 4.) Some sites in the upper basin cannot be sampled during the winter, so the monthly medians for June and November were used to represent parameters during relatively high flow (June) and relatively low flow (November). The June and November medians were ordered along the length of the river from high to low elevation and plotted in a series of bar graphs to reveal the longitudinal trends in water quality parameters.

The 2014 data set included samples from July and September. For comparison, the two samples at each site were plotted on the same bar graphs in Appendix A. Comparisons were also made with the lower River Watch sites in Section 3.

<u>The results of pH, alkalinity and hardness analyses are summarized as follows:</u>

- pH medians at the RM Creek site and at the first site below the RM confluence with the Uncompahgre were the most acidic of the sites analyzed and fell below the pH standard for Aquatic Life. This was true in both June and November, although November low-flow medians (3.4 to 4.6) were much lower than June medians (4.4 to 6.4).
- At sites immediately below Lake Como pH values in 2014 ranged from 4 to about 6.3 but increased to values within the standard range at sites just above the confluence with Red Mtn Creek.
- The alkalinity medians at the RM Creek site and at the first site below the confluence were both zero, explaining the large June to November changes in pH where there was no buffering from alkalinity.
- Alkalinity medians increased steadily below the RM confluence as higher alkalinity water entered the river from tributaries, the river flowed over a streambed containing more alkaline soil, and alkaline runoff from irrigation below Ouray entered the river.
- pH medians were generally greater in November, but with greater alkalinity at the lowest four sampling sites, the pH differences between June and November were less than the differences at sites on the upper part of the river.
- Except at the site below Ridgway Reservoir hardness medians were much greater in November compared to June indicating a dilution of the hardness metals by the greater water volume in June. Two examples from the lower part of the river showed a strong correlation between flow and hardness, with higher flow leading to lower hardness.

- The longitudinal view for June, however, showed a steady rise in hardness medians along the river even as flow increased, indicating the metals (Mg and Ca) responsible for hardness were being added to the river at a rate greater than the flow increase.

The results of metals' analyses are summarized as follows:

[*Note: Median metal concentrations were used in this study. The WQCC bases metal standards attainment on the 85th percentile of the* <u>*dissolved*</u> *concentration of metals like Cd, Cu, Pb, Zn and Mn; and the 50th percentile of the* <u>*total*</u> *concentrations of metals like Al and Fe. In the following results,* <u>*medians*</u> *exceeding chronic standards would also have been in non-attainment of the standards.*]

- The highest cadmium concentrations (≥ 10 µg/liter) were found in the 2014 samples (Appendix A) from Poughkeepsie Gulch just below Lake Como. These were much greater than the acute and chronic TVS for aquatic life. Concentrations decreased to slightly greater than 1 µg/liter (> chronic TVS) at the site above the RM Creek confluence.
- From RW samples dissolved cadmium median concentrations were highest (1.6 – 4 µg/liter) at the RM Creek site and the first site below the RM confluence with the Uncompahgre. June and November medians exceeded chronic TVS at both sites and the acute TVS in November. Although many abandoned mines exist in both the upper Uncompahgre and above Canyon Creek, both streams had Cd concentrations much lower than RM Creek. The dilution by these and other streams led to the steady lowering of median cadmium concentrations below the Hydro Dam. The site just below Ouray was the last (lowest) to have median concentrations that were at or above the chronic TVS for aquatic life.
- November median cadmium concentrations exceeded June medians, except at the Uncompahgre site above the RM Creek confluence where the reverse was true.
- From the 2014 samples, copper concentrations at three sites immediately below Lake Como were much higher than both chronic and acute TVS, but then decreased markedly at lower sites, generally below TVS down to the confluence with RM Creek.
- The longitudinal trend for copper was like cadmium, but median concentrations on RM Creek and the site below the confluence were high enough to exceed both chronic and acute TVS in June and November. The dilution by Canyon Creek and other streams also led to the steady decrease in median concentrations down to the reservoir. The site below Ouray was the last (lowest) where the median concentration exceeded the chronic TVS.
- As with cadmium November median copper concentrations exceeded June medians, except at the Uncompahgre site above the RM Creek confluence where the reverse was true.
- 2014 samples had zinc concentrations above chronic and acute TVS from Lake Como down to the confluence with RM Creek. As with cadmium and copper, the highest sites in Poughkeepsie Gulch had the highest concentrations; greater than 1000 µg/liter in both July and September.
- Median zinc concentrations were highest in RM Creek and steadily declined below the Uncompahgre confluence in both June and November. Chronic standards were exceeded at all sites down to **USGS gauge** in June, but only at **Abv Unc Conf** and **Abv Hydro Dam** in November.

- Monthly zinc medians at the upper Uncompahgre site (**Abv RM Conf**) showed concentrations began increasing in March, peaked in April, and exceeded chronic standards from March through July. Acute standards were exceeded in April, May, and June.
- Median manganese concentrations were also highest in RM Creek and declined in June and November at all sites below the confluence. A secondary manganese standard for water supply was exceeded at nearly all Uncompahgre sites above Ridgway Reservoir.
- Lead concentrations were generally below MDLs, leading to median values below detection at all sites except RM Creek (**Abv Unc Conf**) and **Abv Hydro Dam**. The median at RM Creek exceeded both acute and chronic standards in June and November, and the **Abv Hydro Dam** median exceeded the chronic standard in November.
- 2014 data indicated that iron concentrations on the Upper Uncompahgre from Lake Como down to the confluence with RM Creek were nearly all well below the standard for aquatic life.
- River Watch median iron concentrations exceeded the original chronic standard of 1000 µg/liter at all Uncompahgre River sites, except **Blw Ridgway Res**, in June and November. However, the recently adopted site-specific iron standards were only exceeded at **CR24** in June, and at all sites down to **Potters Ranch** in November. The total iron concentration medians at the upper Uncompahgre site (**Abv RM Conf**) and the Canyon Creek site were below the iron standard in June and November.
- The June trend in median iron concentration along the river indicated that iron is resuspended below Ouray leading to higher concentrations even during high flow. During low flow iron concentration medians gradually declined along the river, similar to the trend for dissolved metals.
- Even though the Uncompahgre is not listed as impaired for aluminum, median concentrations at nearly all the Uncompahgre sites exceeded the chronic standard for aquatic life in both June and November. Exceptions were **Abv RM Conf** and **CR24**, where medians were below the chronic standard in November. As with iron the June trend in medians along the river indicated resuspension of aluminum below Ouray, with a higher median at **CR24** compared to **USGS gauge**.

<u>Estimates of metal loads above and below Ridgway Reservoir were made using River Watch metal concentration data and USGS streamflow data and are summarized as follows.</u>

- Aluminum and iron accounted for about 95% of the metal load entering Ridgway Reservoir and about 87% of the load leaving the reservoir.
- Peaks in aluminum and iron loads above the reservoir corresponded to the peak flow months of May, June, and July.
- On an annual basis load estimates indicated the region between Ouray and Ridgway Reservoir is a source for both iron and aluminum. This finding matched iron and aluminum median concentration trends, which both increased during June high flow in this same region.
- Based on 16-year averages of metal concentration and streamflow Ridgway Reservoir retains 96% (806,923 pounds) of the iron and 94.9% (1,085,166 pounds) of the aluminum entering the reservoir.
- Cadmium, copper, manganese, and zinc are retained in the reservoir at percentages between 77% and 91%.
- For the seven metals analyzed, the overall annual metal load entering Ridgway Reservoir was estimated to be 2,094,479 pounds, and that leaving the reservoir was 105,074 pounds, indicating the reservoir retains 95.0% of the total metal load entering the reservoir.

References and Data Sources

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Mize, S. V. and J. R. Deacon, 2002: Relations of Benthic macroinvertebrates to concentrations of trace elements in water, streambed sediments, and transplanted bryophytes and stream habitat conditions in non-mining and mining areas of the Upper Colorado River Basin, Colorado, 1995-98. U. S. Geological Survey, Water Investigations Report 02-4139, Denver, CO.

River Watch data https://coloradoriverwatch.org/

Uncompahgre Watershed Partnership, 2018: Uncompahgre Watershed Plan 2018, http://www.uncompahgrewatershed.org/

USGS streamflow https://waterwatch.usgs.gov/?m=real&r=co

USGS StreamStat program https://www.usgs.gov/mission-areas/water-resources/science/streamstats-streamflow-statistics-and-spatial-analysis-tools?qt-science_center_objects=0#qt-science_center_objects

Water quality data https://www.waterqualitydata.us/portal/

Woodling, John, 2012: Uncompahgre River Water Quality Report 2012, http://www.uncompahgrewatershed.org/

Appendix A. 2014 water quality data from the Upper Uncompahgre, Red Mtn Creek, and the Uncompahgre River

Figure A1 shows locations of water sampling sites in the Upper Uncompahgre Basis for sampling conducted in July and September of 2014. Figures A2 – A8 below combine data collected in 2014 by UWP/WQCD on the Upper Uncompahgre (Poughkeepsie Gulch) with River Watch data collected on Red Mountain Creek and the Uncompahgre below its confluence with Red Mountain Creek. Sites below the confluence are shown in Figure 1. The UWP data were used to evaluate water quality in the Upper Uncompahgre impacted by various metals (from mining and natural sources). One specific objective was to compare metal concentrations upstream and downstream of the Michael Breen Mine (sites UNR-03 and UNR-04). River Watch data were part of a baseline data set collected monthly on Red Mtn Creek and the Uncompahgre River. In all figures the sampling sites are arranged left to right from high elevation to low elevation within the Uncompahgre Basin. Table Value Standards (TVS) for aquatic life computed from hardness-based equations are shown on the graphs of metal concentration.

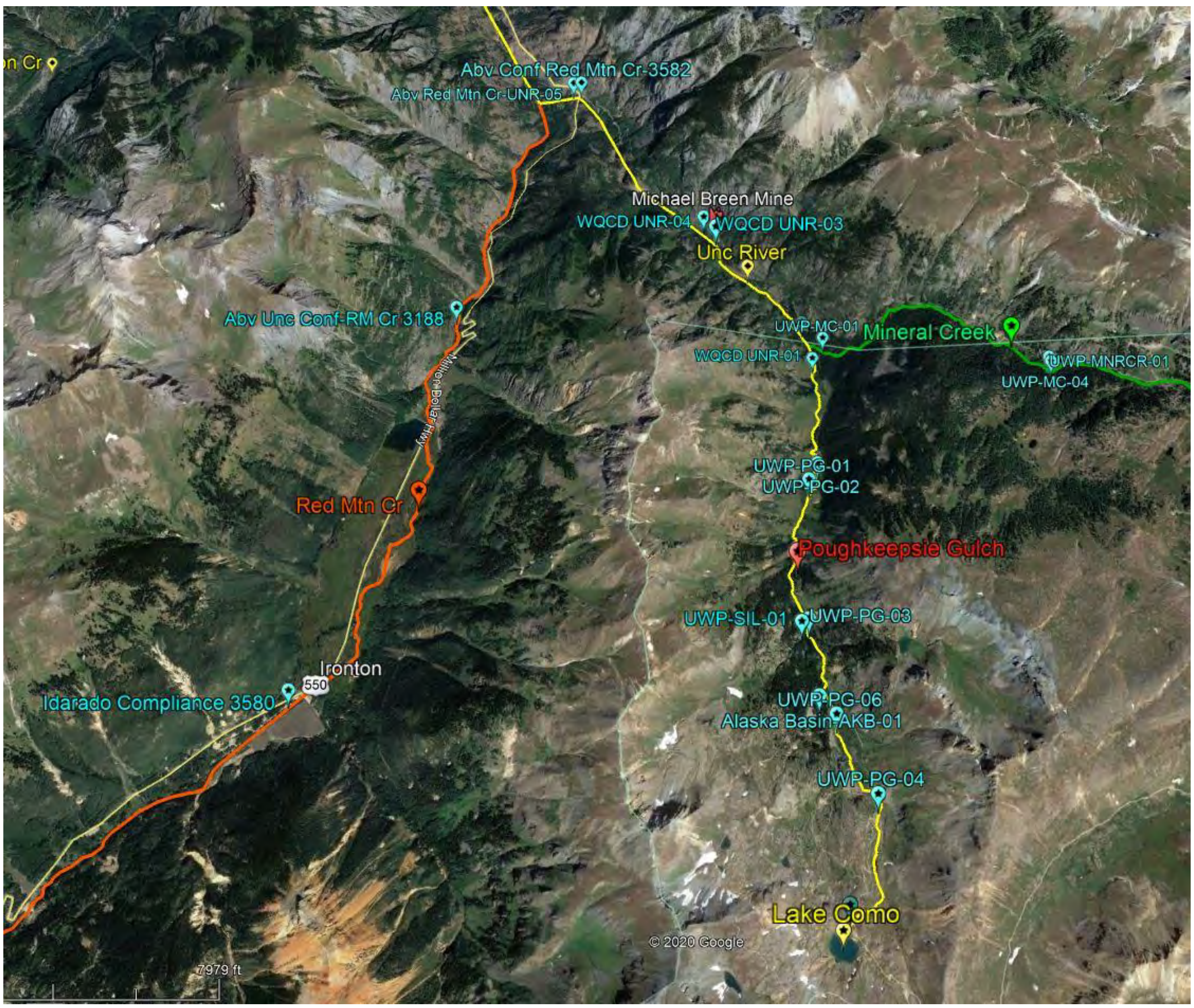

Figure A1. Map of the Upper Uncompahgre Basin south of Ouray, Colorado, from Lake Como to a point just below the confluence of Red Mtn Creek with the Uncompahgre. Uncompahgre River is shown by the yellow line, Red Mtn Creek by the orange line and Mineral Creek by the green line. The sampling sites in Figures A2 – A8 are those shown by blue symbols and labels on the Uncompahgre River.

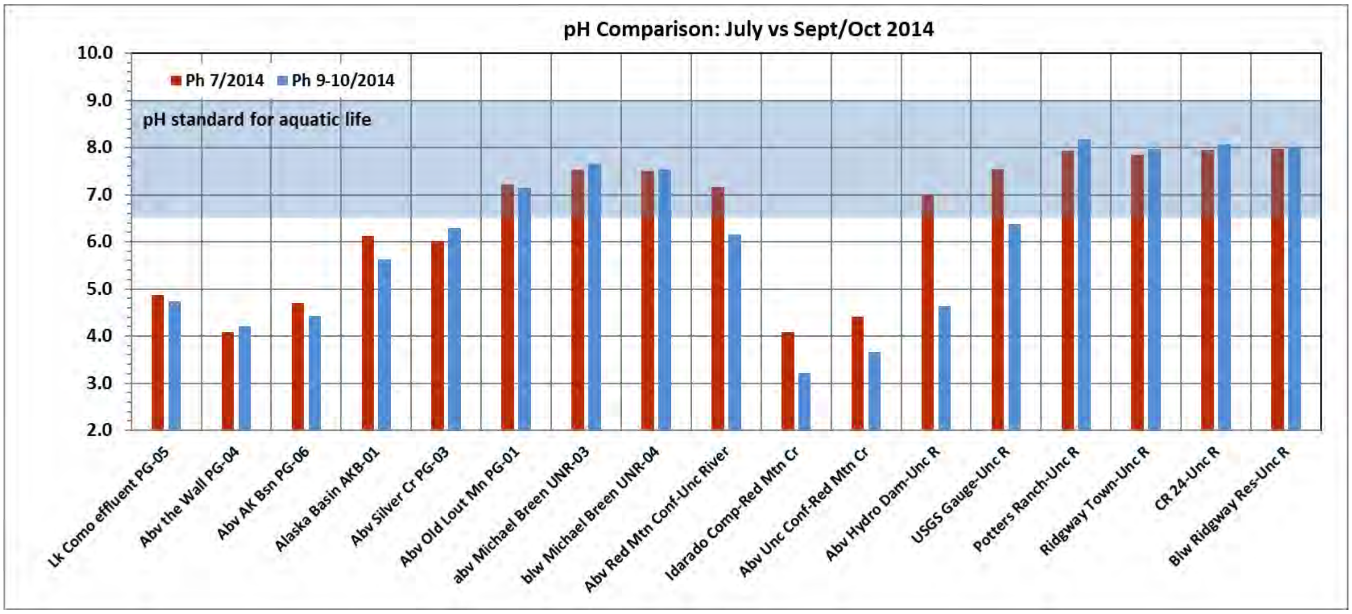

Figure A2. Comparison of pH for 17 sites on the Upper Uncompahgre River, Red Mtn Creek and Uncompahgre River below its confluence with Red Mtn Creek from water samples collected in July and Sept 2014. Left-most site is in Poughkeepsie Gulch just below Lake Como. This and the next eight sites down to the confluence with Red Mtn Creek were sampled by UWP/WQCD. The last eight sites were sampled by River Watch volunteers, where the last on the right is a site just below Ridgway Reservoir. See maps in Figures 1 and A1 for site locations.

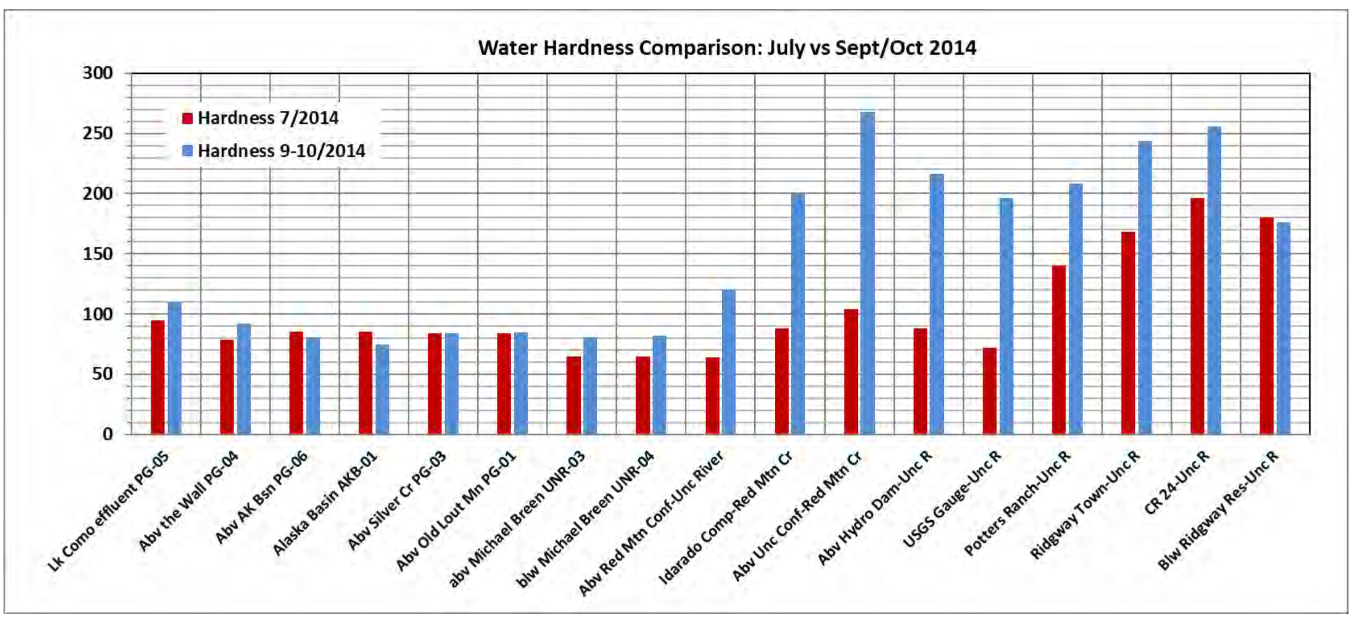

Figure A3. As in Figure A2 except showing a comparison of water hardness in July and September/October 2014.

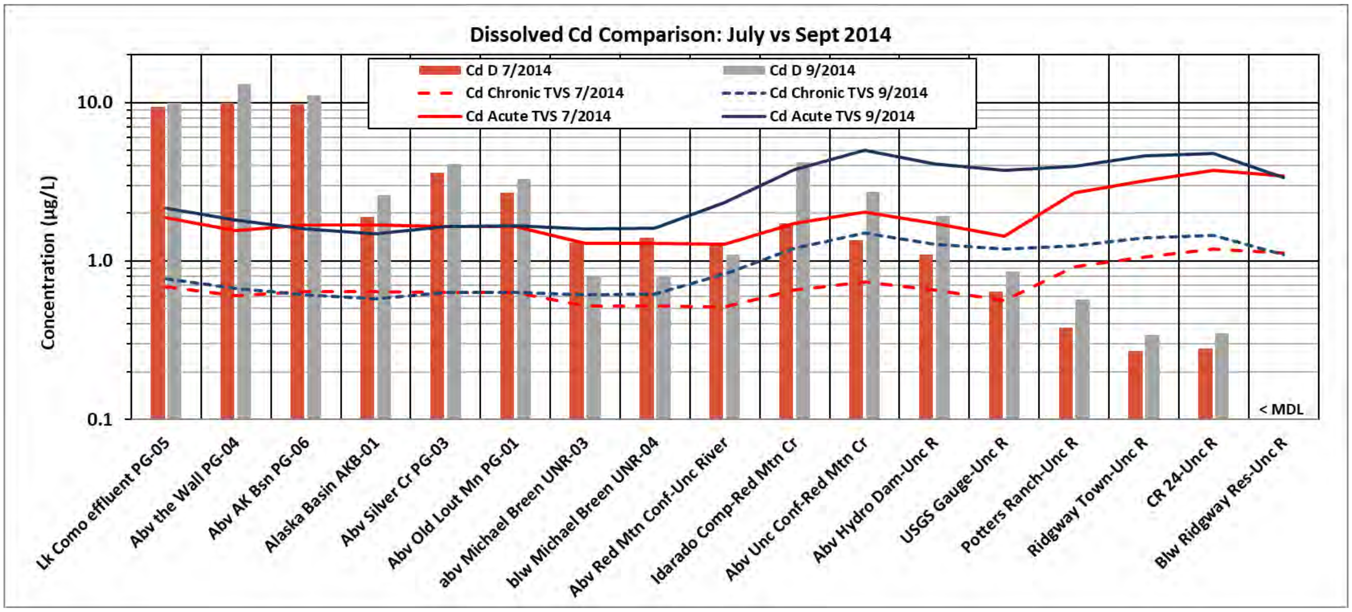

*Figure A4. Comparison of dissolved cadmium (Cd) for 17 sites on the Upper Uncompahgre River, Red Mtn Creek and Uncompahgre River below its confluence with Red Mtn Creek from water samples collected in July and Sept 2014. Chronic and acute TVS for aquatic life are shown by dashed and solid lines. Cd was below the MDL at **Blw Ridgway Res**. See maps in Figures 1 and A1 for site locations.*

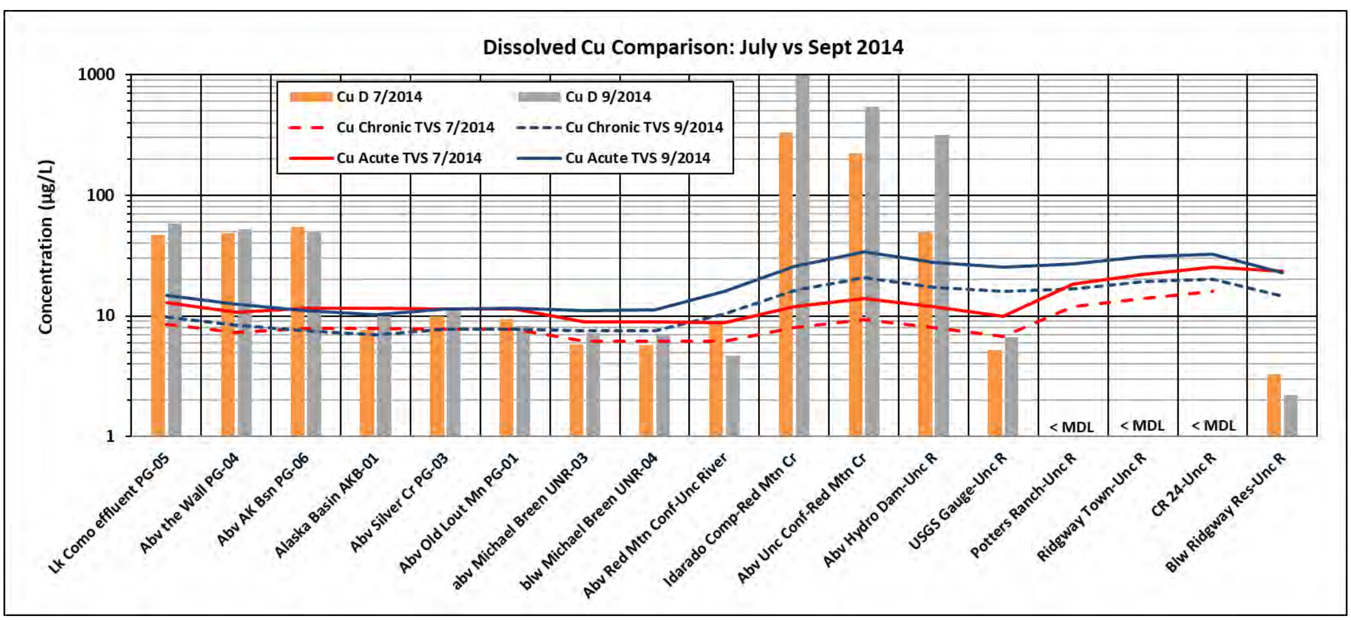

Figure A5. Comparison of dissolved copper (Cu) for 17 sites on the Upper Uncompahgre River, Red Mtn Creek and Uncompahgre River below its confluence with Red Mtn Creek from water samples collected in July and Sept 2014. Chronic and acute TVS for aquatic life are shown by dashed and solid lines. See maps in Figures 1 and A1 for site locations.

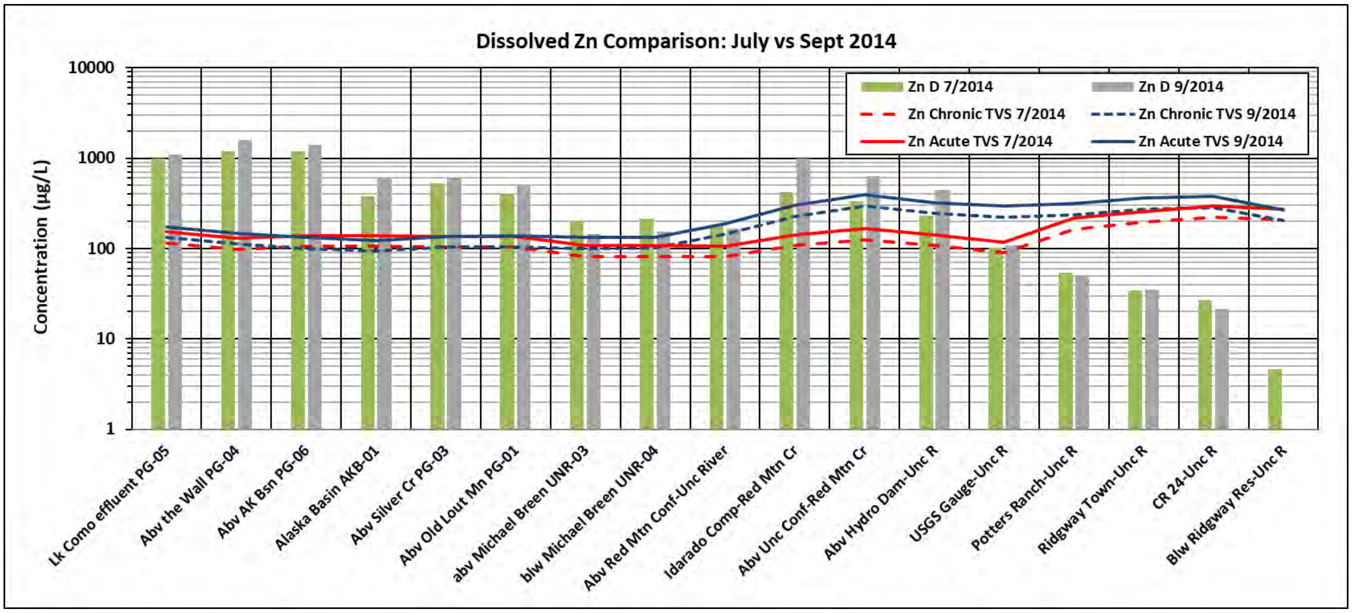

Figure A6. Comparison of dissolved zinc (Zn) for 17 sites on the Upper Uncompahgre River, Red Mtn Creek and Uncompahgre River below its confluence with Red Mtn Creek from water samples collected in July and Sept 2014. Chronic and acute TVS for aquatic life are shown by dashed and solid lines. See maps in Figures 1 and A1 for site locations.

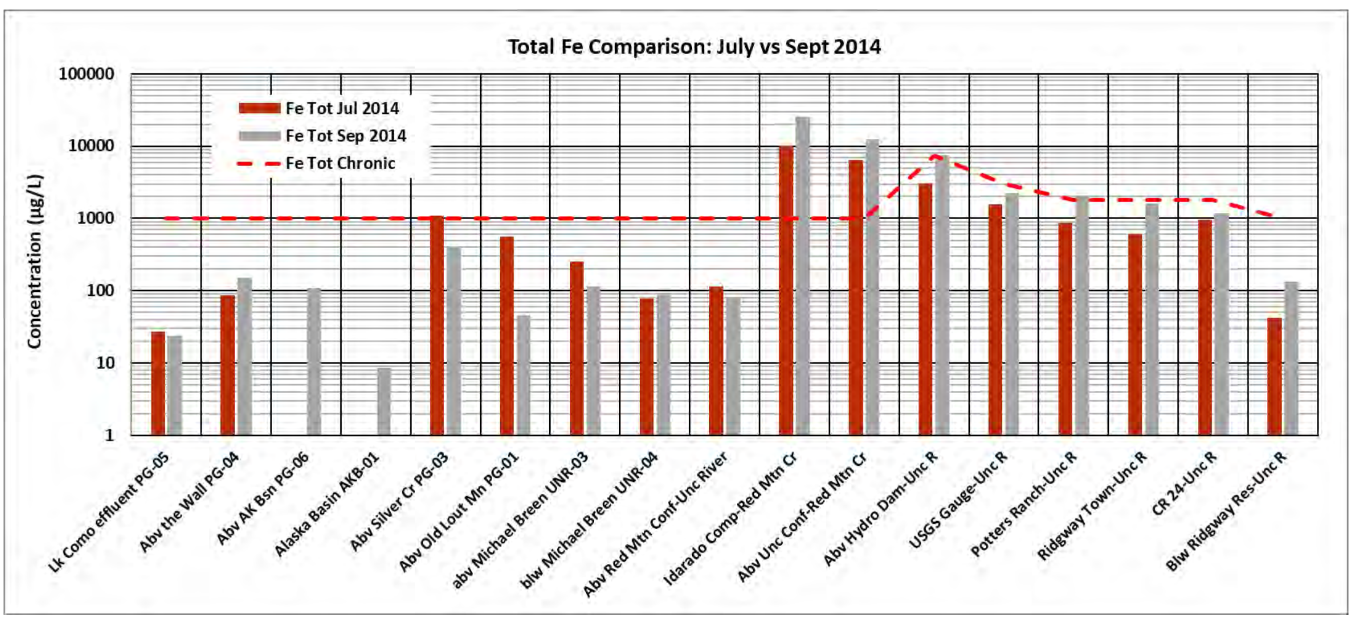

Figure A7. Comparison of total iron (Fe) for 17 sites on the Upper Uncompahgre River, Red Mtn Creek and Uncompahgre River below its confluence with Red Mtn Creek from water samples collected in July and Sept 2014. The Fe standard for aquatic life is shown as the dashed red line. See maps in Figure 1 and A1 for site locations.

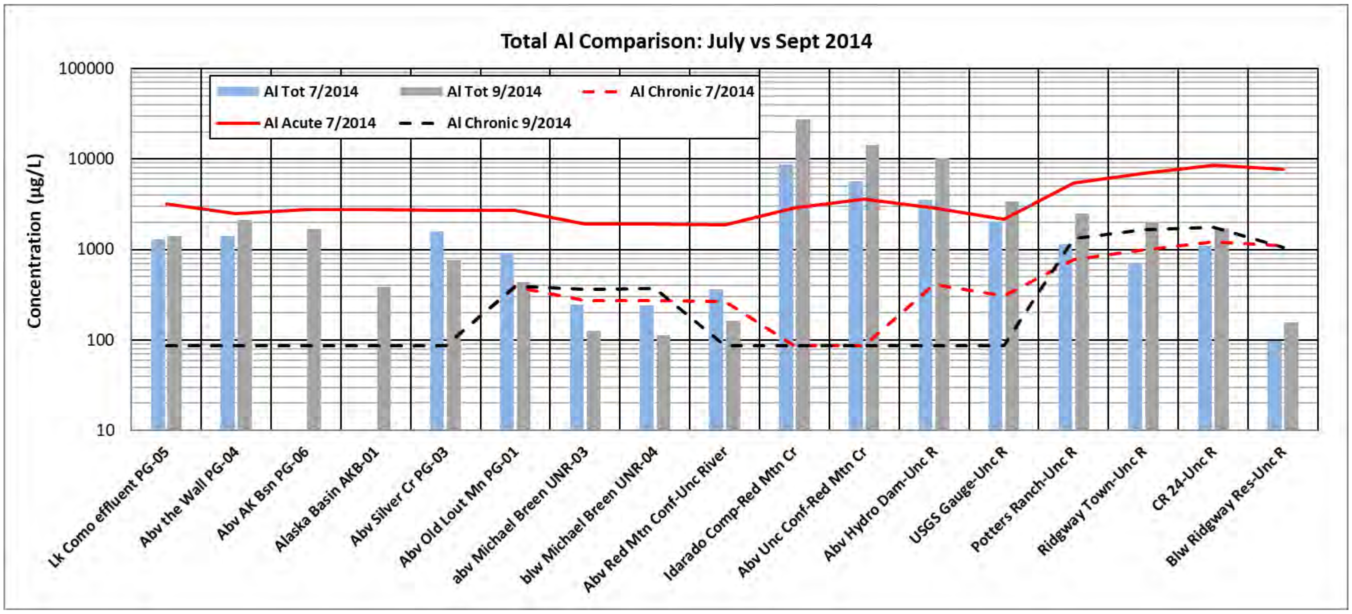

Figure A8. Comparison of total aluminum (Al) for 17 sites on the Upper Uncompahgre River, Red Mtn Creek and Uncompahgre River below its confluence with Red Mtn Creek from water samples collected in July and Sept 2014. Chronic standards (dashed lines) for Al vary with pH; TVS is used where pH ≥7, and for pH < 7 either the TVS or a constant value of 87 µg/liter is used, whichever is less. See maps in Figures 1 and A1 for site locations.