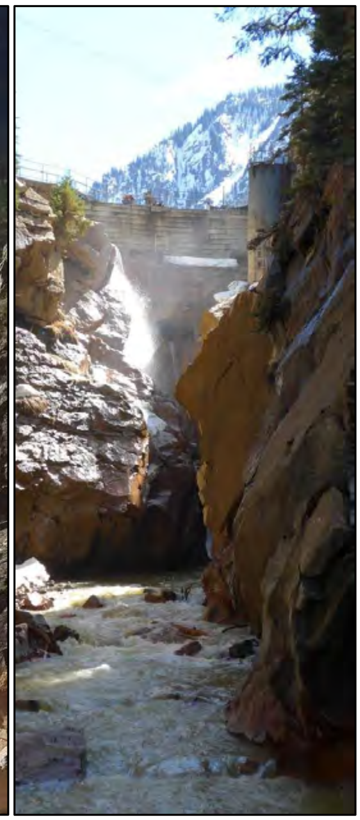
OURAY HYDRODAM MARCH 2017 SEDIMENT RELEASE STUDY: UNCOMPAHGRE RIVER NEAR OURAY, COLORADO



PREPARED FOR THE UNCOMPAHGRE WATERSHED PARTNERSHIP
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1.0 INTRODUCTION

The Ouray Hydroelectric Project (FERC license number 733) is situated in and adjacent to the Uncompahgre River near Ouray, in Ouray County, Colorado. Power has been generated at this site since 1886 and the facilities were built to present form between 1900 and 1902. A concrete and masonry dam spans a narrow gorge of the Uncompahgre River. The dam is 70 feet wide with an effective structural height of 19.7 feet. The dam creates a shallow reservoir that is about 0.48 acres, with a water storage capacity of approximately 0.81 acre-feet at normal full pool elevation.

Water is piped 6,130 feet from the dam to the powerhouse. At the powerhouse, three turbines generate up to 750 kW (total authorized capacity). Currently, the Ouray Hydroelectric Project produces over 4 million kWh of electricity annually. The project operates run-of-river and has a total hydraulic capacity of 40 cfs. After passing through the powerhouse, the water is returned to the Uncompahgre River. The site footprint is 15.35 acres; and 4.25 acres are US Forest Service lands within the Uncompahgre National Forest.

The Uncompahgre River and its steep mountain tributaries transport sediment that accumulates in the reservoir behind the hydrodam. Deposited sediments reduce the water storage capacity of the reservoir and can compromise the productivity of the power generation facilities if sediment obstructs the penstock inlet, which is used to relay water from the reservoir to the powerhouse.

When too much sediment has accumulated in the reservoir, a gate near the bottom of the dam is used to rapidly release water and sediment to the Uncompahgre River; this practice is called sluicing[1]. Sluicing typically occurs in the spring (usually April or May) and continues as needed throughout the spring and summer months. Dam operators are required to follow a notification process to alert and receive approval from designated agencies prior to sluicing. By conferring with Colorado Parks and Wildlife (CPW) and the Colorado Department of Public Health and Environment (CDPHE), dam operators help ensure that sluicing operations will not interfere with brown trout spawning or water quality studies.

The sediment in the upper Uncompahgre Watershed has elevated metal concentrations due to the mineral-rich geology of the area. Historic mining activities, natural erosion processes, and the watershed's topography make the sediment susceptible to transport via streams and rivers.

Although sediment is transported to the reservoir through largely natural processes, there has been public concern that the instantaneous release of the accumulated sediment from the dam may create human-health risks or present an acute environmental risk to downstream aquatic

[1] Dam operators considered mechanical removal of the sediment. Mechanical removal was undesirable due to the disturbance that gravel mining would create in an otherwise quiet and scenic area, potential consequences to changes in the river's bedload, and sediment removal would be far more labor intensive and expensive.

life during sediment releases. In response to public interest, the Uncompahgre Watershed Partnership (UWP) characterized water quality conditions during a sediment release in March 2017.

2.0 LOCAL DRINKING WATER SOURCES

The sections below describe the raw source waters for public drinking water supplies in the study area. This information is intended to provide context regarding the potential risk to public health during sediment release events.

This study did not directly investigate the potential effect of the sediment releases on public water supplies within the study area, private wells, or water supplies downstream of Ridgway Reservoir.

2.1 OURAY

The City of Ouray gathers raw water from the Weehawken Spring (City of Ouray, 2017). The spring is in the Canyon Creek Watershed which is tributary to the Uncompahgre River. Because the spring is upgradient of the Uncompahgre River, the City of Ouray's raw water supply should not be affected by sediment release events from the Ouray Hydrodam.

2.2 RIDGWAY

The Town of Ridgway has four raw water supply sources: Raw Water Reservoirs 3, Happy Hollow, Lake Otonawanda, and Beaver Creek (Town of Ridgway, 2017). Each source is tributary to the Uncompahgre River. Due to the location of Ridgway's raw water sources, the source waters should not be affected by sediment release events from the Ouray Hydrodam.

2.3 LOGHILL MESA AND DALLAS CREEK

The Dallas Creek Water Company supplies water to residents on Loghill Mesa. Raw water is diverted from Dallas Creek. Dallas Creek is a tributary to the Uncompahgre River. Due to it's location the Dallas Creek raw water should not be affected by sediment release events from the Ouray Hydrodam.

2.4 PRIVATE WELLS NEAR THE UNCOMPAHGRE RIVER

The Colorado Division of Water Resources Well Permit Search identified several wells near the Uncompahgre River between Ouray and Ridgway. If these wells are used for drinking water, additional research may be needed to determine each well's susceptibility to contamination from the sediment release events for the Ouray Hydrodam or other sources.

The water quality of private wells is not regulated. The owner of a private well is responsible for assuring that the water is safe for use as a drinking water source. Ouray County can assist to private well owners with water testing.

3.0 Study Questions

The purpose of this study is to better understand water quality conditions and how conditions vary during and following sediment release events, specifically:

- Do stream flows during the sediment release increase at a rate greater than natural flow rate changes?
- How does the sediment release alter metal concentrations in the Uncompahgre River?
- How do metal concentrations, during the sediment release, in the Uncompahgre River vary as distance from the dam increases?
- Do metal concentrations exceed aquatic life standards?
- Do metal concentrations exceed human-health standards (as provided in WQCC Regulation 31)?
- Do metal concentrations during the release exceed metal concentrations typical of natural events (e.g. rising or peak flow conditions or following intense precipitation)?
- Do sediment release events influence aquatic insects?

3.1 Sample Types and Protocols

Surface water, sediment, and macroinvertebrate samples were collected from the Uncompahgre River in March 2017.

Water Quality Samples

Pre- and post-release water quality samples were collected as “grab” samples. During the release, sub-samples were collected and combined into a single composite sample at each location to characterize conditions during the height of the release (see section 2.2). All samples were collected by trained technicians using standard clean hands-dirty hands protocols.

During each sample event, stream temperature, pH, and specific conductance were measured in-situ using a calibrated multi-meter probe. All field notes and parameters were recorded on site.

Water quality samples were collected from the Uncompahgre River at three locations (Figure 1):

- Below Dam: Uncompahgre River downstream of the Ouray Hydrodam: near the end of Ice Park Road, approximately 225 feet downstream of the dam.
- Ouray: Uncompahgre River in Ouray at the USGS gage 09146020; near pedestrian bridge and Chautauqua Lane.
- CR-24: Uncompahgre River north of Ridgway at County Road 24 and USGS gage 09146200.

Water quality samples were submitted to ACZ Laboratories for analysis on April 6, 2017. Metals were analyzed using EPA methods 200.2, 200.7/200.8, 245.1, and 300.0; and Standard Methods 2510B, 2340B, and 4500H+B.

Surface Sediment Samples

Composite surface sediment samples (0 to 0.5 inches) were collected before and after the sediment release. The composite samples were comprised of 12 sub-samples. At each sub-sample location, the sediment corer was inserted to a depth of 12 inches. After the sediment was removed from the corer, the upper 0.5 inch was extracted and added to the composite sample. A GPS point was recorded at each sub-sample location to allow field technicians to return to the sample site following the sediment release event. During the pre-release event, sediment samples were collected approximately 1 foot away from the water's edge to allow the reservoir to fill during the time between sample events. Following the release, technicians used a GPS to return to the sub-sample locations. The post-release samples were collected from nearly identical sub-sample locations.

The sediment samples were collected from the Uncompahgre River in Ridgway Reservoir, near the inlet channel (Figure 1; reservoir). Sediment samples were collected before and after the release on March 18 and March 28, 2017. The sediment samples were submitted to ACZ Laboratories for metal analysis on April 6, 2017.

Macroinvertebrate Samples

Macroinvertebrate samples were collected using a kick net sampler and CDPHE protocols before and after the sediment release on March 18 and March 28, 2017. The macroinvertebrate samples were submitted to Timberline Aquatics for species identification and enumeration on April 17, 2017. Macroinvertebrate samples were collected from:

- Ridgway RW: the Uncompahgre River just north of Ridgway.

Water Quality Reference Data

Local volunteers collect water samples from the Uncompahgre River as part of the River Watch program. Data from two River Watch sites were incorporated into this study; the sites are described below:

- Ouray: the Uncompahgre River in Ouray at the USGS gage 09146020; near pedestrian bridge and Chautauqua Lane.
- CR-24: the Uncompahgre River north of Ridgway at County Road 24 and USGS gage 09146200.

Since 1999, water samples have been collected throughout the year at each site. Water samples are analyzed for several metals and other analytes. Two of the hydrodam study locations were co-located with the River Watch sites to allow for comparison with existing data from the River Watch sites. These comparisons are vital to evaluating the study objectives; however past sediment releases could influence metal concentrations in the River Watch data set. Note, the laboratory analytical methods used by River Watch may differ from the methods used by ACZ in this study. However, the data should be suitable for comparison.

3.2 Sample Collection Timeline

Water quality, sediment, and macroinvertebrate samples were collected before the sediment release to characterize pre-release conditions on March 18, 2017.

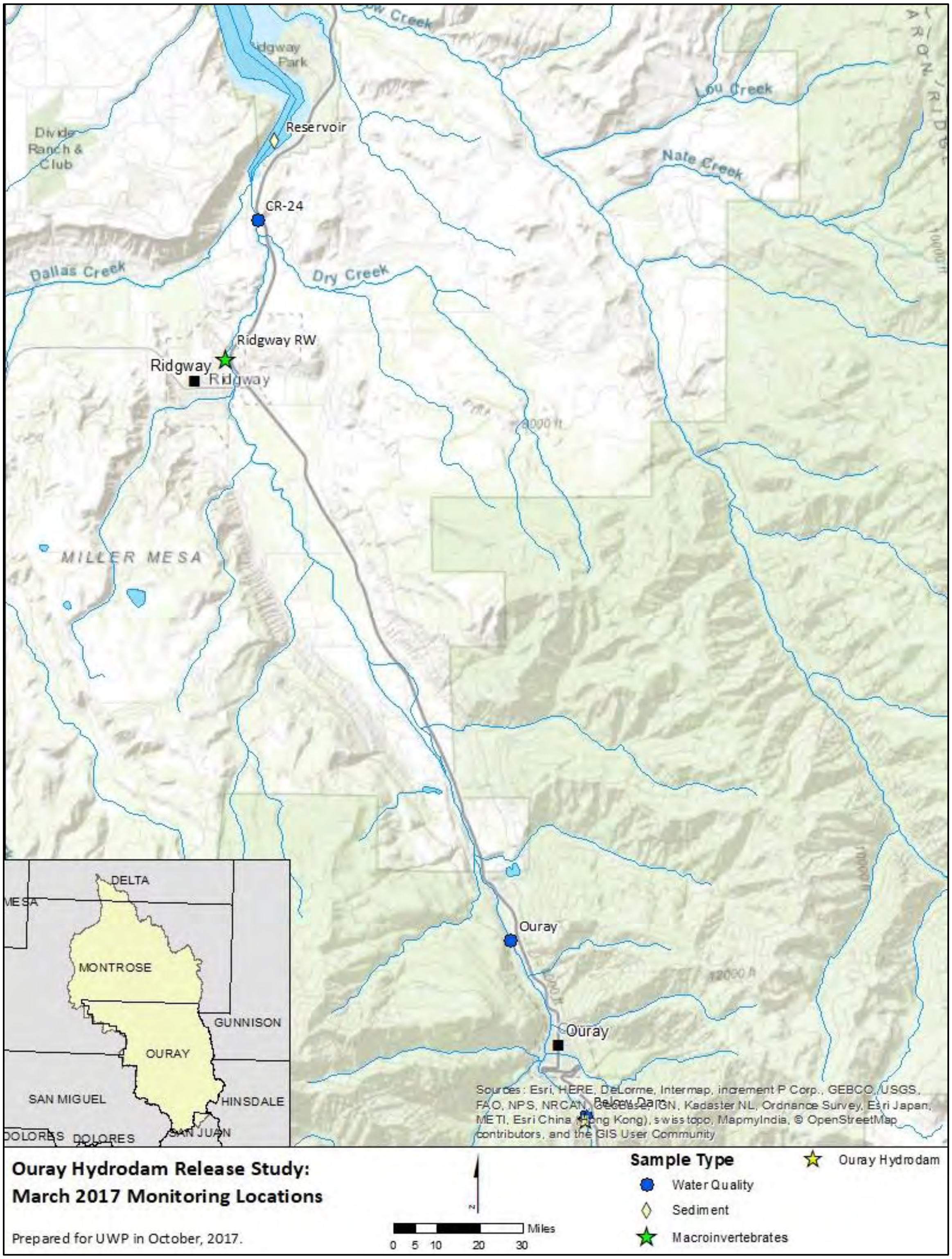
On March 19, 2017 water quality samples were collected from three locations during the release. The goal was to characterize metal concentrations by collecting a composite water sample as the perceived peak of the sediment plume passed through each sample location. Sample collection started below the dam and moved downstream, following the sediment plume.

The dam’s sluice gate was opened at 17:00 on March 19, 2017. Subsamples were collected at the following times and composited into a single sample for each site:

- Below Dam: 17:02, 17:12, and 17:17.
- Ouray: 17:47, 17:52, and 18:07.
- CR 24: 22:40, 22:50, and 23:00.

Water quality, sediment, and macroinvertebrate samples were collected following the sediment release to characterize post-release conditions. Surface water samples were collected on March 31, 2017. Sediment and macroinvertebrate samples were collected on March 28.

Figure 1. Ouray Hydrodam release study sample locations. Sample collection occurred in March 2017 before, during, and after the sediment release. The Ouray Hydrodam is within the Uncompahgre River Watershed in Ouray County, CO. The inset map shows the Uncompahgre River Watershed, which is located primarily in Ouray and Montrose counties and includes a small portion of San Miguel county.



4.0 RESULTS

Surface water and sediment results associated with the study of the March 19, 2017 sediment release are presented in the sections below. The sediment release started at 17:00 hours on March 19, 2017.

4.1 STREAM FLOW

The stream flow assessment has three objectives. First, to characterize how stream flow varied during the release event. Second, to characterize how the peak flow measured during the event varied relative to the preceding day. And third, to evaluate when water quality sample collection occurred relative to when flows peaked during the sediment release.

STREAM FLOW VARIATION NEAR OURAY

In March 2017, stream flow in the Uncompahgre River near Ouray was nearly double median daily flows (Figure 2, faint yellow triangles); indicating that spring snowmelt started earlier than normal.

Immediately prior to the release, at 17:00 hours, stream flow in the Uncompahgre River near Ouray was 141 cfs. During the release, stream flow in the Uncompahgre River near Ouray peaked at 174 cfs at 18:00 hours. The sediment release increased stream flow by approximately 33 cfs. The plume from sediment release took approximately 45-60 minutes to reach Ouray and increased stream flow in the Uncompahgre River near Ouray for less than 30 minutes (Figure 2).

During the sediment release stream flow in the Uncompahgre River near Ouray peaked at 174 cfs at approximately 18:00 hours (Figure 2). The day prior to the release, stream flow peaked at 161 cfs at 19:45 hours in the Uncompahgre River near Ouray. The peak flow measured during the sediment release exceeded the peak flow prior to the release, by 13 cfs, or about 8 percent. During the sediment release, stream flow peaked approximately two hours earlier than typical for mid-March. However, at 18:30 hours steam flow was similar to the flows measured the day before.

The sediment release briefly increased stream flow in the Uncompahgre River near Ouray; but the rate of change and duration did not exceed the rate of change during peak flow or following large precipitation events (i.e. not typical of March conditions, but not likely to be detrimental). For additional context, during peak flow in June 2017, flow varied over 100 cfs within a single day (Figure 3). Because peak flows, and presumably stream power, are likely to be higher in May and June, sediment deposited during early spring release events may be flushed from the stream bed during May or June.

Figure 2. Stream flow in the Uncompahgre River Near Ouray on March 18 (pre-release) and March 19, 2017 (post-release); data provided by USGS Gage 09146020.

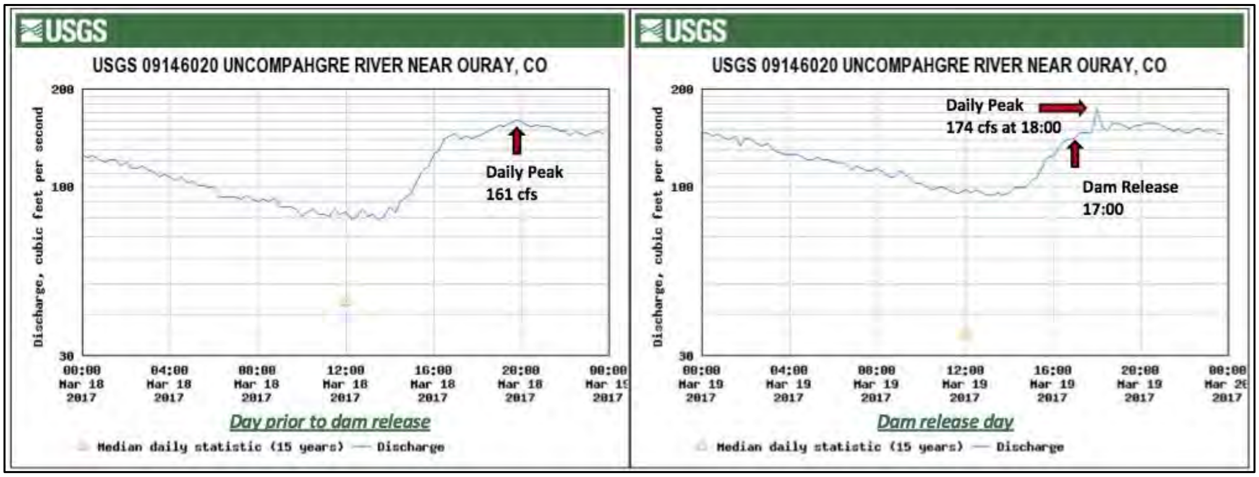
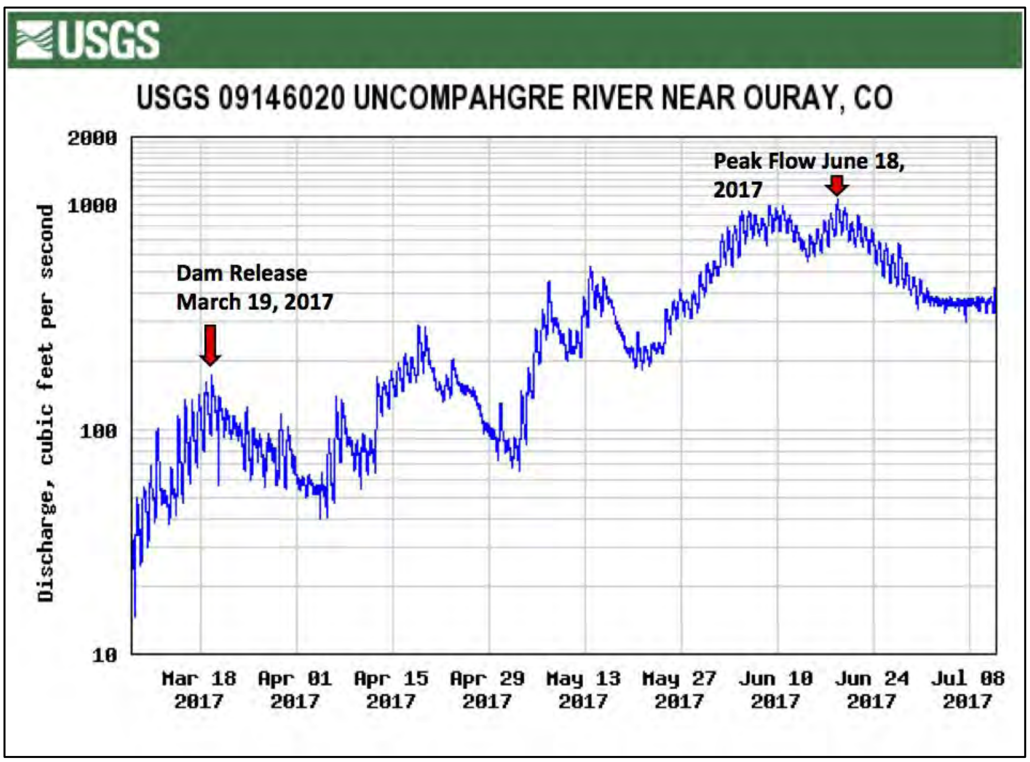


Figure 3. Stream flow in the Uncompahgre River Near Ouray from March to June 2017; data provided by USGS Gage 09146020.

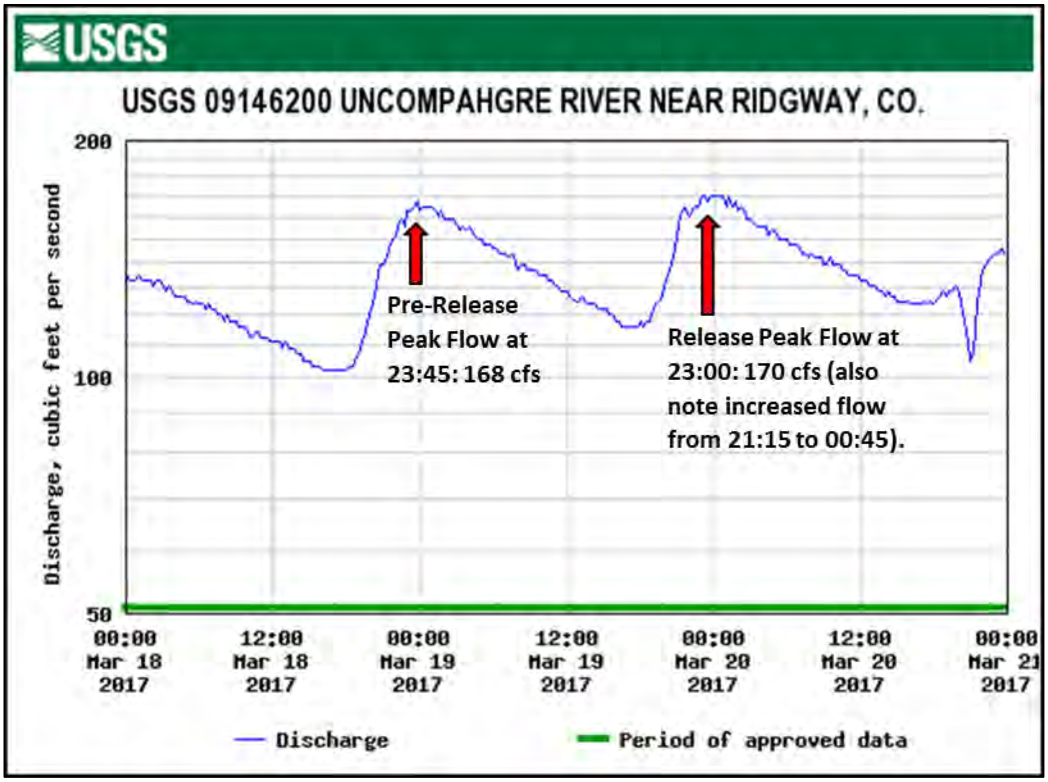


Stream Flow Variation at CR-24 Near Ridgway

In typical years, the median daily flow in the Uncompahgre River near Ridgway is 58 cfs (59-year period of record). On March 18, before the sediment release, stream flow peaked at 168 cfs at 23:45 hours (Figure 4). The daily median flow was well above average indicating that spring snowmelt started earlier than normal.

The plume from the sediment release took approximately 4 hours and 15 minutes to reach the gage near Ridgway. During the sediment release stream flow in the Uncompahgre River near Ridgway was elevated for approximately 3 hours and 30 minutes, from 21:15 to 0:45 hours (Figure 4). As expected the plume was more diffuse in Ridgway than in Ouray (Figures 2 and 4). On March 19, during the sediment release, stream flow peaked at 170 cfs at 23:00 hours, or approximately 45 minutes earlier and 2 cfs higher than the preceding day. The sediment release briefly increased stream flow in the Uncompahgre River near Ridgway; but the rate of change and duration did not exceed the variability of natural events (e.g. following rain on snow).

Figure 4. Stream flow in the Uncompahgre River Near Ridgeway on March 18 (pre-release) and March 19, 2017 (post-release); data provided by USGS Gage 09146020.



Sample Collection Timing: Ouray

The USGS gage provides stream flow measurements in 15-minute increments. In the Uncompahgre River near Ouray, stream flow increased and returned to normal during a 30-minute range between 17:45 and 18:15 hours. Water quality sub-samples were collected at 17:47, 17:52, and 18:07. Sample collection occurred within the range, but may have been slightly early.

Sample Collection Timing: CR-24

In the Uncompahgre River near Ridgway, stream flow increased and returned to normal during a 3.5-hour range between 21:15 and 00:45 hours. Water quality sub-samples were collected at 22:40, 22:50, and 23:00. Sample collection occurred within the range, but samples could have been collected on a longer interval (e.g. 1 hour between each sample) to better capture the entirety of the plume. We understand practical constraints likely dictated sample collection times to some extent.

4.2 Sediment Release Water Quality

Aluminum, iron, and manganese are extremely common components of sediment. During the sediment release, total aluminum, iron, and manganese concentrations increased substantially at all three monitoring locations (Table 1). The increases in total aluminum, iron, and manganese concentrations indicate that a portion of the sediment plume was captured in the composite samples collected from each location. Because of the composite sample method, metal concentrations are a "mixed representation" of the plume, not a peak or median concentration.

Post-release samples were collected on March 31, 2017, twelve days after the sediment release. Stream flows measured in the Uncompahgre River near Ouray and Ridgway returned to normal within hours of the sediment release. Due to the gap between the sediment release and post-release sample collection, post-release metal concentrations may be influenced by other factors.

A review of stream flow data following the sediment release shows a brief period of snowmelt or precipitation that maintained elevated stream flows until March 20, followed by a period of cooling, where additional snowfall likely slowed snowmelt and runoff generation until early April. In late March, stream flow in the Uncompahgre River near Ouray declined more than the Uncompahgre River near Ridgway, due to elevation, which may indicate post-release metal concentrations below the dam and near Ouray are more susceptible to potential changes in chemistry due to the late March weather and flow patterns.

Total metal concentrations are presented first, as changes in the total fraction are more indicative of changes attributed to the release. If the pattern associated with dissolved metal concentrations deviates from total metal concentrations (e.g. total metals rise and fall in response to release event) it may indicate that dissolved metal concentrations were influenced by other factors (e.g. groundwater or surface-based runoff that doesn't entrain sediment).

Uncompahgre River Below Dam

During the sediment release, total metal concentrations increased, in most cases substantially, for all metals (Table 1). Following the sediment release, total metal concentrations measured below the dam returned to pre-release concentrations (Table 1).

Except for iron and manganese, dissolved metal concentrations below the dam remained similar to pre-release conditions or decreased during the sediment release (Table 1). The large instantaneous release of water, used to entrain the sediment, likely accounts for this effect below the dam.

Post-release concentrations of dissolved arsenic, cadmium, nickel, selenium, silver, and zinc returned the concentrations measured prior to the release (Table 1). Following the sediment release, dissolved aluminum, copper, and iron remained elevated. However, other variables were introduced to the post-release data due to the gap between the end of the sediment release and sample collection.

Uncompahgre River Near Ouray

During the sediment release, total metal concentrations increased, in most cases substantially, for all metals (Table 1). Following the sediment release, total metal concentrations measured near Ouray returned to pre-release concentrations (Table 1).

Dissolved metal concentrations near Ouray remained similar to pre-release concentrations or decreased during the sediment release (Table 1). The large instantaneous release of water, used to entrain the sediment, likely accounts for this effect.

Post-release concentrations of dissolved aluminum, arsenic, cadmium, copper, iron, lead, nickel, selenium, silver, and zinc returned the concentrations measured prior to the release (Table 1). Following the sediment release, dissolved manganese remained slightly elevated. However, other variables were introduced to the post-release data due to the gap between the end of the sediment release and sample collection.

Uncompahgre River at CR-24 Near Ridgway

During the sediment release, total metal concentrations increased, in most cases substantially, for all metals (Table 1). Following the sediment release, total metal concentrations measured at CR-24 returned to pre-release concentrations or declined further (Table 1).

Except for manganese and zinc, dissolved metal concentrations near CR-24 remained similar to pre-release concentrations or decreased during the sediment release (Table 1). The large instantaneous release of water, used to entrain the sediment, likely accounts for this effect.

Post-release concentrations of dissolved aluminum, arsenic, cadmium, copper, iron, lead, nickel, selenium, silver, and zinc returned the concentrations measured prior to the release (Table 1). Following the sediment release, dissolved manganese remained slightly elevated. However, other variables were introduced to the post-release data due to the gap between the end of the sediment release and sample collection.

Table 1. Total and dissolved metal concentrations in the Uncompahgre River before (March 18), during (March 19), and after (March 31) the Ouray Hydrodam sediment release on March 19, 2017.

Parameters[1]	Time	Below Dam		Ouray		CR-24	
		Total	Dissolved	Total	Dissolved	Total	Dissolved
Aluminum (ug/L)	Before	4,330	8	2,480	29	2,610	36
	During[2]	21,100	1 (J)[3]	32,500	12	9,720	29
	After	4,440	76	2,230	32	1,410	38
Arsenic (ug/L)	Before	2.6	U[4]	2.1	0.3 (J)	4.3	1
	During	43.8	0.6 (J)	31.5	U	9.9	0.7 (J)
	After	2.4	U	1.8	0.3 (J)	3.2	1.7
Cadmium (ug/L)	Before	2	1.8	1.1	0.8	0.6	0.2 (J)
	During	6.1	U	4.1	0.5	1.8	0.3 (J)
	After	1.9	2	1.1	0.9	0.5	0.3 (J)
Copper (ug/L)	Before	165	13.7	82.4	4	69.2	2.9 (J)
	During	465	U	711	3	312	3.4
	After	189	86.6	110	4.8	39.2	3.2
Hardness (mg/L as CaCO3)	Before		158		186		231
	During	N/A	152	N/A	149	N/A	210
	After		184		215		288
Iron (ug/L)	Before	4,210	284	2,280	U	2,920	U
	During	64,300	1,690	41,500	U	10,200	4 (J)
	After	3,850	517	1,980	6 (J)	1,250	6 (J)
Lead (ug/L)	Before	9.9	U	6.1	U	7.3	U
	During	309	U	177	U	29	U
	After	8.7	U	4.9	U	3.4	U
Manganese (ug/L)	Before	484	440	285	254	175	118
	During	1,940	1,390	1,720	184	398	149
	After	625	585	346	321	173	145
Nickel (ug/L)	Before	5.9	5.7	3.3	3	2 (J)	1.5 (J)
	During	8.2	3.1	13.1	1.9 (J)	4.5	1.4 (J)
	After	7.3	7.2	3.6	3.4	1.9 (J)	1.6 (J)
Selenium (ug/L)	Before	0.3	0.1 (J)	0.3	0.2 (J)	0.6	0.4
	During	0.8	U	0.7	0.2 (J)	0.5	0.4
	After	0.2 (J)	0.2 (J)	0.3	0.3	0.7	0.7
Silver (ug/L)	Before	U	U	U	U	0.06 (J)	U
	During	3.46	U	1.69	U	0.33	U
	After	U	U	U	U	U	U
Zinc (ug/L)	Before	464	411	249	129	124	45
	During	605	174	1,150	116	520	83
	After	442	442	251	118	114	36

Notes:

1. Selected parameters (alkalinity, bicarbonate, calcium, chromium, magnesium, mercury, uranium, sulfate) were omitted due to a large number of undetected or estimated results.
2. Composite samples were collected during the sediment release. Grab samples were collected before and after the sediment release.
3. (J) indicates the parameter was present below quantification limit and is reported as an estimated value.
4. U indicates the parameter was not detected.

4.3 Water Quality Reference Data

Water quality data collected during the March 2017 sediment release study was compared to existing data collected from the Uncompahgre River near Ouray and the Uncompahgre River near Ridgway. The purpose of the evaluation is to better understand how metal concentrations during the sediment release compares to the range of metal concentrations measured at each site during the last 15 years. <u>Metal concentrations measured during monthly sample events could have been increased by past sediment releases, but the timing of past releases was not investigated.</u>

Total aluminum, iron, and manganese were used in the reference data analysis because these metals produced a strong signal during the March 2017 sediment release. Total manganese concentrations are presented below. Based on limited investigation, other metals tended to follow a similar pattern.

Uncompahgre River Near Ouray

Total manganese concentrations measured before and after the sediment release were lower than typically measured in March (Figure 5). Which may be a result weather and stream flow patterns in March 2017.

The total manganese concentration measured during the sediment release was approximately two times higher than typical peak manganese concentrations and about three times the total manganese concentration typically measured in March (Figure 5).

Uncompahgre River at CR-24 Near Ridgway

Total manganese concentrations measured before and after the sediment release were similar to concentrations typically measured in March (Figure 6). The total manganese concentration measured during the sediment release was approximately half the typical peak manganese concentrations, but almost double manganese concentrations typically measured in March (Figure 6).

Figure 5. Total manganese in ug/L by month in the Uncompahgre River near Ouray: 1999 to 2015 (data source: River Watch).

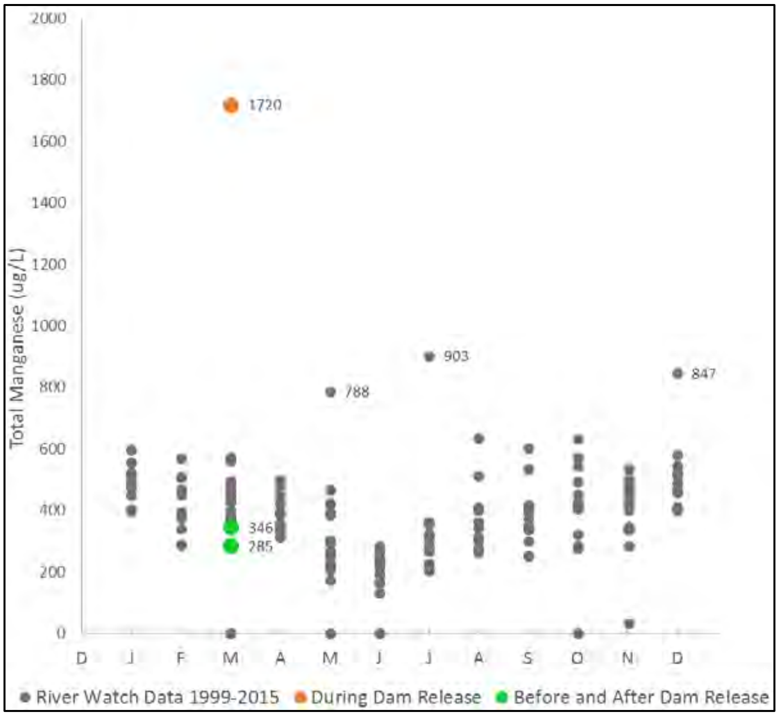
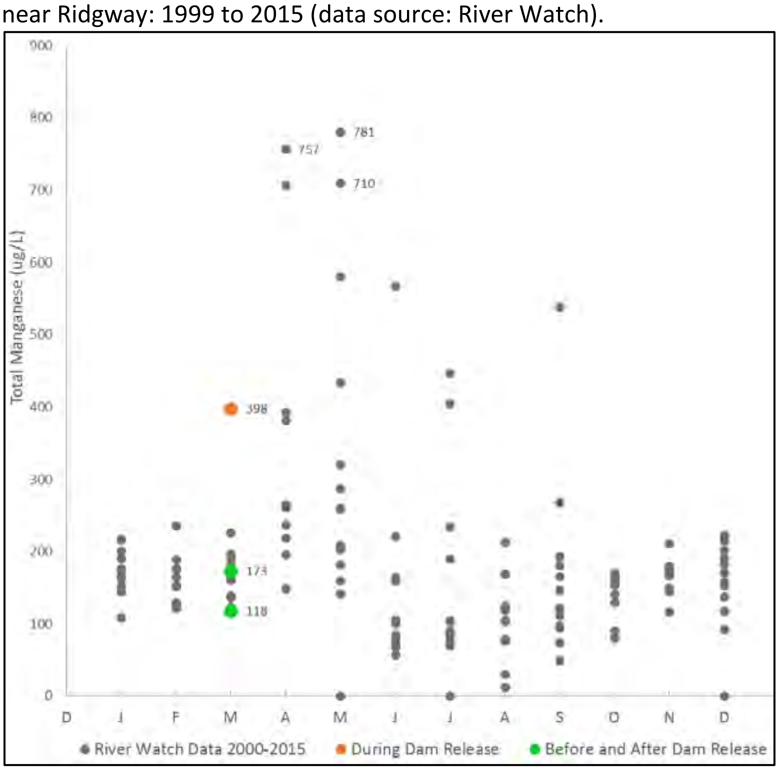


Figure 6. Total manganese in ug/L by month in the Uncompahgre River near Ridgway: 1999 to 2015 (data source: River Watch).



4.4 Water Quality Standards

Colorado recognizes several beneficial water uses. Aquatic life, recreation, agriculture, and water supply uses apply to the Uncompahgre River segments associated with this study. Each of these use classifications has specific water quality standards for multiple parameters. The most conservative criteria (i.e., lowest value) among all beneficial uses for a waterbody is applied as the effective standard for each parameter (e.g., pH, temperature, lead, etc.). This approach assures the protection of all water uses because the beneficial use with the most conservative criteria is applied as the standard. In the Uncompahgre River Watershed, the numeric standards associated with aquatic life, water supply, or human-health in the case of arsenic, are typically the lowest (i.e., most conservative) and are therefore applied for many parameters. Aquatic life standards are typically based on dissolved metal concentrations.

The criteria to protect aquatic life generally have an acute and chronic standard for each parameter. Chronic standards represent those conditions that can cause stress in aquatic organisms during prolonged or repeated exposures and result in physical abnormalities, impaired growth, reduced survival, and lowered reproductive success. Acute standards represent those conditions that can cause extreme stress during instantaneous or brief exposures and result in sub-lethal and lethal effects on aquatic life. This approach requires an understanding of both the species expected in a given waterbody and the tolerance of those species to various water quality parameters. The chronic and acute standards are designed to protect 95 percent of the genera in a given waterbody (WQCC, 2017). Colorado relies on guidance from Federal, State and local scientists to establish these standards which are reviewed on a regular basis. Because chronic standards are designed to prevent problems associated with long term exposure to parameters, the concentration of a chronic standard is always lower than the concentration of the acute standard, which is designed to prevent lethal effects. If the concentration of a given parameter exceeds the applicable standard the quality of the water is not protective of the given use, and is presented as “No” in Tables 2 to 4.

Uncompahgre River Below Dam

During the sediment release, total arsenic concentrations exceeded the water supply standard (Table 2). Dissolved cadmium concentrations exceeded the chronic standard before and after the sediment release. Dilution provided during the sediment release allowed the Uncompahgre River below the dam to attain the chronic standard for a brief time (Table 2). Dissolved zinc and copper concentrations followed a similar pattern. However, dissolved copper concentrations were elevated following the release, which may be attributed to other factors due to the timing of post-release sample collection.

Manganese concentrations measured before, during, and after the release were greater than the water supply standard (Table 2).

Uncompahgre River Near Ouray

During the sediment release, arsenic concentrations exceeded the human-health and raw water supply standards (Table 3). The manganese water supply standard was exceeded before and after the sediment release. During the release, dilution decreased manganese concentrations to less than the standard for a brief time (Table 3). Other metals attained the standards before, during, and after the sediment release.

Uncompahgre River at CR-24 near Ridgway

During the sediment release, total arsenic exceeded the human-health criterion (Table 4). All other metals attained the standards before, during, and after the sediment release.

Table 2. Water quality standards summary for **the Uncompahgre River below the dam** before, during, and after the March 2017 sediment release. Results and standards are dissolved concentrations in ug/L, unless otherwise noted.

Parameter		Before		During		After	
		chronic	**acute**	**chronic**	**acute**	**chronic**	**acute**
Arsenic (chronic= water supply, acute= aquatic life)	Result	2.6 (T)[1,2]	U	43.8 (T)	0.6	2.4 (T)	U
	Standard	0.02-10	340	0.02-10	340	0.02-10	340
	Attainment	Yes[3,4]	Yes	**No**	Yes	Yes	Yes
Cadmium[5]	Result	1.8		U		2	
	Standard	1.0	2.8	1.0	2.7	1.1	3.2
	Attainment	**No**	Yes	Yes	Yes	**No**	Yes
Copper	Result	13.7		U		86.6	
	Standard	13.2	20.7	12.8	19.9	15.1	23.9
	Attainment	**No**	Yes	Yes	Yes	**No**	**No**
Lead	Result	U		U		U	
	Standard	4.1	105.9	4.0	101.6	4.9	124.6
	Attainment	Yes	Yes	Yes	Yes	Yes	Yes
Manganese	Result	440		1,390		585	
	Standard	1,921	3,477	1,896	3,433	2,021	3,658
	Attainment	Yes	Yes	Yes	Yes	Yes	Yes
	WS Standard[6]	200		200		200	
	Attainment	**No**		**No**		**No**	
Selenium	Result	0.1		U		0.2	
	Standard	4.6	18.4	4.6	18.4	4.6	18.4
	Attainment	Yes	Yes	Yes	Yes	Yes	Yes
Silver	Result	U		U		U	
	Standard	0.2	4.5	0.2	4.2	0.2	5.8
	Attainment	Yes	Yes	Yes	Yes	Yes	Yes
Zinc	Result	441		174		442	
	Standard	184	243	177	234	211	279
	Attainment	**No**	**No**	Yes	Yes	**No**	**No**

Notes:

1. All standards are to protect aquatic life and based on the dissolved fraction unless otherwise noted by (T).
2. Where appropriate standards were calculated using paired hardness (dissolved $CaCO_3$).
3. "Yes" indicates the result attained the standard, "No" indicates the result exceeded the standard. The Colorado Water Quality Control Division evaluates water quality data to determine formal attainment with applicable water quality standards. Official attainment information is provided in WQCC Regulation 93.
4. The arsenic standard is a range, where the first number is the human-health standard and the second number is the maximum contaminant level for public drinking water supplies. A waterbody is considered in attainment of the arsenic standard when concentrations remain less than 10 ug/L. A temporary modification is applied for arsenic.
5. Cadmium standard calculated using the 2016 equation.
6. WS= water supply standard

Table 3. Water quality standards summary for **the Uncompahgre River near Ouray** before, during, and after the March 2017 sediment release. Results and standards are dissolved concentrations in ug/L, unless otherwise noted.

Parameter		Before		During		After	
		chronic	acute	chronic	acute	chronic	acute
Arsenic (chronic= water supply, acute= aquatic life)	Result	2.1 (T)[1,2]	0.3	31.5 (T)	U	1.8 (T)	0.3
	Standard	0.02-10	340	0.02-10	340	0.02-10	340
	Attainment	Yes[3,4]	Yes	**No**	Yes	Yes	Yes
Cadmium[5]	Result	0.8		0.5		0.9	
	Standard	1.1	3.2	1.0	2.6	1.3	3.7
	Attainment	Yes	Yes	Yes	Yes	Yes	Yes
Copper	Result	4		3		4.8	
	Standard	15.2	24.1	12.6	19.6	17.2	27.6
	Attainment	Yes	Yes	Yes	Yes	Yes	Yes
Lead	Result	U		U		U	
	Standard	4.9	126	3.9	99.4	5.7	147
	Attainment	Yes	Yes	Yes	Yes	Yes	Yes
Manganese	Result	254		184		321	
	Standard	2,028	3,671	1,884	3,410	2,129	3,853
	Attainment	Yes	Yes	Yes	Yes	Yes	Yes
	WS Standard[6]	200		200		200	
	Attainment	**No**		Yes		**No**	
Selenium	Result	0.2		0.2		0.3	
	Standard	4.6	18.4	4.6	18.4	4.6	18.4
	Attainment	Yes	Yes	Yes	Yes	Yes	Yes
Silver	Result	U		U		U	
	Standard	0.2	5.9	0.1	4.0	0.3	7.6
	Attainment	Yes	Yes	Yes	Yes	Yes	Yes
Zinc	Result	129		116		118	
	Standard	213	281	174	230	243	321
	Attainment	Yes	Yes	Yes	Yes	Yes	Yes

Notes:

1. All standards are to protect aquatic life and based on the dissolved fraction unless otherwise noted by (T).
2. Where appropriate standards were calculated using paired hardness (dissolved $CaCO_3$).
3. "Yes" indicates the result attained the standard, "No" indicates the result exceeded the standard. The Colorado Water Quality Control Division evaluates water quality data to determine formal attainment with applicable water quality standards. Official attainment information is provided in WQCC Regulation 93.
4. The arsenic standard is a range, where the first number is the human-health standard and the second number is the maximum contaminant level for public drinking water supplies. A waterbody is considered in attainment of the arsenic standard when concentrations remain less than 10 ug/L. A temporary modification is applied for arsenic.
5. Cadmium standard calculated using the 2016 equation.
6. WS= water supply standard

Table 4. Water quality standards summary for **the Uncompahgre River at CR-24 near Ridgway** before, during, and after the March 2017 sediment release. Results and standards are dissolved concentrations in ug/L, unless otherwise noted.

Parameter		Before		During		After	
		chronic	acute	chronic	acute	chronic	acute
Arsenic (chronic= water supply, acute= aquatic life)	Result	4.3 (T)[1,2]	1	9.9 (T)	0.7	3.2 (T)	1.7
	Standard	0.02-10	340	0.02-10	340	0.02-10	340
	Attainment	Yes[3,4]	Yes	Yes	Yes	Yes	Yes
Cadmium[5]	Result	0.2		0.3		0.3	
	Standard	1.4	3.9	1.3	3.6	1.6	4.8
	Attainment	Yes	Yes	Yes	Yes	Yes	Yes
Copper	Result	2.9		3.4		3.2	
	Standard	18	30	17	27	22	36
	Attainment	Yes	Yes	Yes	Yes	Yes	Yes
Lead	Result	U		U		U	
	Standard	6.2	159	5.6	143	7.8	200
	Attainment	Yes	Yes	Yes	Yes	Yes	Yes
Manganese	Result	118		149		145	
	Standard	2,180	3,946	2,112	3,823	2,346	4,247
	Attainment	Yes	Yes	Yes	Yes	Yes	Yes
	WS Standard[6]	200		200		200	
	Attainment	Yes		Yes		Yes	
Selenium	Result	0.4		0.4		0.7	
	Standard	4.6	18.4	4.6	18.4	4.6	18.4
	Attainment	Yes	Yes	Yes	Yes	Yes	Yes
Silver	Result	U		U		U	
	Standard	0.3	8.6	0.3	7.3	0.5	12.5
	Attainment	Yes	Yes	Yes	Yes	Yes	Yes
Zinc	Result	45		83		36	
	Standard	260	343	238	314	317	419
	Attainment	Yes	Yes	Yes	Yes	Yes	Yes

Notes:

1. All standards are to protect aquatic life and based on the dissolved fraction unless otherwise noted by (T).
2. Where appropriate standards were calculated using paired hardness (dissolved $CaCO_3$).
3. "Yes" indicates the result attained the standard, "No" indicates the result exceeded the standard. The Colorado Water Quality Control Division evaluates water quality data to determine formal attainment with applicable water quality standards. Official attainment information is provided in WQCC Regulation 93.
4. The arsenic standard is a range, where the first number is the human-health standard and the second number is the maximum contaminant level for public drinking water supplies. A waterbody is considered in attainment of the arsenic standard when concentrations remain less than 10 ug/L. A temporary modification is applied for arsenic.
5. Cadmium standard calculated using the 2016 equation.
6. WS= water supply standard

4.5 SEDIMENT

All metal concentrations except chromium, increased slightly following the sediment release. Percent increases ranged from 0.6% for iron to 18.3% for copper (Table 5). The slight increase in sediment metal concentrations is likely within the range of natural variability. It is not possible to attribute the general increase in metals concentrations to the sediment release. Confounding factors, particularly variable sediment composition (e.g. texture, organic matter content) and differences in sample locations before and after the sediment release, likely account for the apparent change in metal concentrations.

Table 5. Metals concentrations in mg/kg in the Uncompahgre River in Ridgway Reservoir, measured before and after the sediment release.

Parameter	Before 03/18/17	After 3/31/17	Percent Change
Aluminum	18,000	18,800	4.4
Arsenic	24.2	26.6	9.9
Cadmium	3.43	3.68	7.3
Chromium	9.5	9.4	-1.1
Copper	175	207	18.3
Iron	31,000	31,200	0.6
Lead	192	206	7.3
Manganse	1,330	1,380	3.8
Mercury	46.4	51	9.9
Nickel	11.7	12.5	6.8
Selenium	0.75	0.8	6.7
Silver	3.45	3.55	2.9
Uranium	1.31	1.37	4.6
Zinc	538	591	9.9
Percent Solids	60.5%	56.2%	NA

4.6 MACROINVERTEBRATES

The number of macroinvertebrates identified in the sample collected following the release was greater than the number of macroinvertebrates found in the sample collected prior to the release (Table 6). An increase in the number of *Baetis* species (a type of mayfly nymph) accounts for the largest difference between the two samples. The increase in *Baetis* species is likely attributed to phenology (progression of life stages) rather than the sediment release. Shannon-Weaver diversity and HBI were similar in the before and after samples (Table 6). It does not appear that the sediment release altered the macroinvertebrate community in the Uncompahgre River in Ridgeway.

Table 6. Macroinvertebrate sample composition before and after the sediment release in the Uncompahgre River at the Ridgway River Watch site.

Macroinvertebrates (grouped by order or family)	Before (3/18/17)	After (3/28/17)
	Count	
Ephemeroptera (Mayflies)		
Baetis sp.	193	471
Drunella grandis	1	
Ephemerella sp.	12	43
Rhithrogena sp.	5	6
Plecoptera		
Sweltsa sp.		1
Triznaka sp.	9	10
Prostoia besametsa	4	5
Isoperla sp.	6	1
Pteronarcella badia	1	10
Trichoptera (Caddisflies)		
Brachycentrus americanus	4	14
Arctopsyche sp.	1	3
Hydropsyche oslari	1	1
Diptera (Flies)		
Chironomidae (Midges)		
Cricotopus/Orthocladius sp.	3	5
Diamesa sp.	1	
Eukiefferiella sp.		1
Pagastia sp.	1	
Paracladopelma sp.	1	
Other Diptera (Other Flies)		
Atherix pachypus	1	
Neoplasta sp.		4
Wiedemannia sp.		4
Dicranota sp.	1	
Total Count:	**245**	**579**
Shannon Weaver Diversity:	1.47	1.24
HBI:	3.50	3.56
Percent Ephemeroptera:	86.12%	89.81%
EPT Taxa:	11	11
Total Taxa:	17	15

5.0 CONCLUSIONS

The March 2017 sediment release occurred during an early snowmelt period where flows were substantially higher than typical for March. The observations from this study are specific to the March 2017 event. These observations may be similar to other sediment release events completed during snowmelt or peak flow in April, May or June. These observations are less likely to apply to sediment releases completed during low or receding flow conditions (i.e. later in the summer).

5.1 DISCUSSION OF STUDY OBJECTIVES

Stream flow rate of change: As expected, stream flow increased and fell more rapidly near Ouray than in Ridgway, due to proximity to the hydrodam and watershed size. In the Uncompahgre River near Ridgway, stream flow varied at a pace typical of early snowmelt conditions. In the Uncompahgre River near Ouray, stream flow varied at a pace more typical of peak flow conditions.

Water quality changes during sediment release: During the March 2017 sediment release, total metal concentrations increased during the release and returned to concentrations similar to pre-release concentrations. Dissolved metal concentrations decreased for most metals during the release. Dissolved metal concentrations generally returned to pre-release concentrations following the sediment release. Both patterns are expected given the large volume of water and sediment released from the sluice gate during the sediment release.

Relationship between distance from hydrodam and metal concentrations: As expected, metal concentrations increased most near the hydrodam and decreased with increasing distance from the hydrodam.

Manganese concentrations during the sediment release relative to naturally-occurring peak manganese concentrations: Total manganese concentrations measured near Ouray were approximately double naturally-occurring peak metal concentrations. Total manganese concentrations near Ridgway were approximately half of naturally-occurring peak metal concentrations. Additional metals were not evaluated due to a limited budget.

Metal concentrations and aquatic life standards during the sediment release: All metal concentrations attained aquatic life standards during the release.

Metal concentrations and human-health standards during the sediment release: The EPA classifies arsenic as a Class A carcinogen (most dangerous classification). This classification results in a very low human-health standard (0.02 ug/L of total arsenic; WQCC Regulation 31 effective date 1-31-18). An ambient concentration of less than 10 ug/L is considered acceptable for raw drinking water supplies. Arsenic concentrations measured during the sediment release below the dam and near Ouray exceeded the human-health and raw water supply criteria; concentrations at CR-24 near Ridgway exceeded the human-health criterion.

The arsenic concentrations measured at all three locations exceeded the human-health criterion before and after the sediment release. Arsenic concentrations measured in the Uncompahgre River near Ouray and Ridgway occasionally exceeded the human-health and raw water supply criteria during the 15-year period of record.

Although the hydrodam sediment releases influence arsenic concentrations, there may be other sources and controls within the watershed. Additional study may be warranted to better understand arsenic concentrations and sources within the Uncompahgre River Watershed.

Finally, the Colorado Water Quality Control Commission may revise arsenic standards soon (2021), which may result in an increase to the human-health based criterion.

Other metals did not exceed human-health criteria.

5.2 Recommendations for Future Sediment Release Studies

Future studies could benefit from the following:

- Sample water in the reservoir prior to the sediment release.
- Complete a particle size analysis of the reservoir sediments. The particle size analysis could be used to evaluate the potential of effect of the sediment on aquatic habitat (e.g. if the reservoir sediments lack fines (< 2 mm in diameter), the sediment has lower potential to degrade spawning habitat).
- Measure metal concentrations in the reservoir sediments. Samples from multiple depths and locations within the reservoir would be ideal. One existing sample suggests the reservoir sediments are generally benign, but additional samples could increase certainty. Reservoir sediment should be collected when the reservoir is low to allow better access to deposited sediment.
- Manually measure stream stage (water surface elevation) at all sample locations prior to, during, and after the sediment release event. During the event, stream stage should be measured on a one to two-minute interval.
- Increase surface water sample frequency during the sediment release. Without budget constraints, it would be ideal to sample at a higher frequency *without compositing* samples to better characterize the passage of the sediment plume. Auto-samplers are best suited to this work. However, manual sample collection on a 5 to 10-minute interval could also be effective. Analysis costs could be minimized by measuring turbidity or analyzing a sub-sample for aluminum, iron, or manganese to identify the passage of the sediment plume. Samples collected during the sediment plume's passage could be analyzed for a full suite of metals. Other samples would not require further analysis.
- Use a multi-meter probe to continuously log water quality parameters including specific conductance, pH, temperature, dissolved oxygen. Specific conductance could also be used to identify and track the peak of the plume.

- Use stream gage data from 2017 release to estimate transit times at each sample location to help assure that water quality samples are collected during the peak of the plume.
- Collect pre-release water quality samples an hour or less before the sediment release to further reduce uncertainty from natural variability.
- Collect post-release samples 6 to 12 hours after the sediment release to minimize variability attributed to changes in stream flow or other factors.
- Complete the study during low flow conditions (e.g. late summer or early fall). During the summer, macroinvertebrates will be in the water column or near the bed surface. During March macroinvertebrates are most likely burrowed deep in the bed sediments and difficult to sample. Late summer conditions would be more like fall spawning conditions, which is when brown trout spawn. Brown trout are one of the more desirable fish species in the Uncompahgre River.
- If macroinvertebrate samples are included in the next study, use a Hess net. Hess nets include a metal cylinder at the base of the net that allows the equipment to be worked into the bed sediments assuring a better sample. Sampling within the upper few inches of bed sediments could be important as macroinvertebrates may burrow into the sediment during the sediment release.
- Determine a strategy to characterize sediment deposition or erosion before, during, and following a sediment release event. Although the sediment release removes a large volume of sediment from the reservoir, the net effect of the release on the river is unclear. It’s possible that below the dam, where the specific gravity of the water is higher due to the sediment, the released fluid may entrain or move additional sediment. As the distance from the reservoir increases sediment deposition becomes more likely. But the actual pattern during release events is unknown, as is the fate of the sediment. Measuring the specific gravity of the water during the release may help determine whether erosion or deposition occurs at each location.

6.0 REFERENCES

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