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Bonita Peak Mining District:
Seeps, Springs, and Draining Mines

2019 Addendum
to the 2018 Seeps, Springs, and Draining Mines Report

June 2020

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Region 8
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Abbreviations and Acronyms

AT	American Tunnel adit
BPMD	Bonita Peak Mining District
CDPHE	Colorado Department of Public Health and Environment
COC	Chain of Custody
CSM	Conceptual Site Model
eCOC	electronic Chain of Custody
EPA	Environmental Protection Agency
FCS	Flow Control Structure
GK	Gold King Mine, level 7adit
IWTP	Interim Water Treatment Plant
MSI	Mountain Studies Institute
NO	Natalie Occidental mine portal
OSC	On-Scene Coordinator
OU3	Operation Unit 3
QA/QC	Quality Assurance / Quality Control
R&B	Red and Bonita Mine adit
S&S	Seeps and Springs
SAR	Sampling and Analysis Report

1. Introduction

2019 Annual Data Summary Report: Bonita Peak Mining District Hydrology

TechLaw contract number: EP-W-13-028-8

Task order 004 included multiple sub tasks including:

- 2019 field sampling plan and workplan
- High flow and low flow Seeps and Springs (S&S) sampling
- Monthly high temporal resolution sampling
- Data QC and Viper merge
- Stream gaging

Below are details on the field based sub-task and accomplishments for those tasks. Additional data file storage locations will be referenced in the text and may also be included as appendices to this report. The complete set of all raw instrument data files (e.g. stream gage pressure transducers) are routinely uploaded to the EPA BPMD SharePoint file storage system directly to the Mountain Studies Institute (MSI) data folder created and maintained by EPA Region 8. All field data has been uploaded to EPA Survey 123 Arc GIS database and undergone internal QA/QC. All analytical data is maintained by EPA in the SCRIBE database. At the time of this report final cross walking and uploading of 2019 field and analytical data was still being performed by TechLaw and is under delay due to the Covid-19 pandemic. A complete SCRIBE data availability summary was performed by MSI on April 15, 2020 and was shared with TechLaw and EPA data managers to help provide detailed information on remaining issues.

1.1: Seeps & Springs sampling (high flow and low flow) (TechLaw Task 4a)

This task order was a continuation of previous sampling events conducted in 2016-2018 and summarized in the 2018 S&S report (Cowie & Roberts, 2020). Sites sampled during high flow and low flow events of 2019 are located in Figure 1. The 2019 sites were a subset of approximately 30 of the sites sampled in 2016-2018. The 2019 sites were selected by the EPA BPMD hydrogeology team with a focus on the BPMD operable unit #3 (OU3), the Bonita Peak groundwater system. The 206-2018 results from the selected sites had indicated that these locations produced consistent perennial discharges in the area of OU3 and were most representative of the groundwater associated with the Sunnyside mine pool and the draining mine adits surrounding Bonita Peak.

Over the months of June and July 2019, MSI completed sampling of 26 seeps, springs, and draining adits. Several sites were inaccessible due to snow coverage following the historical snowfall during the 2018-19 winter. High flow seeps and springs samples included analysis of dissolved metals, total metals, ions and alkalinity, and stable isotopes. During October 2019, MSI completed sampling of 32 seeps, springs, and draining adits. Several sites were unable to be sampled due to low flow/dry seeps. Samples were collected for analysis of dissolved metals, total metals, ions and alkalinity, and stable isotopes, as well as N_2/Argon gas, Sulfur hexafluoride (SF6), Chlorofluorocarbons (CFCs), and Tritium (H_2). The work included significant additional efforts to sample and ship the groundwater dating analysis samples to multiple contracted labs. Reporting and interpretation of the groundwater age dating data will be completed at a later date in conjunction with reporting of concurrent field studies performed by other BPMD contracts. These supporting efforts include the 2019 USGS tracer study, 2019 EPA ORD and USGS fiber optic distributed temperature sensing and geophysics surveys, and the 2018 EPA rare earth element sampling events. Analytical results, reporting and interpretation of the tracer and groundwater dating results is still pending authorization of data use at the time of this report. All field data from both high and low flow sampling events were submitted to TechLaw. The field parameter data has been downloaded from EPA Arc GIS Survey 123 database and undergone QC. Each field parameter data entry corresponds to a water sample that was submitted to the ESAT laboratory over the course of the 2019 calendar year. Field data collected at locations where no water samples were collected (dry sites) remains in the EPA Arc GIS Survey 123 database which has been shared with EPA data managers and is pending a final data repository location at the time of this report.

1.2: Monthly high temporal resolution sampling (TechLaw Task 4b)

Monthly surface water samples were collected at 12 select locations (Figure 2). The sampling efforts followed procedures described in the BPMD Site-Wide Quality Assurance Project Plan, Field Sampling Plan, and relevant Standard Operating Procedures. The locations included six surface water sites (A72, M34, A68, CC48, CCSG-1, A55) and six draining adits in Cement Creek (CC01B, CC03D, CC06, CC14, CC19, and the Blackhawk Mine (CC50).

The following data were collected:

- Flow
    - Manual flume readings at mine locations
    - Operation, maintenance, and data acquisition from flow monitoring instrumentation at mine locations
    - Flow data was QC'd and uploaded monthly to the EPA SharePoint database
- field measured water quality parameters;
- surface water samples analyzed for:
    - total recoverable metals
    - dissolved metals
    - alkalinity
    - anions
    - stable isotope (collected at mine locations)

MSI performed flow conversion at daily mean flow resolution for all six mine sites except Gold King. At Gold King MSI maintained live data streams for three water depth sensors and water depth (head) values at the flow control structure (FCS), which have been provided to the EPA removal program OSC by MSI. MSI is currently supporting GK discharge data conversion under the EPA removal contract. The final discharge conversions were still ongoing at the time of this report. Therefore, MSI will be using the weekly mean discharge, produced by the Gladstone interim water treatment plant (IWTP), to calculate metals loading from the GK adit. All GK water is treated by the IWTP so water chemistry and metals loading from the GK (CC06) sampling point only represent conditions at emergence point and not a direct discharge to surface waters.

The field data for all monthly high temporal resolution sampling events from June-December 2019 were submitted by MSI to TechLaw in the annual sampling and analysis report (SAR) completed in December 2019 (TechLaw, 2020).

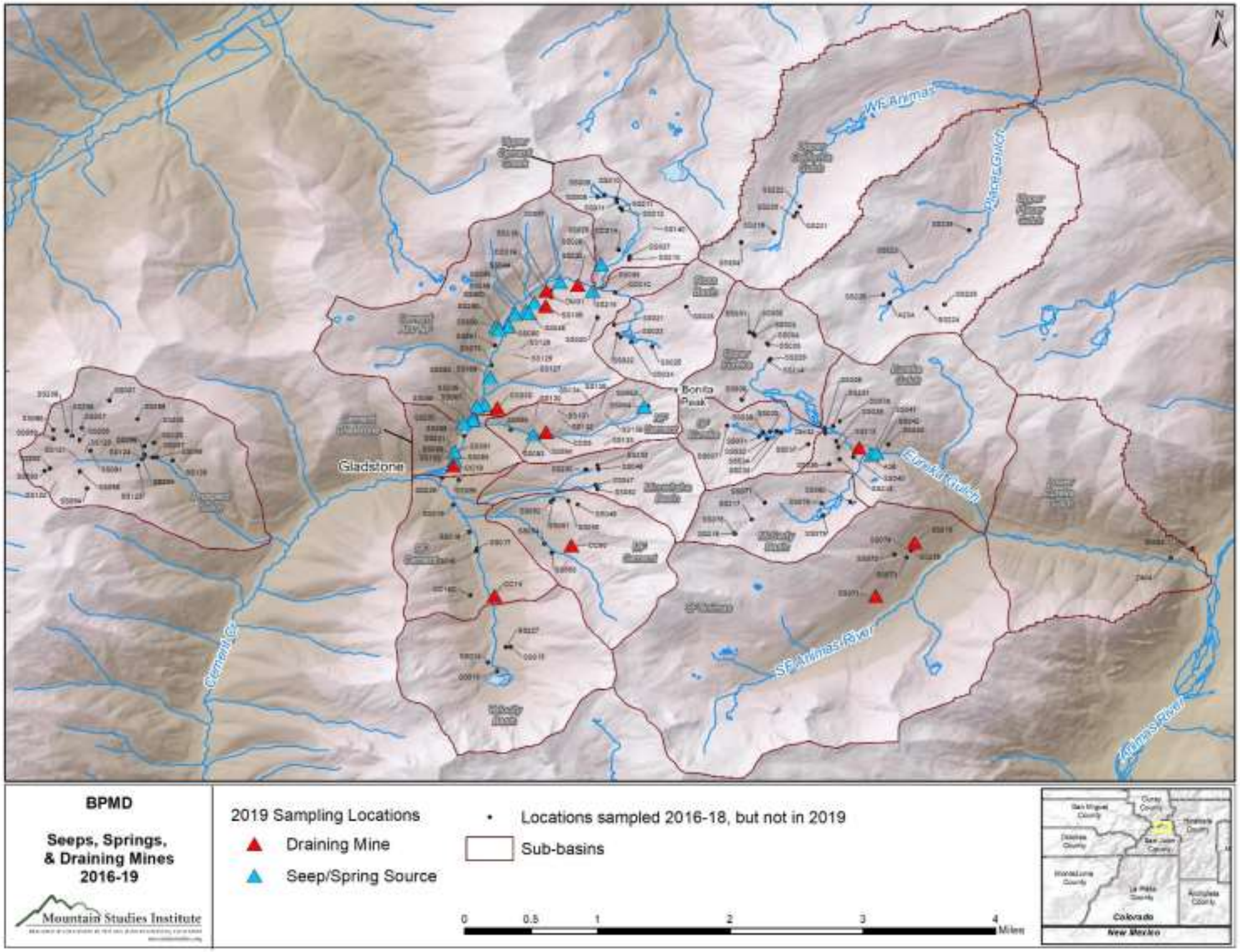

Figure 1: Seeps, springs, and draining mines sampled during 2019 low-flow and high-flow events.

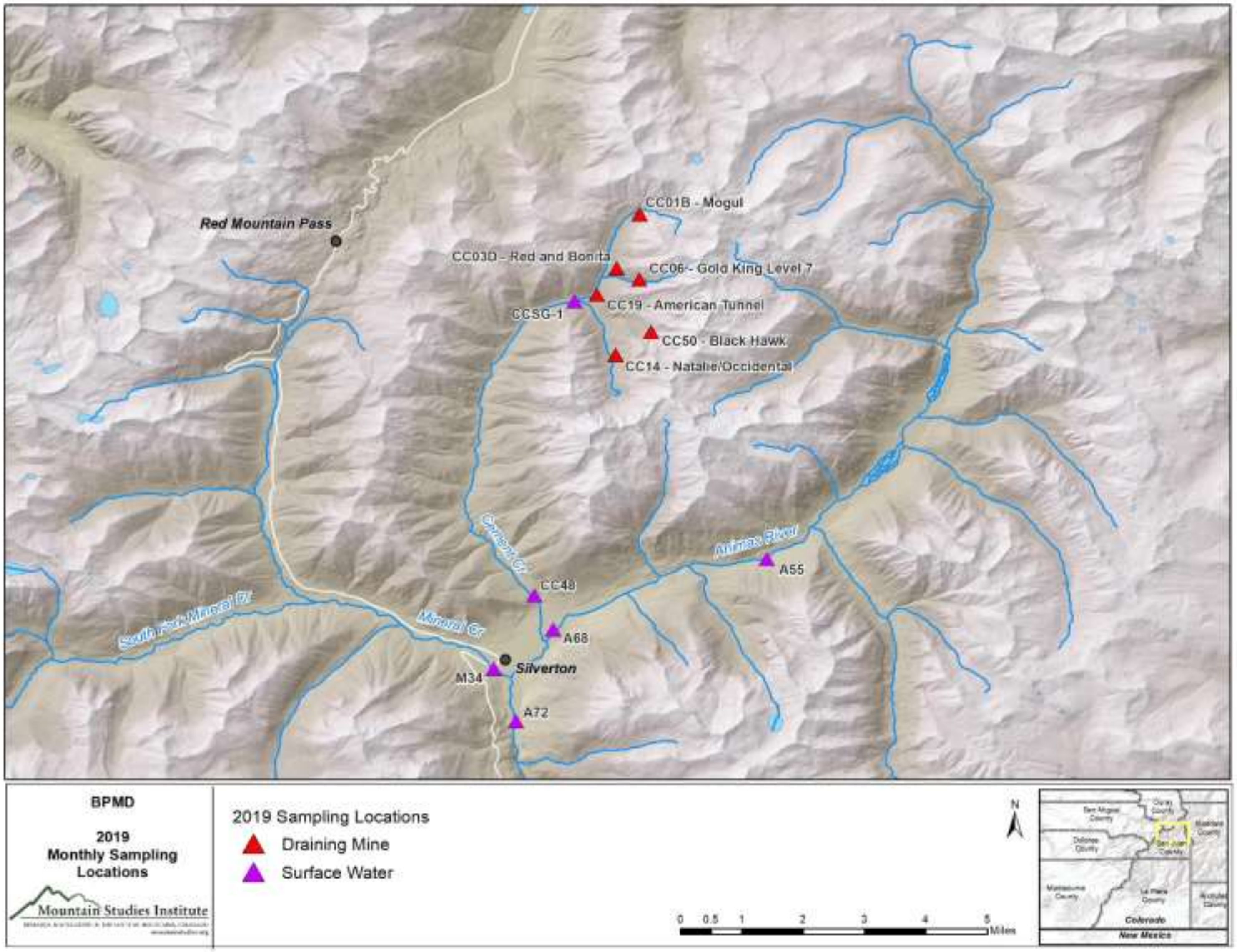

Figure 2: Draining mine and surface water locations sampled monthly in 2019 from June through December.

1.2.1: Stable Water Isotopes

Stable water isotopes were collected during all sampling events. Due to the combined shipping of stable isotopes from multiple dates and eventual third-party laboratory analysis outside of TechLaw/ESAT, MSI included a master eCOC of all 2019 isotope samples to TechLaw in the 2019 SAR. That document was provided as a reference to cross walk all incoming (from third party lab) isotope data results which were still being processed at the time of this report.

Monthly sampling for stable isotopes at draining mine locations was ongoing prior to the start of the monthly sampling task order which started in June 2019. Therefore, MSI provided an additional field parameters file to TechLaw in the MSI annual SAR. This file contained field data associated with all stable water isotope samples collected from January through May 2019 and thus data was combined with the analytical data from the University of Arizona isotope lab when that data was added to SCRIBE.

At the time of this report (June 2020), isotope samples collected in the fall of 2019 had not yet been analyzed by the University of Arizona lab, so summary and interpretation of 2019 stable water isotope data is not included in this report.

1.3: Opportunistic sampling (TechLaw Task 6/1)

Opportunistic sampling was not included in the initial work authorizations but was requested in March 2019 due to the temporary shutdown of the Interim Water Treatment Plant (IWTP) and in October 2019 due to a release from the Silver Wing Mine. The Scope of Work for Opportunistic sampling is as follows: *Collect opportunistic samples as requested by USEPA. These samples may be needed for performance monitoring of remedial or investigation actions, storm events, or other needs as identified at BPMD. These samples may include surface water, sediment, pore water, or other media as needed. It is expected the water samples will include surface water flows, water quality parameters, total metals, dissolved metals, alkalinity, anions, and other parameters as needed.*

Event 1: March 2019 Gladstone Interim Water Treatment plant shutdown sampling

This sampling task was requested by EPA BPMD removal program OSC Kerry Guy. The work agreement was under the MSI subcontract to EPA removal program contractor Environmental Restoration LLC (ER). However, the water samples were shipped to the EPA Region 8 laboratory under coordination with TechLaw and Steve Auer. Therefore, samples and field data collected during this event were reported in the MSI annual report submitted to TechLaw in December 2019. The complete list of MSI collected field parameters and MSI sample shipments (eCOCs) therefore include the March IWTP sampling event. The results from event 1 were published by the EPA and can be found here,
https://response.epa.gov/site/site_profile.aspx?site_id=12109

Event 2: October 2019 Silver Wing Mine release sampling event

This task was directly requested by Techlaw under contract EP-W-13-028-8 and was funded under modification to TechLaw Task order 004. All field data for both event 1 and 2 were sent to TechLaw and EPA at the time of analytical sample submission per request of Kerry Guy and Steve Auer. All field data was also submitted to TechLaw in the 2019 SAR report merging of field data with analytical data in the EPA SCRIBE database is being completed by TechLaw and was ongoing at the time of this report. All analytical samples were sent to TechLaw and the official report has been published here; https://semspub.epa.gov/work/08/100006938.pdf

1.4: Stream Gauge Installation and Operation (TechLaw Task 4c)

In 2019 MSI maintained seven existing stream gauges that were installed in 2017. The effort included installing pressure transducers to measure stage height and to install cameras to photograph staff gauges. This effort included maintenance required to download transducers and cameras on a minimum of a monthly basis with higher frequency during spring high flow from snowmelt runoff. MSI performed data QA/QC review prior to placing the data in a database for archiving. Additionally, the efforts included measuring morphology of the stream at each gaging station to determine if it compares to previously collected data. Manual flow measurements were collected for calibration purposes during the maintenance activities as well as opportunistically (high flow or storm events).

Development of stream gauge rating curves and conversion of stage height data from instruments was not tasked in 2019 so they are not included in this report. MSI anticipates completion of stream gauge data conversion and interpretation in 2020 as part of further development of the Operational Unit 3 (OU3) and corresponding conceptual site model (CSM).

Raw data from stream gauge stations have been uploaded to EPA BPMD SharePoint database and can be accessed following the link below. Stream gauge stage height data will be converted to discharge at each location upon completion of rating curve development by the end of the 2020 water year (ending September 30, 2020).

https://usepa.sharepoint.com/sites/R8_Work/BPMD/Shared%20Documents/Forms/AllItems.aspx?viewid=00000000%2D0000%2D0000%2D0000%2D000000000000&id=%2Fsites%2FR8%5FWork%2FBPMD%2FShared%20Documents%2FData%2FMSI

1.4.1: Stream Gauges: Field Meta Data

The following section details the field activities and meta data for operation of each of the stream gauges in 2019 under task TL 4c.

CSSG1 – Level Troll 700 installed 6/8/2019, removed 10/23/2019. Delay of work authority for instrument deployment resulted in installation issues, low quality of data, and safety concerns with high flows. Since the instrument was not installed until June 8th, accurate high flow measurements were not recorded. In the future, April would be more ideal for installation. During the time between 6/8/2019 and 10/23/2019 MSI completed 10 site visits and downloaded instrument data, took discharge measurements, measured pH, temperature and conductivity. MSI staff completed data QAQC and continued development of stage-discharge rating curves. Due to high flows during installation, the stilling well was not able to be fully secured and may have resulted in noisy data early on. On 6/12/2019 MSI staff observed the stilling well backed up with cobbles, and more holes were cut into PVC so that depth decreased inside PVC.

CCSG2- Level Troll 700 installed 6/8/2019, removed 10/23/2019. Delay of work authority for instrument deployment resulted in installation issues, low quality of data, and safety concerns with high flows. Since the instrument was not installed until June 8th, accurate high flow measurements were not recorded. In the future, April would be more ideal for installation. During the time between 6/8/2019 and 10/23/2019 MSI completed 13 site visits and download instrument data, managed technical difficulties, took discharge measurements, measured pH, temperature and conductivity. MSI staff completed data QAQC and continued development of stage-discharge rating curves. Due to high flows during installation, the stilling well was not able to be secured properly and resulted in loss of data from first 6 days of installation. QAQC revealed the transducer not reading depth reduction while there was a decline in stage and discharge. A follow-up field visit confirmed that the stilling well cap was missing, so MSI staff removed the instrument for further investigation. Level Troll 700 was reinstalled on 8/21/2019 with a horizontal orientation. QAQC on 9/17/2019 revealed little variability in depth of transducer, raising concern about the cable and/or clogging of the stilling well. On 9/25/2019 MSI staff replaced the cable and re-checked sensors on 9/27/2019. MSI's site visit on 10/8/2019 confirmed the instrument was functioning properly, however QAQC revealed that there was not much viable data from this site for the summer of 2019. This confirms the importance of an earlier install to ensure quality data.

CCSG3- Level Troll 700 installed 6/8/2019, removed 10/23/2019. Delay of work authority for instrument deployment resulted in installation issues, low quality of data, and safety concerns with high flows. Since the instrument was not installed until June 8th, accurate high flow measurements were not recorded. In the future, April would be a more ideal timeline for installation. During the time between 6/8/2019 and 10/23/2019 MSI completed 13 site visits and downloaded instrument data, managed technical difficulties, took discharge measurements, measured pH, temperature and conductivity. MSI staff completed data QAQC and continued development of stage-discharge rating curves. Due to the high flows during installation, the instrument could not be installed lower and resulted in negative values later in data. On 8/21/2019 MSI staff reinstalled the transducer lower in the stilling well to adjust for negative values. The stage card experienced sediment build up and required excavating and remounting. This confirms the importance of an earlier install to ensure quality data.

CCSG5- Level Troll 700 installed 6/10/2019, removed 10/22/2019. Delay of work authority for instrument deployment resulted in installation issues, low quality of data, and safety concerns with high flows. Since the instrument was not installed until June 10th, accurate high flow measurements were not recorded. In the future, April would be a more ideal timeline for installation. During the time between 6/10/2019 and 10/22/2019 MSI completed 7 site visits and downloaded instrument data, managed technical difficulties, took discharge measurements, measured pH, temperature and conductivity. MSI staff completed data QAQC and continued development of stage-discharge rating curves. Field visits required removal of avalanche debris that was caught on the stilling well. On 6/12/2019 MSI staff moved the stilling well back into channel.

CCSG6- Level Troll 700 installed 6/12/2019, removed 10/22/2019. Delay of work authority for instrument deployment resulted in installation issues, low quality of data, and safety concerns with high flows. Since the instrument was not installed until June 12th, accurate high flow measurements were not recorded. In the future, April would be a more ideal timeline for installation. During the time between 6/12/2019 and 10/22/2019 MSI completed 7 site visits and downloaded instrument data, managed technical difficulties, took discharge measurements, measured pH, temperature and conductivity. MSI staff completed data QAQC and continued development of stage-discharge rating curves. A site visit on 5/15/2019 revealed avalanche debris covering and obscuring location, blocking access. Installation was delayed due to heavy avalanche debris in the channel that blocked the waterway, took out the stage card, and dislodged the stilling well on 6/10/2019. A tree from avalanche debris was removed on 6/12/2019 in order to install Level Troll 700. By 7/8/2019 the stilling well was very loose, the stage card was missing, and a second tree knocked the stilling well out. Data QAQC revealed the influence of avalanche debris crashing into well and data was removed between 6/25 at 19:50 and 7/11 at 12:10, when the transducer was reinstalled. Inherent challenges during high flow installation proves the need to install before high flow begins.

CCSG7- Level Troll 700 installed 6/10/2019, removed 10/22/2019. Delay of work authority for instrument deployment resulted in installation issues, low quality of data, and safety concerns with high flows. Since the instrument was not installed until June 10th, accurate high flow measurements were not recorded. In the future, April would be a more ideal timeline for installation. During the time between 6/10/2019 and 10/22/2019 MSI completed 8 site visits and downloaded instrument data, managed technical difficulties, took discharge measurements, measured pH, temperature and conductivity. MSI staff completed data QAQC and continued development of stage-discharge rating curves. Site visits required removal of avalanche debris. Due to high flows during installation, the stilling well could not be installed securely and MSI staff had to reposition on 8/15/2019 due to debris and on 10/9/2019 due to lower water levels. This confirms the importance of an earlier install to ensure quality data.

EGSG2- Level Troll 700 installed 7/17/2019, removed 10/17/2019. Delay of work authority for instrument deployment resulted in installation issues, low quality of data, and safety concerns with high flows. Since the instrument was not installed until June 8th, accurate high flow measurements were not recorded. In the future, April would be a more ideal timeline for installation. During the time between 7/17/2019 and 10/17/2019 MSI completed 8 site visits and downloaded instrument data, managed technical difficulties, took discharge measurements, measured pH, temperature and conductivity. MSI staff completed data QAQC and continued development of stage-discharge rating curves. Site visits and installation were delayed due to inaccessibility caused by historic snowfall.

EGSG1- MSI staff could not install instrumentation, stage card or camera due to channel changes and avalanche debris. There is evidence of some unquantified amount of water escaping into the other channel probably via subsurface flow under avalanche debris, thus sampling/discharge location was likely not capturing complete flow. In Spring of 2020 the EGSG1 site was re-established in the newly defined channel which did not change following the 2020 spring runoff season. A new rating curve for this site will be developed in 2020.

1.5: Seeps and Springs Reporting (TechLaw Task 6)

The 2016 to 2018 Seeps and Springs report was submitted to Techlaw on 12/31/19. This task involved significant effort to reconcile multiple data sets collected over the past three years under multiple sub-contract agreements to different EPA contractors. The final report by Cowie and Roberts (2020) has been published and is now available on the EPA BPMD website; https://semspub.epa.gov/work/08/100007694.pdf

1.6: Viper merge and data QC (Tech Law Task 8)

MSI worked with EPA data management team in 2019 to develop data work-flow procedures and methods for migrating field and instrument data to EPA managed storage locations. This work enabled MSI to migrate all raw data to EPA SharePoint folders and begin the QC process to make data compatible with the EPA online data network Viper. MSI also worked to QC and mange field data collected using EPA Arc GIS Survey 123 software. As a sub-contractor MSI was required to retrieve all data entered into the Survey 123 applications and then submit to TechLaw for combining with laboratory analytical data and upload to EPA SCRIBE database. One exception is the field site photos collected in the Survey 123 app. These photos are stored on the EPA Arc GIS server but do not go to SCRIBE. MSI was not contracted to QC or manage these data/photo files in 2019 so no additional reporting is available at this time. Additionally, all documented "dry" mine sites that were collected during field events are stored in the Survey 123 database and will not be uploaded to SCRIBE because the field data does not correlate to any laboratory analytical data. MSI has not been tasked with data management or reporting of this information at the time of this report.

Unfortunately, all data management communications with EPA data management office ending in the summer of 2019 with the departure of the EPA Region 8 data manager, who was coordinating the efforts. MSI was able to continue to access EPA SharePoint files and upload raw data through 2019. Data management communications have resumed in the first and second quarters of 2020 and shall remain ongoing.

MSI has continued to maintain live streaming data from the Gold King Mine to the EPA managed In-Situ online interface, which is accessible to EPA if they choose to merge the data into the Viper or other system. MSI log in information is provide below if access is needed. Please note that the NFPZ well data is live only for three parameters (pressure, temperature, level) because the current EPA contract to In-Situ only covers posting of three parameters. However, all parameters are downloaded by MSI and a complete set of raw data is uploaded to the EPA SharePoint data folder monthly.

Log in info:
www.isi-data.com
U/N: MountainStudies
P/W: BonitaPeaks

MSI has also maintained live streaming data from the BPMD weather stations which is accessible to EPA via static IP address which has been provided to the EPA. The data is also available via an MSI hosted webpage. The static IP address to the web page is: http://205.220.219.73/

For all data acquisition inquires please contact MSI field and operations manager Nate Rock (rockn@mountainstudies.org). The ongoing labor involved in data acquisition and upload from the Gold King and BPMD weather stations has been funded by the EPA removal program and is was not part of the TechLaw Task 8 but has been necessary to produce the data that is intended to go to EPA Viper or other data storage system.

2. Results: Draining mines

2.1: Mine discharge monitoring instrumentation

Draining mine discharge has been continuously recorded since the fall of 2016 at six key locations including the Gold King, Red and Bonita, American Tunnel, Mogul, Natalie Occidental, and Blackhawk mines.

The installation, operation, and maintenance of this instrumentation was funded by the EPA Removal program through contract with the site prime contractor, Environmental Restoration (ER). Monthly operation, maintenance, and sampling has been ongoing since 2017 and data is regularly uploaded by MSI to the EPA SharePoint database.

Gold King

A total of four independent water level sensors were installed behind the Gold King Flow Control Structure (FCS) at the time of installation in 2017. The instruments measure water level behind the FCS which is controlled by a weir box at the outlet portal of the FCS. MSI has performed annual maintenance and calibration of the sensors since date of install in coordination with EPA removal activities at the site.

There is one sonic water level sensor and three vented pressure transducers with one transducer located above water level and only serving as back up in the event of a large rise in water levels behind the FCS. The two active pressure transducers are co-located at the same depth to provide duplicate data streams. These sensors are connected to an iridium satellite communication network and produce live data as described in section 1.4. Flows used in this report are the weekly values provided by the IWTP due to ongoing conversions of water level instrument data from the FCS at the time of this report.

Installation of the water level monitoring devices adjacent to the weir box behind the Gold King flow control structure, October 4, 2018.

R&B

A pipe flow sensor was installed in November 2017 and continuous data has been collected since January 2018. Live readings of the sensor were used as the field-based discharge value at the time of all water samples collected since 2018. The sensor is located on the discharge pipe downstream of the bulkhead and inside of the portal air door (see photo). Data is stored on a battery powered data logger and manually downloaded each month when accessible. Data is QC'd and uploaded to EPA SharePoint folders monthly. This site has limited access during winter months (Jan-May) due to snow and avalanche conditions near the portal. Remote communication networking of the sensor data is planned in 2020 to improve real time monitoring capabilities.

Flow sensor and data logger for the R&B discharge pipe, installed November 2017. Sensor located inside the mine tunnel but downstream of the bulkhead. Data logger powered by battery located in the adjacent storage box.

Mogul

A flume was installed in October of 2018. Pressure transducer data are downloaded monthly as part of the mandatory operation and maintenance of the flume to prevent drift from sludge accumulation. The flume measures discharge of all mine tunnel water inflow downstream of the bulkhead. All raw and QC'd data is uploaded to EPA SharePoint files monthly.

Installation of fiberglass Parshall flume at the Mogul mine portal, October 2018.

American Tunnel

An existing flume (prior to MSI involvement in 2016) was initially used to monitor discharge from the American Tunnel. A new flume was installed inside the portal in October 2018 in coordination with EPA Removal activities related to managing the tunnel and portal discharge pathways (see photo). The current flume measures flow as it exits the tunnel ditch and before it enters the pipe and manhole conveyance system installed by EPA in 2018. The flume measures all water that has entered the tunnel downstream of the outer most bulkhead (AT bulkhead #3) prior to reaching the portal. Monitoring at this location has been difficult due to sensor drift associated with precipitate accumulation. The precipitate accumulation has caused two pipe backups; one in spring 2019 and again in spring 2020, resulting in the loss of significant portions of time-series data. The blockage of flows in 2019 caused a data gap from May 17 to June 26 which may have eliminated the opportunity to observe seasonal discharge fluctuations observed at other mine discharge sites. Maintenance and cleaning of the flume and monitoring devices is required at 30-day or shorter intervals to maintain accurate data collection. MSI continues to work with the EPA removal program to improve the accuracy and resolution of discharge data from the American Tunnel.

Installation of fiberglass flume in the American Tunnel drainage ditch, October 2018. The downstream end of the flume is a fill basin connected to a pipeline that conveys water out of the mine portal. Second photo is an example of sludge build up on the pressure transducer at American Tunnel in less than 30 days.

Installation of the monitoring well behind bulkhead #3 in September 2019 and installation of associated monitoring devices will greatly enhance the ability to monitor pressure changes behind the bulkhead and may be far more accurate than observations and flows collected at the portal due to physical constraints of sludge accumulation at the flume. MSI has maintained data collection from the monitoring well (ATPZ-2) since October 2019.

American Tunnel monitoring well (ATPZ_2) instrument installation, November 2019.

Natalie Occidental

A custom weir box with instrumented stilling well was installed in 2017. The custom shape (not a standard throated flume) was necessary to accommodate large fluctuations in flow and significant iron precipitate buildup (see photo). The weir box also enables manual discharge measurements with a flow meter because discharges are larger than can be measured with the standard flumes at the other sites. The flume was covered by a snow shed in 2019 to improve year-round monitoring abilities.

Natalie Occidental custom weir box installed summer 2017. The 30" wide weir box designed to measure large variations (>1,000 GPM) in flow and enable use of a flow meter to accurately measure discharge.

Blackhawk

A temporary flume was installed in 2017 and replaced with the current fiberglass flume in 2018. The flume installation was performed at the same time that EPA Removal program secured the portal collapse and created a uniform discharge point from a culvert. The flume is located just downstream of the discharge culvert but upstream of a perennial seep which discharges directly into the lined channel flowing over the mine dump. During installation MSI noted large variability in mine discharge depending on sampling locations due to additional flows from the adjacent seep and/or significant water loss into the mine dump if the lined channel was compromised. Therefore, MSI suggests that all flow measurements collected/measured prior to 2017 to be flagged and potentially removed from any further interpretation of discharge conditions prior to the current installation.

The flume is protected by a snow shed for year-round monitoring. The snow shed protects the fiberglass flume from snow compaction and the energy (heat) in the mine discharge water keeps the flume area open and free flowing throughout the winter, even under 20 ft of snow.

Left; Blackhawk flume and snow shed, installed fall 2018. Right; Location of functioning flume protected by the snow shed, May 15, 2019.

2.2 Mine discharge data

Flows were manually measured approximately monthly to quarterly at each of the six mine sites from 2016 through 2017. Instrumentation has been added to sites in 2017 and 2018 and were operating throughout 2019. All sites record data at hourly intervals and all raw data is uploaded to EPA SharePoint. Discharge data has been converted to mean daily discharge and combined with manual measurements collected since 2016 (figure 3). The frequency of discharge data increased significantly in the fall of 2018 at all sites following installation of instrumentation as described in section 2.1. The increased data resolution has enabled much more detailed understanding of the flows and significantly reduces previous uncertainties about discharge between manual measurements which had gaps of months or entire seasons prior to 2017. The high-resolution data is also able to monitor for magnitude and duration of any unexpected releases or water surge events that can occur at any time.

The discharge results in figure 3 highlight several significant findings which will be important for future development of the OU3 Bonita Peak groundwater conceptual site model (CSM). First, it is important to note that in 2018 there was a below average winter snowpack while in 2019 there was an above average winter snowpack. A detailed analysis of the relationship between mine discharge and overall water balance budgets for the local watersheds is beyond the scope of this report update, but this data will support future analysis of specific relationships between discharge and precipitation for the OU3 CSM.

The mine adits with closed bulkheads, Mogul and American Tunnel, have the lowest flows and show the least variability over time. This result suggests that the existing bulkheads are able to withstand the seasonal increases in groundwater flows or pressure head with minimal increases in flow from seepage around the bulkheads occurring during annual snowmelt periods. MSI field observations from the Mogul Mine suggest that the minor increases in flows measured at the portal flume is predominantly from direct tunnel inflows from snowmelt and shallow groundwater near the portal, further reducing the actual change in discharge around the bulkhead during spring snow melt.

The other four adits (R&B, Gold King, Natalie Occidental, and Blackhawk) all show seasonal variation with increases in discharge occurring during or after the spring snowmelt. Specifically, the Natalie Occidental adit shows the largest seasonal changes in discharge with a rapid doubling or tripling of flows occurring in June and July with the Gold King, R&B, and Blackhawk discharges increasing with a lag of weeks to months after the response at the Natalie Occidental. The measured increases in discharge at the Natalie Occidental were rapid and the importance of high-resolution flow data is very evident in figure 3 because the timing of high flow sampling must occur in a narrow window to accurately capture conditions. The R&B and Gold King flows have similar trends with nearly no seasonal increase in summer of 2018 and then rapid increases occurring in June-July of 2019. The Natalie Occidental had a large increase in all three years of record, including 2018, which suggests that the groundwater discharging from this adit undergoes a separate source water recharge mechanism than do the R&B and Gold King adits. Specifically, the rapid and large increase in discharge suggests recharge from a short pathway such as a shallow groundwater flow path or direct inflow from the surface via mine workings or other void space. Interestingly, the Blackhawk Mine had an increase in flow each year but that increase occurred later in the summer than the other adits further suggesting that the seasonal recharge source waters and flowpaths for the Blackhawk are different than those to the Gold King and Red and Bonita.

When the discharge data (figure 3) is compared to the stable water isotope results presented in the 2018 report (Cowie and Roberts, 2020) the data are complementary. Specifically, the R&B and GK have similar seasonal discharge responses while maintaining the same consistent stable water isotope values. These quantitative results suggest that the source water is a large well mixed reservoir and that seasonal inputs are increasing the overall volume or pressure (head) on the water but not directly contributing to the source of water at the discharge points (mine adit R&B and GK). If the seasonal increases in discharge at a particular mine adit were from an additional contribution from a localized source, such as direct snowmelt infiltration into nearby mine workings, then the stable isotope values would change as a reflection of the change in seasonal source water contributions. This change has not been observed at the R&B an GK mines.

Additional information was collected in 2019 with the groundwater age dating (residence time) sampling and further interpretation of all results will support this initial interpretation. Specifically, if the tracers providing residence times (tritium, CFCs, SF6, etc.) indicate that emerging mine water discharges are significantly different (have a longer residence time) than other seasonal or modern source waters, that data further supports this initial interpretation of a long slow flow path from point of infiltration to point of emergence. A complete analysis of the 2019 age dating tracers will require further interpretation and collaboration with appropriate subject matter experts from the laboratories and agencies who produced the analytical results and is therefore beyond the scope of this report update.

2.3 Metals loading from draining mines

Analytical results from the draining mine sites sampled in 2019 are in the SCRIBE database. Metal concentration data from the six draining mines have been collected since 2016 with all data through 2018 presented in the 2016-2018 Seeps, Springs, and Draining Mines Characterization Report (Cowie and Roberts, 2020). Additional sampling occurred in 2019 as part of the high flow and low flow sampling and monthly from July through December 2019 as part of the high temporal resolution (HTR) sampling task. The HTR task is slated to continue through June 2020. Due to contractual limitations and the Covid-19 pandemic, the only samples collected and analyzed since January 2020 were from February 2020 and those results have been included in calculation of metals loading from mines. The significant increase in sampling frequency of the draining mines in 2019 created more detail on the seasonal and monthly variability of overall metal loading to Cement Creek. A complete interpretation of draining mines metals chemistry and load will be completed after the completion of the 12 months of HTR sampling in July 2020. However, the metals loading data available at this time provide initial insights to overall trends from the draining mines in Cement Creek. The metal loadings are summarized below for the several of the main metals of concern including Al, Cu, Fe, and Zn.

Total Aluminum

The total Al load from the six mines ranged from a low of 29 kg/day in February 2020 to a high of 254 kg/day in June of 2017. The GK produced the majority (73-92%) of the total Al load throughout the study. The second highest Al load producing mine was the R&B during low flow conditions (10-15%) but switches to the Natalie Occidental during high flow where it was nearly 20% of the total Al load in June 2019. The high temporal resolution data indicates that the R&B and AT loads remained relatively constant over the winter while the GK, NO, and Mogul loads decreased through winter resulting in a steady increase in total % Al contribution from R&B relative to the other mines.

Total Copper

Total Cu load from the six mines ranged from a low of 5 kg/day in February 2020 to a high of 34 kg/day in June 2017. The GK produces nearly all of the Cu load (88-99%) during the study period with the highest loads occurring in June of 2017 and July of 2018. Interestingly, the total Cu load from the GK did not increase above typical low flow loads during July of 2018, the dry year with lower overall increases in discharge from the GK than in July of other years in the data record.
At the same time (July 2018) the total Cu load increased from the R&B bringing its total contribution up from less than 1% to > 7% of the Cu load from the six mines in June and October of 2018. The NO had the second highest contribution of total Cu at 10% of the total load from the six mines in June 2019. Copper load remained low (>0.1 Kg/day) at the other three mines throughout the study.

Total Iron

Total Fe load ranged from 340 kg/day in February 2020 to a high of 1440 kg/day in June 2017. The GK produced 24-66% of the load with the highest loads occurring in June 2017 (947 kg/day) and the lowest in February 2020 (81 kg/day). The R&B load remained relatively constant at 100-200 kg/day throughout the study which represented 14-49% of the daily load depending on season. The R&B Fe load was greater than the GK load in October 2018 and again in 2019 with the % load from the R&B increasing throughout the winter of 2019-2020 as a result of decreasing load from GK over the same period. The NO shows a large increase in Fe load just during melt runoff and no major seasonal changes in total Fe load are observed at the AT, Mogul, or BH mines.

Total Zn

Total Zn loads ranged from 57 kg/day in February 2020 to over 190 kg/day in July 2017. Total Zn load was not analyzed at the Mogul in June 2017 so a total percentage could not be calculated for that sampling period. GK Zn load varied greatly from 20 to over 134 kg/day during the study, greater than the change at the other sites.

The GK produced 2-4 times as much Zn than the next nearest mine, the R&B, for the majority of the study until fall of 2019 when GK Zn loads began decreasing significantly. The R&B loads increased slightly over the fall and winter of 2019 and actually surpassed the GK load in February 2020 for the first time of the study period. One hypothesis of the shift in Zn load from GK to R&B is a delayed change in the flow paths of OU3 groundwater emerging at the two mine portals that is a remaining legacy of the "time to equilibrium" for the system following the large disruption caused by the 2015 GK release. This hypothesis is supported by fact that the GK flows were much higher for the entire year of August 2016 through August 2017, a time in which the groundwater entering GK working and proceeding to the portal was still "draining down" following the 2015 release. The 2015 release was a rapid draining of the water volume filling mine workings void spaces, where as the elevated flows in 2016-2017 (see figure 3) were dominated by draining of secondary porosity (fault/fracture) pore space immediately adjacent to the mine workings that had been "filled" during the build-up time prior to portal release. The drain down around the GK working appears to have continued straight through until the spring of 2019 when the seasonal melt pulse influence again raised flows. Moving forward from summer 2019 to present, the flows from GK and R&B are much more similar to each other and could represent a steadier state "sharing" of the overall discharge of the OU3 groundwater. Continued high resolution flow data from these sites is critical to continued tracking of this hypothesis.

The potential shift in Zn load between the GK and R&B is critical information for the BPMD remedial investigation, and we recommend further discussion and interpretation of these results by the BPMD hydrogeotechnical team. The results also highlight the tremendous importance of continuing collection of monthly samples from the mines to better understand the observed and currently changing variability which is missed with only seasonal sampling. We understand that Zn is one of the most important and impactful metals of concern within the BPMD and therefore reiterate the recommendation to further monitor and interpret the finding presented in this report.

In 2018 the Zn loads did not increase during high flow at the GK while they more than doubled during high flow in 2017 and 2019. There was also less of an increase in R&B loads in 2018 than other years. The inter-annual variability is clearly correlated to the forcing of climate variability. Therefore, we strongly recommend that the physical hydrologic parameters (water balance) of the OU3 system be quantified and correlated with the above presented results to further the interpretation of findings.

One important note on the consistency of the existing data is that the July 2018 high flow sampling may have missed the early snow melt pulse in 2018, but without higher resolution data we are unable to accurately determine the observed cause and effect relationship. For example, an alternative interpretation of the results is that the OU3 groundwater system sourcing the R&B and GK flows did not receive a significant enough slug of recharge to raise water levels (increase head pressure) in the mine workings so there was much less of a sign of the annual "flush" of metals from seasonally inundated mine workings, especially Zn, that were measured in the other years. It is therefore premature to provide complete interpretation of the observed and measured trends without additional data to support particular hypotheses.

2.4 Metals loading from seeps and springs

Analytical results from the seeps and springs sampled during low-flow and high-flow sampling events in 2019 are in the SCRIBE database and presented in Table 1 for select analytes. These 2019 data complement data collected from BPMD seeps and springs from 2016-18 and reported on in Cowie and Roberts 2020. The 2016-19 seeps and springs dataset serve as baseline data for several purposes including site characterization, loading estimation and modeling, toxicity source identification, and evaluation of whether changes occur in seeps and springs and draining mines in conjunction with remediation efforts such as the closure of the R&B bulkhead.

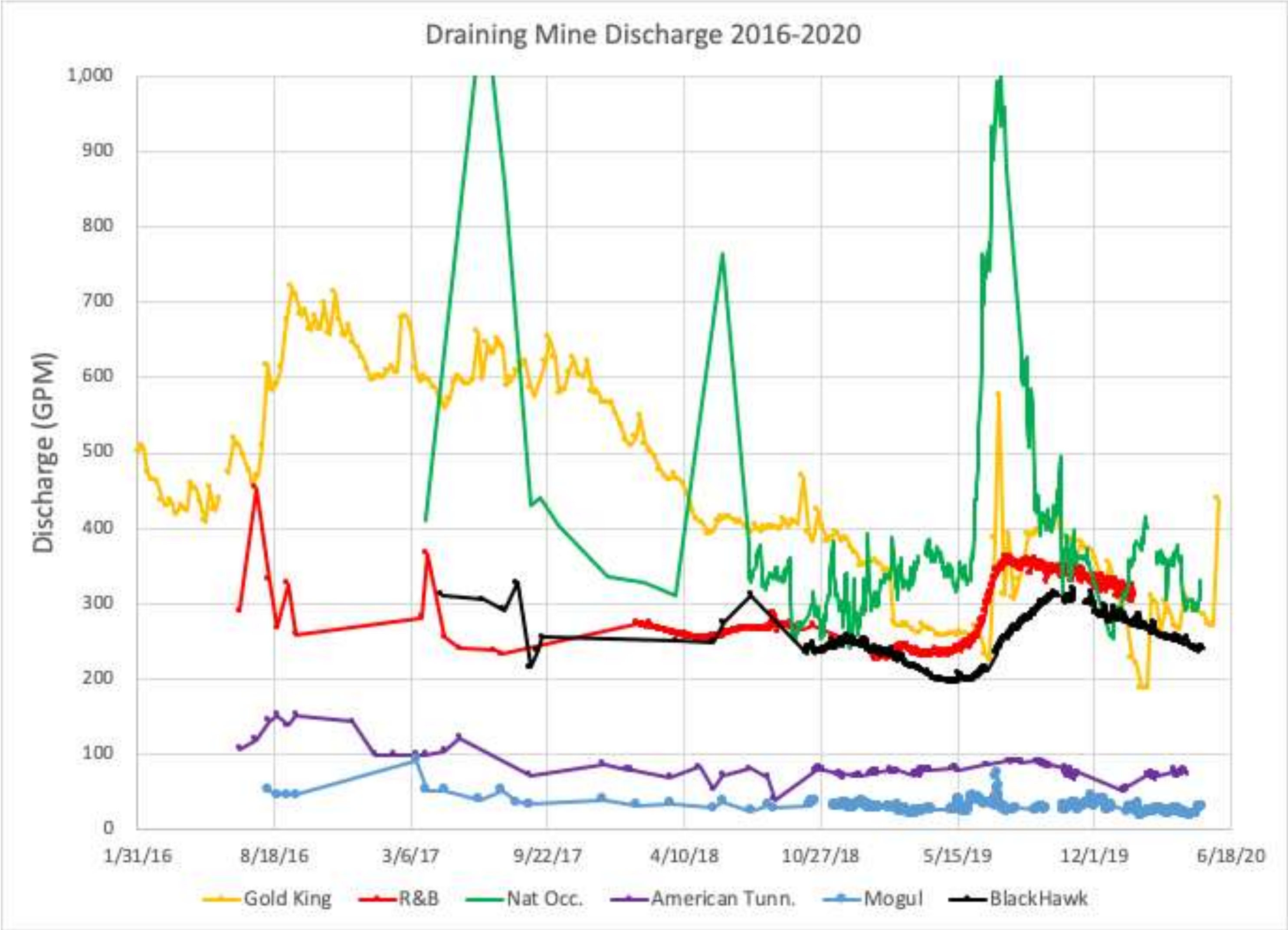

Figure 3: Mean daily discharge from six draining mine adits on Cement Creek. Gold King discharge is weekly mean discharge. Lines added between values to depict higher resolution sampling from July 2019 forward.

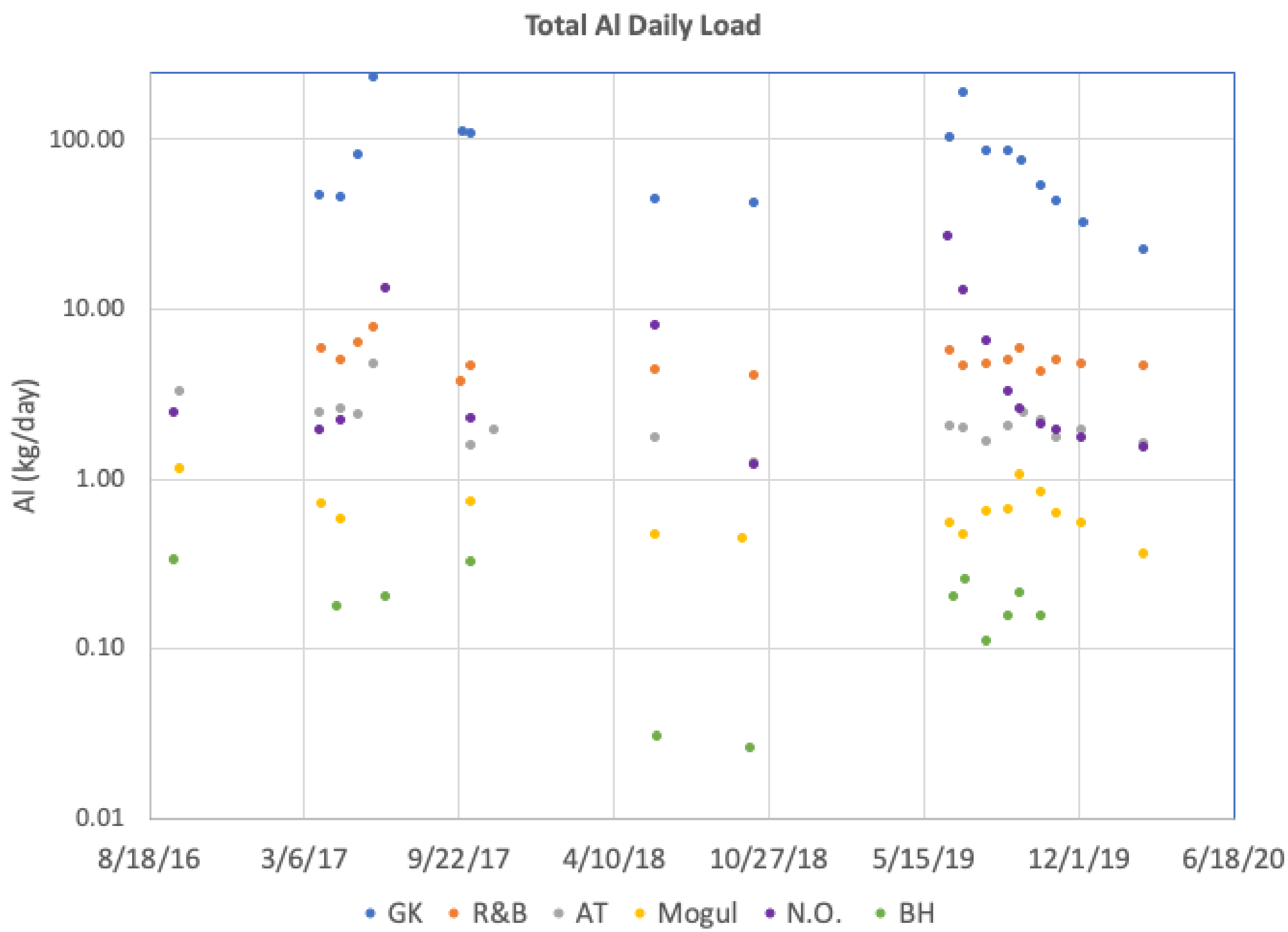

Figure 4: Mean daily total aluminum load from six draining mine adits on Cement Creek (log scale).

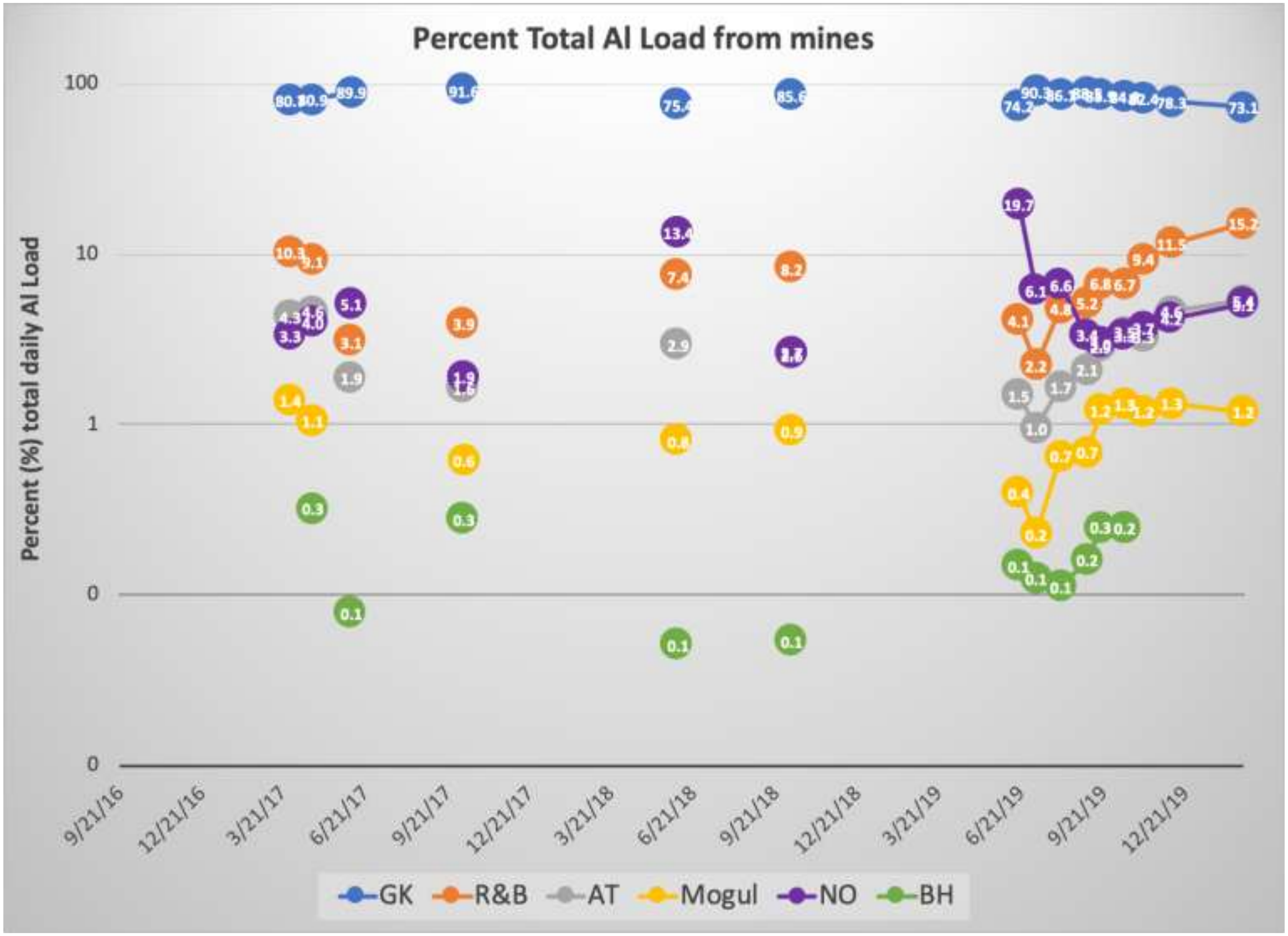

Figure 5: Percent daily total aluminum load from six draining mine adits on Cement Creek (log scale). Lines added between values to depict higher resolution sampling from July 2019 forward.

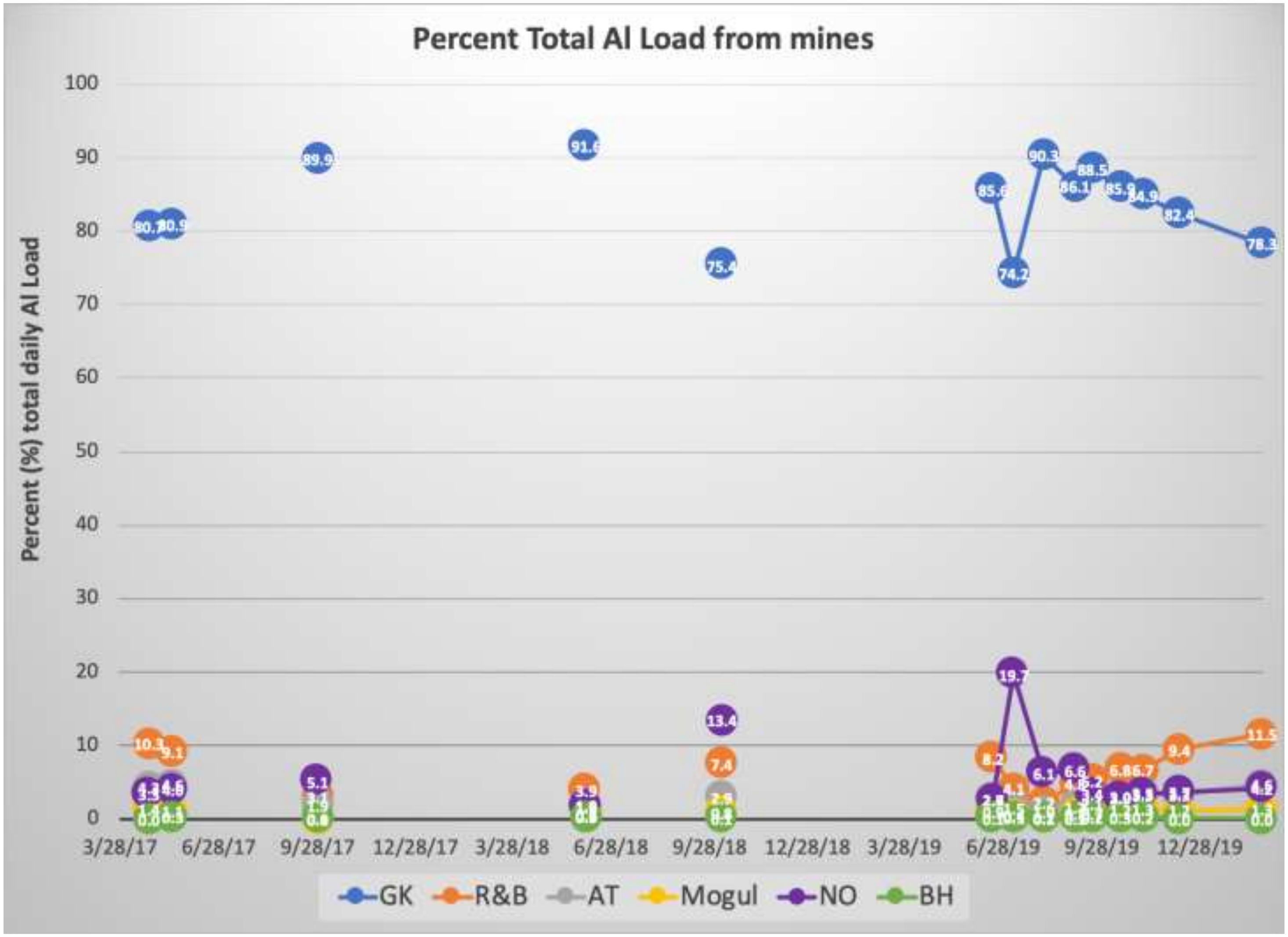

Figure 6: Percent daily total aluminum load from six draining mine adits on Cement Creek. Linear Scale to highlight the separation of load between GK and other adits. Lines added between values to depict higher resolution sampling from July 2019 forward.

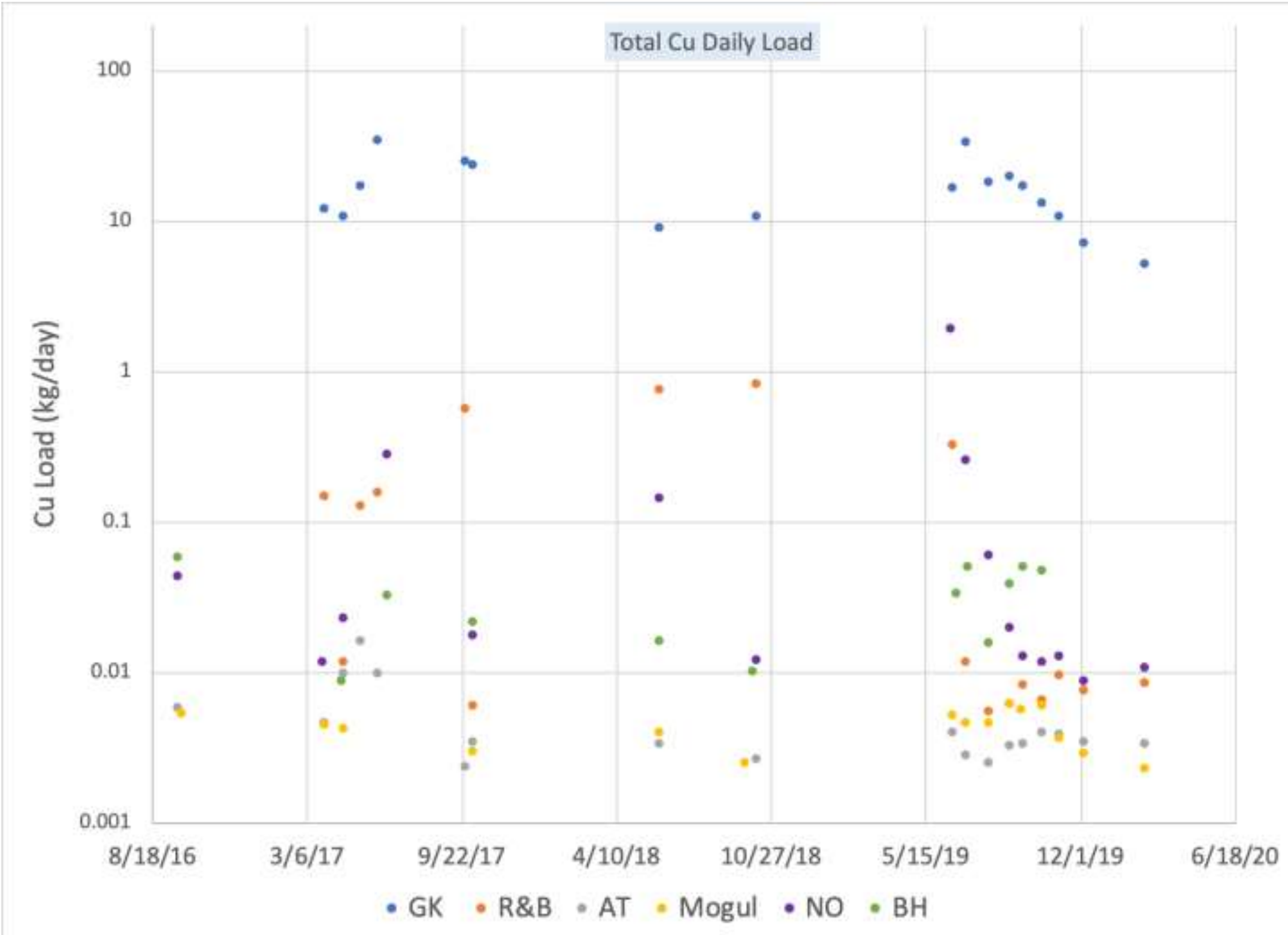

Figure 7: Mean daily total copper load from six draining mine adits on Cement Creek (log scale).

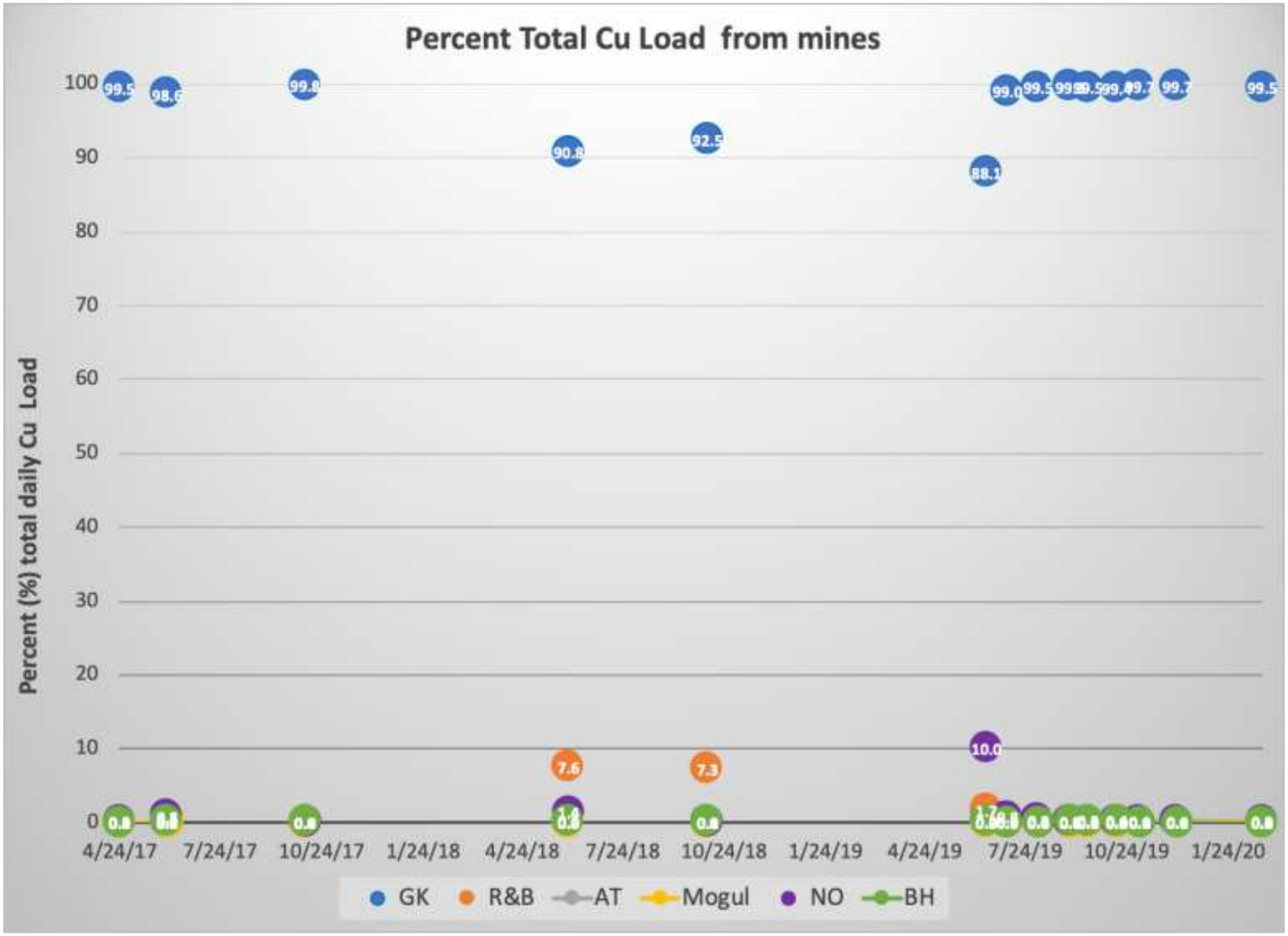

Figure 8: Percent daily total copper load from six draining mine adits on Cement Creek.

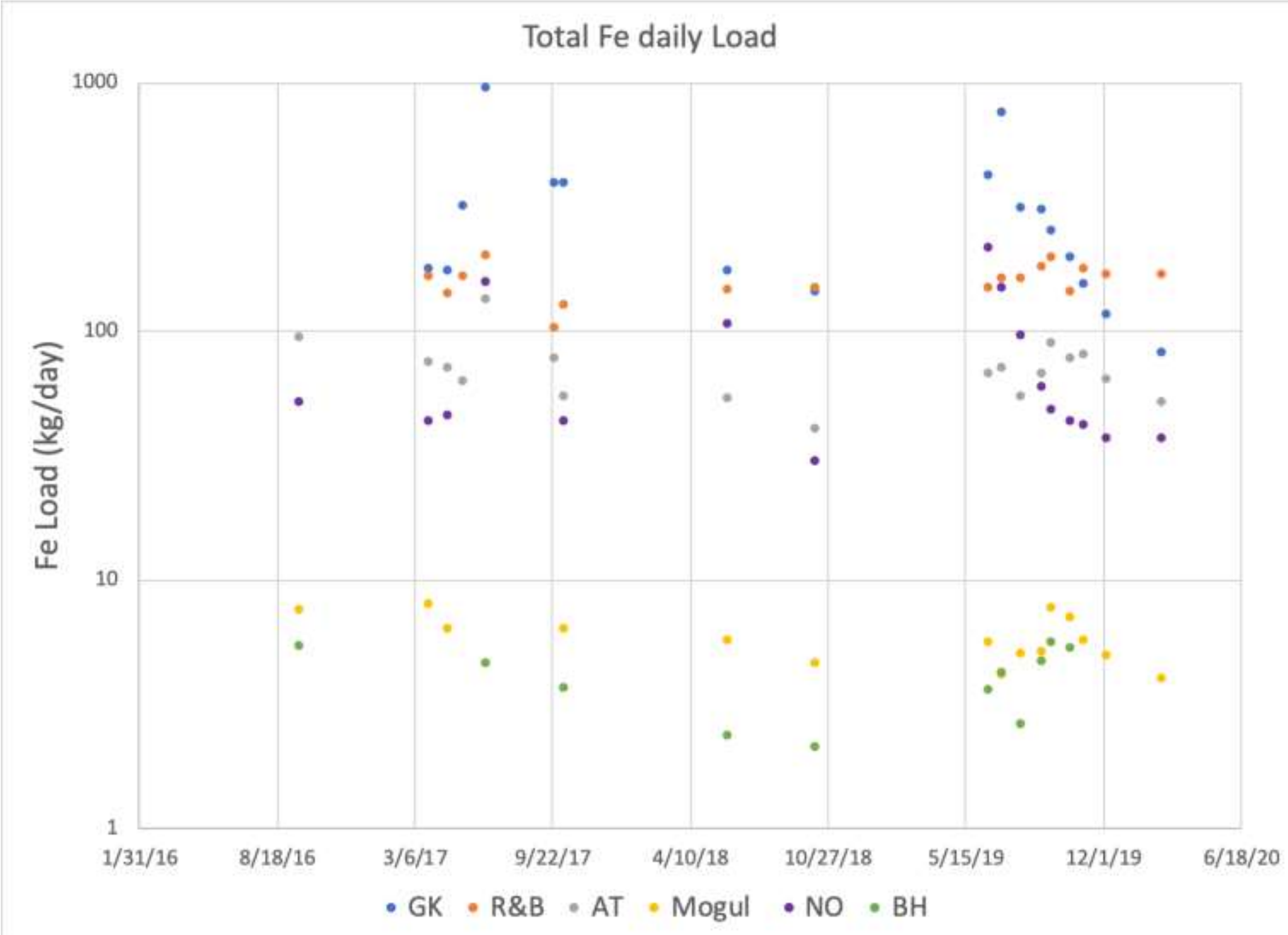

Figure 9: Mean daily total iron load from six draining mine adits on Cement Creek.

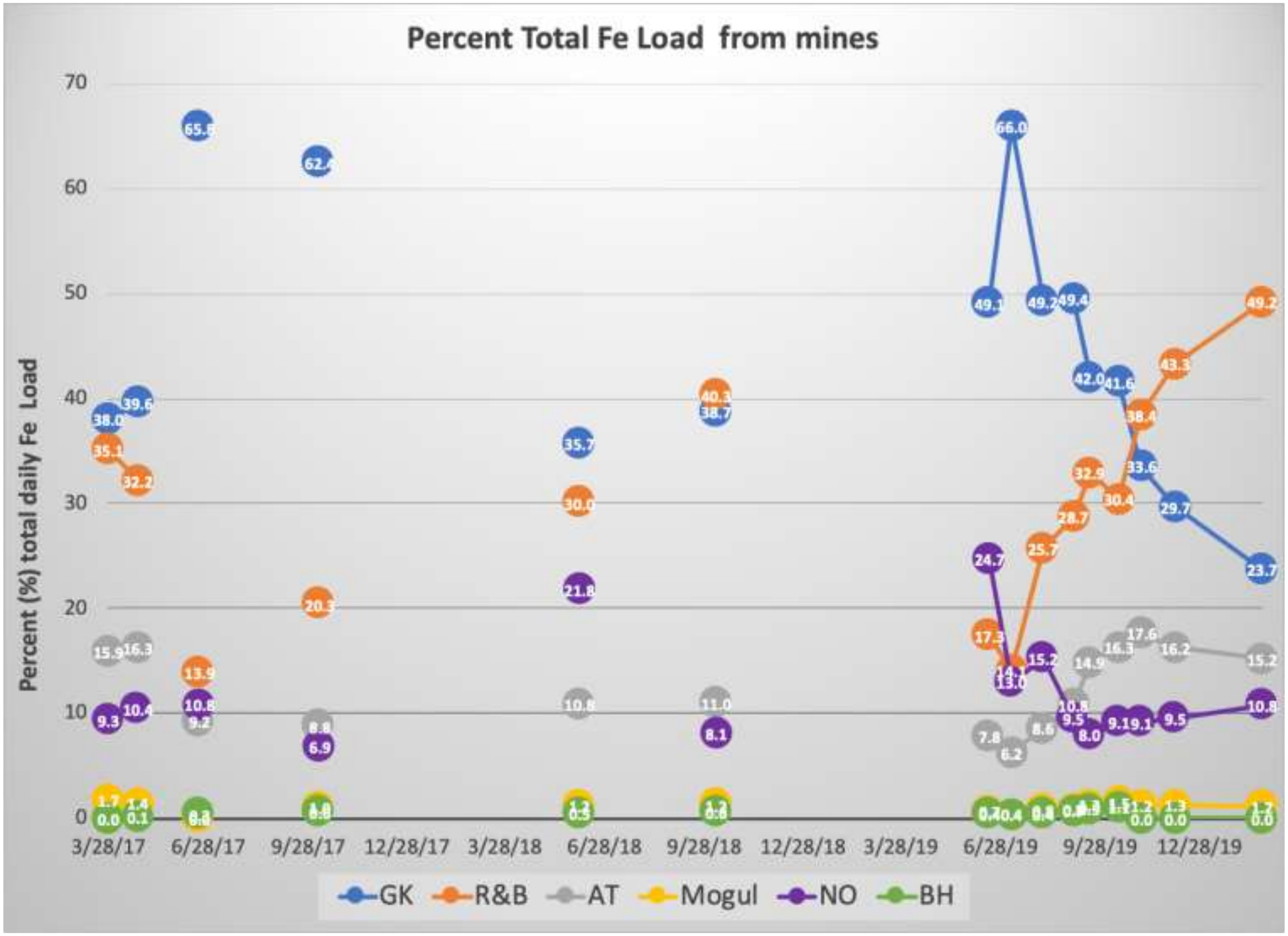

Figure 10: Percent daily total iron load from six draining mine adits on Cement Creek.

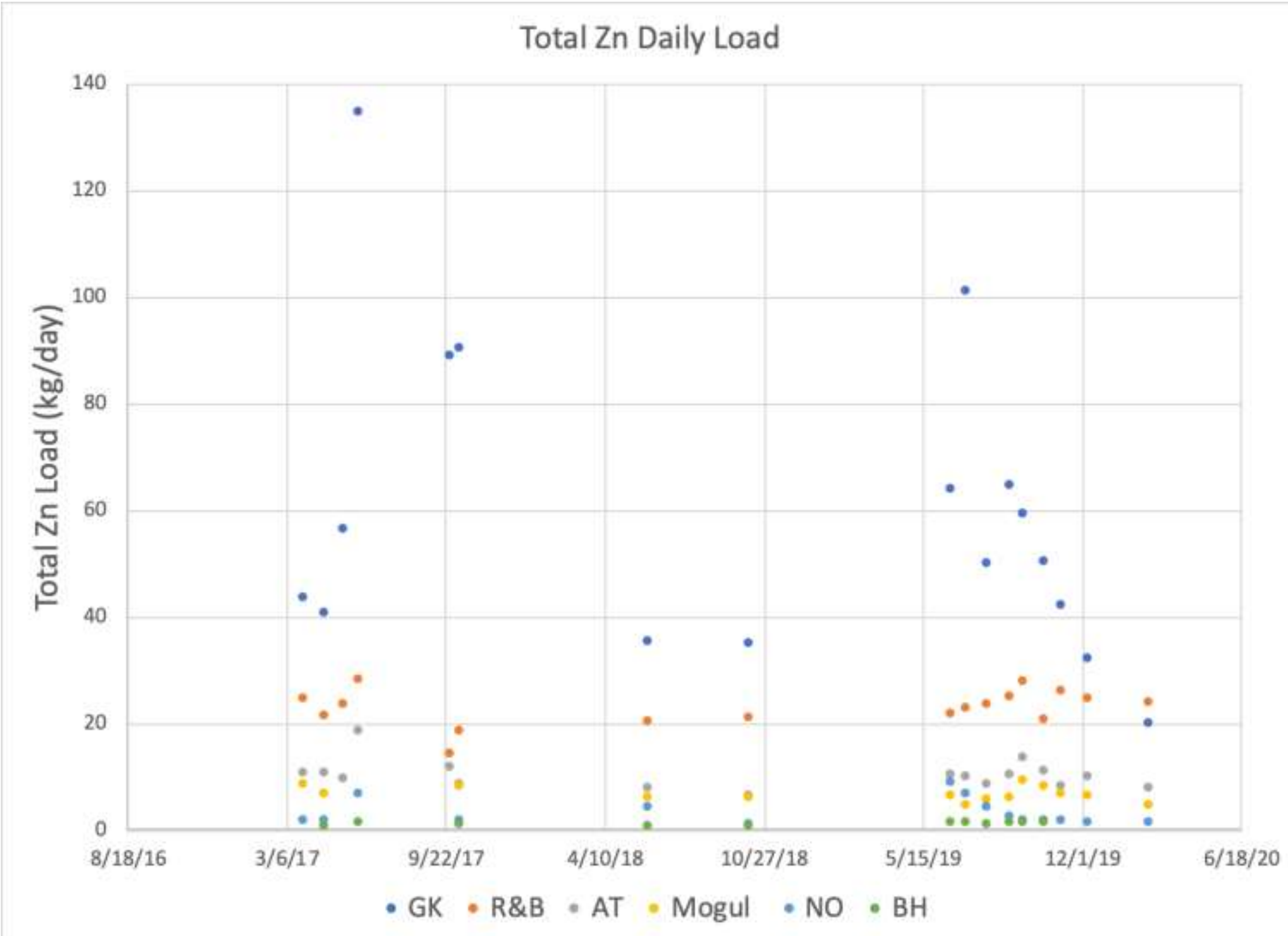

Figure 11: Mean daily total zinc load from six draining mine adits on Cement Creek.

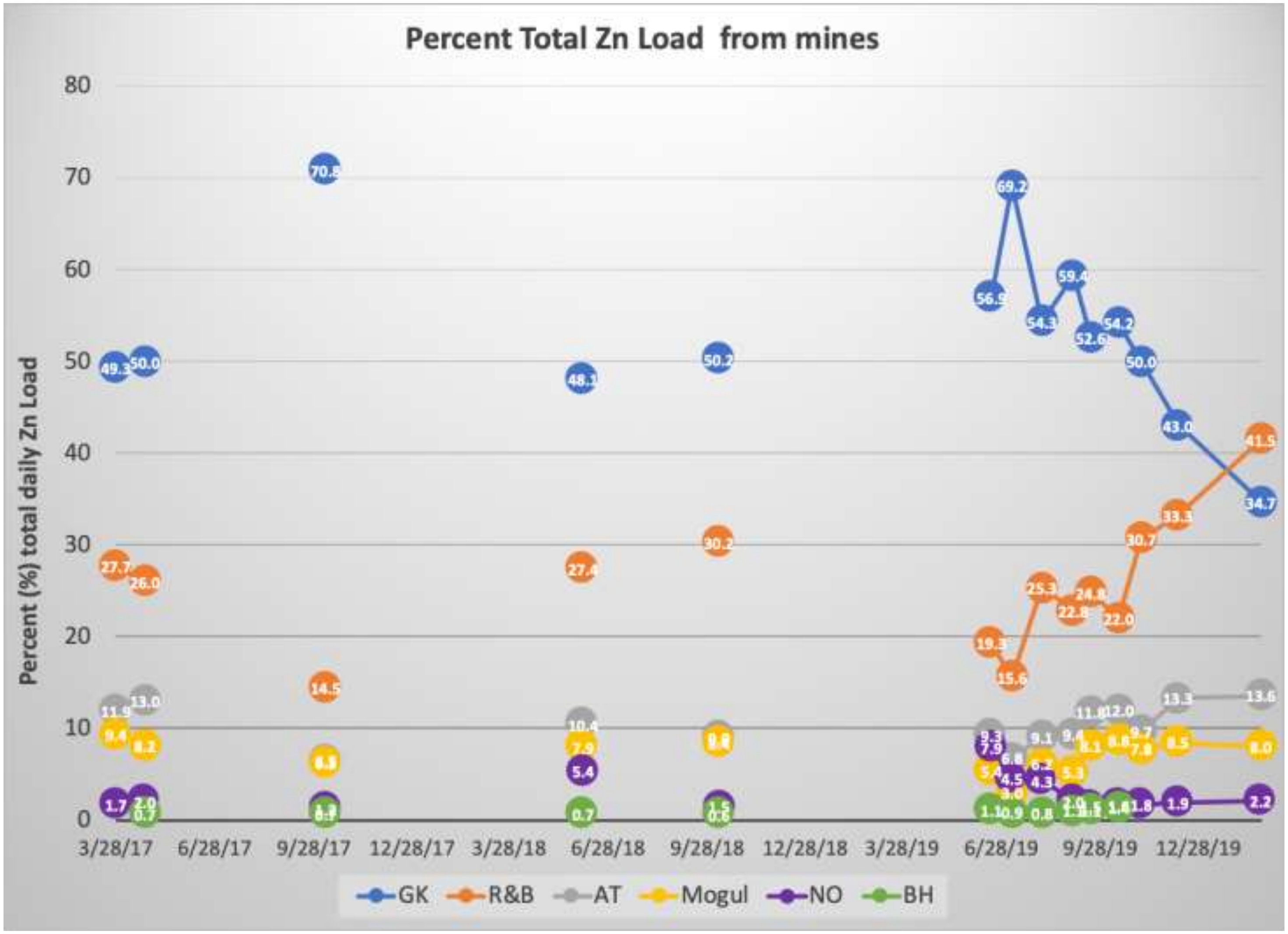

Figure 12: Percent daily total zinc load from six draining mine adits on Cement Creek.

Table 1: Seeps and Spring loads (Al, Cd, Cu, Fe, Pb, and Zn) sampled during 2019 low-flow and high-flow sampling events.

LocationID	SITE_TYPE	SampleDate	SampleTime	2019_LF	2019_HF	Flow(cfs)	Al T Ld	Cd T Ld	Cu T Ld	Fe T Ld	Pb T Ld	Zn T Ld
SS029	SS	7/19/2019	10:20	1	1	0.2500	0.2465	0.0017	0.0028	0.0612	0.0003	0.4165
SS029	SS	9/17/2019	15:00	1	1	0.1670	0.1140	0.0011	0.0013	0.0409	0.0002	0.3227
SS041	SS	9/16/2019	12:30	1		0.0130	0.0049	0.0001	0.0005	0.0049	0.0001	0.0250
SS042	SS	9/16/2019	13:00	1		0.0029	0.0001	0.0000	0.0000	0.0007	0.0000	0.0036
SS044	SS	9/17/2019	12:30	1		0.0795	1.5304	0.0122	0.0484	0.5698	0.0152	6.2227
SS045	SS	6/24/2019	13:25	1	1	0.0350	0.0596	0.0004	0.0002	0.0086	0.0000	0.0394
SS045	SS	9/17/2019	14:00	1	1	0.0012	0.0032	0.0000	0.0000	0.0003	0.0000	0.0020
SS046	SS	9/17/2019	13:15	1	1	0.0032	0.0241	0.0002	0.0002	0.0800	0.0002	0.0242
SS046	SS	6/24/2019	13:40	1	1	0.0030	0.0178	0.0001	0.0001	0.0357	0.0002	0.0197
SS056	SS	6/24/2019	10:55	1	1	0.0053	0.0054	0.0000	0.0000	0.0405	0.0000	0.0032
SS057	SS	7/19/2019	12:15	1	1	0.0084	0.0027	0.0000	0.0001	0.2435	0.0000	0.0086
SS057	SS	9/20/2019	11:40	1	1	0.0002	0.0001	0.0000	0.0000	0.0048	0.0000	0.0015
SS058	SS	7/19/2019	11:50	1	1	0.0843	0.0170	0.0001	0.0008	0.0206	0.0002	0.0227
SS058	SS	9/20/2019	10:20	1	1		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SS059	SS	9/19/2019	13:45	1	1	0.0171	0.0372	0.0000	0.0002	0.0042	0.0000	0.0263
SS059	SS	6/24/2019	12:50	1	1	0.0100	0.0135	0.0001	0.0001	0.0024	0.0000	0.0105
SS060	SS	6/24/2019	11:25	1	1	0.0570	0.1237	0.0002	0.0072	0.0139	0.0001	0.0503
SS060	SS	9/19/2019	14:00	1	1	0.0035	0.0059	0.0000	0.0003	0.0009	0.0000	0.0031
SS062	SS	9/18/2019	15:15	1	1	0.0006	0.1327	0.0003	0.0010	0.1199	0.0004	0.1284
SS062	SS	6/24/2019	9:50	1	1	0.0350	0.0027	0.0000	0.0000	0.0214	0.0000	0.0006
SS064	SS	9/18/2019	13:15	1		0.0024	0.0016	0.0000	0.0000	0.0018	0.0000	0.0012
SS065	SS	6/20/2019	13:21		1	0.5000	2.2386	0.0016	0.0031	0.1223	0.0006	1.9450
SS067	SS	6/24/2019	9:15	1	1	0.0020	0.0617	0.0001	0.0011	0.0352	0.0000	0.0412
SS067	SS	9/19/2019	11:00	1	1	0.0006	0.0255	0.0001	0.0005	0.0203	0.0000	0.0166
SS068	SS	6/24/2019	9:15	1	1	0.1140	0.6833	0.0017	0.0259	0.1328	0.0070	1.1798
SS068	SS	9/19/2019	11:30	1	1	0.0020	0.0224	0.0000	0.0009	0.0107	0.0001	0.0356
SS069	SS	9/20/2019	12:45	1	1	0.0003	0.0891	0.0005	0.0024	0.0189	0.0000	0.1380
SS069	SS	6/24/2019	10:30	1	1	0.0130	0.0026	0.0000	0.0001	0.0001	0.0000	0.0042
SS084	SS	9/19/2019	16:00	1		0.0124	0.1922	0.0002	0.0215	0.6022	0.0002	0.0575
SS200	SS	6/24/2019	15:00	1	1	0.0140	0.0080	0.0000	0.0001	0.0891	0.0001	0.0066
SS200	SS	9/19/2019	11:00	1	1	0.0082	0.0019	0.0000	0.0001	0.0815	0.0000	0.0054
SS236	SS	6/24/2019	9:50	1	1	0.2270	3.3822	0.0107	0.1222	0.1916	0.0114	3.3156
SS236	SS	9/20/2019	14:30	1	1	0.0047	0.1314	0.0003	0.0035	0.0045	0.0001	0.0893
SS250	SS	6/24/2019	11:10	1	1	0.0230	0.0027	0.0001	0.0003	0.0659	0.0003	0.0115
SS250	SS	9/19/2019	12:30	1	1	0.0223	0.0011	0.0000	0.0001	0.0071	0.0000	0.0057
SS301	SS	9/23/2019	13:10	1		0.0088	0.3567	0.0001	0.0009	0.3048	0.0002	0.2421

3. Interpretation of tracer results

In 2018 and 2019 several different natural tracers were sampled at sites across the BPMD. The additional sampling occurred during high flow and low flow seeps, springs, and draining mine sampling events and were conducted by MSI under various contract agreements with EPA. The additional sampling included rare earth elements (REE) in 2018 and for CFC, SF6, and N2/Ar in the low flow sampling event of 2019. The results will be compared to the tritium, stable isotopes and water chemistry data to provide more information on groundwater residence times and source water mixing scenarios. The results from these natural or existing conservative tracers will provide information on similarities and differences between sources of different ground water emergence locations (mines and S&S) in relation to the OU3 (Bonita Peak Groundwater) study area defined by the EPA. The tracer results will also be compared with results from the USGS stream tracer study and other EPA ORD studies including the fiber optic distributed temperature sensing studies to develop a conceptual site model and provide constraints and inputs for future OU3 groundwater modeling efforts. The groundwater age dating data and other tracer data will be combined with the existing SCRIBE database data at a later date. The interpretation of these results is anticipated to occur as a future task order.

4. Works Cited

Cowie, R. and S. Roberts. 2020. Bonita Peak Mining District 2016-2018 Seeps, Springs, and Draining Mines Characterization Report. https://semspub.epa.gov/work/08/100007694.pdf

Techlaw. 2020. 2019 Bonita Peak Mining District Sampling Analysis Report….***Need citation from EPA/TechLaw****