Technical Assistance Services *for* Communities
Summary of "Red and Bonita Mine Bulkhead Closure Evaluation 2017 Update"
August 2017

Contract No.: EP-W-13-015
Task Order No.: 18 OSRTI-Multi Regions
Technical Directive No.: R8 3.3.2 Bonita Peak Mining District (BPMD)

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Introduction

The Bonita Peak Mining District (BPMD) is located just north of Silverton, Colorado, in the San Juan Mountains. District mines yielded gold, silver, copper, lead and zinc. Some of the mines operated until 1991 although most of the mining took place before then. Today, only three active mine permits remain, but mining is not active. As groundwater moves through the area, it carries mining-related minerals and acidic waters into nearby waterways. Mining-related waste piles, shafts and tunnels can worsen this process. In the spring of 2016, the U.S. Environmental Protection Agency (EPA) identified 48 mines and mine-related areas such as waste piles that are the largest sources of mining-related minerals in the watershed. These areas are the Superfund site.

The Bonita Peak Planning Group, composed of stakeholders from the Town of Silverton and San Juan County, requested EPA's Technical Assistance Services for Communities (TASC) program to conduct a technical review of the Red and Bonita Mine Bulkhead Closure Evaluation 2017 Update (Bulkhead Closure Evaluation). The Bulkhead Closure Evaluation was completed by a consulting company, Deere and Ault Consultants Inc., with the goal of understanding the possible impacts of closing the Red and Bonita Bulkhead valve on the movement of minerals in the water and the stability of other mine systems in the BPMD.

This TASC document summarizes the findings of the report in plain language and identifies areas where the community could consider following up with EPA, noted in "TASC Comment" boxes. This is not an EPA document. Independent consultants from EPA's TASC program, including technical advisors and hydrogeology expert Dr. William Sanford, produced this document. The contents do not necessarily reflect the policies, actions or positions of EPA.

Geology

In the upper Cement Creek area, the Gold King Mine, Red and Bonita Mine, and American Tunnel are all located within the same geologic feature, the Burns member, of the inactive Silverton volcanic feature. The upper part of the Burns member contains most of the gold in BPMD and is divided from the bottom by a 25-foot layer of volcanic rock containing pumice and pebbles. This layer may block or allow water movement depending on conditions not specified in the report.

> *TASC Comments:*
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> The Bulkhead Closure Evaluation states the Burns member could be a water barrier or source of water. The community could ask for clarification about when the Burns member acts as a barrier or a source of water throughout the study area. The tunnels go from the upper to the lower Burns layer in some places, making it important to understand which direction water moves.

The lower North Fork of Cement Creek below the Gold King Mine is within the fractured rocks of the lower Burns member. The fractures in the rock in this zone are close together near the surface and get farther apart deeper in the ground. A fault and associated fractured rock zone below the creek previously sent groundwater into the American Tunnel at rates up to 900 gallons per minute (gpm).

There are three main faults in the area – the Bonita Fault, Ross Basin Fault and Toltec Fault. The Bonita Fault, below Bonita Peak and between American Tunnel Bulkheads 1 and 2, previously sent water into the Gold King Mine but not into the American Tunnel, which is deeper than the Gold King Mine.

A vein in the rock running north-south between the Adams and Red and Bonita Mines could be a subsurface dam to stop groundwater flows towards Cement Creek. A drain to groundwater flows parallel to Cement Creek. There are two springs where the vein crosses the North Fork, which supports this observation.

Background

Mining companies actively mined several sites at and around the Red and Bonita Mine, including Sunnyside Mine, Gold King Mine, Mogul Mine, Pride of Bonita Mine, Lead Carbonate Mine, Adams Mine and exploration adits or mine entrances.

Beginning in 1900, the American Tunnel was constructed from Gladstone to beneath the Gold King Mine; it was widened in 1961 and extended to the Sunnyside Mine for drainage and hauling. The North Fork Cement Creek fracture zone contributed water to the American Tunnel. In 1978, Lake Emma broke into the Sunnyside Mine, allowing precipitation to flow into the mine workings. Over time, a number of bulkheads or walls were built in tunnels, affecting water flow through the mine system. American Tunnel Bulkhead 1 and Terry Tunnel Bulkhead 1 were closed in 1996 and Terry Tunnel Bulkhead 2 was closed in 2000, reducing drainage from

Sunnyside Mine. After the closures, water levels in the Sunnyside Mine rose 1,071 feet. A few years later, American Tunnel Bulkheads 2 and 3 and the Mogul Bulkhead were closed. Water levels were at the same level as the Gold King Mine Level 7 adit and the portal at the adit was closed in 2009 with a soil berm to prevent people from accessing it.

From 2011 to 2016, a number of actions were taken at the Red and Bonita Mine, including modifying the water flow from the portal, evaluating and mapping the mine, assessing water movement in the mine and constructing a concrete bulkhead. The bulkhead valve is currently left open. Uphill of the Red and Bonita Mine, EPA stabilized the Gold King portal in 2015 and 2016 and sent water to the Gladstone treatment plant. Downhill of the Gold King tailings pile, a vertical piezometer (a device used to measure the pressure of the groundwater) was installed in the fractured rock zone along the North Fork of Cement Creek to determine groundwater connections to the American Tunnel. The monitoring showed that water drains from the area of highly fractured rock along the American Tunnel structure towards the creek. Some of the water may exit through a seep on a hillside next to the creek (seep SS-84). EPA is monitoring the water quality of this seep.

Deere and Ault Consultants Inc. developed a three-dimensional model of the site in 2017 including faults and mine workings. The model currently uses the U.S. Geological Survey (USGS) National Elevation Dataset digital elevation model for the surface topography. The model can include seeps, water pressure, monitoring wells and drill holes as information becomes available.

TASC Comments:

Generally, water quality at the seep gives an indication of the impacts of water flowing through a chemically weathered zone, which leads to the water becoming acidic and picking up dissolved metals that can be detrimental to stream chemistry. The community could ask EPA about what current water quality says about the source of the water in the seeps and how bulkhead closure could affect water quality.

The community could ask how EPA intends to use the three-dimensional model for decision making and how EPA has validated the model if it is to be used for that purpose. Validation could include field surveys of certain features in the model, such as the USGS elevation model.

Flows from Adits

The Bulkhead Closure Evaluation report states that data on water levels behind the various bulkheads are very limited, but some data on water flow from adits exist. If water is not coming out of the adit, the groundwater level is likely below the level of the adit. Flow from Gold King Level 7 has occurred since the early 1900s. During the American Tunnel extension in the 1950s, water from the North Fork Cement Creek fracture zone and Gold King area drained into the tunnel. After the American Tunnel is plugged, water may again flow as seepage into the North Fork of Cement Creek and from the Gold King and Red and Bonita adits. Flow monitoring increased in the 1990s, including at the Sunnyside, American and Terry Tunnels, and at the Gold

King, Mogul and Red and Bonita Mines. Water has not been seen flowing from the Adams Mine, Lead Carbonate Mine, Pride of Bonita Mine or Adit 268-21; no water was flowing in the summer of 2016.

In addition to connections between adits and mine workings, precipitation patterns affect the amount of water in the mines. The Red Mountain Pass Snotel Station in the BPMD measures both rainfall and snow water equivalent (SWE) data. Precipitation affects water flow in the following ways:

- Blackhawk and Silver Ledge Mine flows are thought to be controlled by infiltration of precipitation and surface water instead of coming from the Sunnyside Mine Pool, possibly due to the North Fork Cement Creek fault acting as a barrier.
- After the American Tunnel bulkheads were closed, groundwater levels in Bonita Peak rose since the tunnel no longer acted as a drain.
- A higher mine pool at Sunnyside and elevated precipitation in 2004 and 2005 may have led to increased flows from the Red and Bonita and Gold King Mines. Flows have increased in the last few years as precipitation and groundwater recharge have increased.
- Flows from the Mogul Mine are also affected by precipitation.

Bulkhead construction substantially reduced flow in many adits. When the Mogul Bulkhead was constructed, the barrier to the Sunnyside Mine Pool led to flows decreasing from 100-249 gpm to an average of 22 gpm. Bulkhead 2 closed off the North Fork Cement Creek fracture zone, decreasing flows from the American Tunnel from 833 gpm to 63 gpm, but flows have since increased, suggesting leakage past the bulkhead. Similarly, flows from the American Tunnel slowed down when Bulkhead 3 was constructed. The Red and Bonita Mine responded with time-lagged flow increases following bulkhead closures.

The Bulkhead Closure Evaluation report suggests a connection between the Gold King Mine and Red and Bonita Mine through the faults and fracture zones; as flows from the Gold King Mine increase, they decrease from the Red and Bonita Mine, while the overall flow remains the same. For example, during the 2015 release from the Gold King Mine, flows from the Red and Bonita Mine dropped and flows from Gold King increased.

TASC Comments:

The community could ask for a formal assessment of flows and models, given the limited availability of flow data. The community could ask for a map or table of flows to show the spatial relationships across the site and the effects of precipitation and bulkhead closures on flows. Based on the information in the Bulkhead Closure Evaluation, three areas of data collection could be beneficial for the community: 1) water levels over time, 2) more purposeful collection of flow rates over time, and 3) an understanding of the effect of wet and dry years on mine workings. For instance, Figure 3 of the Bulkhead Closure Evaluation suggests there might be a lag period between precipitation and flows. Understanding this relationship will be important for larger precipitation events, the stability of bulkheads and water quality in waterways.

Groundwater and the Impact of Closing the Red and Bonita Bulkhead

The Bulkhead Closure Evaluation report says that bulkheads are underground dams and should be treated similarly. This includes slowly filling the pool behind the bulkhead in stages and monitoring the response of the mine system using rainfall data, water levels, flows and seeps over a period of time. Closing the Red and Bonita Bulkhead may increase seepage from nearby mines (such as Gold King) and seeps into Cement Creek and the North Fork of Cement Creek. Impacts to bulkhead stability are less likely.

Before mining, the Bonita and Ross Basin faults acted as a partial barrier to water movement by preventing water from reaching downstream areas like Cement Creek. The Gold King and Sunnyside Mines created holes in this barrier, allowing water to flow more freely. The groundwater level is not known, but was estimated by assessing water levels from existing data from seeps, a monitoring well and the amount of water flowing from the Gold King adit. Groundwater levels were higher in 2016 than in 2002. After mining, the groundwater levels are thought to be approximately 11,500 feet above sea level along the American Tunnel, above the Red and Bonita portal elevation of 10,957 feet and Gold King portal elevation of 11,436 feet.

In its assessment, the State of Colorado determined that the Red and Bonita Mine is connected to the American Tunnel Bulkhead 2 Mine Pool by the North Fork Cement Creek fracture zone. The Bulkhead 2 design assumes that groundwater will only rise to the level at which it can seep into the North Fork of Cement Creek, but it is not clear to what level seepage into the creek will limit the level of groundwater rise. If water flows in faster than it seeps into the creek, groundwater in the area can rise. Closing the Red and Bonita Bulkhead could raise groundwater levels in other areas, including the Gold King Mine. Closing the Red and Bonita Bulkhead could cause water to build up and emerge from the currently dry Adams Mine.

TASC Comments:

Surface water dams are usually filled in stages to test the dam design and look for potential bypass flow and changes to the structural integrity of the dam and of the surrounding geology (to prevent landslides into the reservoir). Likewise, the pool behind the Red and Bonita Bulkhead could be raised in stages by adjusting flow through the bulkhead. By raising the water levels in stages, the effects of the increased pressure on potential seepage, piping and hydraulic jacking, which all result in bypass flow around the bulkhead, can be monitored. If bypass flow is observed, remedial actions can take place to prevent this. In addition, this will allow for observing whether the design pressure of the bulkhead will be reached before the bulkhead's complete closure. This could prevent failure of the bulkhead. As the water level increases, the community could ask EPA to monitor water elevations in the surrounding rock and look for the development of new seeps and additional flow out of existing mine tunnels. The community could ask for more information on the type of monitoring and response to unexpected seepage or water bypassing the bulkhead.

American Tunnel Bulkheads

The American Tunnel bulkheads are the most important features for predicting the effects of closing the Red and Bonita Bulkhead. The bulkheads were placed to control the Sunnyside Mine Pool, inflow from the North Fork of Cement Creek and flows into the first section of the tunnel.

Seepage and piping are the most likely problems. American Tunnel Bulkheads 1 and 2 have low enough pressure to avoid hydraulic jacking, but Bulkhead 3 is at risk if water pressure increases when the Red and Bonita Bulkhead is closed. Shear and structural failure are not very likely. Risk of concrete degradation in the American Tunnel bulkheads was reduced by using either Type II (moderate sulfate resistance) or Type V (high sulfate resistance) cement. The Red and Bonita Bulkhead is designed to use Type V cement. However, the level of acidity is not monitored at the bulkheads, providing limited information on the risk of degradation.

Potential Bulkhead Failure Modes

Seepage and piping is when water finds fractures to bypass the bulkhead and, in severe cases, washes out joint materials. Risks can be reduced by installing bulkheads in stable rock and grouting the surrounding rock.

Hydraulic jacking is when water pressure behind the bulkhead is higher than the surrounding area, creating openings in the joints in rocks. Placing bulkheads deeper in the ground can reduce the risk.

Shear failure is when the bulkhead shifts, allowing water through. Grouting, roughening surrounding rocks and ensuring the rock is stable can reduce risks.

Structural failure is when the concrete in the bulkhead fails. Risks can be reduced by installing rebar at both ends and by extending the length of the bulkhead.

Concrete degradation is when acid mine water breaks down the bulkhead concrete. Risk can be reduced by using sulfate-resistant cement.

The Bulkhead Closure Evaluation report provides support for grouting bulkheads to 2.5 times the water pressure in the tunnel, and to grout into the rock surrounding the bulkhead. Grouting involves filling cracks in rock with cement to prevent water from moving around the bulkhead. For Bulkhead 1, grouting did not penetrate the surrounding rock and was rated for 100 to 500 pounds per square inch (psi) (compared to potential water pressure at the bulkhead of 670 psi). For Bulkhead 2, grouting did not penetrate the surrounding rock and was rated for approximately 200 psi (compared to potential water pressure at the bulkhead of 277 psi). For Bulkhead 3, grouting was placed into some drill holes in the surrounding rock and was rated for approximately 200 psi (compared to potential water pressure at the bulkhead of 450 psi). However, because there is water on both sides of Bulkheads 1 and 2, they can resist higher pressures than if there were only air on the downstream side. This is because the weight of water pushing on the upstream side of the bulkhead could compromise the bulkhead, but the risks would be less if pressure was pushing from the other side, balancing the stress on the bulkhead.

During construction of the American Tunnel bulkheads, analyses were conducted to assess the risk of structural failure. The analyses found minimal risks for this type of failure at the bulkheads. During bulkhead construction, seepage and piping were not considered, nor was the

type or stability of the surrounding rock. Seepage and piping are most likely occurring at Bulkhead 2. However, the amount of water flowing downstream from the bulkheads has remained stable, which is a good sign. The source of this water is unknown. Bulkhead 3 could provide the greatest chance of increased flows and risk of a blowout from seepage or piping, even without the Red and Bonita Bulkhead closure, since the condition of the bulkhead is unknown.

The Bulkhead Closure Evaluation report states that monitoring to assess the capacity of the bulkheads could be useful. A groundwater monitoring well currently measures groundwater levels and water pressure at Bulkhead 2. Data from the well are used to understand potential impacts of the Red and Bonita Bulkhead closure. Monitoring at Bulkhead 3 could include a well to measure pressure at the bulkhead and annual inspections of the bulkhead for seepage and stability by creating a new portal for access.

TASC Comments:

The section titled "Flows from Adits" in the Bulkhead Closure Evaluation report states that some seepage could be making it past the American Tunnel Bulkhead. The community could ask for clarification about the extent of seepage and whether enough information is available to understand the chance that the bulkhead will fail. For example, an assessment of pressure on the bulkhead compared to the amount of pressure the bulkhead was designed for could be useful.

The report suggests insufficient grouting around the bulkheads. The report also states that shear and structural failure are not very likely. The community could ask if a more detailed evaluation of grouting rating, stability of grout and types of failure will be completed.

The grout being used will be sulfate resistant. The amount of sulfate resistance differs based on additives in the cement, even within a type of grout. The community could ask for clarification on the source and standards of the cement grout class and if any additives are used, and the concentration of the additives. Data sheets with tests of acid mine water exposure could be helpful.

Conclusions and Recommendations

The Bulkhead Closure Evaluation report provides recommendations for the Red and Bonita Bulkhead closure. Groundwater levels across BPMD are relatively unknown, and flows have increased over the past decade. The largest risk of failure is seepage past the bulkhead, primarily at American Tunnel Bulkhead 3. Bulkhead 3 would be at greater risk from rising groundwater levels across BPMD rather than from the direct effects from the Red and Bonita Bulkhead closure.

Seepage and increased flows from other mines and surface features are likely once the Red and Bonita Bulkhead is closed. This is particularly true for the Adams Mine, Adit 268-21 and the drainage between them. The Bulkhead Closure Evaluation report suggests increasing the number of flow monitors at Sunnyside Mine Pool, especially upstream of Bulkhead 3. The report also

recommends measuring the chemical content of the water at all accessible locations to evaluate if there are different sources of water found at each location.

Red and Bonita Mine Bulkhead: The Bulkhead Closure Evaluation report suggests a monitoring program could be implemented before the valve is closed. Parts of the program are already in place or will be in 2017, including a monitoring well upstream of American Tunnel Bulkhead 2, and flow monitoring at Red and Bonita Mine, Mogul Mine and American Tunnel. Additional monitoring could include flows at Adams Mine, Gold King and Adit 268-21, water pressure at Mogul and Red and Bonita Bulkheads, seeps along Cement Creek and the North Fork of Cement Creek, and preparing Gold King Level 7 for higher flows.

The Bulkhead Closure Evaluation report recommends that various actions be taken before the Red and Bonita Bulkhead is pressurized above 50 feet of head. These include real time monitoring of water pressure at the Red and Bonita Mine Pool; flow control and monitoring at the Gold King portal; monitoring for American Tunnel Bulkhead 3, the Adams Mine and Adit 268-21; and re-establishing access at Bulkhead 3. Also, because water can flow between the Red and Bonita Mine and the Gold King Mine, a flow control structure and monitoring of flow between the two would be beneficial prior to bulkhead closure at Red and Bonita.

TASC Comments:

The community could benefit from additional information on the following:

Additional discussion of the status and characteristics of the Red and Bonita Bulkhead. What tests will be conducted to understand the effects of closing the Red and Bonita Bulkhead? What will happen if the design limit is exceeded, and how will this be determined? As was stated in the report, a phased approach of filling in stages is useful for monitoring stability.

Monitoring wells behind bulkheads will capture water in the tunnel. However, water is stored within fractures in the rock surrounding the tunnels. Monitoring in the tunnel does not provide information on water in the fractured rock. The community could ask for more information and monitoring of water stored in the fractured rock.

The types of water quality measurements are not discussed in detail. The community could ask for a table of water quality measurements, both current and proposed. For instance, water that is more acidic could affect the stability of the bulkheads.

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