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Hydrogeochemical effects of a bulkhead in the Dinero mine tunnel, Sugar Loaf mining district, near Leadville, Colorado

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ABSTRACT

The Dinero mine drainage tunnel is an abandoned, draining mine adit near Leadville, Colorado, that has an adverse effect on downstream water quality and aquatic life. In 2009, a bulkhead was constructed (creating a mine pool and increasing water-table elevations behind the tunnel) to limit drainage from the tunnel and improve downstream water quality. The goal of this study was to document changes to hydrology and water quality resulting from bulkhead emplacement, and to understand post-bulkhead changes in source water and geochemical processes that control mine-tunnel discharge and water quality. Comparison of pre-and post-bulkhead hydrology and water quality indicated that tunnel discharge and zinc and manganese loads decreased by up to 97 percent at the portal of Dinero tunnel and at two downstream sites (LF-537 and LF-580). However, some water-quality problems persisted at LF-537 and LF-580 during high-flow events and years, indicating the effects of the remaining mine waste in the area. In contrast, post-bulkhead water quality degraded at three upstream stream sites and a draining mine tunnel (Nelson tunnel). Water-quality degradation in the streams likely occurred from increased contributions of mine-pool groundwater to the streams. In contrast, water-quality degradation in the Nelson tunnel was likely from flow of mine-pool water along a vein that connects the Nelson tunnel to mine workings behind the Dinero tunnel bulkhead. Principal components analysis, mixing analysis, and inverse geochemical modeling using PHREEQC indicated that mixing and geochemical reactions (carbonate dissolution during acid weathering, precipitation of goethite and birnessite, and sorption of zinc) between three end-member water types generally explain the pre-and post-bulkhead water composition at the Dinero and Nelson tunnels. The three end members were (1) a relatively dilute groundwater having low sulfate and trace element concentrations; (2) mine pool water, and (3) water that flowed from a structure in front of the bulkhead after bulkhead emplacement. Both (2) and (3) had high sulfate and trace element concentrations. These results indicate how analysis of monitoring information can be used to understand hydrogeochemical changes resulting from bulkhead emplacement. This understanding, in turn, can help inform future decisions on the disposition of the remaining mine waste and water-quality problems in the area.

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1. Introduction

Mine waste and draining, abandoned mine tunnels can degrade water quality in areas where historic mining has occurred. Active and passive treatment technologies can help improve water quality (Walton-Day, 2003; Johnson and Hallberg, 2005) where site conditions support success of such technologies and where funding exists for construction and maintenance. Draining mine adits and tunnels are particularly difficult to remediate with active treatment technologies because operation and maintenance can be of unlimited duration and cost prohibitive. A more passive solution is the installation of tunnel plugs, or bulkheads, which limit the flow of water and contaminants from the draining tunnel creating a mine pool and increased water-table elevations behind the bulkhead. Bulkhead installation may improve water quality if submersion of open mine workings in the mine pool behind the bulkhead limits oxygen that fuels the generation of acid mine drainage. However, bulkheads also can redirect mine drainage to the surface at other locations. In the worst case, a bulkhead may fail, resulting in catastrophic release of the contained mine pool to receiving waters (Limerick et al., 2005). Nonetheless, bulkheads are still being installed where improving water quality is a goal and where other solutions are not cost, or practically, effective. Post-bulkhead monitoring is generally somewhat limited to ensuring that the bulkhead remains intact and decreases the flow of water from

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the affected tunnel. Detailed monitoring beyond the geographic extent of the tunnel and select downstream monitoring locations is not generally attempted.

The Sugar Loaf mining district is an abandoned, historic mining district located west of Leadville, Colorado (Fig. 1). The mining district operated from about 1880 until the 1920s and produced primarily silver, but also some gold, lead, and zinc from metal-sulfide rich veins in Precambrian granite, schist, and gneiss bedrock (Singewald, 1955).

Currently (2015), mine waste and discharge of water from mine tunnels degrade water quality in Lake Fork Creek which drains most of the mining district. Previous studies indicated that during

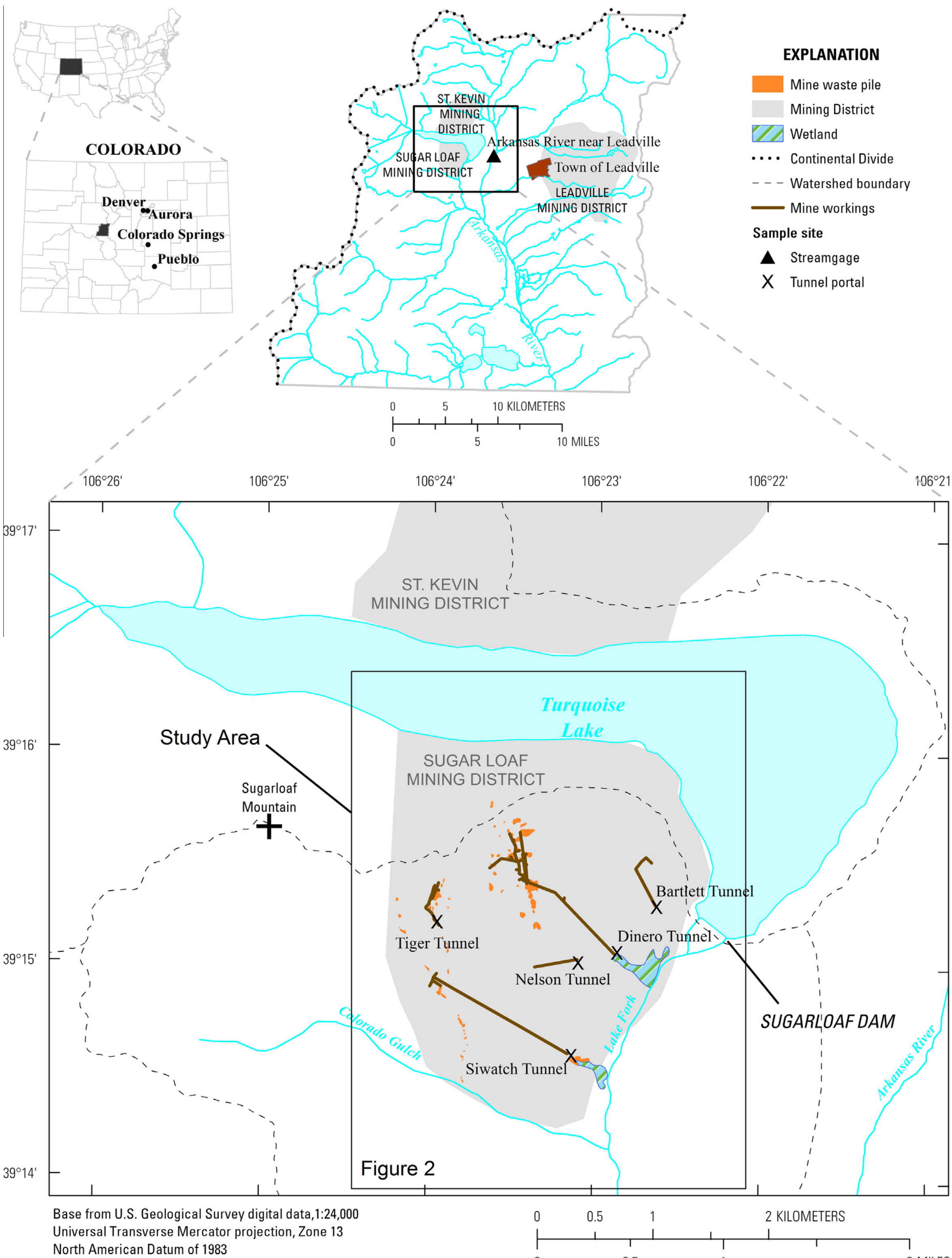

Fig. 1. Location of study area near Turquoise Lake, in Lake County, Colorado.