Increasing ARD and rare earth metal concentrations in an alpine watershed

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Abstract The coupled environmental impact of acid rock (ARD) and acid mine drainage (AMD) is a problem facing many waterways across the Rocky Mountains and throughout the world, particularly in areas of historic mining. Here we examine the Snake River watershed, located near the former mining boomtown of Montezuma, Colorado. Over the last three decades, researchers for numerous government agencies, the Institute of Arctic and Alpine Research, and graduate students from the University of Colorado have monitored changes in Snake River water chemistry and metal contamination present in its tributary streams.

Keywords rare earth, acid rock drainage

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The Snake River watershed represents a unique water quality challenge because its headwaters are impacted by ARD, and downstream tributary inflows compound this with AMD. These acidic, metal-rich inflows create an acutely toxic environment for fish and most aquatic organisms. Long-term data sets of precipitation, temperature, river discharge at many sites throughout the Colorado Rockies show decreasing trends in summer flows (Rood *et al.* 2008) which correlate to other, more recent findings which highlight a snowpack that is melting 2–3 weeks earlier (Clow 2010). Using snow water equivalent measurements from SNOTEL sites nearest to the Snake River, a trend was shown between advancement of peak stream flow by an earlier melt season and rising metal concentrations in summer months (Todd *et al.* 2012). A 30-year water chemistry data set from the upper Snake River further show that fluctuations from 100–400 % of baseline are occurring during these low-flow months. Over the last 10 years, more frequent drought conditions and earlier occurrence of peak spring snowmelt have further reduced water quality during low-flow conditions. In addition to lower flows, changes in water chemistry have been driven by increased weathering rates of exposed sulfide minerals, resulting in decreased pH. The additional acid production has caused dissolution of metals from the host rock and enrichment of the stream with these solutes, which are mobilized greater distances down the reach.

Iron is the predominant metal present in the upper Snake River, but upon mixing with pristine neutral inflows precipitates as iron oxides (McKnight *et al.* 1988). Zinc, however, is less affected by this increase in pH and remains dissolved well downstream of the ARD and AMD sources. Of particular concern is that stream chemistry data has shown a four-fold increase in zinc concentrations in the last 10 years, with a transition from a steady linear increase over a previous 20-year record to that of an exponential trend (Crouch *et al.* 2012). More recent study of the upper Snake River and its contributing streams led to the discovery of rare earth metals in high concentrations. For example, neodymium is present in one particular tributary in levels as high as 120 µg/L. Retesting of archived samples going back as far as the 1990s has confirmed a continued presence, proving an intriguing issue for further study. The hydrologic and geochemical changes observed in this watershed may have important implications for mitigation as well as remediation of mine sites.

References

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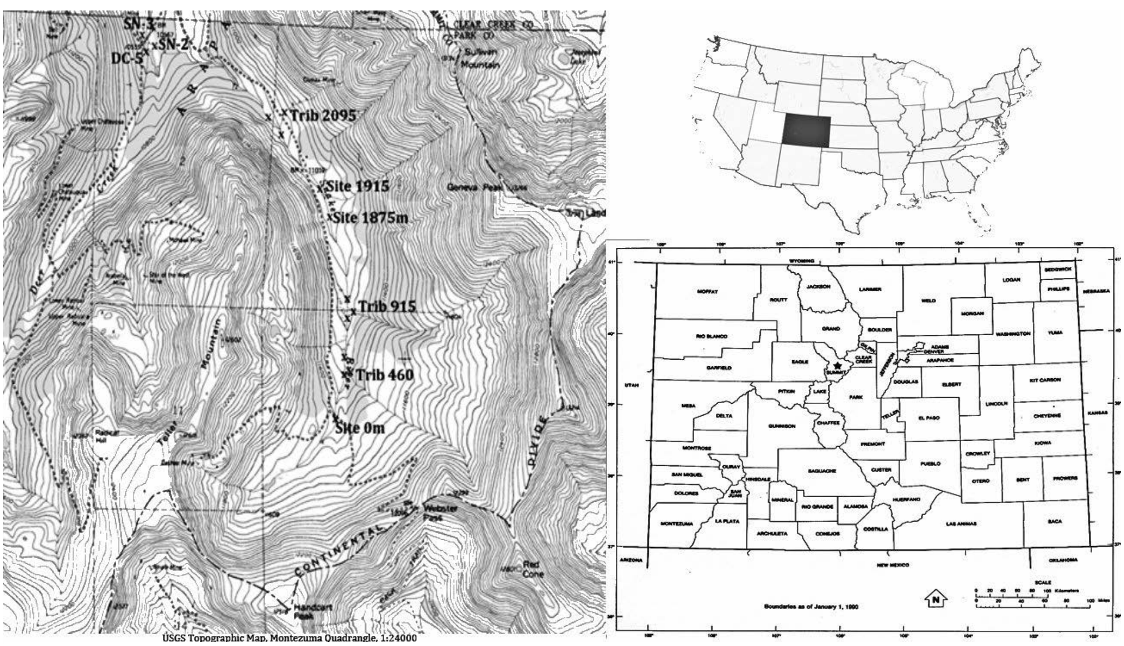

Fig. 1 *Site location*

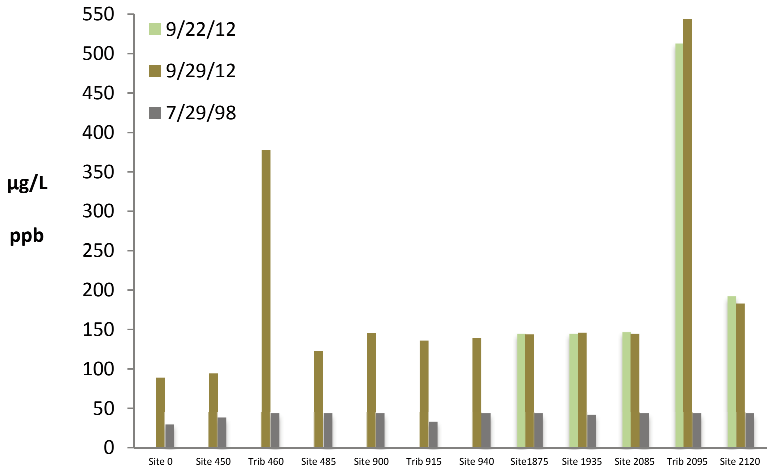

Fig. 2 *Sulfate solute concentrations for various sampling sites and dates*

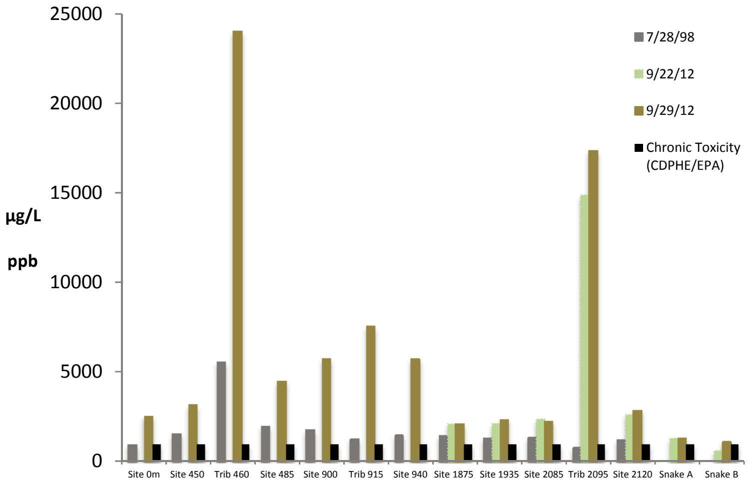

Fig. 3 *Iron concentrations in the upper Snake River and Colorado Aquatic Life Standards*

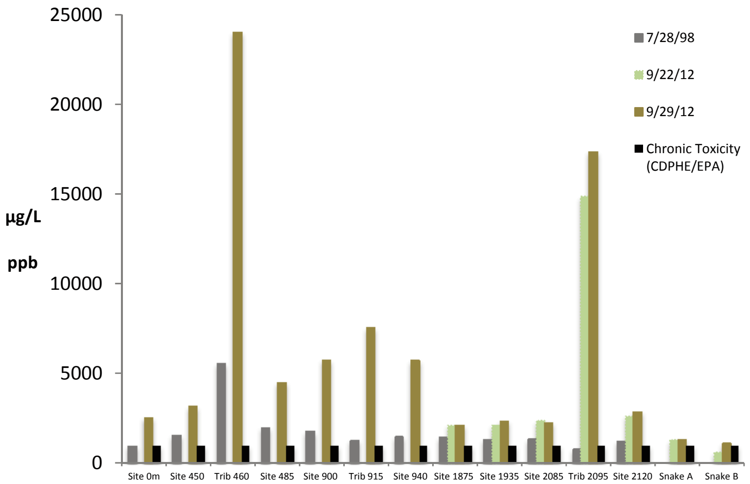

Fig. 4 *Zinc concentrations in the upper Snake River and Colorado Aquatic Life Standards*

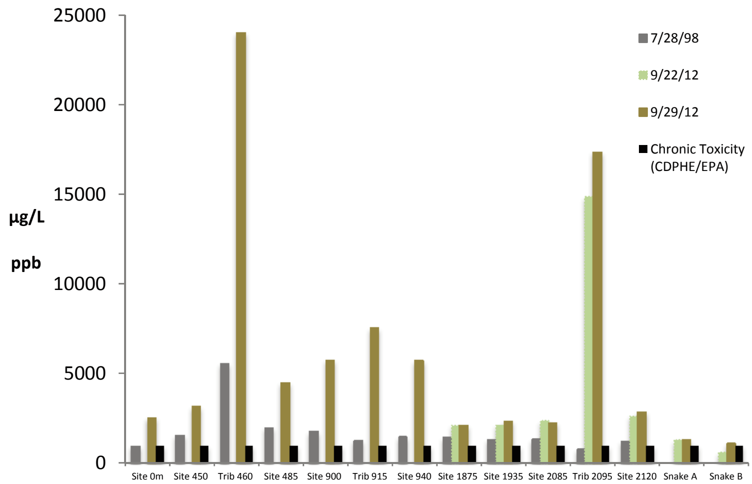

Fig. 5 *Mean of September zinc concentrations at SN-2, 1980–2012*