CHARACTERIZATION AND TREATMENT OF METAL CONTAMINATED IRRIGATED MEADOWS ADJACENT TO THE ARKANSAS RIVER NEAR LEADVILLE, CO[1]

S.R. Jennings[2], J. Christner, R. Merrick, D. Wall and M. Holmes

Abstract. Releases of mine waste, contaminated water and sediments with elevated levels of metals have impaired productivity of agricultural land adjacent to the Arkansas River and downgradient from the historic mine districts of Leadville, Colorado. Historically irrigated agricultural meadows outside the floodplain contaminated by low pH, metal enriched irrigation water were sampled. The resultant depositional pattern shows the influence of irrigation ditches in conveying contaminated materials as expressed by bare ground and sparse vegetation cover dominated by metal tolerant species. The co-occurence of phytotoxicity with acidic soil was described during pre-treatment sampling.

Additional Keywords: acid sulfate soil, phytotoxicity, metal contamination

---

[1] Paper was presented at the 2009 National Meeting of the American Society of Mining and Reclamation, Billings, MT, ***Revitalizing the Environment: Proven Solutions and Innovative Approaches*** May 30 – June 5, 2009. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

[2]Stuart R. Jennings, Environmental Geologist and Principal, Reclamation Research Group, LLC., Bozeman, MT 59715.

Proceedings America Society of Mining and Reclamation, 2009 pp 633-644
DOI: 10.21000/JASMR09010633
http://dx.doi.org/10.21000/JASMR09010633

Introduction

Historic mining near Leadville, CO occurred at the headwaters of the Arkansas River. Uncontrolled releases of mine waste beginning in the late 1800's caused deposition of metal-enriched mine waste within the floodplain of the Arkansas River as well as outside and above the floodplain when agricultural irrigation ditches were overwhelmed by flood water and sediments originating in the mining district. The resulting pattern of deposition shows varying depths of metal contamination, most typically 5-25 cm in the irrigated meadows. Deposits of waste and contaminated soil are deepest adjacent to historic irrigation ditches and are visible as bare and sparsely vegetated soil. The contaminated floodplain and irrigated meadows are designated as Operable Unit (OU) 11 of the California Gulch Superfund Site. Fluvial tailing deposits within the floodplain of the Arkansas River are not addressed in this paper. EPA has performed remedial and removal projects to assess the extent of contamination and demonstrate potential remedial techniques for OU 11. A Record of Decision (ROD) was signed in September 2005 designating remedial actions to reduce the risk to human health and the environment posed by site contamination (EPA 2005). The remedial objectives for OU11 include:

1. Minimize future human exposures of heavy metals as defined in the human health Baseline Risk Assessment (SRC 2004).
2. Minimize erosion of Fluvial Mine Waste Deposits into the Arkansas River as determined necessary to prevent further harm to aquatic life.
3. Control leaching and migration of metals from contaminated materials into groundwater.
4. Reduce toxins in plants and improve plant demographics in the Irrigated Meadows, Riparian Areas, and Fluvial Deposits as determined necessary (EPA 2003).
5. Reduce exposures of wildlife and livestock to heavy metals in soil and vegetation at toxic concentrations via direct exposure or bioaccumulation (EPA 2003).

Soil amendments are required as part of remedial action within Operable Unit 11 (OU 11) of the California Gulch Superfund Site near Leadville, Colorado. Acidic soil conditions caused by oxidation of sulfide minerals in mine tailings deposited on irrigated meadows near the floodplain of the Arkansas River have been mapped. Barren deposits of contaminated soil and mine waste visually demarcate the extent of low pH and phytotoxicity. Additional areas of sparse vegetation are the result of elevated metal rootzone conditions. Prior demonstration projects and greenhouse studies using lime and organic matter have demonstrated the success of in-situ treatment (Svendson et al, 2007; Brown et al., 2005). Remediation of the affected land area was initiated in 2008 by scaling-up the soil treatment prescription developed during earlier research and shown in field test plots. Soil amendments were procured, hauled to the site and tilled into the soil by a construction contractor. Alkaline amendments, compost and P fertilizer were added prior to seeding and mulching.

Pre-treatment Characterization

Soil sampling occurred in the irrigated meadows during July and August of 2006. A sampling grid system was laid out across the irrigated meadows on a 91 m (300-foot) spacing. Soil samples were collected from the 0-15 cm depth interval and analyzed on-site using a mobile laboratory and X-ray Fluorescence Spectroscopy (XRF). At several opportunistic locations soil samples were collected at 5 cm intervals to assess the depth of contamination from the surface down to underlying alluvial rock (Fig. 1) as well as between transects to assess spatial variability (Fig. 2). Samples were analyzed for total metals and pH in the field. Subsequent wet chemical analysis was performed on a subset of samples for total metals, acid-base account, organic carbon and Hg. Vegetation condition was also recorded at each sampled location. Figure 3 reports soil Pb and Zn levels as a function of vegetation condition.

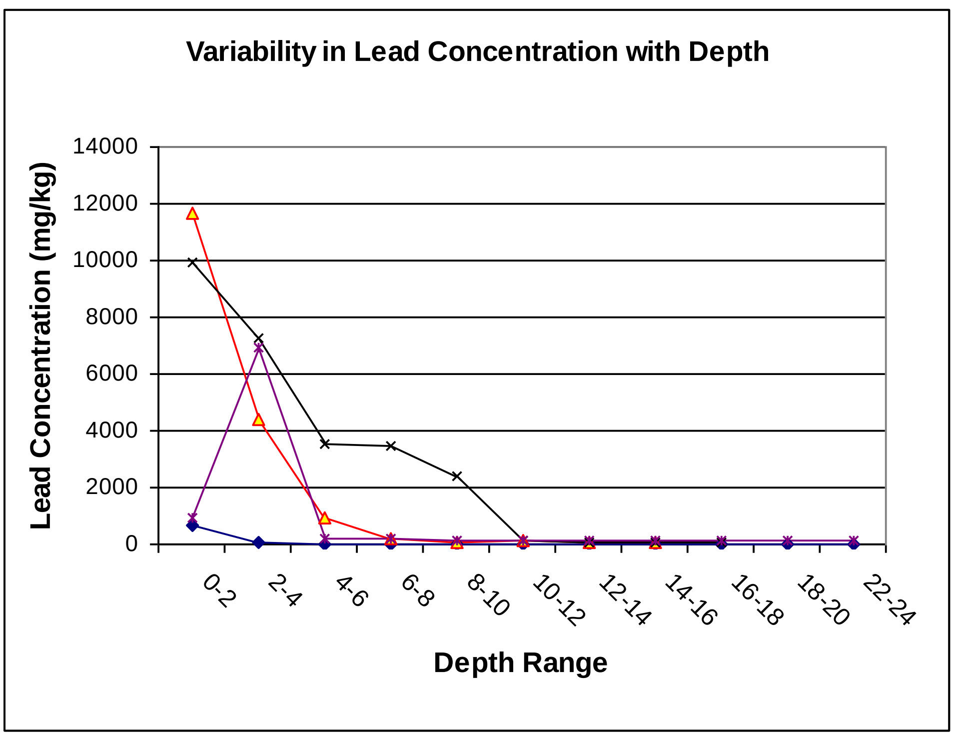

Figure 1. Total Pb levels is soil by depth measured in inches for 4 unique soil pits.

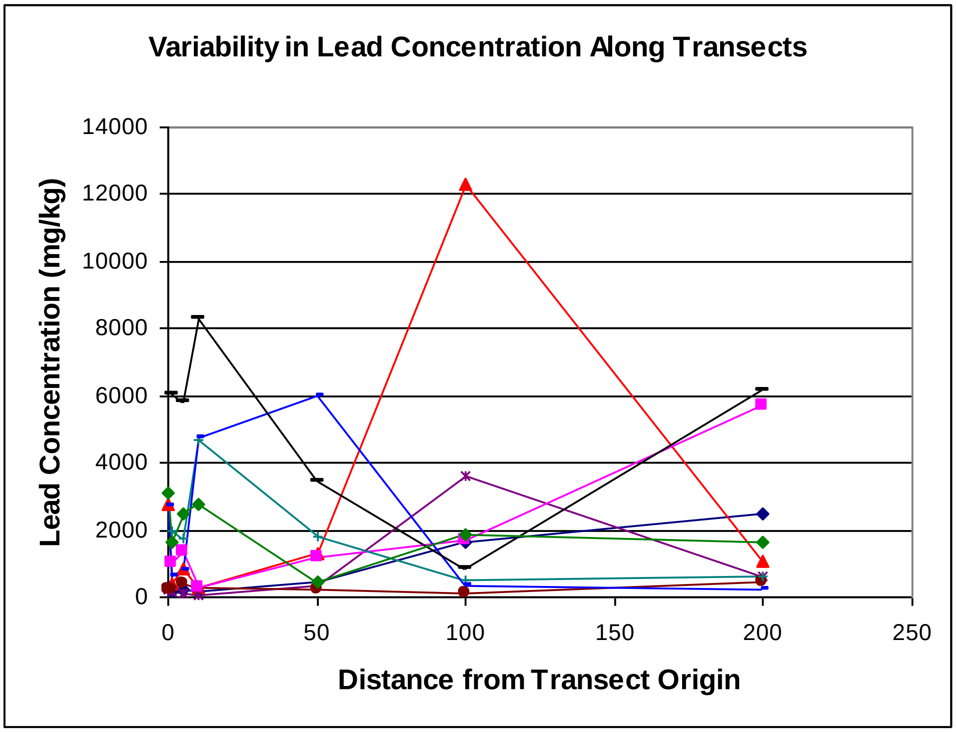

Figure 2. Total Pb levels in 0-15 cm soils with varying distance between grid points. Samples were collected at 1, 2, 5, 10, 20, 50, 100 and 200 feet between 300 foot grid points. Each series represents a unique and randomly selected location.

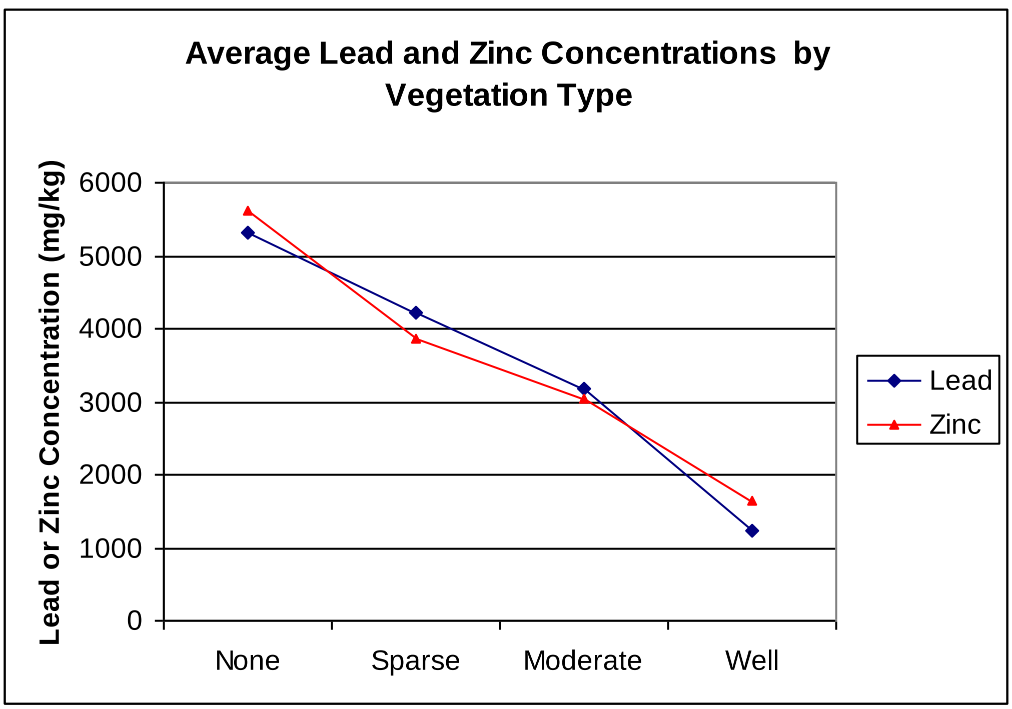

Figure 3. Soil Pb and Zn levels as a function of vegetation condition determined at the time of sampling by ocular estimate.

A Remedial Work Plan was written (URS and RRG, 2007) based on site collected data and soil treatment experience from Superfund sites in Montana's Clark Fork River Basin (Neuman et al., 2005). Construction was initiated in the irrigated meadows in August 2008 and will continue during the 2009 construction season.

Site Treatments

Two irrigated meadow areas were evaluated during sampling, a southern parcel (Fig. 4) managed by BLM for open space and wildlife use and a northern privately owned parcel managed for livestock production (Fig. 5). Contaminated soil was frequently encountered across both parcels (Table 1). Depressed soil pH (minimum=3.5) and elevated metals (mean Zn and Pb>3000 mg/kg) appear to be the causative factor in reduced plant cover and evident phytotoxicity. However, several sampled areas exhibiting modest to good vegetation condition by ocular estimation also revealed prominently elevated metal levels.

Table 1. Soil chemical data from irrigated meadows, OU 11, August 2006.

	pH	Total As (mg/kg)	Total Cd (mg/kg)	Total Cu (mg/kg)	Total Mn (mg/kg)	Total Pb (mg/kg)	Total Zn (mg/kg)
# samples	347	276	100	328	338	347	347
Minimum	3.5	10	29	17	86	27	135
Maximum	8.1	1445	200	1380	21638	49346	24957
Average	6.2	153	61	178	1513	3062	3192

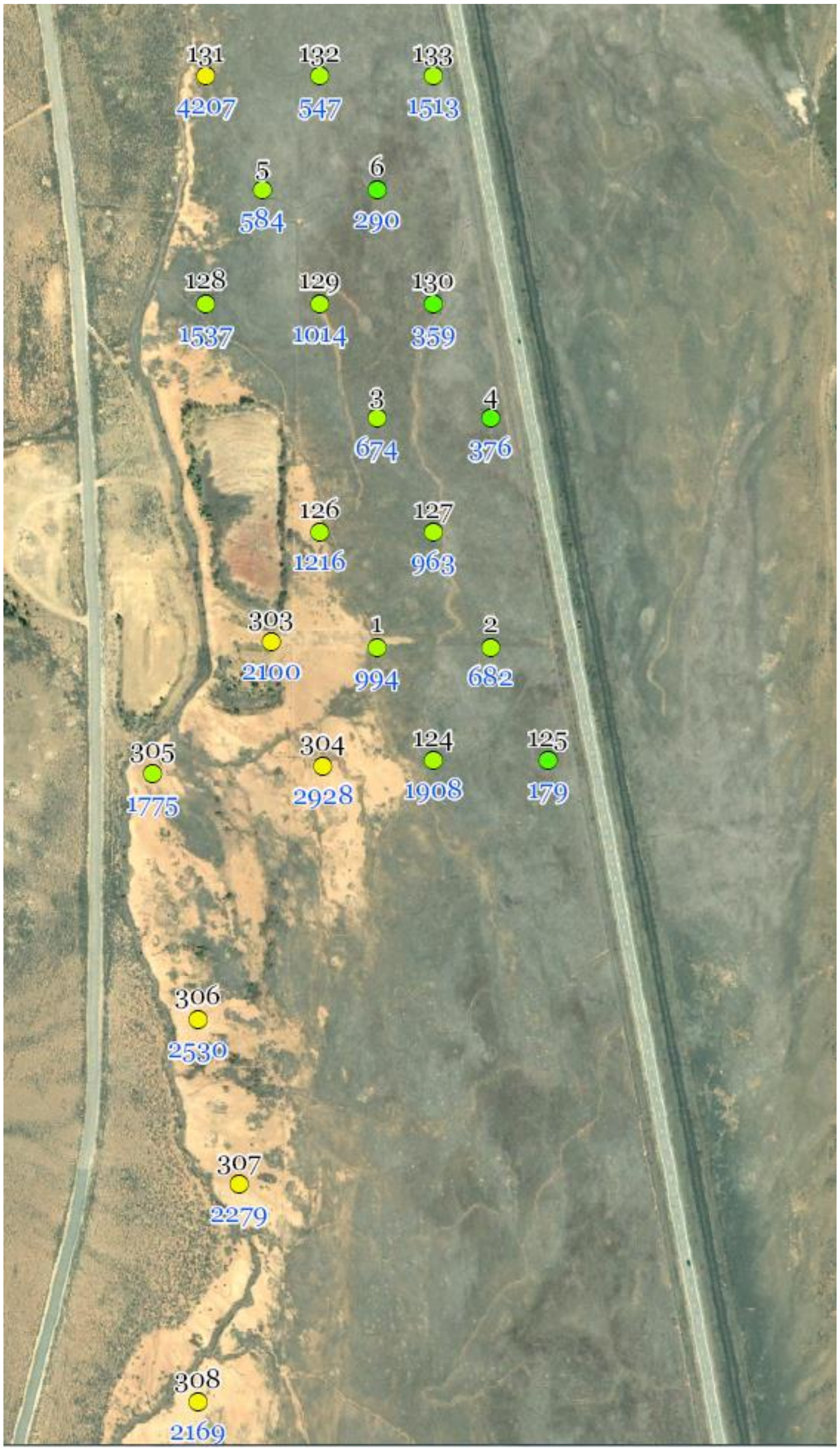

Figure 4. Irrigated Meadow soil sampling locations (upper black number) and Zn levels in 0-15 cm soil intervals (lower blue numbers) from a portion of the southern treatment area.

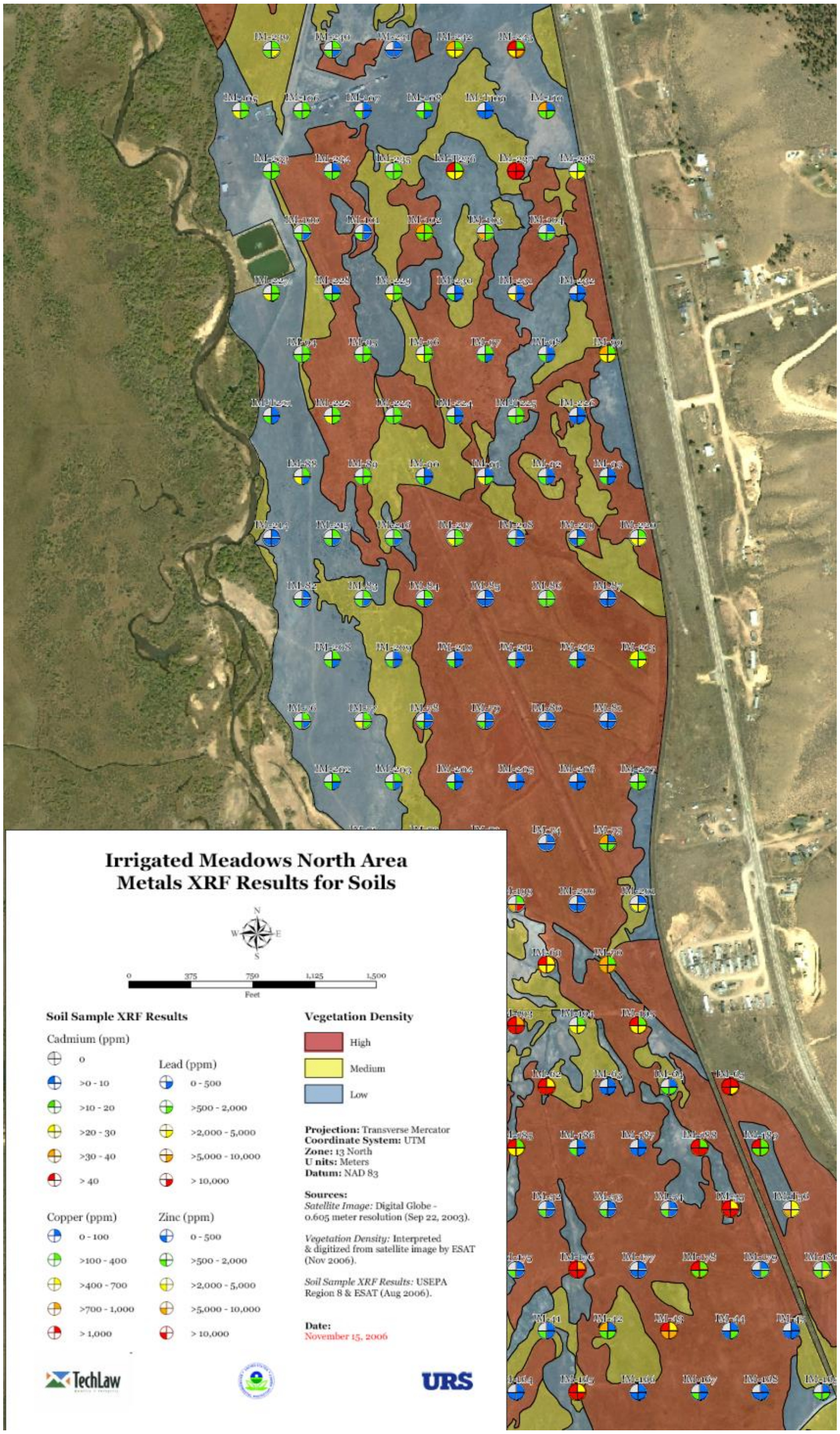

Figure 5. Irrigated Meadow soil sampling locations coded by concentrations of Cd, Pb, Cu and Zn. Vegetation condition is shown in the underlying polygon shapes.

A combination of soil chemical data and ground-truthing resulted in delineation of remedial treatment polygons. Polygons requiring soil treatment were mapped. Figure 6 shows a portion of the southern BLM irrigated meadows while Figure 7 shows a portion of the privately owned land treatment areas. Pink coding corresponds with 30 cm tillage while yellow coding represents areas tilled to 15 cm during treatment. Land treatment areas were delineated on the ground using paint, wooden stakes and flagging and GPS. Lime amendment was procured from a sugar beet processing facility near Longmont, CO and transported to the site and stockpiled. The base lime rate for the irrigated meadows was 2.2% on a weight basis (22 tons/1000 tons) for the 15cm tillage areas and 2.2% on a weight basis (44 tons/2000) tons for the 30 cm tillage areas (Jennings 2008). The field lime application rate was adjusted for lime quality, particle size and moisture content. Phosphorous fertilizer was applied as triple super phosphate (0-45-0) at a rate of 171 kg/ha (153 pounds per acre) for the 15 cm tillage areas and 343 kg/ha (306 pounds per acre) for the 30 cm tillage areas. A target soil organic carbon level of 2.5% was selected based on the success of earlier demonstration work and samples indicating the pre-disturbance soils exhibited similar levels of soil organic carbon. Composted organic matter was transported from a feedlot source to the site and incorporated into either the top 15 or 30 cm of the treated soil. Seeding and mulching followed soil treatment. Revegetation seed mixes were specific to landowner management preferences. Crimped straw mulch was used for short-term soil stabilization.

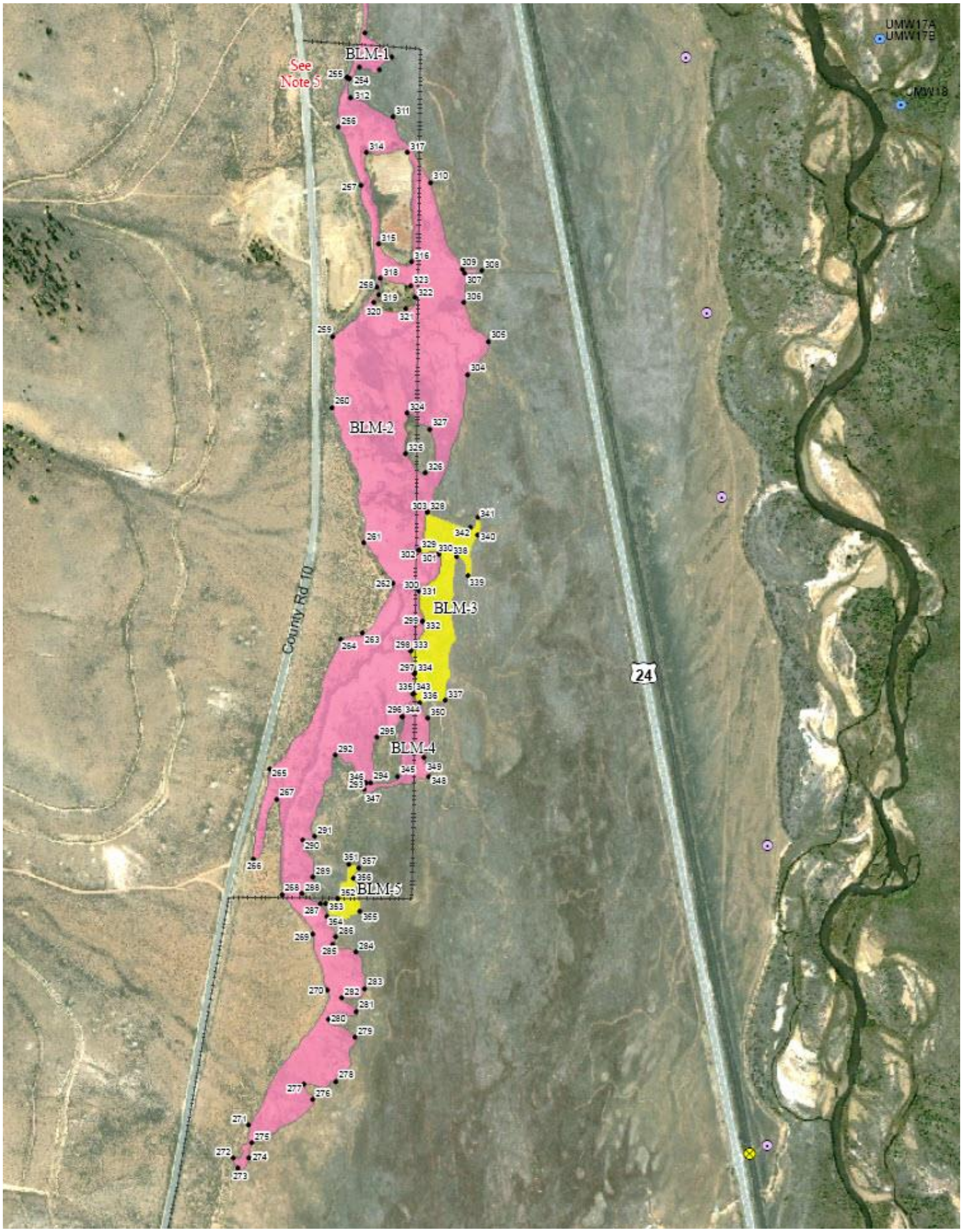

Figure 6. Treatment areas delineated for remedial action based on soil chemical characteristics and vegetation condition. Pink color coding indicates 30 cm tillage; yellow color coding indicates 15 cm tillage.

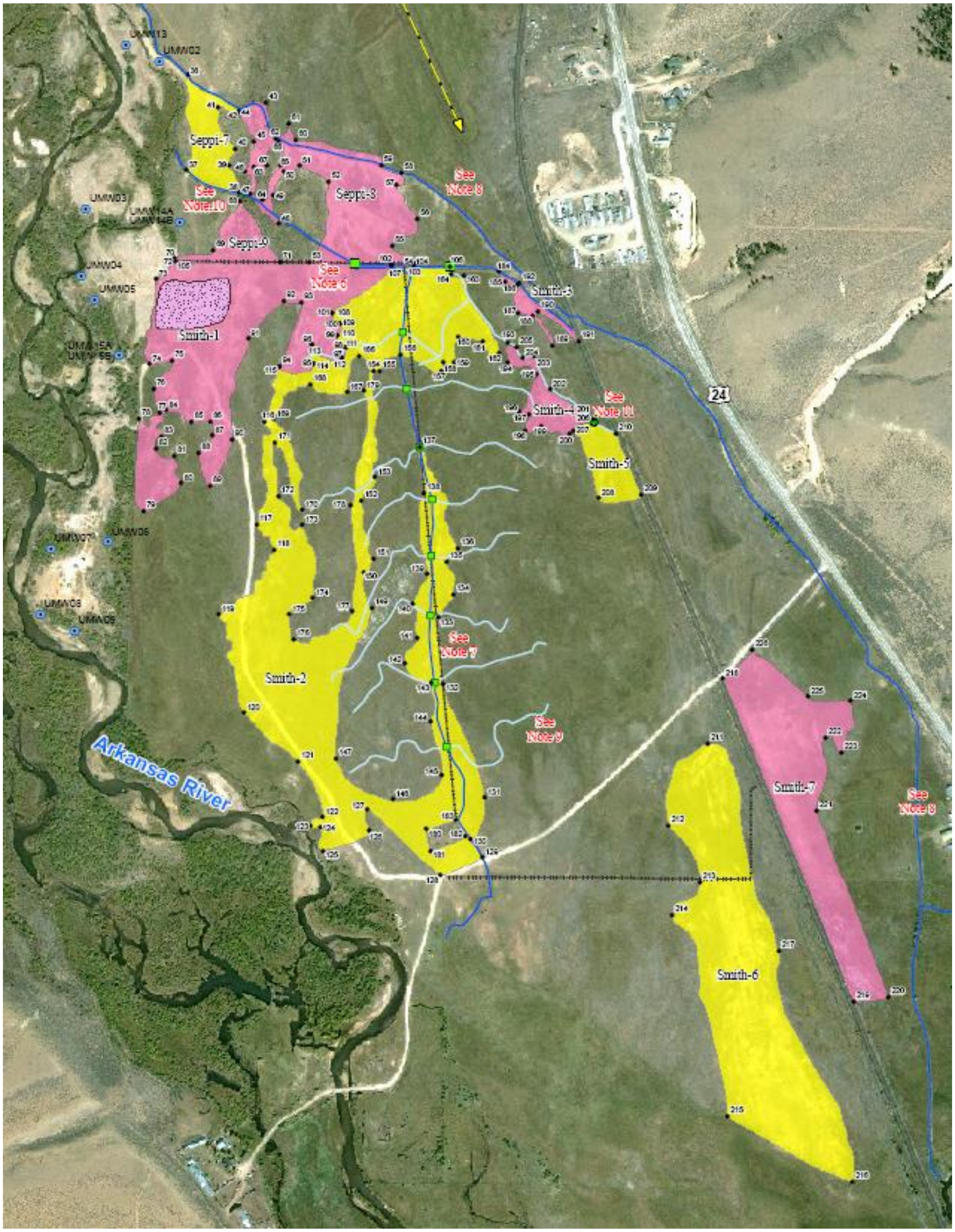

Figure 7. Treatment areas delineated for remedial action based on soil chemical characteristics and vegetation condition. Pink color coding indicates 30 cm tillage; yellow color coding indicates 15 cm tillage.

Future Monitoring

Historically irrigated agricultural pastures were contaminated by water and sediments enriched in metals derived from mining near Leadville, CO. Soil sampling identified mean total Pb and Zn concentrations in the upper 15 cm of the irrigated meadows in excess of 3000 mg/kg. Depressed pH in combination with enriched metal concentrations resulted in large areas of phytotoxicity evident by barren and sparsely vegetated areas. Phytotoxic soil areas were mapped and soil treatment prescriptions developed using lime, compost and high rates of P fertilizer. During the 2008 construction season large areas of the irrigated meadows were treated followed by seeding with landowner-specific seed mixes. Implementation of remedial treatments will continue during the 2009 construction season followed by monitoring. The monitoring program will assess plant community demographics as well as vegetation tissue metal levels. A multi-year monitoring effort is envisioned to ensure attainment of remedial action objectives.

Literature Cited

Brown, S., Sprenger, M., Maxemchuk, A., and H. Compton. 2005. Ecosystem Function in Alluvial tailings after Biosolids and Lime Addition. Journal of Environmental Quality 34:139-148.

There is an unknown error in this citation as otherwise it should have had a link.

Jennings, S.R. 2008. Lime Amendment of Contaminated Soil and Acid-producing Fluvial Tailing Deposits along the Upper Arkansas River, Colorado. Proceedings of the EPA/National Groundwater Association Remediation of Abandoned Mine Lands Conference, Denver, CO.

Neuman, D.R., F.F. Munshower and S.R. Jennings. 2005. In-Place Treatment of Acid Metalliferous Mine Wastes, Principles, Practices, and Recommendations for Operable Unit 11 of the California Gulch NPL Site. Reclamation Research Unit Publication, Montana State University, Bozeman, MT.

Svendson, A., Henry, C. and S. Brown. 2007. Revegetation of High Zinc and Lead Tailings with Municipal Biosolids and Lime: Greenhouse Study. J Environ Qual 36:1609-1617. http://dx.doi.org/10.2134/jeq2006.04117.

Syracuse Research Corporation (SRC). 2004. Screening Level Human Health Risk Assessment for Ranchers and Fishermen Exposed to Mine Wastes along the Upper Arkansas River. December 3, 2004.

URS Operating Service and Reclamation Research Group. 2007. Remedial Work Plan, California Gulch OU 11, Leadville, Lake County, CO. TDD No. 0509-13. U.S. EPA Contract No. EP-W-05-050, Denver, CO.

U.S. EPA. 2003. Ecological Risk Assessment for the Terrestrial Ecosystem, California Gulch NPL Site, Leadville, Colorado, Addendum, Evaluation of Risks to Plants and Herbivores in the Upper Arkansas River Flood Plain. By U.S EPA, U.S. Fish and Wildlife Service, and Syracuse Research Corporation. July 2003.

U.S. EPA. 2005. Record of Decision, Operable Unit 11, California Gulch Superfund Site, Leadville, Colorado. September 2005. EPA Region VIII, Denver, CO.