

## **7.0 SMELTER-EMISSIONS AIRSHED**

### **7.1 Purpose and Objectives of Airshed Survey**

Deposition of airborne stack emissions from historic smelter operations occurred in areas surrounding the smelters within the Leadville Mining District. Smelter emissions consisted of gasses and particles. The residue of gaseous emissions has dissipated over time; however, particulate deposition is still evident. Particulate smelter emissions contain metals derived primarily from ore. Predominant metals that would have been associated with historic smelter emissions in the Leadville area include arsenic, cadmium, copper, lead, and zinc. Delineation of the area of deposition of smelter-stack emissions (or the smelter “Airshed” as defined by the Work Plan) is of interest in evaluating the potential for specific smelter-related impacts to the natural resources of the UARB.

The objectives of the airshed delineation are to identify the information available to characterize the smelter-emissions depositional zone and to determine if additional data are needed to define the boundaries of the smelter airshed. To meet these objectives, surficial soil metals concentrations from existing data sources were mapped using a GIS. The GIS mapping results were further considered with regard for the potential for injury to natural resources from historic smelter deposition. Because of the overlap of smelter deposition with areas of mining disturbance it is important to consider the characteristics that distinguish smelter-emission deposition from other mining-related impacts to soils and/or vegetation.

### **7.2 Approach**

The majority of the smelting activities in and around Leadville occurred during the late 1800s and very early 1900s. Smelters in the UARB have not operated for many years. Metals delivered to soil via airborne emissions may have since been influenced by water and/or wind erosion or by dissolution in and transport by infiltrating water. For these reasons, the entire area of smelter-emissions deposition may no longer be readily apparent. Investigations at other historical smelter sites (e.g., Black and Veatch 1988; Wixson et al. 1988; Dames and Moore 1991; Bechtel 1992) have shown that areas of smelter deposition may be identified from the relative concentrations of metals found in undisturbed, or minimally disturbed, surficial soils. Those studies have also confirmed that the total metals content of undisturbed soils decreases with increasing distance from smelter-emission sources, as expected for an air emissions source. Metals concentrations at the outer extent of the deposition area, where relatively small amounts of particulate emissions were deposited, may be indistinguishable from their background concentrations

in soil. Therefore, delineation of the airshed must focus on the areas where soil conditions due to smelter-emissions deposition are readily distinguishable from natural variability.

Relatively insoluble metals with limited mobility in the soil environment (e.g., lead), serve as the best indicators of historical smelter emissions because their distributions in soil are the least likely to change over time. Lead contamination of soil is expected to be persistent due to lead's low solubility and mobility in soil. For this reason, the lead concentration in undisturbed soil often serves as a useful indicator of past deposition of emissions from smelters. The other metals found in Leadville district ores, such as arsenic, cadmium, copper, and zinc, may also be useful for identifying soil impacted by smelter emissions. Data describing the concentrations of these metals in soil are included in the project database.

As described in prior report sections, there are a number of other sources of lead to the soils in Leadville in addition to smelter emissions. These sources include the natural (or background) sources of lead to soils; mining-related sources such as ore and waste rock piles, mine-waste and slag; and other sources not related to mining activities such as historic automobile emissions and deteriorated lead-based paint. In order to delineate an area of smelter-emissions deposition using lead concentrations in soil, it is important to be able to distinguish smelter-emissions from other sources of lead.

Several types of information may be used to assess the relative importance of smelter emissions compared to other source emissions in contributing to the current levels of soil contamination and delineating the smelter airshed in the UARB, including:

- Locations and operating histories of smelters;
- Long-term meteorological data describing predominant wind directions and wind speeds;
- Metals concentrations, especially lead, in shallow undisturbed soils; and
- Characterization of the solid-phase (i.e., mineral) associations of metals, especially lead, related to smelter emissions as opposed to metals from other sources.

The following section identifies the data that are currently available to provide the information listed above.

### **7.3 Existing Sources of Relevant Data**

A review of existing reports and data lead to several sources of information that are relevant to delineation of the smelter airshed. The data discovered and compiled through this effort originate primarily, although not exclusively, from investigations of the California Gulch Superfund/NPL Site (the Site). A summary of the information found in existing sources is provided below.

#### **7.3.1 Historical Smelter Information**

The Site includes a number of former smelters where lead-silver and lead-zinc ores were processed. A report prepared by Jacobs Engineering for the USEPA (Jacobs 1991) contains a brief history of each of 17 smelters identified within the Site, including information describing the smelter facilities, smelting methods, and dates of operation. This information, summarized in the Jacobs report, was used to develop sampling plans for remedial investigations within the Site (Table 7-1).

Smelters previously operating in the vicinity of Leadville processed primarily lead-silver and lead-zinc ores from the Leadville Mining District. Smelting operations in this area started in 1875, and by 1879 there were 15 smelters in operation in the immediate vicinity of Leadville. However, most of the smelting operations were relatively short-lived, and by 1900 there were only three operating smelters remaining. The last smelter to cease operation was the Arkansas Valley (AV) Smelter, which operated nearly continuously from 1879 to 1961.

Several smelters were located along California Gulch west of the City of Leadville (Grant/Union, Leadville, Western Zinc, La Plata, American, AV, California, Lizzie, and Malta Smelters, listed from east to west). Among these, the AV Smelter, the longest operating smelter in the area, was located on the north side of California Gulch at Stringtown. Smelters were also located along Evans Gulch (Ohio and Missouri, Cummings and Finn, Gage-Hagaman, and Raymond, Sherman and MacKay Smelters), within the City of Leadville (Harrison Reduction Works) and east of Leadville (Adelaide and Little Chief Smelters). The locations of these smelters are shown on Figure 7-1 (Walsh 1993a, adapted from Jacobs 1991).

When operating, smelters generated slag, flue dust, fugitive emissions, and stack emissions. Dust chambers were typically used to retain dust before furnace gases were vented through a stack. Dust retention was later improved through the use of bag houses. By approximately the mid 1890s, bag houses, which reduced the amount of dust in stack emissions, were used by most of the Leadville-area

smelters. Stack emissions also contained metallic and sulfur vapors. In addition, the smelter stacks were “blown” when furnaces needed repair or cleaning or were shut down. When the stacks were blown the emissions would have also contained the smelting residue coating the furnace walls and stack.

### **7.3.2 Remedial Investigation of California Gulch Soils**

A soil investigation study was performed to obtain the data necessary to conduct feasibility studies and baseline risk assessments for the NPL site (CDM 1994). These data were used to determine the concentrations of the elements of potential concern (identified by USEPA as arsenic, cadmium, lead, mercury, and zinc) and their distribution in soil, as well as to identify the source(s) of the elements of potential concern.

A total of 3,589 soil samples were collected from 719 locations during 1991 and 1992. At most locations, samples were collected from five depth intervals (0 to 1 inch, 1 to 2 inches, 2 to 6 inches, 6 to 12 inches, and 12 to 18 inches). Soil sample locations were dictated by a grid pattern that extended over the entire site and some adjacent areas. At each sampling location, the soil was classified according to location, surface cover, and soil type (native, fill, or mine-waste). Native soils were also described as undisturbed or disturbed.

All samples were dried and sieved prior to analysis for eleven elements (silver, arsenic, barium, calcium, cadmium, copper, iron, manganese, nickel, lead, zinc) by x-ray fluorescence spectrometry (XRF). Selected samples were also submitted to CLP laboratories for analysis of the same elements plus potassium, magnesium, aluminum, and mercury. For each sample, two size fractions (less than 2 mm and less than 250  $\mu\text{m}$  in diameter) were analyzed. Data analyses were performed using the results from XRF analyses. A metals speciation study was conducted independent of the soil investigation using a subset of the samples collected for the soil investigation study. The results from the speciation are presented elsewhere (see below).

The distributions of metals in soils were presented on two sets of contour maps using data from (1) all soils, and (2) undisturbed native soils. Kriging analysis was used to generate the iso-concentration maps presented in the report.

The lead iso-concentration contour map for “all soils” (Figure 7-2, from CDM 1994) shows elevated concentrations in several areas of the site, including: east of the City of Leadville, where mine-waste piles are present; northeast of Leadville near the historic Evans Gulch smelter area; lower



California Gulch around Stringtown and the AV Smelter site; extending north and south from California Gulch; and near Colorado Mountain College at Georgia Gulch. An iso-concentration contour map for lead in relatively undisturbed native soils only (Figure 7-3, from CDM 1994) shows more limited areas of elevated lead concentrations. Evans Gulch and lower California Gulch – are revealed as the dominant areas of elevated lead concentrations in the top 1 inch of undisturbed native soil likely associated with former smelting activities.

### **7.3.3 Smelter Remedial Investigation**

The focus of the Smelter Remedial Investigation (RI) (Walsh 1993a) was to collect data to identify and evaluate the impacts of historical smelting operations on human health and the environment within the boundaries of the California Gulch NPL Site. The Smelter RI was performed concurrently with the Soil Investigation (CDM 1994) discussed above, and data from both studies were used to support this investigation.

The purpose of the Smelter RI was to describe the geographic distribution of soil metals (primarily arsenic, cadmium, lead, and zinc) originating from the smelter facilities. The Smelter RI consisted of several tasks including: literature and document review; site reconnaissance of smelter sites to identify potentially contaminated areas (e.g., historic bag houses and dust chambers); air-dispersion modeling to establish probable wind depositional patterns and the potential extent of airborne emissions; soil sampling and laboratory testing and analysis; and data evaluation and summary.

Air-dispersion modeling was performed to evaluate historic depositional patterns and identify potential locations for sampling associated with maximum deposition of airborne emissions from the 17 historical smelter operations identified by Jacobs. The Industrial Source Complex Short Term (ISCST) model was used to estimate the contributions of four metals (arsenic, cadmium, lead, and zinc) in historic smelter emissions to their concentrations in soil across the site. This model requires meteorological data and information to describe stack emissions from the various historical smelters.

The meteorological data used to define the model input parameters were collected for a one-year period in 1990 and 1991 at two locations, the Yak Tunnel and Colorado Mountain College. These data indicate that wind directions and wind speeds vary seasonally and that the annual prevailing wind directions, in order of greatest duration, are expected to be from: (1) northwest to northeast 35 percent of the time, (2) east northeast to east southeast 31 percent of the time, and (3) south to west southwest less than 20 percent of the time.

The information available to describe past smelter operations and stack emission characteristics was extremely limited. The types, durations and rates of historic emissions from stacks associated with the 17 smelters identified in the Leadville area were variable over time and among the different smelters. Input parameters used in the ISCST model were generally based on assumptions about operations rather than documented practices.

Given these inputs, the resultant model predicted metals concentrations across a rectangular grid of emission receptor points that extended 15.5 kilometers (km) north to south and 18.5 km east to west across the study area. These results are presented on metals distribution maps showing the cumulative total metals (sum of arsenic, cadmium, lead and zinc) contribution to soil from all smelter emissions combined. These results were then used to select the locations and extent of soil sampling used to support the Smelter RI. Given the uncertainty in the model inputs and resulting output, the model results were not used to delineate the airshed area without field confirmation through soil sampling and analysis.

Soil samples (3,589) were collected from 719 locations during the soil investigation study (Camp Dresser & McKee (CDM) 1994), and Walsh analyzed an additional 276 samples that they collected from 80 new locations. The area where soil sampling was performed lies roughly within the boundaries of the California Gulch NPL Site except to the south of Smelertown in California Gulch and also immediately south of the East Fork Arkansas River where additional soil samples were collected outside the NPL site boundaries. The additional soil samples were analyzed for arsenic, cadmium, lead, and zinc by XRF. The same sample depths and sample preparation and analysis methods were used by CDM and Walsh, and the results from these two studies are considered comparable. During soil sampling, each sample location was evaluated by a soil scientist, and the soil was described as either disturbed or undisturbed based on whether or not mine-waste, fill material, or human artifacts were present.

The largely undisturbed area to the south of California Gulch and downwind of the former AV, California, La Plata, and American smelters was presumed to be an area impacted exclusively by smelter emissions and was used as the control area. The smelter-emissions control area is bounded by Georgia Gulch to the east, California Gulch to the north, Highway 24 to the west, and the southern boundary of the study area. Most of this area lacks any evidence of historic mining activities, yet metals concentrations in soils are high relative to other undisturbed areas. The smelter-emissions control area is predominantly forested but also includes bare ground immediately south of the former AV Smelter.

Metals ratios in soils from the smelter-emissions control area were used to characterize a signature associated with soils that contain smelter-emissions fallout. The data from the less than 2-mm

size fraction and 0- to 1-inch depth interval were used to characterize the smelter-emissions signature. The control-area approach is based on the assumption that the chemical and physical changes that have taken place at the control site are representative of chemical and physical changes that have occurred in other areas where smelter emissions have been the primary source of metals to soils. Given this assumption, the signatures of the smelter-emissions control area reflect both the effects of smelter-emission fallout and the chemical and physical changes that have occurred since the cessation of smelting in this area.

Linear-regression methods were used to describe co-variation of lead concentrations with the concentrations of other metals in soils from the smelter-emissions control area. The linear relationships identified were then used as the basis for comparison to metals concentrations in soils from other parts of the study area. For control sites, regression analysis was used to identify metal pairs having significantly correlated (99 percent confidence) concentrations. The metal signature was then described for significantly correlated combinations, plus or minus one standard deviation of the regression equation. A total of nine metals correlations were found to be significant in 0- to 1-inch depth soils from the smelter-emissions control area.

Using the metals signature from control-area soils at the 0- to 1-inch depth, the metals contents of 0- to 1-inch deep soils from the other sites were tested for positive or negative agreement with the smelter-emissions signature. For example, the results of comparison of the control lead:zinc ratios to the same ratio in undisturbed soils across the study are shown on Figure 7-4 (Walsh 1993a). In cases where at least seven of nine of the metals ratios were shown to have metals contents consistent with the control-area signature, the soil from that location was considered to share the smelter-emissions signature, as shown on Figure 7-5 (Walsh 1993a). As shown on Figure 7-4, there are a number of locations where the lead:zinc ratio in undisturbed surface soil does not match the smelter-emissions control-area signature, even though the location clearly lies within the expected boundaries of the smelter airshed. These examples likely result from the difficulties in predicting a smelter signature that would apply to emissions from numerous smelter operations that operated differently and at different periods of time within the same area. For this reason, the accuracy of the smelter-signature approach developed by Walsh for this study remains unknown.

Results obtained from the smelter-signature comparison method were used to delineate an area impacted by smelter emissions as shown on Figure 7-6 (Walsh 1993a). The shaded area on Figure 7-6 represents the distribution of sampled sites that have a metals signature resembling the smelter-emissions control area, including both undisturbed and disturbed sites. The undisturbed locations resembling the control area are also shown individually. The shaded area was delineated using a 750-foot buffer zone

around each sample site that resembled the control area. The width of the buffer zone is appropriate to the sampling grid dimensions of 1,000 ft<sup>2</sup> in unpopulated areas and 500 ft<sup>2</sup> in populated areas.

Based on these results, the areas exhibiting smelter-emission signatures include:

- Areas south of U.S. Highway 24 and between upper California Gulch and the Arkansas River;
- The west and northwest portions of the study areas; and
- Portions of Evans Gulch that correspond to the former smelter sites in the gulch and a small area near the Little Chief Smelter site.

Areas determined to be impacted primarily by sources of metals other than smelter emissions (e.g., mine-waste, mine-waste slag) include:

- Much of the City of Leadville, which contains various types of fill;
- The eastern portion of the study area, which contains alluvial mine-waste and mine-waste rock;
- California and Malta Gulches, which contain alluvial mine-waste and/or mine-waste rock;
- Hecla mine-waste area;
- Lake Fork Trailer Park area, which consists of fill material; and
- Channels and low terrace deposits along the Arkansas River at California Gulch, which are impacted by fluvial mine-waste.

This empirical approach was described as having several benefits over a modeling approach in delineating the deposition airshed, as follows:

- Model input parameters were estimates and subject to error; and
- Observed metals concentrations relative to a control site are good indicators of smelter-emission deposition because the metals contents of soils are not expected to have changed significantly following deposition, except possibly in areas subject to erosion (steep slopes, stream channels, etc.).

### 7.3.4 Characterization of Pre-Mining Soil Conditions

In support of the smelter investigations, Walsh also performed a study to describe pre-mining soil geochemistry within the Leadville Mining District (Walsh 1994). The data used for this study were primarily from other soils investigations of the California Gulch Site, including the Smelter RI (Walsh 1993a) and Soils Investigation (CDM 1994), but they also included metals data for soils collected from undisturbed sites within the mineralized areas around the Site. Statistical methods (cumulative probability plots) were used to differentiate between the “pre-mining” concentrations of metals, or background concentrations, and their concentrations in soils disturbed by mining activities. Detailed soil and surficial geology maps were also produced as part of this study. Information from the detailed soil and surficial geology maps was used to identify and define seven soil-geologic units, which are consequently tied to both the geomorphology and geochemistry of the soil parent materials.

The soil-geologic-unit map shows the locations of these seven general units. Areas of native, undisturbed soils are shown as well as soils containing construction fill, mine-waste, waste rock and slag, mechanically altered soils, eroded soils, and areas covered by buildings and parking lots. The native, undisturbed soils have all soil horizons present and no evidence of man-made disturbance.

Pre-mining (or background) metals concentrations are presented for soils by “landscape position” and by soil-geologic unit. The landscape position refers to either upland or alluvial soils. The findings (Table 7-2) show that metals contents in alluvial soils are generally higher than those in upland soils, primarily due to natural weathering and transport processes that concentrate heavier minerals, such as common metallic-ore minerals, in depositional environments. In upland areas, background metals concentrations were generally found in soil below the A horizon, suggesting that the downward transport of metals is not a very active process in upland landscape positions. The metals concentrations of alluvial soil horizons are more variable than the upland horizons, perhaps due to greater mobility of metals in the alluvial soils. The pre-mining metals contents of soils from upland areas are within the low end of the ranges of metals contents reported by Schacklette and Boerngen (1984) for soils of the western United States. The arsenic and lead contents of pre-mining alluvial soils, however, appear greater than those reported for western U.S. soils.

Walsh (1994) also identified background metals concentration ranges for each of the soil-geologic units, but concluded that the ranges given for upland and alluvial landscape positions may better represent pre-mining metal ranges over the entire site. Interestingly, the mean arsenic, cadmium, copper,

and lead concentrations of the top 1 inch of undisturbed soils are generally higher than in the top 1 inch of disturbed soils for a number of the soil-geologic units described. Walsh explained that the elevated metals contents in the top 1 inch of undisturbed soils relative to disturbed soils may be due to:

- The relative immobility of metals in arid climates with soils of near neutral pH, such as Leadville;
- The higher organic matter content of surficial soils, which leads to greater sorption of positively charged metal cations such as copper and lead; and
- Surficial soil contamination by non-disruptive processes, such as air deposition of metals.

### **7.3.5 Lead Speciation Studies**

Several studies were performed to describe the solid-phase associations of metals present in soils and other environmental media from the California Gulch NPL Site. The information provided by these studies is useful for distinguishing soils where elevated metals contents have resulted from smelter-emissions deposition rather than from other mining, or non-mining, related sources.

Selected soil samples from the studies described above were included in a site-wide metals speciation investigation. The final metals speciation report was prepared jointly by CDM, University of Colorado and the R.J. Lee Group (CDM et al. 1994; Drexler and Weston 1995) and includes raw data from a total of 320 samples of soil, mine-waste (waste piles and mine-waste), environmental sample types (residential soils and interior dust), and fluvial deposits/stream sediments. Approximately 15 of the soil samples included in this study are from locations within the area delineated by Walsh (1993a) as impacted by smelter emissions. Maps included in this report show that the lead mass in surficial soils from these areas is primarily associated with iron and manganese oxides, phosphate, and organic carbon phases, with minor amounts of lead in silicate and “slag” phases.

Walsh also performed a lead speciation study (Walsh 1993b), to support the selection of the hillside south of the AV Smelter site as a control area for smelter emissions and to provide additional characterization data for identification of soils containing metals derived from smelter emissions. Soils from the hillside south of the AV Smelter site have lead levels ranging from several hundred mg/Kg to almost 9,000 mg/Kg in surface samples. Other metals are also enriched compared to their concentrations observed in the other parts of the study area (Walsh 1993a). The AV hillside soils lie downwind from the smelter site and are likely to have been impacted primarily by airfall products from the AV Smelter.

These soils have a low pH (4.5 to 6) due to the low buffering capacity of the soils and the past deposition of SO<sub>2</sub> gases from smelter emissions. The undisturbed soil surface on this hillside has a dark, sooty coating that resembles desert varnish. This coating is thin but high in lead-carbon-oxygen compounds. The majority of the lead-bearing particles observed in these soils consist of various carbonaceous and siliceous fly-ash particles, some of which can be up to several millimeters in diameter. Walsh described an ash particle with a siliceous, low-iron, glassy matrix (in contrast to the high-iron matrix of slag) containing numerous small particles of lead oxide and sulfate.

In the samples considered representative of soils containing stack fallout, Walsh observed a small proportion of lead in organic and high-silica materials (carbonaceous and siliceous ash), a larger proportion of lead in relatively soluble forms, such as lead oxide (PbO) and lead sulfate (PbSO<sub>4</sub>), and/or readily exchangeable surface sorption sites and the highest proportion either chemically sorbed to soil minerals, such as iron and manganese oxides, and contained in oxide and phosphate phases, or bound with more resistant mineral phases, such as sulfides and silicates. The presence of carbonaceous and siliceous ash particles, even in small amounts, appears indicative of the presence of smelter-emissions fallout.

### **7.3.6 Baseline Risk Assessments**

The Baseline Human Health Risk Assessment (Weston 1996) and the Ecological Risk Assessment for the Terrestrial Ecosystem (Weston and Terra 1997) rely on soils data collected by Walsh (1993a and 1994) and CDM (1994) in the studies described above as well as data from other sources for residential environmental media, mine-wastes, and plant and animal tissue. The lead dataset used to perform the risk assessments is described in Consolidated Findings of Soil-Lead Investigations at the California Gulch NPL Site (Weston 1994). Human health risks were evaluated using data describing the metals concentration from the top 6 inches of soil (as a depth-weighted average) from residential areas. Ecological risks were evaluated primarily using data describing the metals contents (arsenic, cadmium, copper, lead, and zinc) in the top 2 inches of soil from nonresidential areas.

The ecological risk assessment also utilized data for waste rock, mine-waste piles, slag, fluvial mine-waste, and sediment from nonresidential areas and biological data (small mammals and vegetation) collected by Asarco and Resurrection (Stoller 1996). The metals concentration data for co-located surficial soil and vegetation samples are included in the project database. Data collected for Resurrection from the upper California Gulch area show little correlation between total metals contents and surface soils and plant ecosystem diversity or plant metals content. In addition, AB-DTPA extractable metals (a

potential measure of bioavailable metals) contents are not correlated with the total metals contents in soils or co-located plant metals contents (Stoller 1996). Stoller (1996) reported that the only areas in upper California Gulch showing evidence of phytotoxic stress are areas adjacent to mine-wastes. Evidence of phytotoxic stress is absent from other areas remote from mine-waste.

### **7.3.7 Other Investigations**

In addition to the studies performed to support investigations of the California Gulch Superfund Site, there are several other studies that provide data that are useful to delineate the smelter airshed. Those data are described below.

#### **7.3.7.1 BLM Soils Investigation**

During the summer of 2000, the BLM collected soil samples from the upper 1 inch of soil at approximately 70 locations within the UARB. Thirteen of those were upland locations within Iowa Gulch, approximately 1.5 miles south of California Gulch. These samples were referred to as the "airshed" samples. Soils were also collected from a variety of 2- to 6-inch depth intervals to a maximum depth of 26 inches at locations predominantly within riparian areas along the Arkansas River from California Gulch downstream to Pueblo. All of the soil samples were analyzed for iron, lead, manganese, and zinc. The locations, sample depths, and soil lead concentrations for samples collected in the vicinity of former smelters within California Gulch are shown on Figures 7-7 and 7-8 along with data from the other sources described in this report.

The lead concentrations in the Iowa Gulch samples are generally lower than in soil collected approximately one mile north and within the California Gulch drainage. The southernmost soil samples from California Gulch have lead contents ranging from 713 to 2,223 mg/Kg. The lead concentrations in the Iowa Gulch soils range from 252 to 924 mg/Kg. All of the Iowa Gulch soils have lead concentrations greater than Walsh's characterization of background concentrations in upland soils (150 mg/Kg, Table 7-2).

Samples collected north of Leadville, along the East Fork of the Arkansas River and upstream of Evans Gulch, have lead concentrations within the range for background soils. West of the Arkansas River, near the confluence with California Gulch, lead concentrations range from 20 to 1,824 mg/Kg but only exceed the background concentration in alluvial soils (870 mg/Kg, Table 7-2) at one location.



These data demonstrate a trend of decreasing lead concentrations in undisturbed surface soil with increasing distance from the historic smelter operations in the Leadville area.

#### **7.3.7.2 Levy Study**

In the summer of 1988, Levy and others (Levy et al. 1992) sampled surface soils (upper 1 inch) at one location in Tennessee Park. The sample was analyzed for a suite of metals, including lead. The total lead concentration at this location was 275 mg/Kg, which further supports the conclusion of decreasing lead concentrations in undisturbed surface soils with increasing distance from the historic smelter operations in the Leadville area.

#### **7.3.7.3 National Uranium Resource Evaluation Program Data**

The U.S. Geological Survey's National Uranium Resource Evaluation (NURE) program provides geochemical data for sediment and water samples collected from across the United States. More than 1,700 sediment samples were collected from the Leadville Quadrangle (2 degree sheet) and sediments from approximately 30 locations within the UARB were analyzed for metals, including arsenic and lead. The NURE sampling locations extend beyond the area where soil samples have been collected in support of the various investigations described above. However, because the metals contents were measured in sediment samples, these data are not directly comparable to the metals data for upland soils. For this reason, the NURE data were not used to assist in airshed delineation and are not included in the GIS used to prepare the map figures in this section.

#### **7.3.7.4 U.S.G.S. Investigation of Fluvial Tailings**

The U.S. Geological Survey, in cooperation with USEPA and the Bureau of Reclamation, studied the effects of fluvial tailings deposits on soils, surface water and groundwater along a 3-mile reach of the Upper Arkansas River (Walton-Day et al. 2000). The study area is located approximately 6 to 9 miles downstream of the confluence of California Gulch with the Arkansas River. This work included collection and analysis of 13 soil samples. Eleven of the soil samples were collected from the floodplain in areas expected to have elevated metals concentrations due to fluvial deposition of visible tailings

deposits. The remaining two samples were collected from above the floodplain in areas apparently unaffected by fluvial tailings deposits; these two samples are referred to as background samples.

The samples were analyzed for 13 metals/metalloids, including arsenic and lead. The arsenic concentrations in both background samples were 10 mg/Kg. Lead concentrations in these samples were 180 and 200 mg/Kg.

#### **7.3.7.5 USGS Remote Sensing Studies**

Remotely sensed multi-spectral reflectance data were collected by the U.S. Geological Survey (Swayze et al. 1996) and processed to characterize and identify localized sources of acid mine drainage and contamination from waste rock piles within the California Gulch NPL Site. The interpretive map developed from the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) reflectance data shows an area of “smelter effluent ground coating” on the hillside south of the AV smelter site, the same area as used in the Smelter RI (Walsh 1993a) as the control area for smelter impacted soils. This area was spectrally mapped as an area where amorphous iron-hydroxide is present at the surface. Field investigation of the area showed rocks coated with a grayish coating of material described as condensed, arsenic-rich “effluent” that reportedly originated from the nearby AV Smelter stacks. Although multi-spectral reflectance data were useful for identifying probable smelter-related mineral phases in soils from a largely unvegetated area, their usefulness in more heavily vegetated areas has not yet been demonstrated.

#### **7.3.8 Summary of Findings to Delineate Smelter Airshed**

Based on results from the previous studies described above, the following understanding is provided:

- The smelter airshed may be delineated using data describing the metals content in undisturbed surface soils in the areas surrounding former smelter operations. The lead distribution map provided by CDM (1994) shows the areas where lead concentrations in the upper 1-inch of undisturbed soil are relatively high. The areas highlighted based on this map are: (1) an area south of the former Malta, Lizzie, California, AV, and American smelter sites that extends south outside the California Gulch site boundaries, and (2) a smaller area to the northeast of the former Elgin, Raymond, Sherman and McKay, Gage-

Hagaman, Cummings and Finn and Ohio and Missouri Smelter sites north of the City of Leadville.

- Similar areas were identified by Walsh (1993a) in the Smelter RI based on comparisons of the relative abundances of metals to their relative abundances in soils from a smelter-emissions control area. The control area for soils within the smelter airshed is located due south of the former AV Smelter site and is believed to have received smelter-emissions fallout from several smelters over an extended period, but it has not been subject to other mining-related disturbances. The area identified by Walsh (1993a) as impacted by smelter emissions is based on empirical data describing the metals content and metals ratios in the top 1-inch of soil. These areas are delineated on Figure 7-6 (from the Smelter RI) and include the same areas south of the AV Smelter site and northeast of Leadville as described above, as well as broader areas to the north and south of the former Malta, Lizzie, California, AV, American, La Plata, Grant Union, Western Zinc, and Leadville smelter sites. The smelter airshed shown by Walsh extends south of the NPL site boundary.
- An air-dispersion model was also developed for the Smelter RI using limited meteorological data and uncertain smelter-operations information. The resultant predicted, or modeled, metals contents in soil were not consistent with observed metals contents in soil. The lack of correlation between predicted and observed results is likely due to uncertainty in the input parameters used for the model and the complexity of modeling emissions from multiple smelters across this site each with different operating histories.
- Data collected by the BLM demonstrate a trend of decreasing lead concentration in undisturbed surface soil with increasing distance south, north, and west of the former smelter locations. Lead concentrations approach their background ranges at the locations sampled by BLM to the south in Iowa Gulch and north and west of California Gulch.

#### **7.4 Description of Airshed Based on Existing Data**

All of the studies described above provide data relevant to delineation of the smelter airshed, and the best approach for defining the extent of the airshed utilizes the combined data from these various sources.

The following data compilation and analysis steps were performed to assemble the best available dataset for use in delineating the smelter airshed:

1. All available data describing metals concentrations in soil samples (less than 2-mm size fraction) collected from the 0- to 1-inch or 0- to 2-inch depth intervals of undisturbed native soils were compiled in an electronic database along with any available information describing sample locations and soil characteristics (e.g., upland vs. alluvial soils). Based on the findings of previous studies (CDM 1991; Walsh 1993a; and Walsh 1994), these are the sample types that are considered most appropriate for delineating an area of smelter deposition. In addition, metals concentrations data for soil samples collected from other surface depth intervals (e.g., 0 to 6 inches from Keammerer data set) were also included in the electronic database. Sample depth information was retained for each metals concentration result included in the database to distinguish true surface soils from the uppermost 2 inches of soil, from deeper soil sections.
2. The samples collected from undisturbed native soils were identified using GIS methods to select the sample locations within areas delineated on Walsh's (1994) detailed soil map as undisturbed, native soil types. For samples collected outside the extent of Walsh's soil map (and with no information provided to describe the soil type or soil disturbance), the sampling locations were assumed to be undisturbed native soil.
3. Maps showing the lead and arsenic concentrations at each of the locations within undisturbed, native-soil types were generated (Figures 7-7 and 7-9). These maps also identify locations where lead or arsenic concentrations exceed their background concentration in upland soil (Pb>150 mg/Kg, As>30 mg/Kg) and in alluvial soil (Pb>870 mg/Kg and As>120 mg/Kg). Note that for the locations within a 500-year floodplain, the comparison to the upland background is conservative because the background lead and arsenic concentrations determined by Walsh for alluvial soils are actually much higher.
4. The area where lead and/or arsenic concentrations in the 0- to 2-inch depth interval exceed upland background concentrations was delineated using a 750-foot buffer zone around each sampling location where surface soil exceeded the background value, and these areas were shown together in map view (Figure 7-11). This mapping approach is consistent with that used by Walsh in the Smelter RI. The area of overlap was highlighted.

The maps produced from these steps are included as Figures 7-7 through 7-11. The area that includes soils containing higher than background concentrations of lead and arsenic is shown along with areas defined as higher than background based on lead or arsenic alone. The area identified from lead concentrations is nearly the same as the area identified using arsenic concentrations. As shown on Figure 7-7 and 7-9, the background concentrations of lead and arsenic are exceeded at the majority of locations where undisturbed native soils have been sampled and analyzed. The combined area where undisturbed soil lead or arsenic concentrations exceed their respective background concentrations is the area likely to lie within the smelter airshed.

The area identified as likely to be within the smelter airshed (Figure 7-11) is also shown over a perspective view of the region, including the Leadville Mining District, on Figure 7-12. The view is from the west side of the UARB looking east towards the Tenmile Range. This view is helpful when considering the effects of prevailing wind directions and topography on the shape and extent of the smelter-emission airshed. Prevailing wind directions are from the north-northwest and from the east-northeast. As a result, a relatively large amount of smelter emissions would have been transported south-southeast and west-southwest from the former smelter locations than in the other directions; the effects on soil from the resultant airshed would also be most evident in these directions. This effect is borne out immediately south of the AV Smelter where the hillside along the south side of California Gulch has higher metals concentrations in soil and sparser vegetation than the neighboring hillsides. In addition, because the smelters were located primarily in relatively low topographic positions along California Gulch, the surrounding valley topography would be expected to trap smelter emissions during calm or low-wind conditions. As a result, the California Gulch valley would have received a relatively larger amount of smelter-emission deposition than higher, outlying topographic positions. The areas with the highest metals concentrations shown on Figures 7-11 and 7-12 are consistent with the shape of a smelter airshed expected to develop within the meteorologic and topographic conditions described here.

Although Figures 7-11 and 7-12 delineate a general area considered to lie within the smelter airshed, they do not delineate the airshed boundaries. Defining an absolute boundary for an airshed associated with a point source or multiple point sources would be misleading as air emissions travel considerable distances at gradually lower and lower atmospheric concentrations that eventually approach zero at some distance from the source. Because a condition of zero smelter-emissions deposition cannot be accurately defined, or measured in soils, it is not possible to make an absolute delineation of the airshed boundaries. Instead, a general pattern of decreasing metals concentrations, approaching the background conditions, with distance from the source may be used as a more practical indicator of the measurable extent of the airshed.

Figures 7-13 and 7-14 show the areas where lead and/or arsenic concentrations in soil are greater than their background concentrations in upland soils as well as the locations where lead and/or arsenic concentrations in soil are within the background range. Figure 7-13 is based on comparisons to the upland background range, whereas Figure 7-14 is based on comparisons to the alluvial background. Given the difficulty in distinguishing the outer edges of the airshed from true background conditions, results shown on Figure 7-14 provide a clearer picture of the metals concentration gradient with distance from the former smelters. Based on either of these representations of the data, it is clear that the incidence of metals concentrations greater than background is highest in close proximity to the smelters and that incidence declines with distance in all directions (north, south, east, and west). The existing data

best characterize the extent of the airshed, as defined by estimated background conditions, to the north and west of California Gulch. South of California Gulch, existing data show that soil metal concentrations approach their background ranges in the vicinity of Iowa Gulch. Directly east of Leadville, there are some locations where soil metals concentrations are within their background range, but there is no consistent trend with distance west from the former smelter locations. The lack of a recognizable trend toward lower metals concentrations may be due to the effects of large-scale mining disturbances and the presence of the ore-grade mineral deposits within the upper portions of Evans Gulch, Stray Horse Gulch, and California Gulch on soil metals contents. These additional factors make airshed delineation east of Leadville particularly difficult.

## **7.5 Summary**

In general, the available data allow for identification of the smelter airshed. For the purposes of evaluating natural resource injury, the airshed boundaries may be defined by the areas where soil metals concentrations, specifically lead and arsenic, are distinct from expected background concentrations in undisturbed, upland soils. This is a conservative approach because the metals present in soil may originate from numerous sources other than historical smelter-emissions deposition and some of the soil samples used in this process are from alluvial soils, which have higher background metals concentrations.

The area where the airshed has been identified with highest confidence is the area shown on Figures 7-11 and 7-12 as the highlighted area of overlap for locations with both lead and arsenic concentrations in soil above their expected background concentrations at upland locations. This includes most of the NPL site as well as areas south and west of the NPL-site boundaries. Although there is no absolute delineation of the airshed boundary on these figures, Figures 7-13 and 7-14 show areas where the soil metals concentrations do not exceed their background concentrations. If these areas lie within the airshed, they are likely to be at its periphery where the soil conditions are not readily distinguishable from those outside the airshed. These locations may be used from Figures 7-13 and 7-14 to identify the approximate outer extent of the airshed.

## **7.6 Potential for Natural Resource Injury within Airshed**

A specific concern was raised by USFWS regarding the potential for injury to Penland alpine fen mustard (*Eutrema penlandii*), a rare species found in the Mosquito Range in central Colorado. Its preferred habitat is characterized by wet, organically rich soils at elevations above 12,000 feet. There are

no reported populations of this species within the airshed and no evidence to indicate that previous smelter emissions would have impacted any populations of these species.

The existing total metals data for surficial soils provide an estimate of the extent of historic metals deposition from smelter emissions. In order to fully evaluate the potential for injury to other resources within the airshed boundaries, additional data may be appropriate to describe the plant availability of metals in surface soils and the possible phytotoxic effects of soils within the airshed. Total metals concentrations could be used as a conservative guide in identifying locations for plant-available sampling and evaluating the current extent of smelter deposition that may represent potentially phytotoxic conditions. Review of existing total metals data indicate that the currently defined Airshed reasonably bounds the area of potential phytotoxic concern. Therefore, any sampling for the purpose of evaluating phytotoxicity would be limited to the area defined in Figures 7-11, 7-13, and 7-14.

Figures 7-13 and 7-14 are used to define the potential for injury to natural resources within the airshed boundaries. These figures show the airshed soil concentration gradients for lead using background concentrations of  $\geq 150$  mg/Kg (Figure 7-13) and  $\geq 870$  mg/Kg (Figure 7-14). The boundaries of the airshed are defined by the areas where lead concentrations are distinct from expected background concentrations in undisturbed, upland soils (150 mg/Kg) and undisturbed alluvial soils (870 mg/Kg). This is a conservative approach for delineating the airshed boundary because metals may originate from numerous sources other than depositions from historical smelter emissions. It is clear that the occurrence of metals concentrations greater than background is highest in close proximity to the former smelter locations and these concentrations decline with distance from the smelters in all directions. There are only two exceptions to this general trend that can be found northeast of Crystal Lakes (1 sample site) and west of the Arkansas River and north of the Lake Fork drainage (1 sample site). Each exception is one location among a larger group of sample sites (1 site out of 13 and 1 site out of 30) from the BLM (2000) data set. It is highly unlikely that the lead concentrations reported for these sites are from smelter emissions because the lead concentrations in soils surrounding each site are at or below background.

Figures 7-13 and 7-14 establish the boundaries that represent the areas of smelter deposition and therefore establish the boundaries of potential injury. These boundaries are highly correlated with existing conditions in the field. For example, the area with the highest soils concentrations of lead are found south of California Gulch. This area is most likely devoid of vegetation because of elevated concentrations of arsenic and zinc. It is important to note that the area of injury associated with smelter emissions is contained within the NPL site.

## **TABLES**



Table 7-1

Smelter Production Summaries and Locations <sup>1</sup>

Smelter Site Location	Operating Facility (Other historic name/geographic location)	Yr. Start	Yr. End	Length of Operation	Size of Production	Map Location
Malta Smelter	Malta Smelter	1875	1880	5 yrs.	Very Small	1
Lizzie Smelter	Lizzie Smelter	1876	1879	3 yrs	Small	2
California Smelter	California Smelter (Chicago Reduction Work/Survey Nos. 930, 931, 932)	1879	1880	1 yr	Small	3
Western Zinc	Western Zinc Mining and Reduction Co.	1914	1926	12 yrs	Large	4
AV Smelter	AV Smelting Co. Billing-Eilers (Utah) Smelter (ASARCO/Kansas City/Survey No. 389)	1879 1879	1960 1882	81 yrs 3 yrs	Very Large Medium	5 5
American Smelter	American Smelting Company	1879	1893	15 yrs	Large	6
La Plata Smelter	La Plata (Berdell and Witherells) Smelter Bi Metallic Smelter	1878 1892	1887 1900	10 yrs 8 yrs	Large Large	7 7
Grant/Union Smelter	Grants Smelter Union Smelting Company (Holden)	1878 1892	1882 1896	4 yrs 5 yrs	Large Large	8 8
Leadville Smelter	Leadville Smelting Company	1877	1880	3 yrs	Very Small	9
Harrison Reduction Works	Harrison Reduction Works (St. Louis Smelter/Thomas Starr Placer claim/Survey No. 225)	1877	1893	16 yrs	Very Large	10
Adelaide Smelter	Adelaide Smelter	1879	1879	1 yr	Very Small	11
Little Chief Smelter	Little Chief Smelter	1879	1880	2 yrs	Small	12
Ohio and Missouri Smelter	Ohio and Missouri Smelter (E. Warner Claim/Survey No. 522)	1879	1880	2 yrs	Medium	13
Cummings and Finn Smelter	Cummings and Finn Smelter (Fryer Hill Smelting Co./Mandela Claim)	1879	1885	6 yrs	Large	14
Gage-Hagaman Smelter	Gage-Hagaman Smelter (Smithy Mine Claim/Survey No. 382)	1879	1880	2 yrs	Small	15
Raymond, Sherman, and McKay Smelter	Raymond, Sherman, and McKay Smelter (Raymond Claim/Survey No. 458)	1879	1879	1 yr	Very Small	16
Elgin Smelter	Elgin Smelter (Elgin Mining and Smelting) Boston Gold-Copper Smelting Co. Republic Smelting and Reduction Co. (Manville)	1879 1900 1902	1900 1901 1903	24 yrs 1 yr 1 yr	Large Large Large	17 17 17

Note: <sup>1</sup> From Jacobs (1991)

KEY: Size Total Production  
 Very Small 2,000 tons or less  
 Small 2,000 to 10,000 tons  
 Medium 10,000 to 100,000 tons  
 Large 100,000 to 1,000,000 tons  
 Very Large 1,000,000 tons or more

**Table 7-2**

**Estimated Background Metals Concentrations for Soils in Upland and Alluvial Landscape Positions <sup>1</sup>**

Landscape Position	Arsenic (mg/Kg)	Cadmium (mg/Kg)	Copper (mg/Kg)	Lead (mg/Kg)	Zinc (mg/Kg)
Upland	0.3 – 30	0.01 - 4	0.4 - 40	8 - 150	16 – 100
Alluvial	0.7 – 120	0.5 - 8	8 - 190	80 - 870	37 - 660

<sup>1</sup> Data from Walsh (1994)

## FIGURES

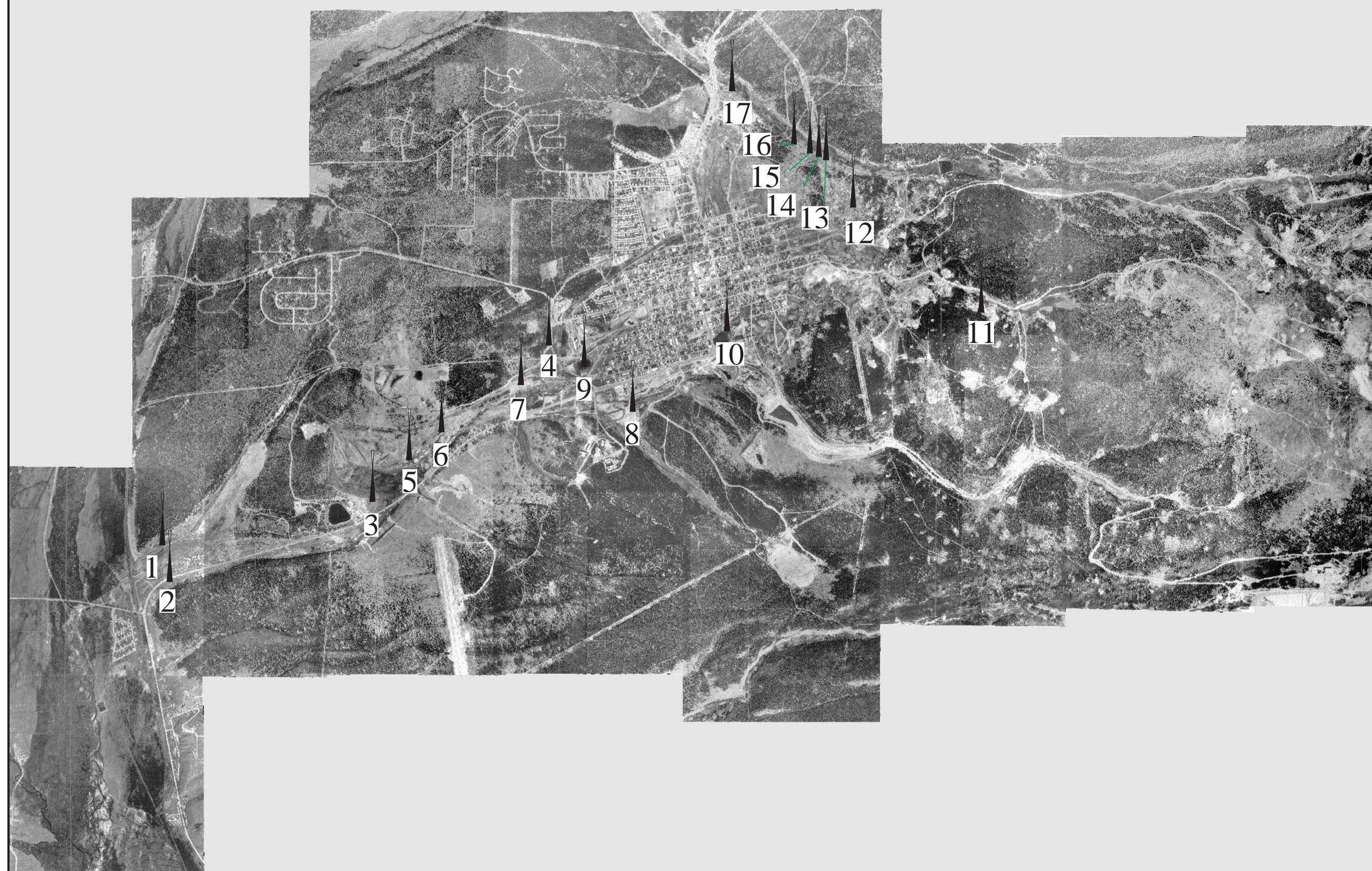


EXPLANATION

Former Smelter Locations



- 1 Malta Smelter
- 2 Lizzie Smelter
- 3 California Smelter
- 4 Western Zinc
- 5 Arkansas Valley Smelter
- 6 American Smelter
- 7 La Plata Smelter
- 8 Grant/Union Smelter
- 9 Leadville Smelter
- 10 Harrison Reduction Works
- 11 Adelaide Smelter
- 12 Little Chief Smelter
- 13 Ohio and Missouri Smelter
- 14 Cummings and Finn Smelter
- 15 Gage-Hagaman Smelter
- 16 Raymond, Sherman, and McKay Smelter
- 17 Elgin Smelter



SCALE IN FEET



UPPER ARKANSAS RIVER BASIN  
SITE CHARACTERIZATION SUMMARY

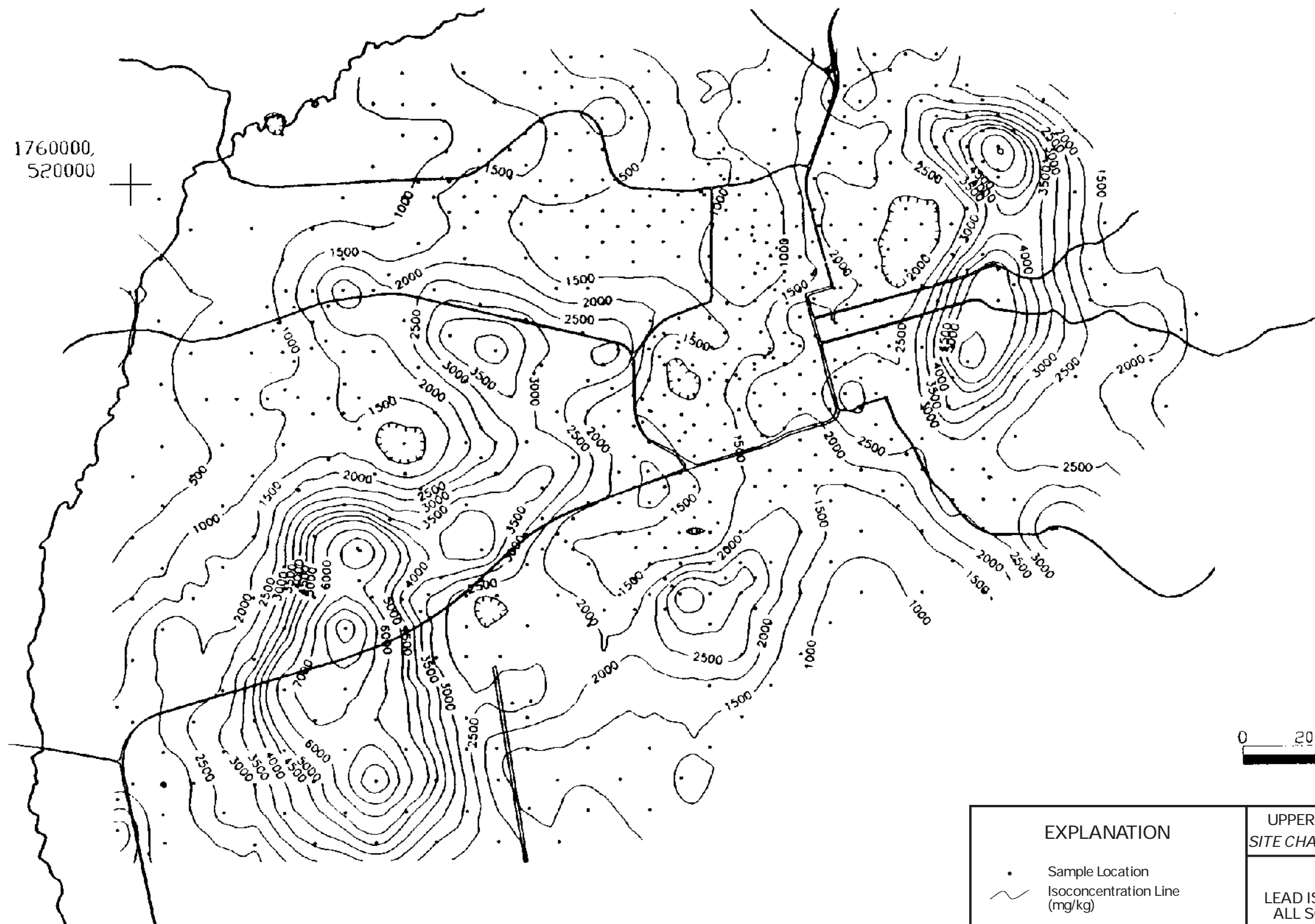
FIGURE 7-1

HISTORIC SMELTER LOCATIONS  
FROM WALSH, 1993

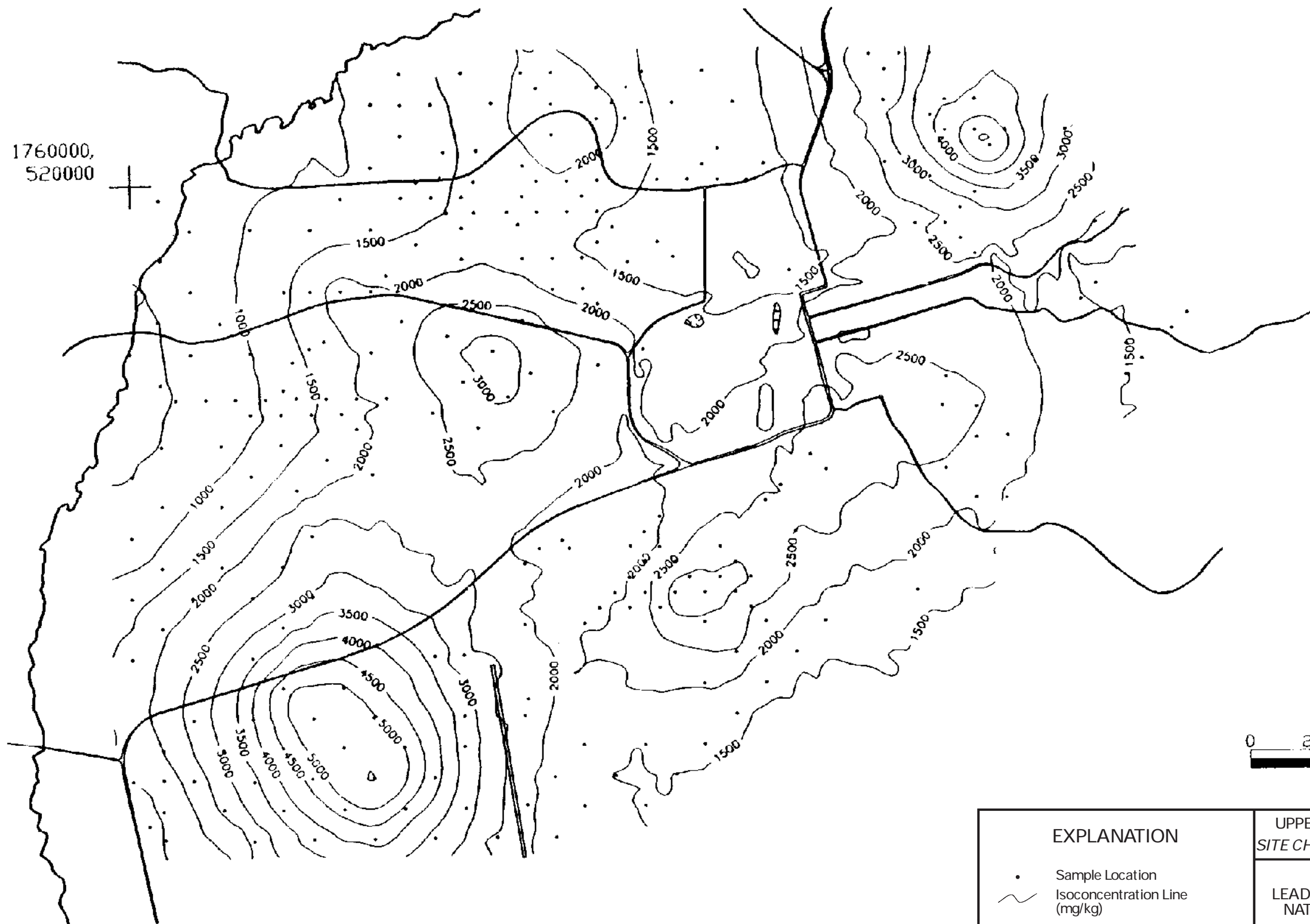
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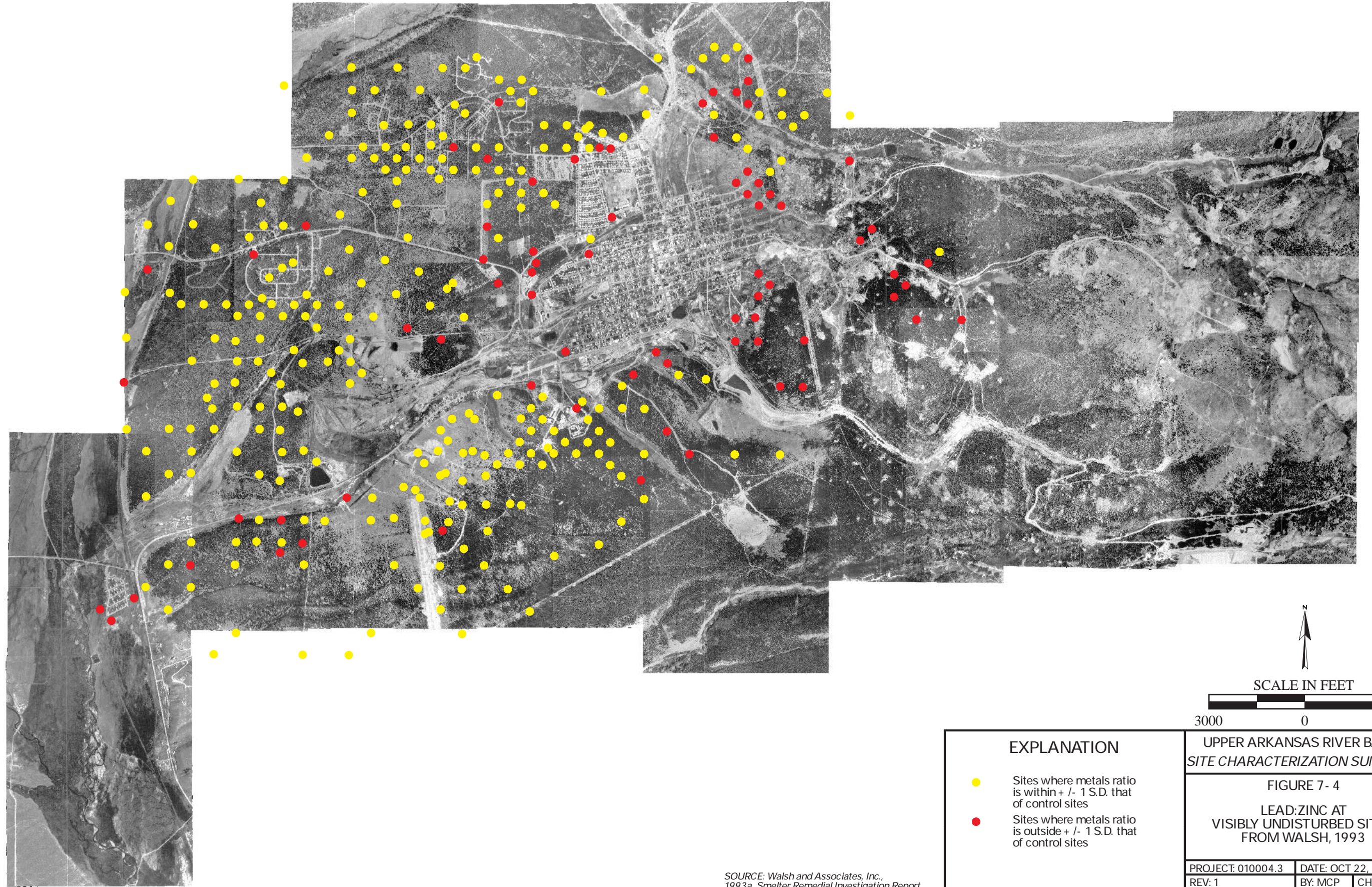


<p><b>EXPLANATION</b></p> <ul style="list-style-type: none"> <li>• Sample Location</li> <li>~ Isoconcentration Line (mg/kg)</li> </ul>	<p>UPPER ARKANSAS RIVER BASIN SITE CHARACTERIZATION SUMMARY</p>	
	<p>FIGURE 7- 2 LEAD ISOCONCENTRATION MAP, ALL SOILS, 0 TO 1 INCH DEPTH FROM CDM, 1994</p>	
<p>Original Figure from CDM, 1994 Final Soils Investigation Data Report California Gulch CERCLA Site Leadville, Colorado</p>	<p>PROJECT: 010004.3 REV: 1</p>	<p>DATE: OCT 22, 2002 BY: ALB   CHK: KJT</p>
<p><b>MFG, Inc.</b> consulting scientists and engineers</p>		

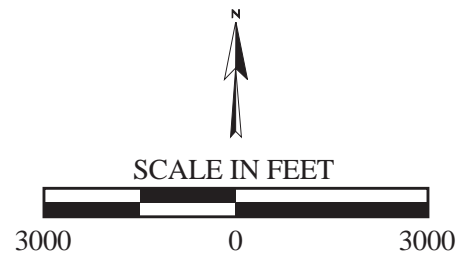


<p><b>EXPLANATION</b></p> <ul style="list-style-type: none"> <li>• Sample Location</li> <li>~ Isoconcentration Line (mg/kg)</li> </ul> <p><small>Original Figure from CDM, 1994 Final Soils Investigation Data Report California Gulch CERCLA Site Leadville, Colorado</small></p>	<p>UPPER ARKANSAS RIVER BASIN SITE CHARACTERIZATION SUMMARY</p>	
	<p>FIGURE 7-3 LEAD ISOCONCENTRATION MAP, NATIVE UNDISTURBED SOILS, 0 TO 1 INCH DEPTH FROM CDM, 1994</p>	
<p>PROJECT: 010004.3</p>	<p>DATE: OCT 22, 2002</p>	
<p>REV: 1</p>	<p>BY: ALB</p>	<p>CHK: KJT</p>
<p><b>MFG, Inc.</b> <i>consulting scientists and engineers</i></p>		





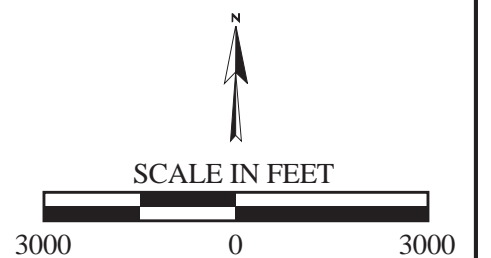
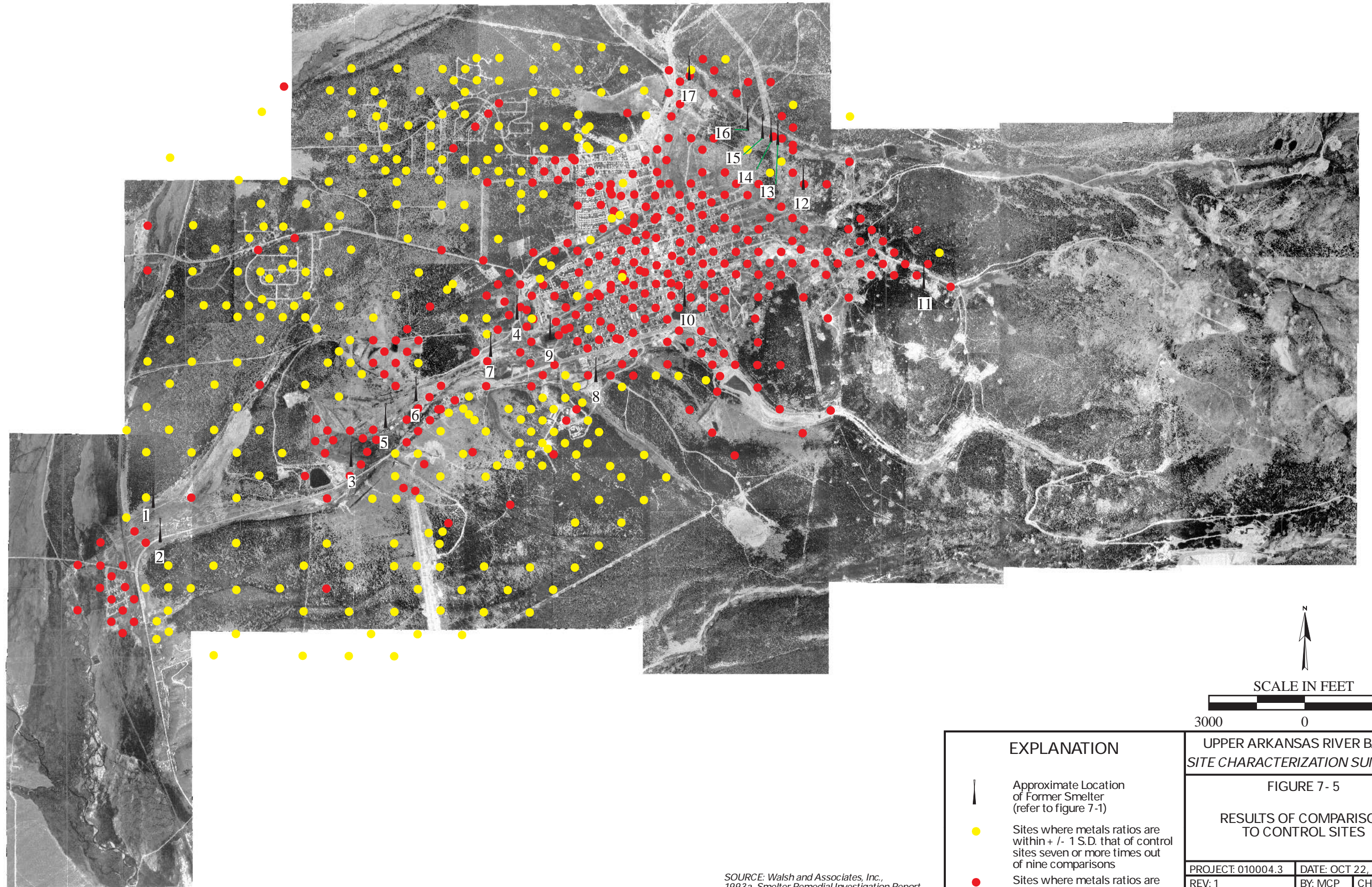
EXPLANATION	
●	Sites where metals ratio is within +/- 1 S.D. that of control sites
●	Sites where metals ratio is outside +/- 1 S.D. that of control sites



*SOURCE: Walsh and Associates, Inc., 1993a. Smelter Remedial Investigation Report, California Gulch Site, Leadville, Colorado. Prepared for ASARCO, Incorporated, Leadville, Colorado, May 3, 1993.*

<b>UPPER ARKANSAS RIVER BASIN SITE CHARACTERIZATION SUMMARY</b>		
FIGURE 7-4 <b>LEAD:ZINC AT VISIBLELY UNDISTURBED SITES FROM WALSH, 1993</b>		
PROJECT: 010004.3	DATE: OCT 22, 2002	
REV: 1	BY: MCP	CHK: KJT
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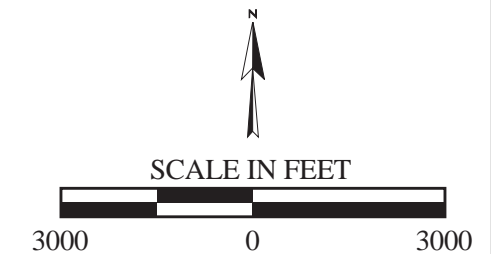
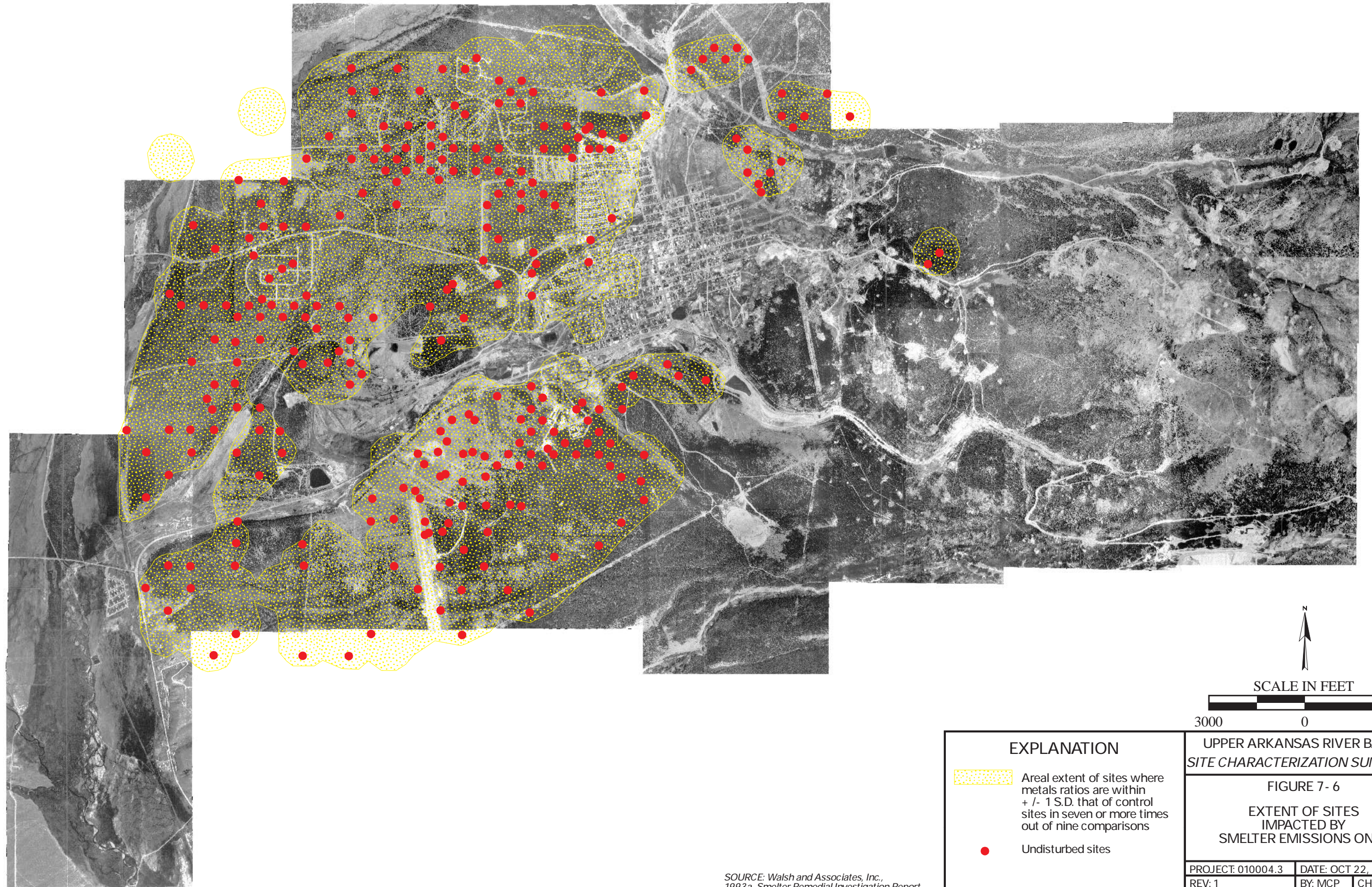






EXPLANATION		UPPER ARKANSAS RIVER BASIN SITE CHARACTERIZATION SUMMARY	
	Approximate Location of Former Smelter (refer to figure 7-1)	FIGURE 7- 5 RESULTS OF COMPARISON TO CONTROL SITES	
	Sites where metals ratios are within +/- 1 S.D. that of control sites seven or more times out of nine comparisons		
	Sites where metals ratios are within +/- 1 S.D. that of control sites three or less times out of nine comparisons	PROJECT: 010004.3	DATE: OCT 22, 2002
		REV: 1	BY: MCP   CHK: KJT
		<b>MFG, Inc.</b> <i>consulting scientists and engineers</i>	

*SOURCE: Walsh and Associates, Inc., 1993a. Smelter Remedial Investigation Report, California Gulch Site, Leadville, Colorado. Prepared for ASARCO, Incorporated, Leadville, Colorado, May 3, 1993.*



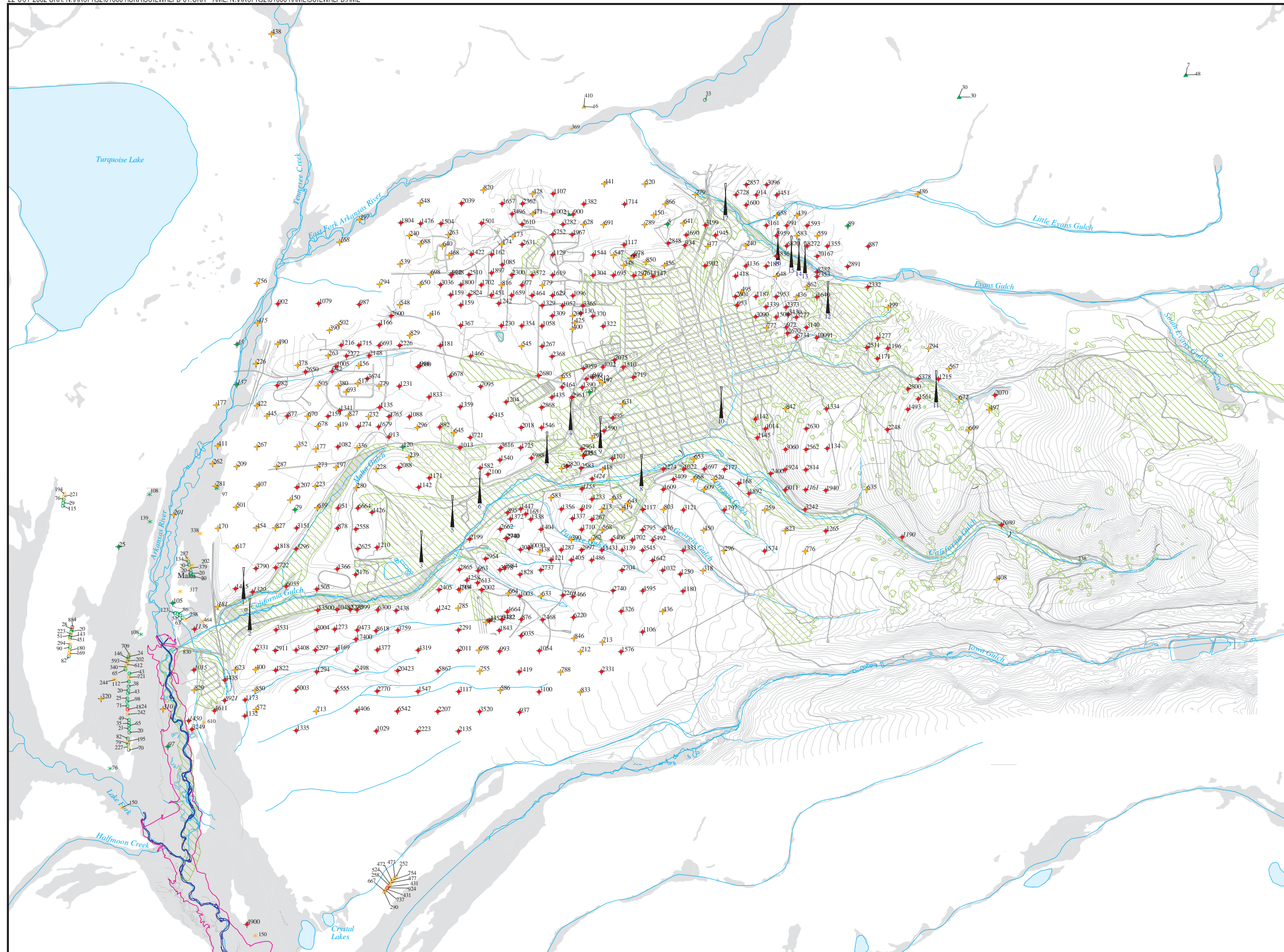


EXPLANATION	
	Areal extent of sites where metals ratios are within $\pm 1$ S.D. that of control sites in seven or more times out of nine comparisons
	Undisturbed sites

<b>UPPER ARKANSAS RIVER BASIN SITE CHARACTERIZATION SUMMARY</b>		
<b>FIGURE 7-6 EXTENT OF SITES IMPACTED BY SMELTER EMISSIONS ONLY</b>		
PROJECT: 010004.3	DATE: OCT 22, 2002	
REV: 1	BY: MCP	CHK: KJT
<b>MFG, Inc.</b> <i>consulting scientists and engineers</i>		

*SOURCE: Walsh and Associates, Inc., 1993a. Smelter Remedial Investigation Report, California Gulch Site, Leadville, Colorado. Prepared for ASARCO, Incorporated, Leadville, Colorado, May 3, 1993.*





### EXPLANATION

**Hydrology**

- River or Stream

**Airshed Sampling Locations**

CDM/Walsh Soil Sampling Location (LNRD- 061)

- Sampling Location and Concentration (Alluvial samples concentration in italics)
- Lead Concentration < 150 mg/Kg
- Lead Concentration > = 150 mg/Kg and < 870 mg/Kg
- Lead Concentration > = 870 mg/Kg

**Other Sampling Locations**

BLM Soil Sampling Location (LNRD- 057)

- Lead Concentration < 150 mg/Kg
- Lead Concentration > = 150 mg/Kg and < 870 mg/Kg
- Lead Concentration > = 870 mg/Kg

Keammerer Soil Sampling Location (LNRD- 016)  
NOTE: Keammerer samples are 0- 6" depth

- Lead Concentration < 150 mg/Kg
- Lead Concentration > = 150 mg/Kg and < 870 mg/Kg

BLM Soil Sampling Location (1997)

- Lead Concentration < 150 mg/Kg
- Lead Concentration > = 150 mg/Kg and < 870 mg/Kg

**Other Features**

- Approximate Location of Former Smelter
- Disturbed or Non- Native Soil Areas (Walsh, 1994)
- Lowland Zone - Based on presence of riparian species (CDOV Vegetation Mapping, 2001)

For sample depth intervals, refer to Figure 7- 8

SCALE IN FEET

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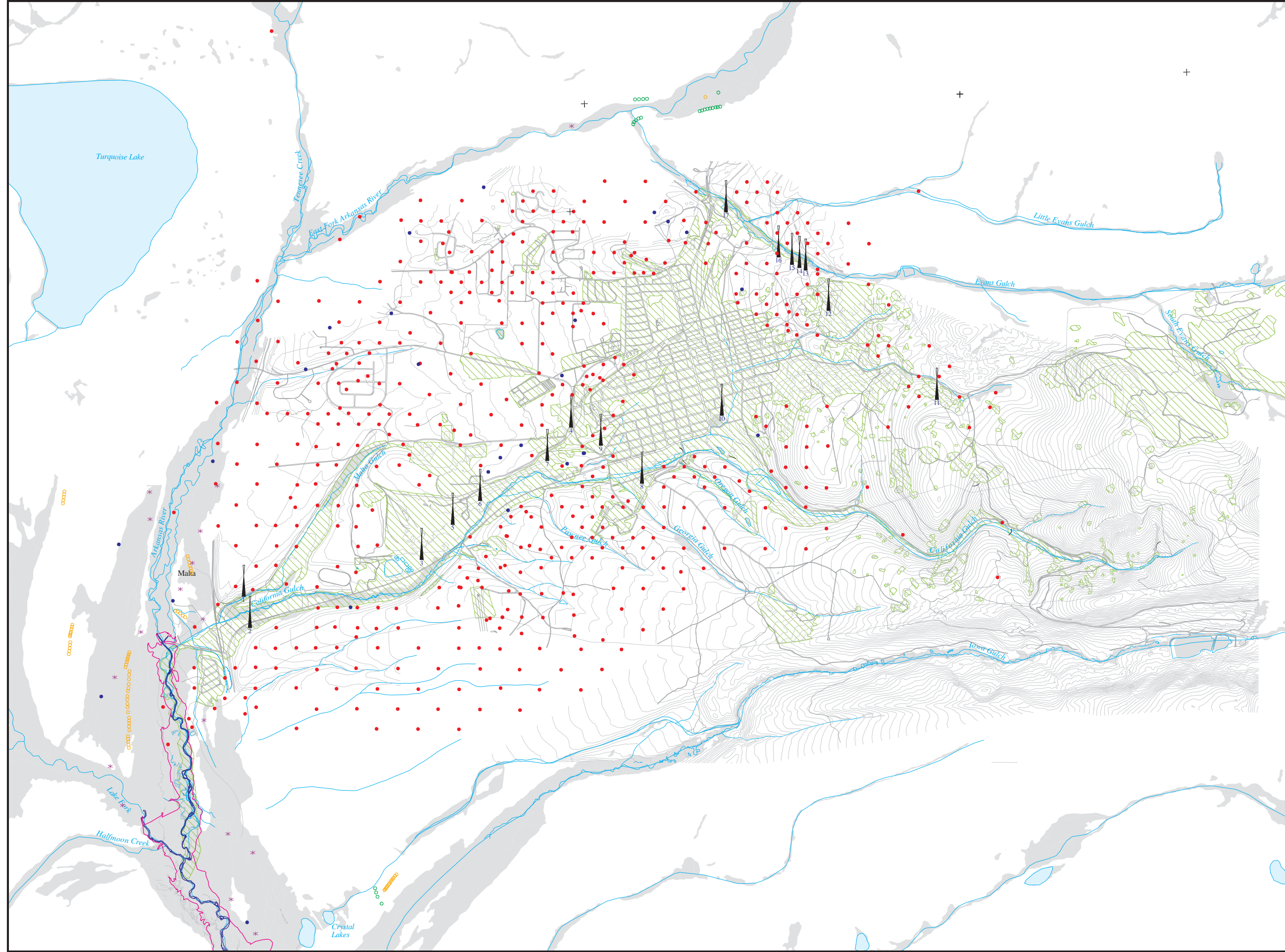
**UPPER ARKANSAS RIVER BASIN  
SITE CHARACTERIZATION SUMMARY**

**FIGURE 7- 7  
LEAD CONCENTRATION (mg/Kg)  
UNDISTURBED  
NATIVE SOIL**

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**EXPLANATION**

**Hydrology**

- River or Stream
- 500- Year Floodplain

**Airshed Sampling Locations**

CDM/Walsh Soil Sampling Depth (LNRD- 061)

- 0"- 1" Soil Depth
- 0"- 2" Soil Depth

**Other Sampling Locations**

BLM Soil Sampling Depth (1997)

- No depth data available

BLM Soil Sampling Depth (LNRD- 057)

- 0"- 1" Soil Depth
- 0"- 3" Soil Depth

Keammerer Soil Sampling Depth (LNRD- 016)

- 0"- 6" Soil Depth

**Other Features**

- Approximate Location of Former Smelter
- Disturbed or Non- Native Soil Areas (Walsh, 1994)
- Lowland Zone - Based on presence of riparian species (COW Vegetation Mapping, 2001)

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SCALE IN FEET

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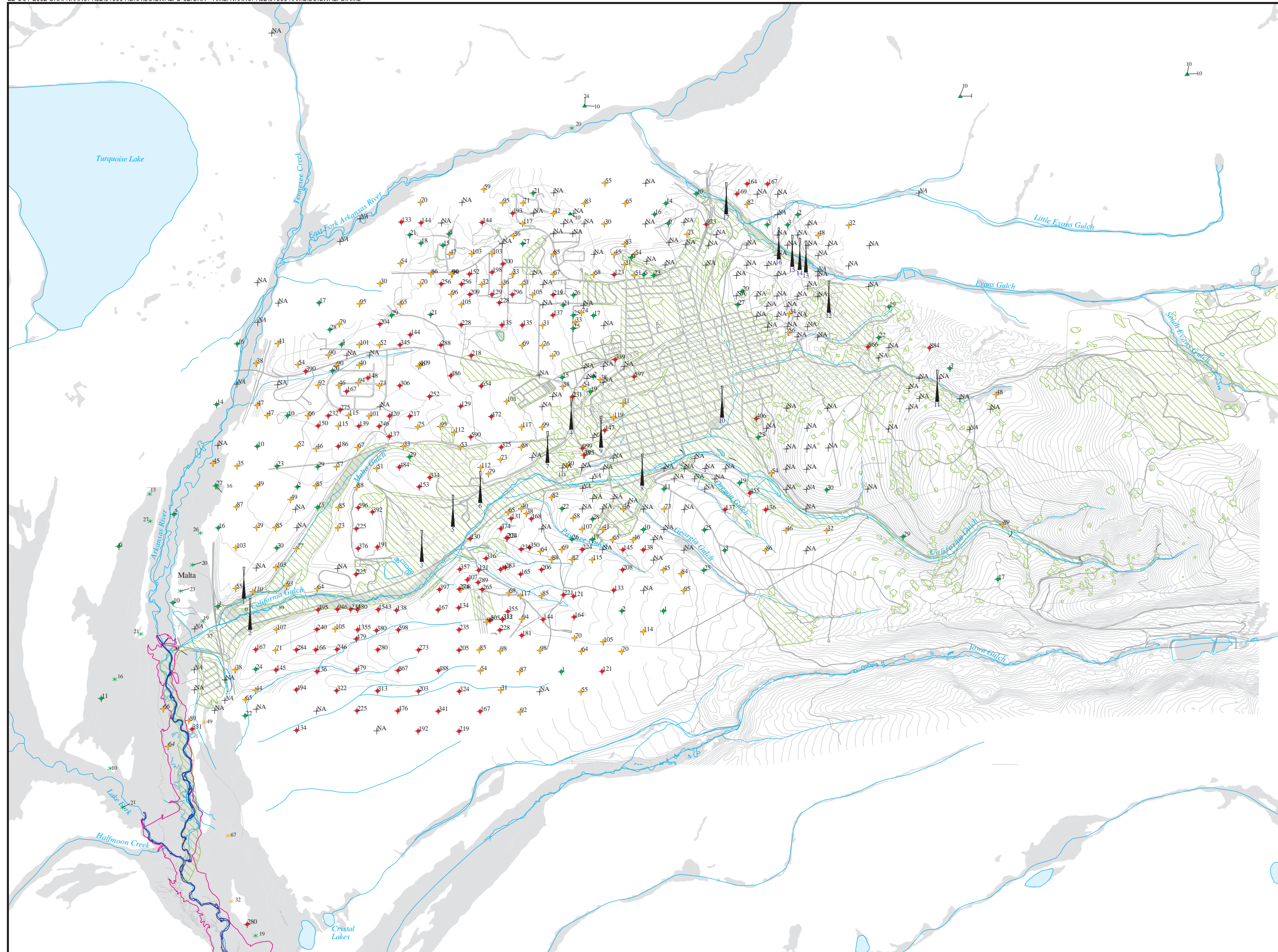
**UPPER ARKANSAS RIVER BASIN  
SITE CHARACTERIZATION SUMMARY**

**FIGURE 7- 8**

**SOIL SAMPLE DEPTH  
FOR LEAD SAMPLE LOCATIONS**

PROJECT: 010004.3	DATE: OCT 22, 2002
REV: 1	BY: MCP    CHK: KJT

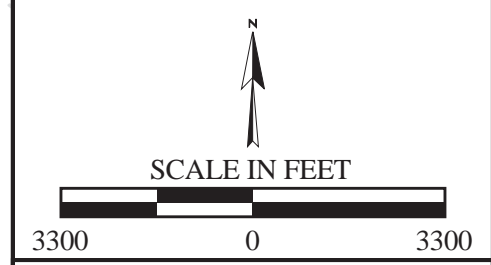




### EXPLANATION

- Hydrology
  - River or Stream
  - 500- Year Floodplain
- Airshed Sampling Locations
  - CDM/Walsh Soil Sampling Location (LNRD- 061)
    - Sampling Location and Concentration (Alluvial samples concentration in italics)
      - Arsenic Concentration < 30 mg/Kg
      - Arsenic Concentration > = 30 mg/Kg and < 120 mg/Kg
      - Arsenic Concentration > = 120 mg/Kg
  - Other Sampling Locations
    - Keammerer Soil Sampling Location (LNRD- 016)
      - NOTE: Keammerer samples are 0- 6" depth*
      - Arsenic Concentration < 30 mg/Kg
      - Arsenic Concentration > = 30 mg/Kg and < 120 mg/Kg
      - Arsenic Concentration > = 120 mg/Kg
    - BLM Soil Sampling Location (1997)
      - Arsenic Concentration < 30 mg/Kg
- Other Features
  - Approximate Location of Former Smelter
  - Disturbed or Non- Native Soil Areas (Walsh, 1994)
  - Lowland Zone - Based on presence of riparian species (CDOW Vegetation Mapping, 2001)

For sample depth intervals, refer to Figure 7- 10



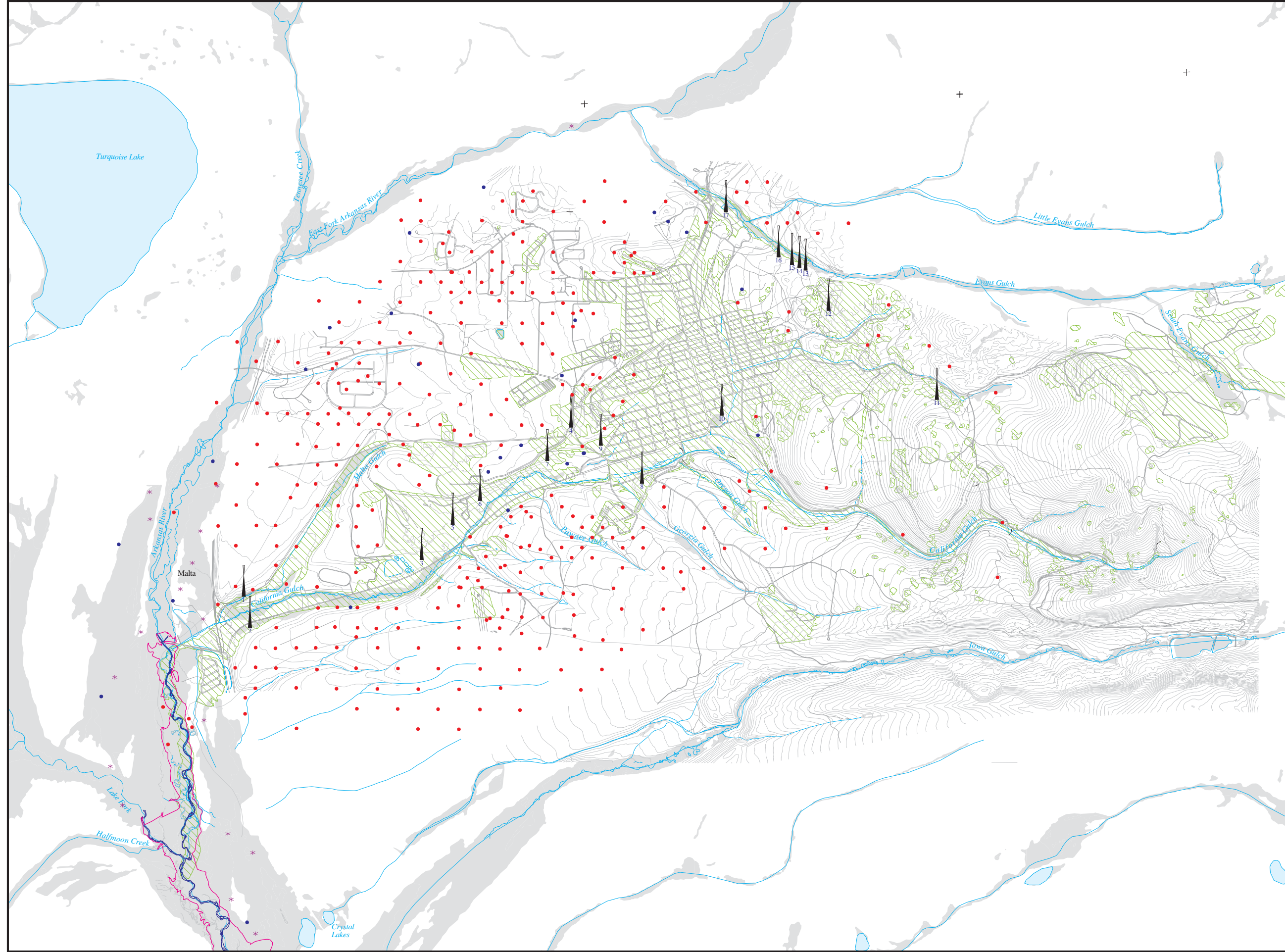
UPPER ARKANSAS RIVER BASIN  
SITE CHARACTERIZATION SUMMARY

FIGURE 7- 9  
ARSENIC CONCENTRATION (mg/Kg)  
UNDISTURBED  
NATIVE SOIL

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**EXPLANATION**

**Hydrology**

- River or Stream
- 500- Year Floodplain

**Airshed Sampling Locations**

CDM/Walsh Soil Sampling Depth (LNRD- 061)

- 0"- 1" Soil Depth
- 0"- 2" Soil Depth

**Other Sampling Locations**

BLM Soil Sampling Depth (1997)

- No depth data available

Keammerer Soil Sampling Depth (LNRD- 016)

- 0"- 6" Soil Depth

**Other Features**

- Approximate Location of Former Smelter
- Disturbed or Non- Native Soil Areas (Walsh, 1994)
- Lowland Zone - Based on presence of riparian species (CDOW Vegetation Mapping, 2001)

SCALE IN FEET

3300 0 3300

**UPPER ARKANSAS RIVER BASIN  
SITE CHARACTERIZATION SUMMARY**

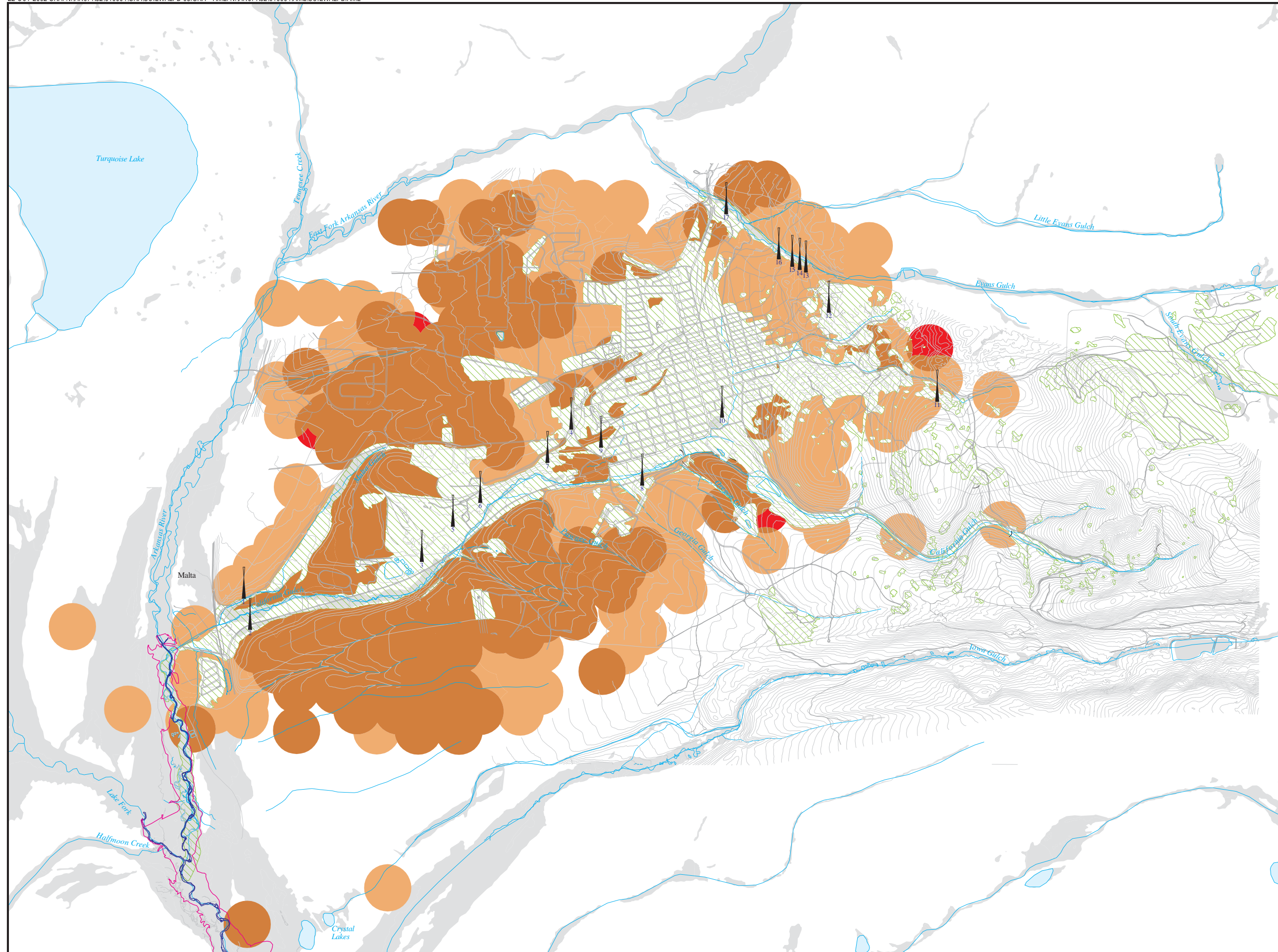
**FIGURE 7- 10**

**SOIL SAMPLE DEPTH  
FOR ARSENIC SAMPLE LOCATIONS**

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**EXPLANATION**

**Hydrology**

— River or Stream

— 500- Year Floodplain

**Airshed Delineation**

■ Airshed Delineation via Arsenic Criteria Only

■ Airshed Delineation via Lead Criteria Only

■ Airshed Delineation via Arsenic and Lead Criteria

**Other Features**

↓ Approximate Location of Former Smelter

▨ Disturbed or Non- Native Soil Areas (Walsh, 1994)

■ Lowland Zone - Based on presence of riparian species (CDOW Vegetation Mapping, 2001)

Note: Data from 0 to 2- inch depth interval



SCALE IN FEET



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FIGURE 7- 11

AIRSHED DELINEATION

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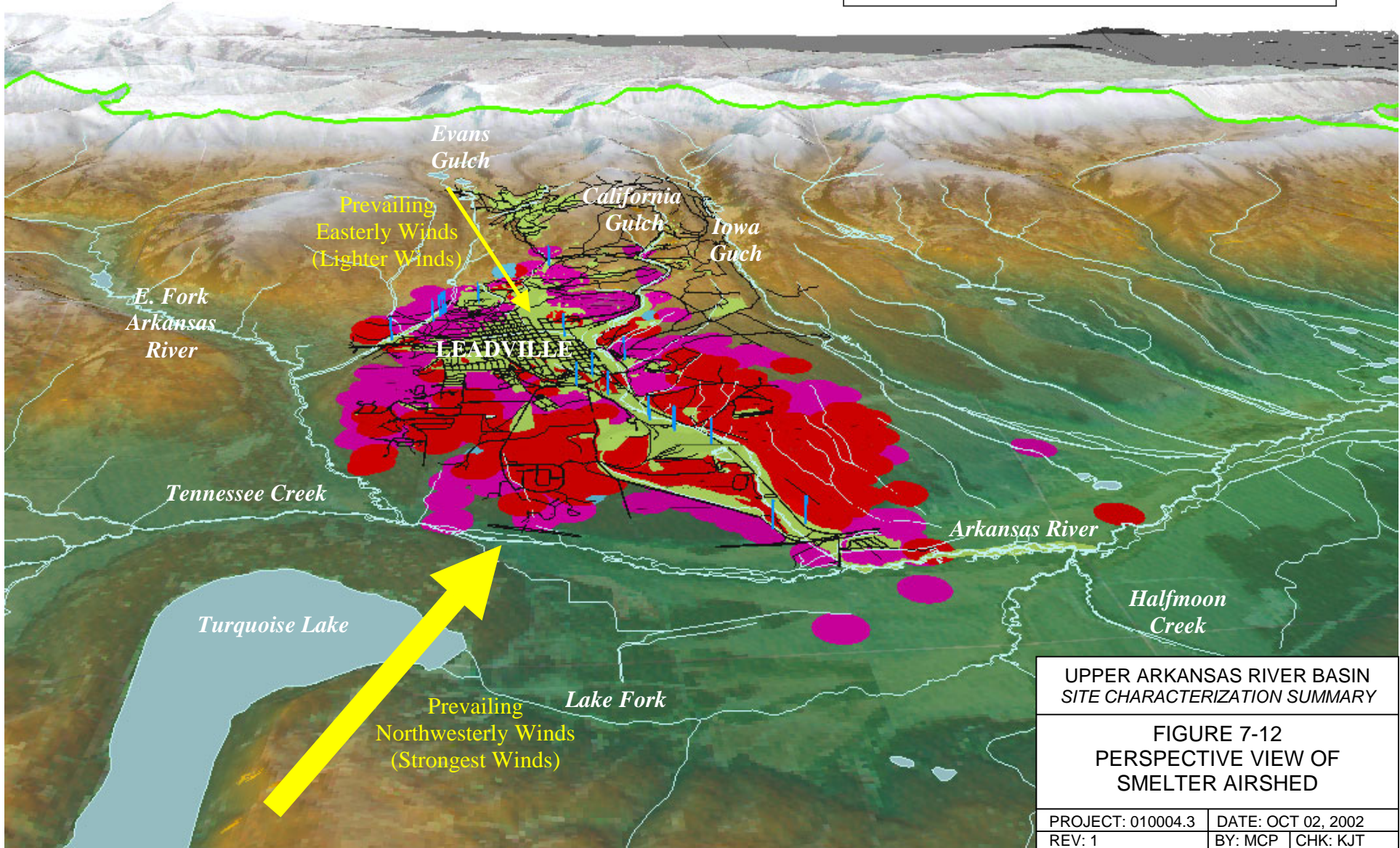
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← North

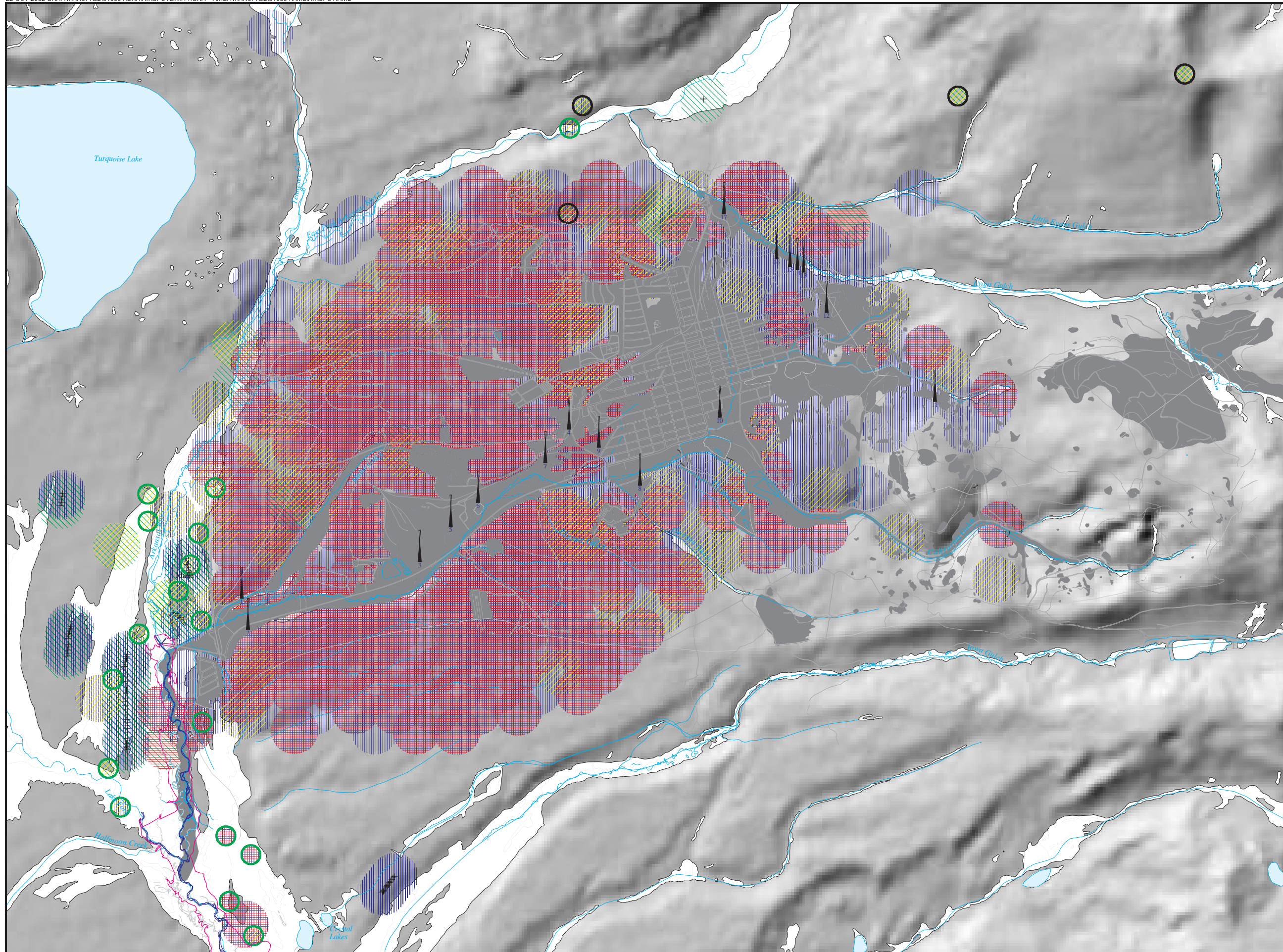
**EXPLANATION**  
 Perspective view looking east from Arkansas River Valley

- Area included within smelter airshed based on the metals data currently available for undisturbed native soils
- Disturbed or Non-native Soil
- Approximate Location of Former Smelter



<b>UPPER ARKANSAS RIVER BASIN SITE CHARACTERIZATION SUMMARY</b>		
<b>FIGURE 7-12 PERSPECTIVE VIEW OF SMELTER AIRSHED</b>		
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**EXPLANATION**

**Hydrology**

- River or Stream
- 500- Year Floodplain

**Airshed Category (Top 0 to 2 inches)**

- Lead Concentration less than 150 mg/Kg (Upland Background)
- Lead Concentration greater than or equal to 150 mg/Kg
- Arsenic Concentration less than 30 mg/Kg (Upland Background)
- Arsenic Concentration greater than or equal to 30 mg/Kg

**Other Samples (Other depth intervals)**

- BLM samples, depth unknown
- Keammerer (0-6") samples

**Other Features**

- Approximate Location of Former Smelter
- Lowland Zone - Based on presence of riparian species (CDOW Vegetation Mapping, 2001)
- Disturbed or Non- Native Soil Areas (Walsh, 1994)
- BLM 2000 Soil Sample Location

SCALE IN FEET

3300 0 3300

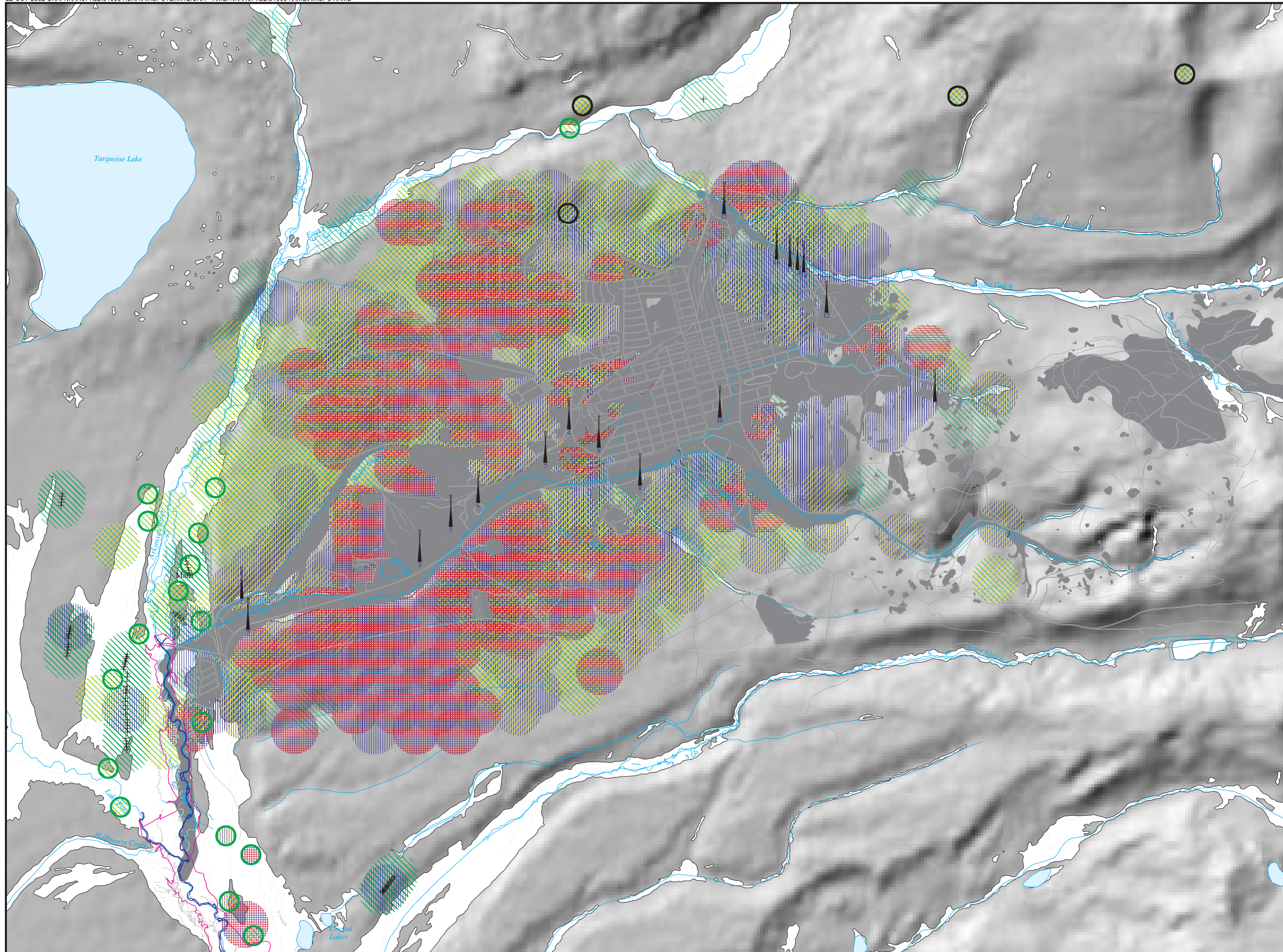
**UPPER ARKANSAS RIVER BASIN  
SITE CHARACTERIZATION SUMMARY**

**FIGURE 7- 13  
AIRSHED METALS  
CONCENTRATION GRADIENT  
(UPLAND BACKGROUND)**

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**EXPLANATION**

**Hydrology**

- River or Stream
- 500- Year Floodplain

**Airshed Category (Top 0 to 2 inches)**

- Lead Concentration less than 870 mg/Kg (Alluvial Background)
- Lead Concentration greater than or equal to 870 mg/Kg
- Arsenic Concentration less than 120 mg/Kg (Alluvial Background)
- Arsenic Concentration greater than or equal to 120 mg/Kg

**Other Samples (Other depth intervals)**

- BLM samples, depth unknown
- Keammerer (0-6") samples

**Other Features**

- Approximate Location of Former Smelter
- Lowland Zone - Based on presence of riparian species (CDOW Vegetation Mapping, 2001)
- Disturbed or Non- Native Soil Areas (Walsh, 1994)
- BLM 2000 Soil Sample Location

SCALE IN FEET

3300 0 3300

UPPER ARKANSAS RIVER BASIN  
SITE CHARACTERIZATION SUMMARY

FIGURE 7- 14  
AIRSHED METALS  
CONCENTRATION GRADIENT  
(ALLUVIAL BACKGROUND)

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