

1.0 INTRODUCTION

This Site Characterization Report (SCR) presents the findings regarding the condition of the Upper Arkansas River Basin (UARB) resources as prescribed by the “Work Plan for Upper Arkansas River Basin Consulting Team: 11-Mile Reach, Downstream Survey, and Airshed Survey” (Work Plan). This characterization relies on existing information that describes the nature and extent of contamination and injuries to natural resources of the UARB that are associated with historic mining and smelting in and around Leadville. This report has been prepared by the consulting team (Dr. Edward Redente, Department of Rangeland Ecosystem Science, Colorado State University, Fort Collins, Colorado; Dr. William Clements, Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, Colorado; Dr. Stanley Schumm, Mussetter Engineering, Fort Collins, Colorado; Mr. Andrew Archuleta, Fish and Wildlife Service, Lakewood, Colorado; and Mr. Steven Werner, MFG, Inc., Boulder, Colorado).

The members of the consulting team are in agreement on the findings presented in this report. There are no dissenting or minority opinions regarding the characterization effort. The opinions presented in this report are those of the consulting team unless otherwise referenced.

Area of Interest

The large geographic perspective of this report includes the 500-year floodplain of the Arkansas River from just downstream of Leadville (California Gulch) to the Pueblo Reservoir (Figure 1-1). This report also considers upland areas peripheral to Leadville. The area of interest for this report can best be described by the following three interrelated areas:

- **11-Mile Reach of the Arkansas River** - This area is defined as the 500-year floodplain from the confluence of California Gulch with the Arkansas River to a point approximately 11 miles downstream, at its confluence with Two-Bit Gulch (Figure 1-2). Irrigated lands adjacent to the 500-year floodplain were also evaluated. The 11-mile reach of concern flows in a wide valley until it enters a canyon downstream of River Mile 11. Within the 11-mile reach, the Arkansas River is a relatively steep, wandering gravel-bed river. For the purpose of this report, River Mile 0 is at the confluence of California Gulch and the Arkansas River.
- **Downstream Area** – This area covers the 500-year floodplain from the downstream end of the 11-mile reach, to and including Pueblo Reservoir.
- **Airshed** – This area is defined as the upland area surrounding Leadville, subject to historic air deposition from Leadville-area smelters.

As shown on Figure 1-3, mining occurred in numerous areas within the UARB watershed. The vast majority of UARB mining and metals refining took place in and around Leadville, Colorado, at the headwaters of the Arkansas River. These areas of mining, milling, and smelting are currently being addressed as a series of Operable Units (OU) within the California Gulch National Priorities List (NPL) Site (NPL Site) (Figure 1-1). Other areas of mining can be identified in UARB tributaries outside of the Leadville district; however, the focus of this report is on impacts from mining in and around Leadville.

The emphasis of this report is on the conditions within the specific areas discussed above and on providing an understanding of how historic fluvial and airborne deposition of mine-waste have impacted the natural resources of those areas. Even though response actions that address the mining, milling, and smelting wastes in the NPL Site are ongoing, evaluation of those specific source areas is mostly outside the scope of this report. However, the ongoing downstream impacts of the entire NPL site contribution are considered when characterizing conditions in the areas of interest.

It should be noted that the 11-mile reach study area overlaps with a portion of OU-11 of the NPL Site. The area of overlap is the 500-year floodplain of the UARB between California Gulch and the confluence of Lake Fork. USEPA has been conducting remediation work on selected fluvial mine-waste deposits in the 11-mile reach and is currently investigating the concentration and toxicity of metals in irrigated land surficial soils in the same areas. Actions to date include addition of amendments, revegetation efforts, and some limited stream stabilization. These remediation efforts are considered to be preliminary by USEPA and could be characterized as field-scale pilot treatability studies. The effectiveness of the USEPA response actions in improving environmental conditions within specific portions of the 11-mile reach as well as new data regarding irrigated lands are being evaluated and will be considered fully in the consulting team's subsequent Restoration Alternatives Report.

Purpose/Approach

According to the above-referenced Work Plan, the purpose of this report is to provide the following for the 11-mile reach of the Arkansas River:

- Description of the nature and extent of contamination;
- Maps of areas affected by mine-waste;
- Description of injuries to natural resources;
- Identification of potential contaminant pathways; and
- Definition of areas where restoration is needed to obtain a healthy, functioning ecosystem and to mitigate exposure pathways.

Also in accordance with the Work Plan, this report provides a literature review regarding injuries to natural resources in the Downstream Area. The purpose of the literature review is to determine the type of information available for evaluating the potential for injury to natural resources from the release of hazardous substances from mining activities. Per subsequent direction from the MOU Parties, the authors have also examined the available information in order to provide a characterization as to whether there are current injuries attributable to historic mining and to identify the source of any injuries.

This report includes a literature review regarding potential injuries to natural resources in the UARB that result from the release of hazardous substances through smelter stack emissions and subsequent deposition in the surrounding Airshed. As with the Downstream Area, the purpose of the literature review is to determine the type of information that is available for evaluating the potential for injury. Although not specified in the Work Plan, this report also presents a compilation of existing soils data in order to map the likely extent of airborne deposition and examine whether it is likely that there are current injuries attributable to historic smelter emissions.

This characterization of conditions has been conducted in order to describe the cause, nature, and extent of any injuries to natural resources of the UARB. An overarching objective of this report is to identify those portions of the injured natural resource requiring restoration measures. This requires further evaluation and interpretation of all of the available information, including information describing injury, in order to assess whether identified injuries result in a reduction in the expected baseline level of services provided by the injured resource. Identification of a reduction in the expected level of services can be accomplished with existing information. However, accurate quantification of any reduction in services attributable solely to the identified injury is difficult under many circumstances. It is particularly difficult for the UARB when considering the long duration since the initial release of mine-waste and the concurrent shifts in land use patterns and resource management. In order to accurately measure a reduction in services attributable to mining impacts, it would be necessary to sort and quantify the role of all of the overlapping natural and anthropogenic influences on the UARB. Such an effort goes beyond the level of understanding that could be garnered from existing information and may not be possible given the dynamic nature of the system, even with years of study. However, this does not mean that the overarching objective of identifying resources that would benefit from restoration cannot be addressed.

Recognizing the difficulties associated with quantification and the overarching objective, this report presents a practical level of understanding for any identified or reasonably expected impacts to resource use or productivity. This understanding is based on knowledge of the underlying cause for service reduction, comparison with control areas and the experience of the authors. Although the

reduction in services has not been quantified through this process, it is identified. Correspondingly, the need for restoration of a resource is identified and, based on an understanding of the cause, specific geographic areas are targeted for restoration measures. In that practical manner, this characterization serves as a basis for identifying and evaluating restoration alternatives by the consulting team.

The site characterization was conducted utilizing the large amount of information available (see Appendices A, C₁, C₂ and E). Although the vast majority of available information was not collected as part of an assessment of injury, the relevant information has been organized and evaluated to correspond to the pertinent portions of the Natural Resource Damage Assessment (NRDA) regulations for injury determination and quantification (43 CFR Part II, subpart E) that are summarized below.

The NRDA process has two fundamental phases that are consistent with the objectives of the Work Plan: injury determination and injury quantification. In simplest terms, injury determination requires evaluating conditions of the resource to see if regulatory definitions of injury have been met and whether those defined injuries have resulted from the releases of hazardous substances. Injury quantification addresses the relationship of the identified injuries to any reduction in the services provided by the natural resource.

Injury determination must identify the pathways for transport and exposure to mining-related hazardous substances. This portion of the process is similar to the problem-definition approach utilized by a variety of regulatory programs (e.g., RI/FS process), whereby the current nature and extent of contamination and/or biological response is linked to the various contaminant transport mechanisms (pathways) that may be available at a given site (e.g., leaching of contaminants resulting in groundwater contamination). Therefore, much of the available information from other regulatory efforts or agency studies can be readily integrated to characterize the nature and extent of contamination and identify exposure pathways. However, as noted previously, the available information was often not collected as part of an injury assessment and, therefore, must now be considered in terms of defining injury to the resources of the UARB. This requirement applies not only to relatively current information, but also to information describing historic conditions of the resource. The following discussion identifies the resources of interest within the UARB and provides a summary of the primary regulatory definitions of injury against which the existing data are considered, as well as related benchmarks used to provide a better understanding of the nature and extent of injury. Complete definitions of injury and further explanation of the role of benchmarks can be found in the DOI regulations at 43 CFR 11.62.

Although the benchmarks used in this report do not formally define injury, they provide a valuable point of comparison in terms of gaining a better understanding of the nature and extent of

mining- and non-mining-related impacts. The benchmarks utilized in this characterization came from a variety of sources. In some instances, values from literature are utilized. However, where possible, the benchmarks were derived from data collected at other locations that form a logical point of reference. The NRD regulations anticipate the use of reference or “control” areas to define baseline [43 CFR 11.72(d)]; where baseline is to reflect the conditions expected, but for the release of the hazardous substance in question. As discussed below, in the case of the 11-mile reach of the UARB, the area upstream of the confluence of the Upper Arkansas River with California Gulch (Reach 0) provided the most logical point of comparison for a number of resources.

In order to make meaningful comparisons, it is best if both control and impacted areas are located within the same watershed. Geomorphological, mineralogical, vegetation, and ecological characteristics vary greatly among watersheds and complicate using reference site(s) outside of the Arkansas River Basin. Overall comparisons should also be between areas that have the same historical and current type and intensity of non-mining impacts. Areas that differ both in basic aspects of the environmental setting as well as occurrence of non-mining impacts provide little or no useful information for comparison. Although not identical to the 11-mile reach, the portions of the UARB drainage upstream of the 11-mile reach (Reach 0) provide the best baseline against which to evaluate injuries due to the releases of hazardous substances. Therefore, use of Reach 0 as a within-watershed control site greatly enhances the ability to characterize injury to certain resources in the UARB.

Reach 0 is used as a “control” area for establishing baseline conditions within the 11-mile reach and for the establishment of specific benchmarks for sediments, benthic macroinvertebrates, fish, vegetation, mammals, and birds. It is important to note that injury to water quality is defined by comparisons to water quality standards. It is recognized that metal levels in Reach 0 have historically exceeded chronic toxicity levels and that the ecological conditions in this reach are not pristine. However, metal levels in Reach 0 have declined significantly since remediation of the Leadville Mine Drainage Tunnel (LMDT) began in 1992 (Figure 1-4). Despite historic levels of elevated metals from the LMDT and Tennessee Creek and infrequent unexplained excursions of zinc, biological conditions in Reach 0 have shown dramatic improvement since remediation of the Leadville Mine Drainage Tunnel. Metal levels have declined, metal-sensitive organisms (Heptageniidae) have recovered significantly (Nelson and Roline 1999) (Figure 1-4), and brown trout populations are relatively healthy and productive. More importantly, based on results of a large-scale monitoring program conducted by U.S. EPA (Clements et al. 1999), benthic communities and overall water quality within Reach 0 are similar to other Colorado streams (Figure 1-5).

Clements et al. (2002) have conducted studies of benthos community dynamics, toxicity assessments, and other evaluations relating sediment concentrations of contaminants in the Arkansas River to the benthic community. Sources of metals-enriched sediments are primarily related to runoff that erodes sediments from mine-waste in California Gulch, upstream areas, and naturally mineralized deposits. Geomorphological assessment indicates that the Upper Arkansas River is a sediment-poor system due to its high gradient, elevation in the watershed, and high spring runoff. Fines are quickly transported down river and deposit only in areas where water velocities slow, allowing these materials to settle out of the water column. Although small amounts of sediment with elevated metals concentrations can be found in Reach 0, the primary receptors (i.e., benthic community) are healthy.

Plant community types and the overall health of the vegetation in Reach 0 (plant cover, biomass, and species diversity) are representative of similar habitats found in non-mining impacted areas in Colorado. The condition of the vegetation in Reach 0 is closely linked to the climate and soils of the area and reflects the impact of previous land uses, such as livestock grazing. The soils in Reach 0 are also representative of soils in other subalpine habitats that are removed from the influence of mining activities. Vegetation and soils in Reach 0 provide the best point of reference for the condition of vegetation and soils in the 11-mile reach and therefore the best approach for characterizing injury to these resources in the UARB.

Based on the available habitat and food base, Reach 0 provides representative control conditions for evaluating injury to small mammals and migratory birds. Community composition and density of small mammals in most meadow and riparian habitats is highly variable between years and difficult to characterize without long-term population studies. Even so, Reach 0 provides a basis for evaluating differences in metals exposure and the potential for injury. Grasses and sedges, the primary food source for herbivorous small mammals, in Reach 0 have “normal” metal concentrations and should not affect the distribution or abundance of small mammals. Metal concentration in both soils and plants do not exceed toxic thresholds for small mammals based on comparisons with the literature, thereby providing suitable control conditions for metals exposure and injury. For migratory birds, Reach 0 is representative of low-level food-borne metals exposure characteristic of streams influenced by naturally occurring metal sources. However, because migratory birds may be exposed to elevated metals concentrations outside of Reach 0, data from Reach 0 should be considered along with benchmarks from other areas and literature.

The following section provides a summary of the regulatory definitions of injury utilized for this characterization, along with related benchmarks:

- Surface Water Resources: Injury has occurred to surface water resources if:
 - Definition: Any of the Federal or State water quality criteria or standards have been exceeded [Colorado Table Value Standards (TVS)] (Table 1-1) [43 CFR 11.62(b)]. According to Colorado’s Regulation No. 31 Basic Standards and Methodologies, both acute and chronic numbers adopted as stream standards are levels not to be exceeded more than once every three years on the average. This provision is adopted based on evidence that aquatic life can recover from impacts if not exposed to exceedances more frequently than once every three years. Standards for drinking water supply were not considered for surface water since it is not a source within the 11-mile reach and because the TVSS are lower.
 - Definition: Concentrations and duration of substances on bed, bank, or shoreline sediments are sufficient to cause the sediment to exhibit characteristics identified under or listed pursuant to section 3001 of the Solid Waste Disposal Act (for actual criteria see 40 CFR 261.1) [43 CFR 11.62(b)].
 - Definition: Concentration and duration are sufficient to have caused injury to groundwater, air, geologic, or biological resources, when exposed to surface water, suspended sediments, or bed, bank, or shoreline sediments.

Surface Water Benchmark:

- Comparison to Reach 0 mean concentrations during high and low flow conditions for surface water; reductions in metals concentrations in surface water due to response actions. These comparisons are made for the purpose of understanding where metals contributions enter the UARB and what biological conditions might be expected based on water quality data.

Sediment Benchmark:

- Comparison to Reach 0 sediment concentrations. Ample site-specific data relating sediment metals concentrations to effects in Reach 0 are available.

- Groundwater Resources: Injury has occurred to groundwater resources if:

- Definition: Any of the Federal or State groundwater quality criteria or standards have been exceeded for a domestic supply [43 CFR 11.62(c)].
- Definition: The concentration is sufficient to have caused injury to surface water, air, geologic, or biological resources, when exposed to groundwater [43 CFR 11.62(c)].

Groundwater Benchmark:

- No benchmark comparisons made for groundwater resources.
- Geologic Resources (soil): Injury has occurred to geologic resources if:
 - Definition: Concentrations are sufficient for the materials to exhibit characteristics identified under or listed pursuant to section 3001 of the Solid Waste Disposal Act (for actual criteria see 40 CFR 261.1) [43 CFR 11.62(e)].
 - Definition: Concentrations of substances are sufficient to raise the pH to above 8.5 or reduce it to below 4.0 [43 CFR 11.62(e)].
 - Definition: Concentrations of substances are sufficient to yield a salt saturation value greater than 2 millimhos/cm in the soil or a sodium adsorption ratio of more than 0.176 [43 CFR 11.62(e)].
 - Definition: Concentrations of substances are sufficient to decrease the water holding capacity such that plant, microbial, or invertebrate populations are affected [43 CFR 11.62(e)].
 - Definition: Concentrations of substances are sufficient to impede soil microbial respiration to an extent that plant and microbial growth have been inhibited [43 CFR 11.62(e)].
 - Definition: Concentrations of substances are sufficient to inhibit carbon mineralization resulting from a reduction in soil microbial populations [43 CFR 11.62(e)].
 - Definition: Concentrations of substances are sufficient to restrict the ability to access, develop, or use mineral resources within or beneath the geologic resource [43 CFR 11.62(e)].
 - Definition: Concentrations of substances are sufficient to have caused injury to groundwater from physical or chemical changes in gases or water from the unsaturated zone [43 CFR 11.62(e)].
 - Definition: Concentrations of substances are sufficient to cause a toxic response to soil invertebrates [43 CFR 11.62(e)].
 - Definition: Concentrations of substances are sufficient to cause a phytotoxic response [43 CFR 11.62(e)].

- Definition: Concentrations of substances are sufficient to have caused injury to surface water, groundwater, air resources, or biological resources when exposed to the substances [43 CFR 11.62(e)].

Floodplain Soil Benchmarks:

- Plant-available metal concentrations in floodplain soils in Reach 0 represent valid benchmarks because these values are consistent with concentrations found in non-mining impacted areas at similar elevations and habitat types in Colorado. Plant-available concentration of metals is the best measure of injury determination because the bioavailable fraction of the metal in soil is what determines biotic exposure.
 - Comparisons are made to literature-based soil thresholds of plant toxicity. Metal threshold concentrations from the literature are primarily from hydroponic and sand culture experiments, where total metal concentrations are the same as plant-available concentrations. Therefore, plant-available metal concentrations from field soil samples are an acceptable comparison to total metal concentrations found in the literature.
 - Comparisons of total metal concentrations in mine-waste deposits are made to total metal concentrations in Reach 0 floodplain soils. Plant-available metal concentrations are not used for comparisons involving mine-waste deposits because this information is not available and it is assumed that plant-available concentrations in mine-waste deposits are high enough to be phytotoxic based on the scarcity of plant cover.
- Biological Resources: Injury has occurred to biological resources if:
 - Definition: Concentrations of substances are sufficient to cause the biological resources or its offspring to have undergone at least one of the following adverse changes in viability: death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunction, or physical deformations [43 CFR 11.62(f)].
 - Definition: Concentrations of substances are sufficient to exceed action or tolerance levels established under section 402 of the Food, Drug, and Cosmetic Act, 21 U.S.C. 342, in edible portions of organisms or exceed consumption levels established by the CDPHE (concentrations of tissue residues in fillets compared to risk screening levels for human consumption) [43 CFR 11.62(f)].

Vegetation Benchmarks:

- Plant cover, biomass, and species diversity are typical indicators of the condition of vegetation in non-forested communities. The values for these plant community measures in Reach 0 (percent cover = 52 percent, biomass = 137 g/m², species diversity = 14 species) are similar to non-mining impacted areas in Colorado that have the same elevation, habitat characteristics, and land uses. Therefore, the vegetation in Reach 0 is an appropriate benchmark for the 11-mile reach.
- Comparisons to Reach 0 biomass or above-ground production, which is a measure of the plant mass within a specified area (e.g., g/m²).
- Comparisons to Reach 0 species richness, which is a measure of the number of species present within the area inventoried.
- Comparisons are also made to literature-based plant tissue metal thresholds of plant toxicity. Toxicity thresholds vary among plant species and perennial species are known to be more metal tolerant than annual agronomic species.
- Comparisons to physiological and morphological effects. Elevated metals in soils can lead to physiological and/or morphological changes to plants that affect normal plant function. An example is iron chlorosis that is caused by excessive zinc in plant tissue.

Benthics Benchmark:

- Previous studies have shown that abundance of sensitive macroinvertebrate groups and species richness are good indicators of biological integrity of aquatic ecosystems. Metal levels in benthic macroinvertebrates are an indicator of effects and potential exposure to higher trophic levels (e.g., brown trout). Community composition and metal levels in benthic macroinvertebrates in Reach 0 are similar to unimpacted reference streams in Colorado and therefore are appropriate benchmarks for 11-mile reach.

Brown Trout Benchmarks:

- Abundance, biomass, and length-frequency distributions are typical indicators of the health of fish populations. Metal levels in brown trout tissue are good indicators of metal exposure. Feeding habits of fish are related to prey abundance and availability and reflect overall fish condition. The tissue metal concentrations, feeding habits, abundance, biomass, and length-frequency distribution of brown trout populations in Reach 0 are similar to unimpacted

reference streams in Colorado and are therefore appropriate benchmarks for the 11-mile reach.

- Comparison to Reach 0 abundance, biomass, length-frequency distributions, and feeding habits (where appropriate); temporal variations w/in reach (abundance, biomass, length-frequency distributions).
- Davies and Brinkman (1999) have completed an extensive set of acute and chronic toxicity tests with brown trout. These researchers conducted early life stage tests in which eggs and fry were exposed to zinc for 68 days. Based on measured hatching success and growth, the estimated chronic value for brown trout from these experiments was 381 $\mu\text{g/L}$. In tests in which unacclimated juvenile brown trout were exposed to zinc the chronic value was determined to be 194 $\mu\text{g/L}$. Based on these experiments, Davies and Brinkman (1999) conclude that a zinc standard to protect brown trout should not exceed 200 $\mu\text{g/L}$ at a water hardness of 50 mg/L .
- Physicochemical characteristics of water (pH, hardness, alkalinity, dissolved organic carbon) greatly influence metal toxicity and bioavailability to brown trout. Davies and Brinkman (1999) measured effects of water hardness and alkalinity on the toxicity of zinc to brown trout. Using combinations of high and low hardness and alkalinity, these researchers showed that alkalinity had relatively little effect on toxicity of zinc to brown trout. In contrast, increased hardness had a significant effect on acute and chronic toxicity. Specifically, a 4-fold increase in water hardness (from approximately 50 mg/L to 200 mg/L) resulted in a 5-fold reduction in the chronic value and a 2-fold reduction in acute toxicity.
- Water quality criteria for contaminants represent concentrations that, when exceeded, may harm aquatic organisms. Because criterion values are only available for individual metals, assessing potential impacts in systems receiving multiple metals is difficult. Although some studies have shown that interactions among metals may be synergistic (e.g., greater than additive effects), others have reported simple additive effects at chronic concentrations (Spehar and Fiandt 1986; Enserink et al. 1991). Thus, predicting effects of metal interactions in light of the uncertainty concerning synergistic and antagonistic effects is difficult. While several metals exceed the criterion values in the Arkansas River, zinc is unquestionably the predominant contaminant in the system.

Small Mammal Benchmark:

- Metal levels in small mammal tissues are good indicators of metal exposure and potential effects. Woodward Clyde (1993) collected small mammal tissue data

from Reach 0, however, the number of samples collected was limited by trapping success. Because Woodward Clyde analyzed composite and individual samples inconsistently between sample sites, literature-based benchmarks were used as benchmarks along with Reach 0 data. The literature-based benchmarks are based on a review of both field studies and laboratory experiments. In addition, several secondary sources were consulted (Hoffman et al. 1995; Beyer et al. 1996; Eisler 2000; Shore and Rattner 2001).

Large Mammal Benchmark:

- There are no injury-specific data for large mammals in the UARB and the presence and level of feeding activity has not been documented. Therefore, the potential for injury to large mammals is best characterized by evaluating the potential for exposure to metals of concern. By comparing known vegetation concentrations to literature-based toxicity benchmarks for forage and by estimating the daily intake of metals from forage foods, soils, and water a range of potential exposure scenarios could be evaluated. The metal intake rate for an exposure scenario is compared to Toxicity Reference Values (TRV), which represent intake rates corresponding to known levels of toxicity and injury (USEPA 1993, 1997b; Eisler 2000). The TRV benchmarks are based on No Observed Adverse Effect Levels (NOAELs) for sublethal systemic or reproductive effects and chronic exposure durations (Horwitt and Cowgill 1971; Sutou et al. 1980; Sample et al. 1996). NOAELs represent concentrations below those expected to elicit adverse effects (i.e., the threshold exposure for inducing effects is higher than the NOAEL). Risk of adverse effect was characterized using the hazard quotient (HQ) approach (USEPA 1997b). The HQ is the ratio of estimated site exposure to the TRV (i.e. [site exposure]/[TRV]). A HQ greater than 1 indicates site exposures that exceed the TRV. The benchmarks for large mammals are the TRV's, which represent metal intake rates at which no effects were observed. Potential metal intake rates from each reach (site exposure) were compared to the TRVs. Further discussion of appropriate benchmarks for large mammals is provided in Appendix J.

Bird Benchmark:

- Metal levels in bird tissue and enzyme levels are good indicators of metal exposure and potential effects. However, because birds generally migrate from lower elevations to higher, tissue metal concentrations can be confounded by exposure received while migrating or by movement between areas. Birds sampled in Reach 0 may have moved up from lower reaches unless they are nestlings or nesting adults that have had sufficient time to depurate metals accumulated at other sites. Of the two studies available, one study (Custer et al. 2003 In Press) sampled only nestlings that have been fed organisms from the

general vicinity of the nest while the other study included both nestlings and mobile adults (Archuleta et al. 2000). To account for this potential bias, the benchmarks used for comparing bird tissue data are 1) out-of-basin Study Reference data, and 2) literature-based benchmarks. The literature-based benchmarks are based on a review of the literature comprising both field studies and laboratory experiments. In addition, several secondary sources were consulted that support the benchmarks chosen by the consulting team (Hoffman et al. 1995; Beyer et al. 1996; Eisler 2000).

- For some metals, there are no benchmark values reported in the literature. This is true for copper, which is a dietary requirement, and toxicity from food-borne environmental exposure is rare or undocumented. For some tissues, there are no benchmark values reported in the literature. This is generally the case when accumulation does not occur in that tissue or the effect occurs in a different tissue. Enzyme levels are species specific and no literature-based benchmarks were found for the species studied here. For the cases where there are no literature-based benchmarks, Reach 0 and the Study Reference data were used as the benchmark.

Comparison of the available data with the above definitions/benchmarks and identifying sources and responsible exposure pathways comprise the injury definition phase. The next phase is to better define the extent of injury. An initial step, therefore, is to assess the spatial and temporal extent of injury. This aspect of the quantification phase is fulfilled by analysis of the data/information describing the nature and extent of contamination. Although data that can be used to define the current level of injury are prevalent, data describing the historical conditions of the resource are not. Prior to 1980, data are sparse and often unreliable due to less sophisticated sampling and analytical techniques, lack of supporting documentation, and relatively poor QA/QC. For this reason, the emphasis of the characterization is on the more recent data; however, information describing past conditions is included where available.

As explained earlier, quantification of a reduction in the past or current level of resource services attributable solely to an identified injury is beyond the scope of the SCR. This is in large part due to the complexities of sorting the cumulative effects of mining impacts from non-mining impacts. Although the relative role of non-mining impacts cannot be quantified, they can however be identified and considered. The SCR, therefore, provides an identification and discussion of all activities that have affected the ecosystem in the UARB over the past 130 years, when evaluating the role of mining impacts. In the UARB, there are several factors related to land use and water management (e.g., trans-mountain water diversions) that are considered to be important (Appendix G).

Another important consideration is an understanding of the relationship between the injuries and any reductions in the baseline of services provided by the resource. For example, injury to surface water is initially determined relative to the period of record, and the frequency and extent of exceedances of the relevant water-quality criteria. However, the impacts of the water-quality exceedances are ultimately quantified in terms of a reduction in services provided by that resource. In the case of the UARB, this may potentially be measured both in terms of limitations of the uses of the surface water (e.g., agricultural waters and/or drinking water) and the impacts on dependent resource components (e.g., fish). From this perspective, although an injury may have been defined for a resource, it may or may not result in a quantifiable reduction in resource services. In simple terms, a healthy and productive aquatic community may exist in spite of minor exceedances of water quality criteria.

Also to be considered in the quantification phase is whether the resource is recovering. An evaluation of recovery should consider temporal changes in the nature and extent of injury as well as whether or not uses and services are recovering and will achieve the expected baseline. Evidence of, or expectations for, resource recovery are important to evaluating the need for and extent of future restoration activities. Consistent with the regulatory requirement to examine natural recovery of the system as a restoration alternative, the SCR should consider information pertinent to the ability of the UARB resources to recover from the effects of the 100+ year history of mining impacts (43 CFR § 11.82[d]). Changes in water quality due to recent upstream source control activities, the long period of time since initial release, and ongoing response actions are factors that may contribute to resource recovery and may be apparent in an evaluation of spatial and temporal trends. Conversely, short-term impacts from remedial activities or long-term changes in land use may adversely affect recovery trends. Although the natural resources of the UARB are recovering in certain areas, it is important to identify where mining impacts in the 11-mile reach will negatively affect or preclude resource recovery.

All of the above injury determination and quantification considerations contribute to the overarching objective of identifying resources of the UARB that would benefit from restoration measures:

- The determination of injury by resource and by geographic area allows for focus within the 11-mile reach and downstream;
- The identification of sources and pathways provides further focus on the fundamental resources (soil, water, sediment) that may cause injuries to biologic resources;
- An understanding of the extent and magnitude of the injuries and analysis of the relationship of those injuries to a reduction in the baseline level of services provides further insight as to the need for specific restoration measures; and

- An understanding of the role of non-mining impacts on the injured resource allows for a sensible evaluation of the likely benefits of restoration.

Although not always identified, these underlying premises are inherent in the process utilized to develop this SCR.

1.1 Background/History

The setting and history of the areas of interest are varied, as are the natural resources being characterized. The following discussion highlights the history of activities in the UARB that should be considered in evaluating current conditions. Particular emphasis is given to the mining history of the area.

1.1.1 Summary of Mining History In and Around Leadville, Colorado, at Headwaters of the Arkansas River

The mining history in the headwaters region of the UARB is long and varied. In the late 1850s, placer gold deposits were discovered at the mouth of California Gulch. This discovery began a period of placer gold mining and more aggressive forms of hydraulic mining of alluvial and terrace deposits in the headwaters area that was to last for several decades. By the late 1860s, crude stamp mills were developed to assist in the extraction and concentration of gold ore. The stamp mills would crush the mined materials, and a separation process was used to extract the gold from the pulverized rock.

By 1875, the gold rush had somewhat slowed and hard rock mining for silver and lead ores had begun. Within a year, the first smelter was constructed in the area, and shortly after, the community at the center of this burgeoning mining district became known as Leadville. From roughly 1875 to 1900, numerous prospects were discovered, spawning the development of many milling operations and smelters. It has been noted by many that the primary production for the Leadville district occurred during this 25-year period. During this period there were many experiments and advances in the mining and milling of ores, as well as in smelting. Although the early focus on gold continued, mining and refining of silver, lead, and copper ores became most prevalent, with a number of small custom smelters being constructed. For many of these smelters, the operational life span was short.

By the early 1900s, production of zinc had become economically viable. Over the next 25 years, many of the remaining milling and smelting operations closed, and the surviving consolidated operations focused on zinc and lead. Again, changes in production were driven by changes in mining, milling, and refining practices.

From the 1920s to the 1970s, the mining economy of the Leadville district ebbed and flowed with the national economy, war efforts, and advances in mining and refining technology. Numerous ventures were created to recover metals by reprocessing historic mine and mine-waste dumps. This was economically feasible because continued changes in technology had both improved efficiency and made other metals more accessible. For example, the Climax molybdenum mine was developed in 1918 at the headwaters of the East Fork of the UARB. Although mining in the Leadville district has continued until very recently, the last 75 years represented a dramatic reduction in production relative to the peak years of the late 1800s and early 1900s.

The above general chronology of the more notable events in the Leadville district metals, mining, and refining history is helpful in terms of characterizing today's environmental conditions. This report focused on those areas of the UARB that have been impacted by the downstream movement of mining and milling wastes from their place of historic origin and the deposition of airborne emissions from smelting operations. A pairing of the general mining history with knowledge of the types of mining and milling practices employed, the corresponding wastes generated, and disposal activities, however, provides further insight as to current conditions.

As noted above, the earliest activities in the district involved hydraulic mining for gold. Hydraulic mining involves harnessing the hydraulic force of a watercourse to excavate large portions of the streambed, banks, and adjacent slopes for further "washing," to separate gold from the lighter materials. Records and visual observation of hydraulic mining spoils indicate that it took place primarily in and along tributary drainages such as California Gulch and Box Creek. Hydraulic mining dramatically altered the channel and valley morphology in these tributaries, sometimes washing away the alluvium to bedrock. This activity liberated large amounts of sediment and river rock for downstream movement into the broader UARB floodplain below Leadville. Although metals-bearing sediment may have been liberated in this process, there was no concentrating of metals in the spoils; therefore, the primary impacts were physical degradation of the mined area (loss of riparian areas) and downstream sedimentation. The negative effects on water quality and the fishery from hydraulic mining were noted as early as 1889 (Jordan).

The development of milling (grinding or crushing of ore) techniques to isolate the target metals (concentrates) from waste materials (tailings) resulted in changes in mining practices. Advances in milling technology allowed greater efficiency in the capture of metals, and as milling techniques further evolved they could be modified to target specific metal recovery and accommodate specific ore types. This in turn created new opportunities for mining of different or lesser-grade ore bodies. The shift to hard-rock mining and milling from hydraulic mining resulted in production of different types of waste material. As such, further understanding of these mine-wastes and their current potential to serve as a source of metals to the environment is appropriate.

- Waste Rock is material removed during development of a mine to obtain access to ore. Waste rock is the non-ore-bearing host rock separated from the ore. Large quantities of waste rock can still be observed immediately adjacent to the mine workings from which it originated. The vast majority of waste rock at these locations was generated long ago. Given the district geology and mine development process, most waste rock is expected to be relatively low in metals content and is coarse-grained (typically greater than one inch in diameter). Although less common, some waste rock may be finer in diameter and/or have higher metals content. In some locations in the tributary drainages, waste rock overlies (or has otherwise become mixed with) historic mill tailings. The large size of the rock fragments and lower metals concentration generally limits the potential for erosion and for waste rock to be a source of dissolved metals.
- Tailings are waste materials that result from the milling process to concentrate ore. Milling in the Leadville district to improve the capture of gold started in approximately 1868. The original Leadville mills were known as stamp mills and involved a crude crushing process followed by density separation and sometimes amalgamation. Crude milling procedures based on stamping (crushing) of the ore and water gravity separation were prevalent for gold, lead, and silver ores until the early 1900s. Because of the crude methodology, tailings from these operations had relatively high residual ore (metals) content and were coarse sand to gravel-size particles. As other metals became a focus, milling operations were adapted for the target metals.

In the early 1900s, the flotation milling process was introduced to the Leadville district in conjunction with zinc production. The flotation milling process is more efficient and is based on a fine grinding of the ore and suspension of the ground ore in a froth or emulsion to better separate concentrates from the non-metals, based on density. Although much finer grained (silt size), the more efficient process resulted in much lower residual metals content in the tails than in prior efforts using stamp mills. As noted previously, this new milling technique allowed for reprocessing of stamp mill tailings and waste-rock deposits from prior efforts. The flotation milling process also allowed for easier management of tailings, which could be slurried to downstream discharge points and, in later years, impounded.

Because the milling process often required large amounts of water and because transportation of ore added expense, most mills were located in drainages situated as close as feasible to the ore source. Most of the tributary drainages of the UARB are relatively narrow and were often occupied by the mill structure and attendant operations. Because of the lack of area for storage of waste materials and a lack of understanding of today's environmental concerns, wastes from milling were often released directly to the floodplain as a measure of disposal. This resulted in the downstream movement of tailings (and, to some degree, waste rock) during periods of normal flow, with large transport events during flooding.

The historical production of mine-waste (collectively referred to as tailings and waste rock), along with other factors, has direct bearing on the current conditions along the upper 11-mile reach of the UARB. Waste rock is less likely to be a concern than tailings because it is typically coarse material that cannot easily be transported in the surface water system.

Tailings deposits are, therefore, the primary concern in and along the 11-mile reach and also further downstream. Based on the milling history and fluvial processes, early coarse tailings from stamp mills would be expected to have higher metals concentrations and not move as readily through the surface water system. Such coarse mine-waste would have settled out in the first low-gradient stretch of floodplain and have a greater tendency to remain intact. Therefore, it is expected that older mine-waste deposits would reside nearer the tributary sources within the 11-mile reach and have higher metals concentrations and/or greater potential to contribute dissolved metals.

Flotation mine-wastes are less likely concentrated within the 11-mile reach due to their fine size. Flotation mine-waste can move rapidly through a surface-water system such as the UARB because the fine particles are readily entrained, allowing for continued downstream movement. However, they may be broadly distributed across the floodplain due to flooding events and possible entrainment in irrigation waters. Broader dispersion coupled with lower metals concentration lessens the likelihood of flotation tailings being a large source of dissolved metals loading within the 11-mile reach.

Another factor in the relationship of current conditions to historical practices is the nature of the ore body being mined. The Leadville district is a highly mineralized area and, as demonstrated by the mining history, evidence of the mineralization was present at the surface in placer deposits in several tributary drainages. However, also as demonstrated by the mining history, the characteristics of the ore bodies and their host rock varied substantially within the district.

An understanding of the geology and mineralogy of the Leadville district has been critical to the success of mining and refining efforts. The mineralogy also has importance to understanding current conditions, the primary issue being the acid-generating potential of the mine-waste material. Mine-waste originating from carbonate sources will have a near-neutral pH and therefore will not be susceptible to acid generation and co-release of the soluble metal forms. On the other hand, ore bodies with a significant sulfide composition (e.g., pyritic) will have a tendency to generate excess acid once exposed to the atmosphere and water, and correspondingly readily liberate metals in a dissolved form. From this perspective, current deposits of mine-wastes along the 11-mile reach may be of greater or lesser concern depending upon their origin and the extent of commingling of historic deposits. The pH within the existing mine-waste deposits may therefore provide information with regard to the potential for ongoing contribution of metals to the aquatic environment as well as availability to plant species.

Another important aspect of the onset of hard-rock mining was the need to de-water the workings that were being developed. The mining resulted in production of low-quality metals-laden waters due to increased contact with ore bodies. However, the main concern to the mining operations was flooding of the workings. Two major tunneling efforts were conducted to address the issue of dewatering: the Canterbury and Yak Tunnels (Yak) in 1920, and the Leadville Mine Drainage Tunnel (LMDT) in 1950. These tunnels continue to drain poor quality water from the extensive underground working of the Leadville district today.

In addition to mining and milling, smelting occurred. This pyrometallurgical process resulted in air emissions of gases (SO₂, NO₂) (which produce aerosol acids) and particulate releases of metals (e.g., lead) and other trace metals/metalloids (e.g., arsenic). These releases may occur from stacks or as lower-level fugitive releases to the atmosphere. Some portions of the particulate emissions are deposited in the immediate vicinity (within the Airshed) and can result in elevated metals concentrations and low pH in surface soils within the deposition zone.

1.1.2 Summary Of Historical Non-Mining Land Development in the UARB, and Current Land Use

When evaluating injuries/impacts from mining (release of hazardous substances), it is necessary to also consider the role of other activities in the area for which conditions are being characterized. These activities can directly impact the condition of the natural resources relative to prior conditions and/or they may also influence the extent and magnitude of impacts from mine-waste. In the case of the UARB, mining as well as other baseline impacts have evolved over a period of more than 130 years. Therefore,

the relationship of non-mining impacts to Leadville-district mining impacts is not always immediately evident nor is it readily quantifiable. The following baseline issues are identified in this report relative to the chronology of mining impacts. It should also be noted that, in addition to the Leadville district, mining and metals refining has occurred in other areas of the UARB watershed. Because these mining areas may provide a pathway for metals, the potential for contribution from these sources must also be considered. Metals contributions from mining sources are identified upstream of Reach 0 and on Lake Fork. For the most part; however, mining and metals refining outside of the Leadville district occurred downstream of the 11-mile reach. The potential impacts to the surface water resource from those mining operations must be factored in as part of the baseline relative to the downstream impacts of the Leadville district.

The Arkansas River has long been utilized as a source of water for development. Along with the settlement of the area came the use of the Arkansas flows for local irrigation. Jordan (1889) provides perhaps the earliest qualitative information about the condition of the fishery during this time period. Placer mining and agricultural irrigation are cited as the two primary factors impacting the trout fishery in the Arkansas River, as well as in many other Colorado rivers. Jordan (1889) described the mining impacts and effects of mineralization as follows:

“In some cases placer-mining and stamp mills have filled the water of otherwise clear streams with yellow or red clay, rendering them almost uninhabitable for trout. Parts of the upper Arkansas and Grand Rivers have been almost ruined as trout streams by mining operations. In a few streams the presence of iron springs seems to exclude all fishes.”

He goes on to describe the agricultural irrigation impacts, where he writes,

“In some valleys, as in the San Luis, in the dry season there is scarcely a drop of water in the river bed that has not from one to ten times flowed over some field, while the beds of many considerable streams are filled with dry clay and dust. Great numbers of trout, in many cases thousands of them, pass into these irrigation ditches and are left to perish in the fields. The destruction of trout by this agency is far greater than due to all others combined, and it is going on in almost every irrigating ditch in Colorado.”

Within the 11-mile reach, historical irrigation practices also appear to have exacerbated the impacts of mining by distributing metals from the river and tributary gulches to surficial soils in broader areas of the floodplain (Figure 1-6).

Early on in the development of the relatively arid Front Range communities, it was recognized that the Arkansas River could be used to transport flows from water-rich alpine areas to more arid portions of the state. Hence, since 1908 the flows of the Arkansas River have been augmented upstream of and within the 11-mile reach (Figure 1-7). The following lists some of the major water diversion activities affecting flows in the Arkansas River:

- 1905 – Dam constructed at Twin Lakes
- 1908 – First trans-mountain diversion at Ewing Ditch
- 1920 – Canterbury and Yak Tunnels built to dewater mines
- 1925 – Busk-Ivanho Tunnel completed for trans-mountain diversion
- 1931 – Columbine Ditch constructed for trans-mountain diversion
- 1932 – Wurtz Ditch constructed for trans-mountain diversion
- 1968 – Homestake Tunnel constructed for trans-mountain diversion
- 1972 – Boustead Tunnel constructed for trans-mountain diversion
- 1972 – Imported Fryingpan River water began release through Turquoise Reservoir and increased flows in Arkansas River downstream of Lake Fork Creek
- 1981 – Mt. Elbert conduit began operation and transported water from Turquoise Reservoir to Twin Lakes Reservoir into Lake Creek

Flow augmentation has resulted in peak flows within the 11-mile reach being well in excess of what would occur naturally. In addition, augmented peak flows are often not consistent with normal seasonal peak flows, and the changes in flow due to augmentation can be very abrupt (see Appendix B). In the 1970s, the lower portion of the river was further modified by the placement of a dam, creating the Pueblo Reservoir.

Several studies have been conducted that have examined the complex issues of flow and water use within the UARB. A recent study conducted by the Bureau of Reclamation (Smith and Hill 1999) examined the effects of various flow scenarios on the uses and services of the UARB. A focus of that effort was to evaluate the ranges of augmented flow that might be established to better support a trout fishery, while at the same time satisfying both recreational and water-use considerations. Although the

impacts to the wildlife resources of the Arkansas River from flow manipulation are recognized in these reports, no quantification of those impacts was developed.

The introduction of water from trans-mountain diversions into the 11-mile reach undoubtedly increased the propensity for channel change. Indeed, a study of Lake Fork and Lake Creek for the period 1956 to 1988 shows a 22 to 25 percent increase of width in straight segments of channel as a result of increased discharge (Dominick and O'Neill 1998). Although there is no doubt that if a significant amount of water is added to an adjustable channel, it will usually cause enlargement of the channel. However, it cannot be assumed that the impact will result in continuous change. A new quasi-equilibrium will be achieved, and the rate of change will decrease with time. This is also true when water is diverted from a channel, as when flow from the trans-mountain diversions was routed through the Mount Elbert conduit in 1981.

Other land-use practices within the UARB have also impacted the condition of the resource. Within the 11-mile reach and downstream, open grazing within the floodplain areas has altered the natural state of the riparian zone. In downstream areas, the development of communities such as Buena Vista, Salida, and Canon City, along with the associated municipal and transportation infrastructure, have influenced water quality and impinged upon the riparian areas. It is recognized in many studies that the loss of instream and near-stream habitat and the increased sediment yield and nutrient loading from these land uses have significant negative influences on the condition of a fishery (USFWS 1993). In total, these baseline influences have resulted in a resource often physically fragmented and at times heavily manipulated. The water resources in particular require continued management for the benefit of many diverse users (urban water supply, power generation, agriculture, recreation). Competing interests must often be considered by the various managers of the UARB resources. For example, the State of Colorado has been managing the Arkansas River as a brown trout fishery since the species was introduced in the late 1800s.

Residential development, agriculture, and demand for water will continue into the future, and will further modify the baseline against which mining impacts are being assessed. There is currently much ongoing discussion regarding the City of Pueblo's plans to create a large reservoir on the Arkansas River, upstream near the confluence with Tennessee Creek. However, in the case of the 11-mile reach, recent land acquisitions by the State and County could result in a future reduction in grazing impacts for a significant length of the floodplain riparian corridor. Current land-ownership for the 11-mile reach area is shown on Figure 1-8.

Emphasis on future management of instream flows can also have an impact on the condition of the riparian zone within the 11-mile reach. A less rapid rise or decrease in flow with lower-peak flows when coupled with improving bank vegetation may reduce the potential for erosion and thereby allow for establishment of a more stable channel morphology. Reduced peak flows and seasonal stability may also have lesser impact on the juvenile fish within a recovering fishery (USFWS 1993).

Physical instream and near-stream habitat quality is an important component of the assessment. Land and water use, as well as other resource management practices, can have profound impacts on the quality of the aquatic community. For example, many investigators have documented how flow regulation and augmentation affects the aquatic community and habitat quality and quantity (Rabeni and Smale 1985; Blinn et al. 1995; Scheidegger and Bain 1995; Cereghino and Lavandier 1998; Converse et al. 1998; and Zhang et al. 1998). Because of these recognized effects, information on the habitat quality and quantity of the UARB is included in this document.

1.2 Report Structure and Content

This report has been structured to provide a characterization of conditions consistent with the objectives of the Work Plan, while taking into account the NRDA regulations. In order to meet the objectives for the 11-mile reach and to provide the record necessary to support future decisions on restoration planning, the report must consider numerous categories of information from both a spatial and temporal perspective. As discussed previously, the resources identified as potentially being injured within the UARB are:

- Surface water/sediments (both the chemical and physical aspects of this resource);
- Groundwater;
- Soils; and
- Biota (aquatic and terrestrial components).

Further breakdown within these resource categories is required to fully characterize resource conditions and injury. In addition, other factors (beyond mining impacts) that could be influencing resource conditions have been considered and discussed as part of the characterization.

Where possible, the report has been structured to discuss resource conditions as they have changed over time. Inclusion of spatial and temporal characterization of resource conditions provides

insight as to the magnitude and period of injury, and provides information necessary to evaluate trends in resource recovery pertinent both to injury characterization and restoration planning.

In order to provide the appropriate framework for the subsequent Restoration Alternatives Analysis, the report was further structured based on the geography of the UARB. This approach was contemplated in the Work Plan, with the division of the characterization effort into the 11-mile reach, the Downstream Area, and the Airshed. However, to focus presentation of the information and to provide a basis for planning and decision-making, further breakdown is required, particularly within the 11-mile reach. The primary factors considered in creating the sub-reaches were geomorphology and hydrology, including the locations of tributary inputs. The following sub-reaches were developed (Figure 1-9):

- Reach 0 – Confluence of Tennessee Creek and East Fork Arkansas River to County Road 300 upstream of California Gulch confluence [2.8 river miles (RM)];
- Reach 1 – California Gulch confluence downstream to Lake Fork confluence (1.6 RM) (Rationale = different stream flow dynamics below Lake Fork due to trans-mountain diversion);
- Reach 2 - Lake Fork confluence to Highway 24 Bridge (3.3 RM) (Rationale = stream characteristics and land use patterns);
- Reach 3 - Downstream of Highway 24 Bridge to narrows near Kobe (3.5 RM) (Rationale = break in stream gradient and change in valley width); and
- Reach 4 – Downstream of narrows near Kobe to Two Bit Gulch (1.6 RM) (Rationale = beginning of canyon setting and lack of mine-waste deposits).

To present information in a consistent fashion, the subreaches are used as report subheadings along with the listed resources of the 11-mile reach. Using similar logic, the Downstream Area was divided as reaches 5-10. For further insight, Table 1-1 provides Colorado's stream segments and designated uses and shows where the above-defined reaches fall in relationship to these stream segments.

The following provides a brief description of the structure and content for the remaining report chapters:

- Chapter 2 provides a summary of the data collected and coalesced to characterize the resource conditions of the 11-mile reach. This chapter is supported by Appendix C, which provides further detail regarding the data and describes the contents of an electronic database, Appendix D, which provides data summarizing the physical and

chemical characteristics of mine-waste deposits, and Appendix E, which provides complete listing of all water quality data. Available data are arrayed to identify spatial and temporal trends in resource conditions. Summary comparisons of data to the definitions of injury, characterize the nature and extent of natural resource injuries.

- Chapter 3 is an integration and interpretation of the information presented in Chapter 2. For the 11-mile reach, a determination of injury is made and the relevant data are coupled with other available information to provide a description of the cumulative effects of the identified injuries and the underlying causes. A matrix summarizing injury determination for the 11-mile reach is provided at the end of this chapter. The cumulative effects of the identified injuries are considered relative to the expected level of services to be provided by the UARB resource absent mining impacts. Expectations for conditions within the 11-mile reach are based on conditions observed and documented at control or reference areas. Because of the complex history of mining and other land uses within the 11-mile reach, points of comparison on resource conditions are primarily to Reach 0; however, where appropriate, other comparisons are made. Based on this assessment process, conditions are characterized relative to an expected baseline. A more detailed presentation of baseline considerations can be found in Appendix F. Any data gaps important to defining the nature and extent of injuries and restoration planning are identified.
- Chapter 4 is a further distillation of the information developed in Chapter 3. The Chapter 3 information is considered relative to the overarching objective of identifying specific resource components and corresponding geographic areas where resource conditions could be improved through restoration measures. A Geographic Information System (GIS) was utilized to store and analyze available information on the condition of the resource along the 11-mile reach. The GIS analysis along with interpretation provides identification and prioritization of those areas that would benefit from clean-up/restoration measures.
- Chapter 5 contains a discussion of any obvious restoration measures. These measures were to be identified based upon a consensus that restoration is needed and that the appropriate restoration measures could be readily identified without the need for the development and screening of restoration alternatives.
- Chapter 6 presents the results of a literature review to identify information that will be useful to assess injuries from mine-waste downstream of the 11-mile reach. A listing of all considered literature can be found in Appendix A. The results of further evaluation of the available information with regard to determination of injury and the nature, extent, and cause of injury are presented by reach, and are also further summarized in a matrix for the Downstream Area provided at the end of this chapter. Discussion of the need for additional data collection is provided.

- Chapter 7 lists information relevant to defining the historic Airshed for smelter emissions from the Leadville area. Summaries of the various reports and pertinent data are provided. The identified information is coalesced to provide a definition of the historic Airshed for smelting, based on current evidence. A preliminary interpretation of the identified information is also provided. Although the Work Plan does not specify interpretation of the information, it is necessary to evaluate the available data/information to determine its relevance to characterizing injury. Therefore, it is efficient to capture the results of the evaluation process in this report. The need for any additional efforts to better define the Airshed is also discussed.

TABLES

Table 1-1

Stream Classifications and Water Quality Standards for the Arkansas River

Stream Segment	Description	Designated Uses	Assessed Uses ¹	Numeric Standards for Metals (µg/L)	Temporary Modifications	Corresponding Reach
2a	Mainstem of the East Fork of the Arkansas River and the Arkansas River from a point immediately above the confluence with Birdseye Gulch to a point immediately above the confluence with California Gulch	Aq Life Cold 1	FS	Cd (ac) = TVS (TR), Cd (ch) = TVS		Reach 0
		Recreation 2	FS	Cu (ac/ch) = TVS		
		Water Supply	FS	Pb (ac/ch) = TVS		
		Agriculture	FS	Zn (ac/ch) = TVS		
2b	Mainstem of the Arkansas River from a point immediately above California Gulch to a point immediately above the confluence with Lake Fork	Aq Life Cold 1	PS	Cd (ac) = TVS (TR), Cd (ch) = TVS	Temp. Mod	Reach 1
		Recreation 2	FS	Cu (ac/ch) = TVS	Cd (ch) = 1.3	
		Agriculture	FS	Pb (ac/ch) = TVS	no Zn (ac)	
				Zn (ac/ch) = TVS	Zn (ch) = 270 exp date 3/31/02	
2c	Mainstem of the Arkansas River from a point immediately above the confluence with Lake Fork to a point immediately above the confluence with Lake Creek.	Aq Life Cold 1	PS	Cd (ac) = TVS (TR), Cd (ch) = TVS	Temp. Mod	Reaches 2 - 4
		Recreation 2	FS	Cu (ac/ch) = TVS	no Zn(ac)	Reach 5
		Agriculture	FS	Pb (ac/ch) = TVS	Zn (ch) = 250	
				Zn (ac/ch) = TVS	exp date 3/31/02	
3	Mainstem of the Arkansas River from a point immediately above the confluence with Lake Creek to the inlet to Pueblo Reservoir.	Aq Life Cold 1	FS	Cd (ac) = TVS (TR), Cd (ch) = TVS		Reaches 6-10
		Recreation 1	FS	Cu (ac/ch) = TVS		
		Water Supply	FS	Pb (ac/ch) = TVS		
		Agriculture	FS	Zn (ac/ch) = TVS		

¹ Assessed use support of designated uses reported in the Status of Water Quality in Colorado - 2000.

ac = Acute

ch = Chronic

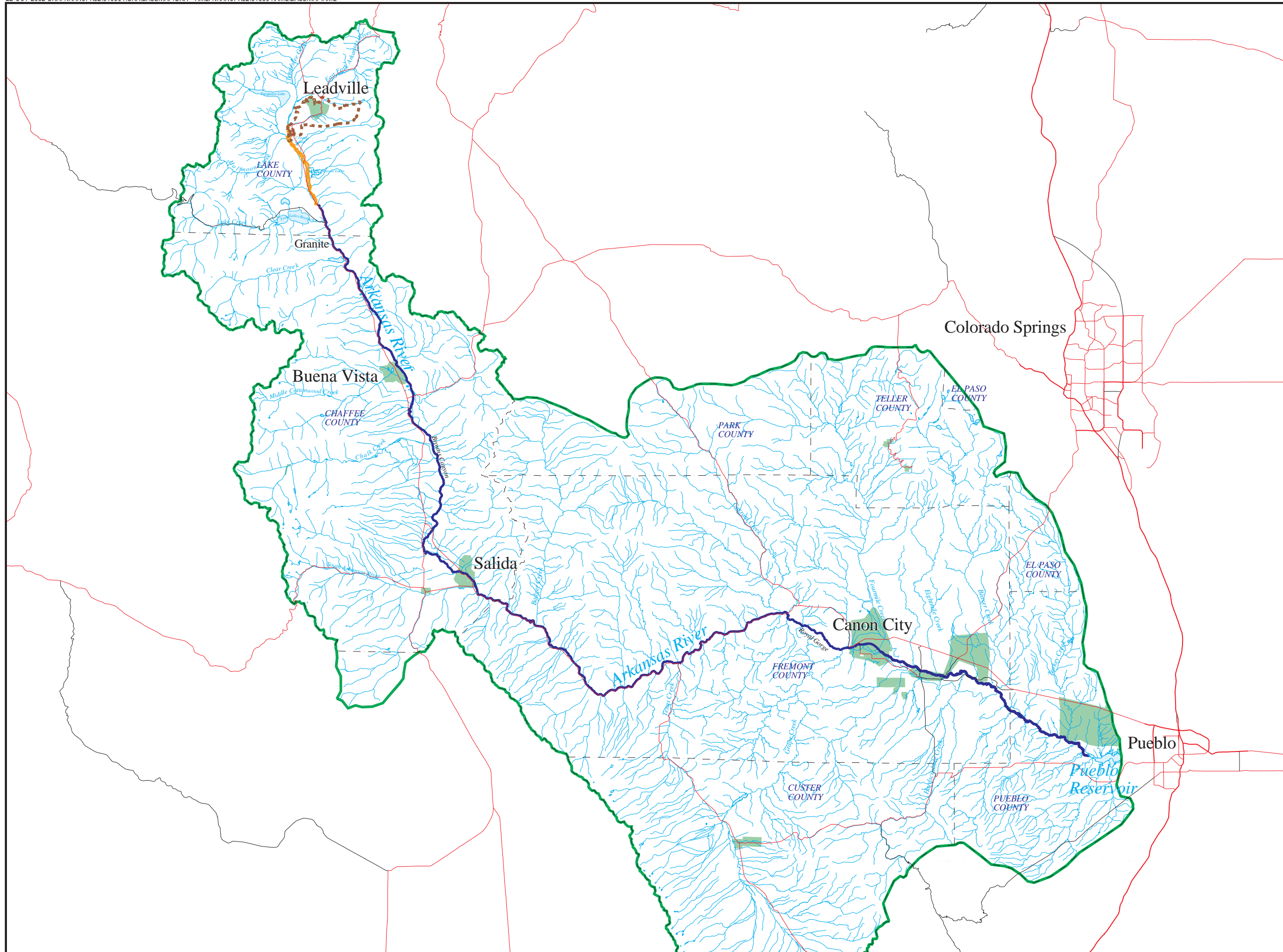
FS = Fully Supporting

PS = Partially Supporting

TR = Total Recoverable




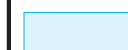

TVS = Table Value Standard

FIGURES





EXPLANATION

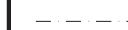


Hydrology

-  Arkansas River Below 11- Mile Reach
-  Watershed Boundary
-  River or Stream
-  Lake or Open Water
-  11- Mile Reach 500- Year Floodplain

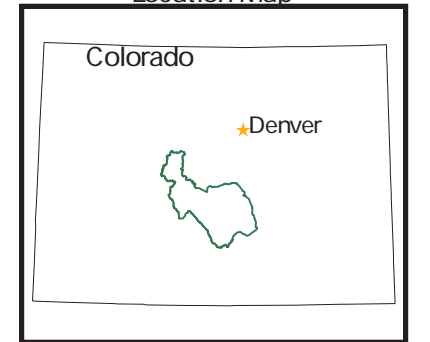
Transportation

-  Primary Road
-  Secondary Road

Other Features

-  County Boundary
-  NPL Site Operable Unit (OU) Boundary/ General Area of Airshed Study
-  Town or Landmark

Location Map



SCALE IN MILES

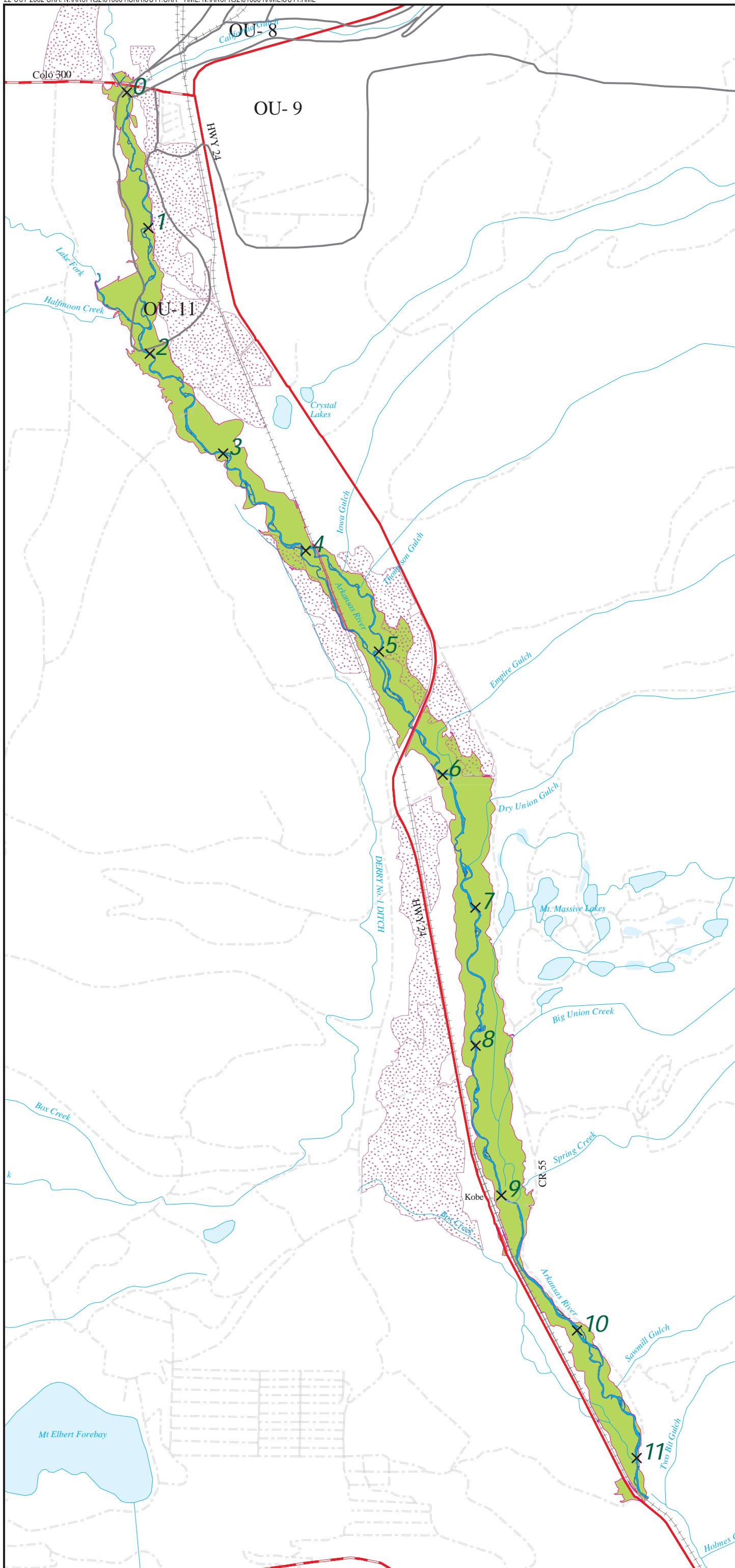


**UPPER ARKANSAS RIVER BASIN
SITE CHARACTERIZATION SUMMARY**

**FIGURE 1-1
DRAINAGE BASIN,
LEADVILLE TO PUEBLO RESERVOIR,
500- YEAR FLOODPLAIN,
NPL SITE,
AIRSHED AND 11- MILE REACH**


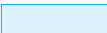




PROJECT: 010004.3	DATE: OCT 22, 2002
REV: 1	BY: MCP CHK: SAW

MFG, Inc.
consulting scientists and engineers




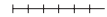


EXPLANATION


Hydrology

-  River or Stream
-  Lake or Open Water
-  11- Mile Reach
-  500- Year Floodplain
-  Irrigated Area (SAIC, 2001)
-  River Mile (from confluence with California Gulch)

Transportation

-  Minor Road
-  Medium Duty Road
-  Highway
-  Railroad

Other Features

-  NPL Site Operable Unit (OU) Boundary



SCALE IN FEET



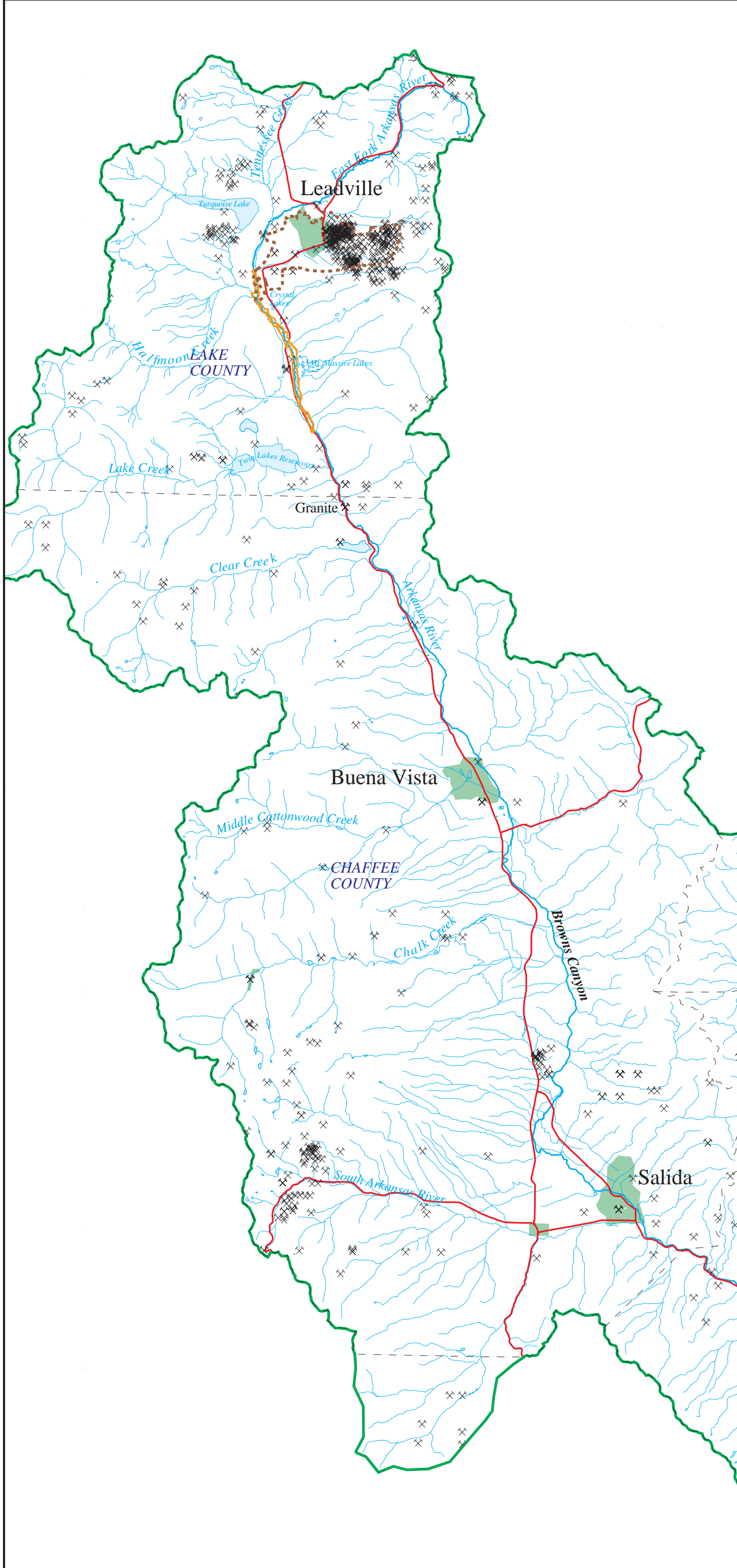
UPPER ARKANSAS RIVER BASIN
SITE CHARACTERIZATION SUMMARY

FIGURE 1- 2

11- MILE REACH
AND OU11 OF NPL SITE

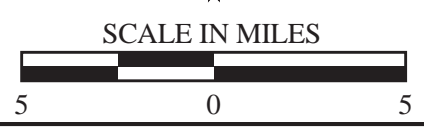
PROJECT: 010004.3	DATE: OCT 22, 2002
REV: 1	BY: MCP CHK: SAW

MFG, Inc.
consulting scientists and engineers



EXPLANATION

- Hydrology**
- River or Stream
 - Watershed Boundary
 - Lake or Open Water
 - 11- Mile Reach 500- Year Floodplain
- Transportation**
- Primary Roads
- Other Features**
- Mining Activity
 - County Boundary
 - NPL Site Operable Unit (OU) Boundary/ General Area of Airshed Study
 - Town or Landmark



UPPER ARKANSAS RIVER BASIN
SITE CHARACTERIZATION SUMMARY

FIGURE 1- 3
MINING ACTIVITY
IN THE STUDY AREA
VICINITY

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

MFG, Inc.
consulting scientists and engineers

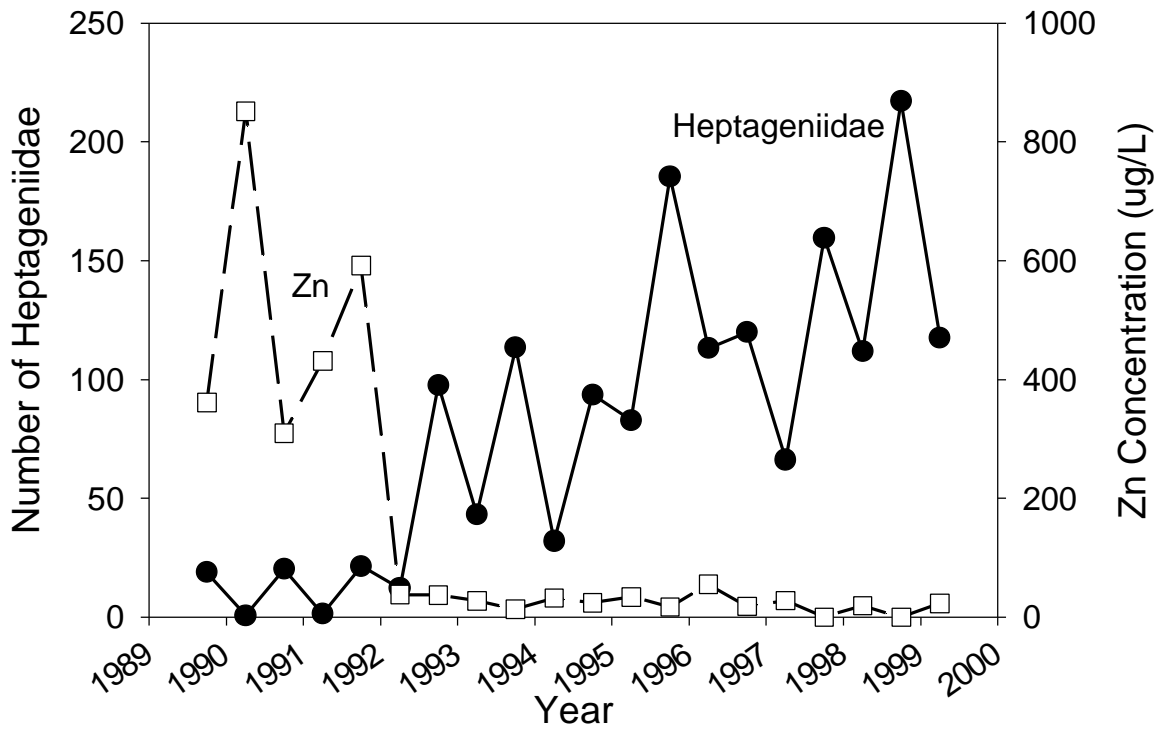


Figure 1-4

Relationship between Zinc Concentrations and Abundance of Metal-Sensitive Heptageniidae at Station AR-1 (Reach 0) from 1989-1999

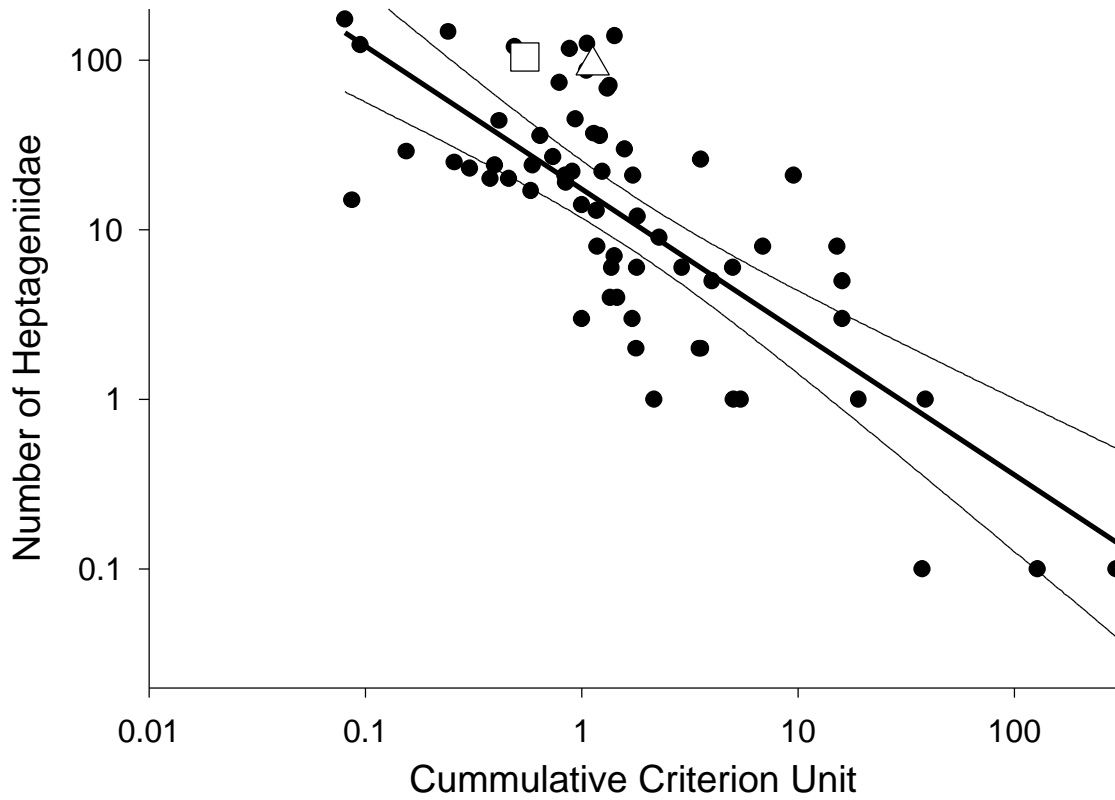
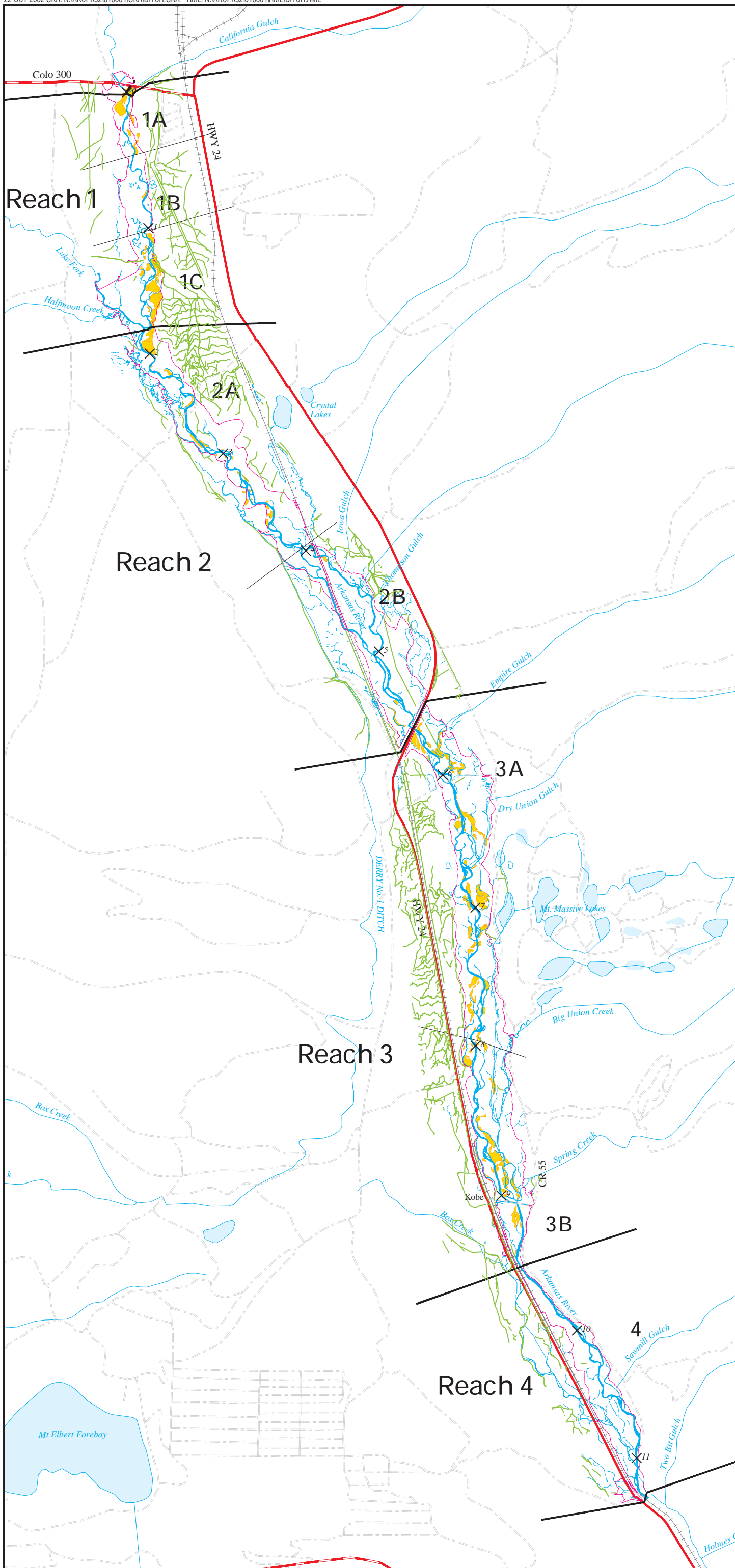


Figure 1-5

Relationship between Heavy Metal Concentrations (expressed as the cumulative criterion unit, CCU) and Number of Heptageniidae in 79 Randomly Selected Streams¹

¹ Data from Reach 0 in the Arkansas River are also shown (open square = AR1; open triangle = EF5). Sites with CCU values less than 1.0 have very low metal levels and are considered reference.



EXPLANATION

Hydrology

- Ditch
- River or Stream
- Lake or Open Water
- 11- Mile Reach
500- Year Floodplain
- × 1 River Mile (from confluence with California Gulch)

Transportation

- Minor Road
- Medium Duty Road
- Highway
- + + + + + Railroad

Other Features

- Mine- Waste Deposit
- Reach Boundary
- Subreach Boundary

N

SCALE IN FEET

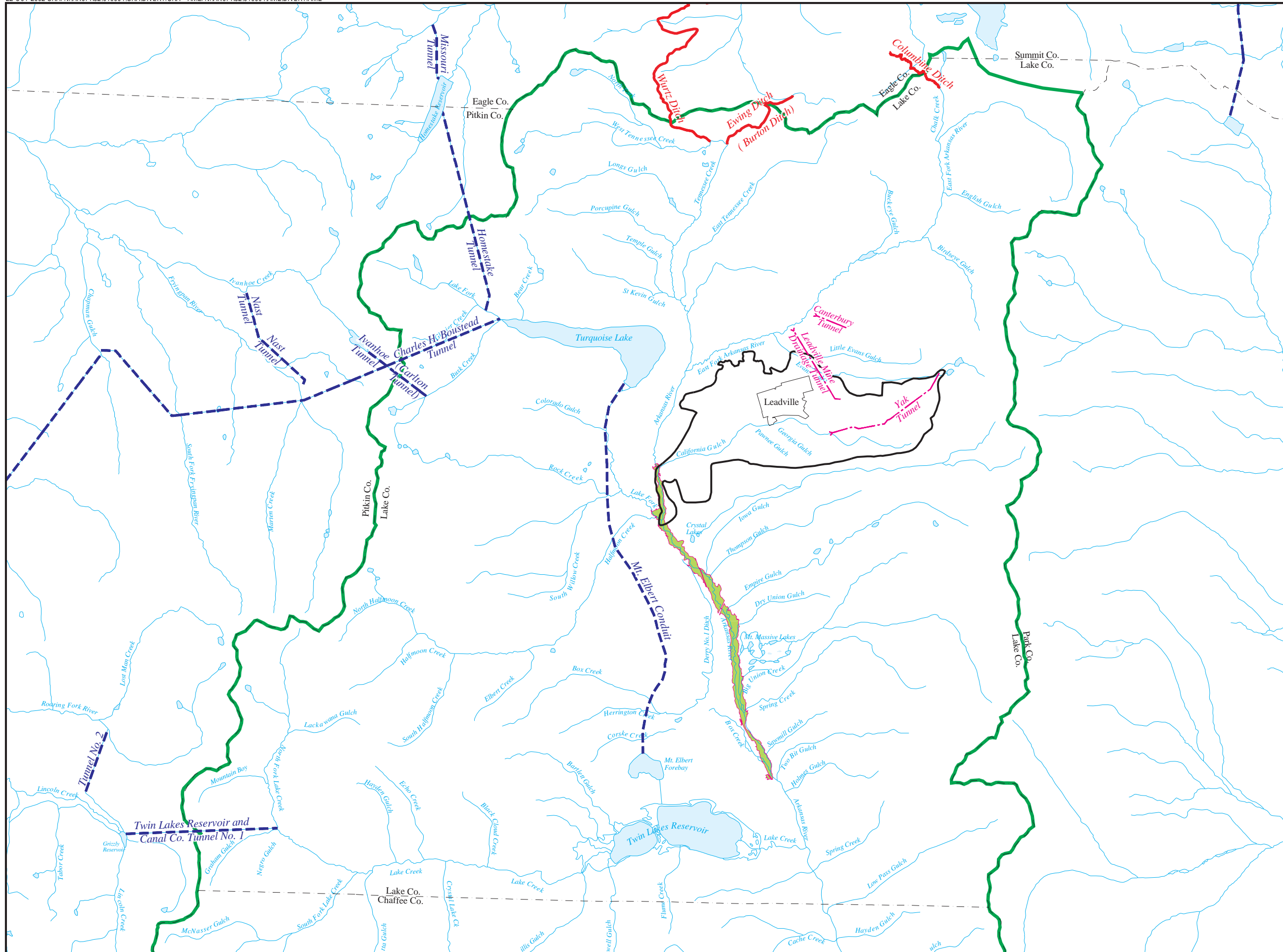
3000 0 3000

UPPER ARKANSAS RIVER BASIN
SITE CHARACTERIZATION SUMMARY

FIGURE 1- 6
IRRIGATION AND
DRAINAGE DITCHES
IN THE 11- MILE REACH
AND VICINITY

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

MFG, Inc.
consulting scientists and engineers



EXPLANATION

Hydrology

- River or Stream
- Lake or Open Water
- 11- Mile Reach 500- Year Floodplain
- Watershed Boundary

Diversions & Tunnels

- Mine Drainage Tunnel
- Water Diversion Tunnel
- Diversion Ditch

Other Features

- NPL Site Operable Unit (OU) Boundary
- Municipality

N

SCALE IN MILES

2.5 0 2.5

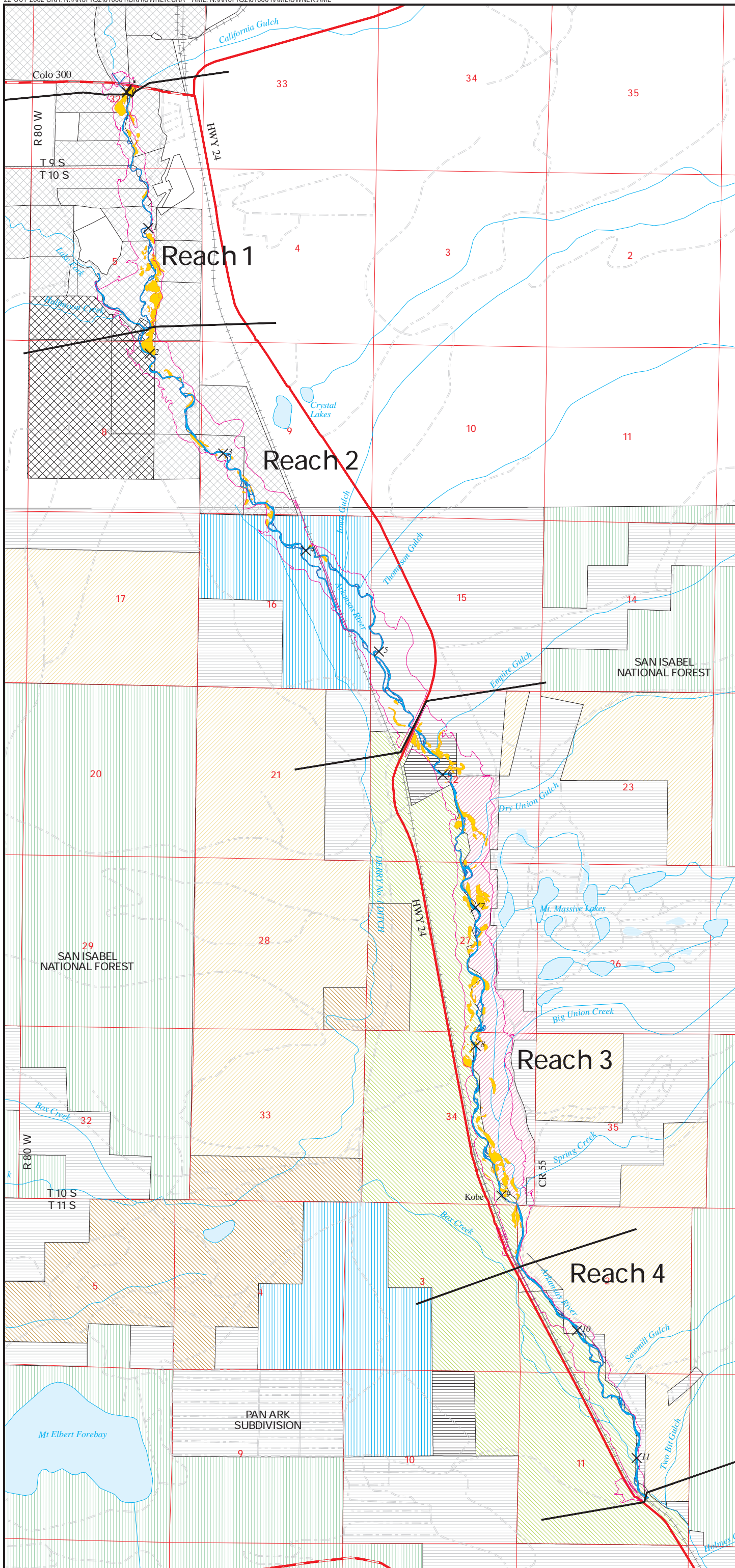
**UPPER ARKANSAS RIVER BASIN
SITE CHARACTERIZATION SUMMARY**

FIGURE 1- 7

**WATER DIVERSIONS
AND MINE DRAINAGE TUNNELS**

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

MFG, Inc.
consulting scientists and engineers



EXPLANATION

Hydrology

- River or Stream
- Lake or Open Water
- 11- Mile Reach
- 500- Year Floodplain
- River Mile (from confluence with California Gulch)

Transportation

- Minor Road
- Medium Duty Road
- Highway
- Railroad

Other Features

- Mine- Waste Deposit
- Reach Boundary

Ownership

(Ownership information from Conlin Associates, 1998)

- Arkansas River Ranch
325 AC.
(Owned by the State of Colorado, as of 2001)
- Bureau of Land Management
3860 AC.
- Hallenbeck Ranch
1200 AC.
(Owned by Lake County, as of 2001)
- Hayden ranch
2100 AC.
(Owned by City of Aurora as part of the Lake County Open Space Initiative, as of 2001)
- Lake County
140 AC.
- State Land Board
1120 AC.
- Private
- San Isabel National Forest

(Ownership information from BLM Mapping, 1995)

- Private
- Lake County
- Ownership not mapped in this area.

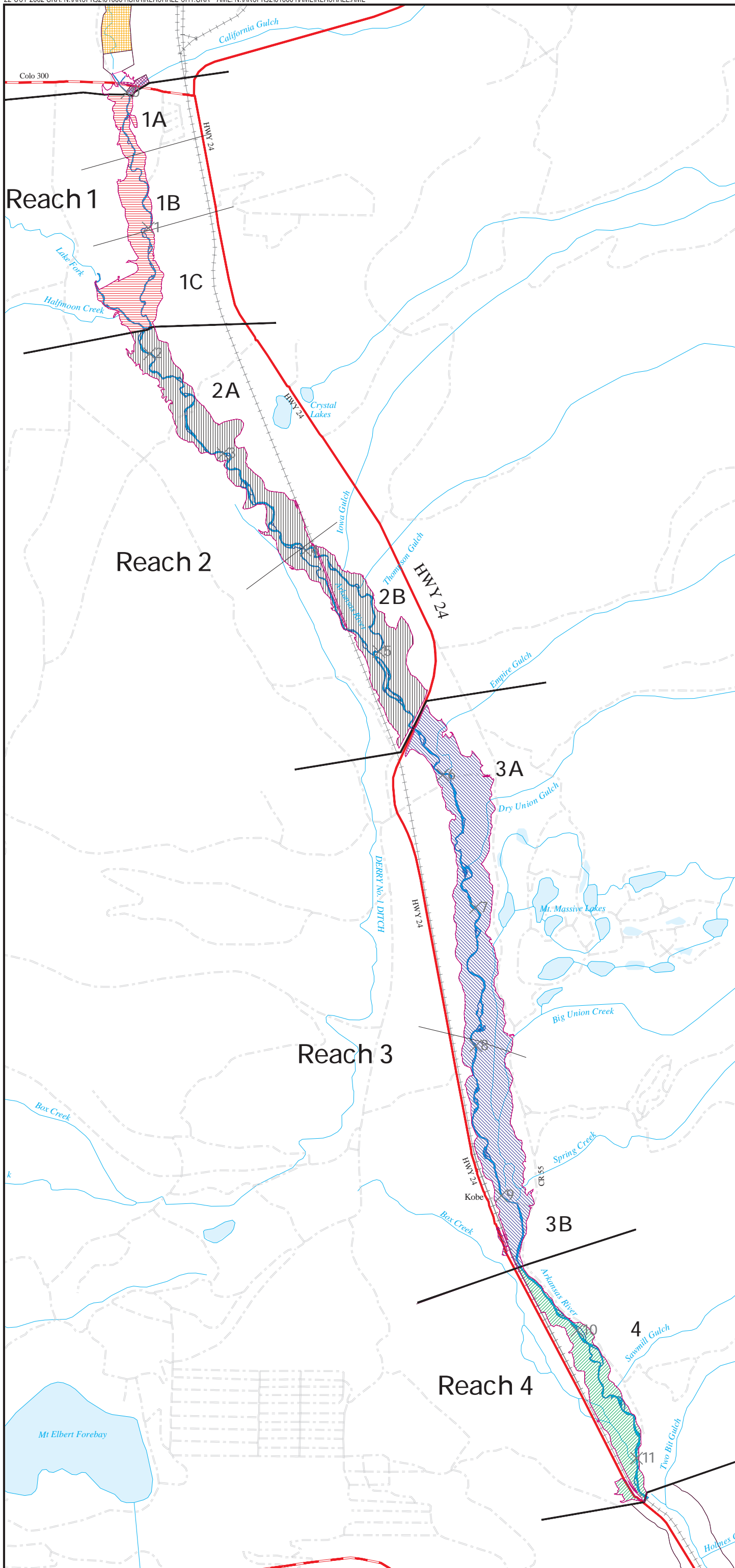
SCALE IN FEET

UPPER ARKANSAS RIVER BASIN
SITE CHARACTERIZATION SUMMARY

FIGURE 1- 8
OWNERSHIP
IN 11- MILE REACH
AND VICINITY

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

MFG, Inc.
consulting scientists and engineers



EXPLANATION

Hydrology

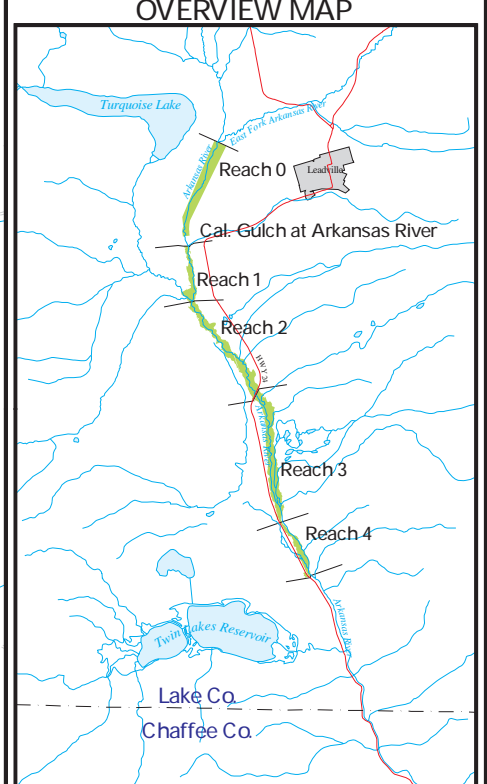
- River or Stream
- Lake or Open Water
- 11- Mile Reach
- 500- Year Floodplain
- Reach 0
- Reach 1
- Reach 2
- Reach 3
- Reach 4
- California Gulch at Arkansas River
- River Mile (from confluence with California Gulch)

Transportation

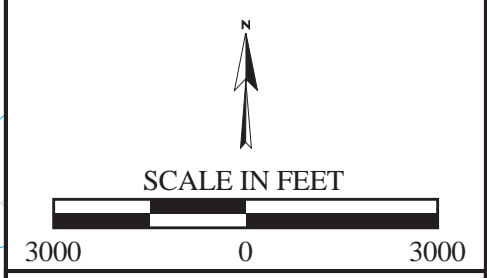
- Minor Road
- Medium Duty Road
- Highway
- Railroad

Other Features

- Reach Boundary
- Subreach Boundary



Reach Definitions:
 1 - California Gulch to Lake Fork
 2 - Lake Fork to HWY 24 Bridge
 3 - HWY 24 Bridge to Narrows below Kobe
 4 - Narrows below Kobe to above Two-Bit Gulch
 0 - From EF Arkansas River to California Gulch



UPPER ARKANSAS RIVER BASIN
 SITE CHARACTERIZATION SUMMARY

FIGURE 1- 9
 SUBREACH MAP
 SHOWING MAIN REACHES 1- 4
 AND REACH 0

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

MFG, Inc.
 consulting scientists and engineers