3.0 DESCRIPTION OF POTENTIAL RESOURCE INJURIES AND RELATED PATHWAYS

The site characterization effort identifies numerous mining related impacts to the natural resources within the 500-year floodplain of the 11-mile reach of the Arkansas River. Injuries to floodplain soil, surface water, and related aquatic and terrestrial biological resources are present throughout the 11-mile reach. Beginning with the onset of hydraulic mining in the late 1860s, discharges of mine-waste and waters with elevated metals concentrations from California Gulch and other tributary drainages resulted in natural resource impacts. The inflow of surface water from California Gulch remains the primary pathway for elevated metals concentrations throughout the 11-mile reach. Floodplain deposits of mine-waste also contribute to the identified injuries.

Currently, inflows from California Gulch result in exceedances of the TVSs in the 11-mile reach for three metals: cadmium, lead and zinc. The elevated concentrations can be directly linked to increased metals concentrations in aquatic biota along with the toxic effects attributable to these increased concentrations. Correspondingly, poor water quality has reduced the productivity of the Arkansas River within the 11-mile reach. However, the level of injury to surface water and related biological resources diminishes with distance downstream.

Aquatic macroinvertebrates in the 11-mile reach are reduced both in abundance and diversity when compared to Reach 0. Despite reasonably good instream habitat for portions of the 11-mile reach, abundance and biomass of brown trout are lower than in Reach 0. In addition to direct exposure to dissolved metals, the aquatic food chain was identified as a pathway for further exposure to metals. Metals concentrations were elevated in periphyton (algal and diatom communities), which serve as a food source for grazing benthic macroinvertebrates. In turn, these organisms are prey to other macroinvertebrates, and both are prey for brown trout. Food chain effects on avian species have also been linked to metals accumulation in aquatic resources. For example, dippers feed on benthic macroinvertebrates, while tree swallows feed on the emergent adult forms. Both of these avian species demonstrated elevated blood lead and depressed ALAD due to metals uptake from their food source.

Figure 3-1 shows the most likely pathways for exposure of brown trout to metals in the Arkansas River. This analysis is based on known relationships between metal levels in water, periphyton, and benthic macroinvertebrates and feeding habits of brown trout in Reach 3 (Clements and Rees 1997). Although the model is based on food chain transport of zinc, other metals would exhibit similar patterns. The analysis shows that water is likely to be a major route of metal exposure to brown trout; however, because of elevated metal levels in other compartments, dietary uptake may also be important. The importance of dietary exposure to metals was supported by laboratory experiments in which fish accumulated significant levels of cadmium and zinc when fed metal contaminated macroinvertebrates (Pickering 1995).

Within the 11-mile reach, injuries were also identified that are directly attributable to shallow deposits of mine-wastes within the floodplain. These fluvially deposited mine-wastes have an average thickness of less than 2.5 feet and typically cover less than an acre. At the location of these deposits, metals concentrations are elevated and expected soil functions (including biological activity) have been inhibited or eliminated due to the overlay of mine-waste. Generally, the extent of floodplain mine-waste deposits diminishes downstream from California Gulch. Very few mine-waste deposits are evident in the lower portion (Reach 4) of the 11-mile reach. On average, the metals concentrations in the mine-waste deposits also diminish with distance from California Gulch. At some locations, metals concentrations exceed phytotoxic concentrations and, in conjunction with low pH and a lack of organic matter, result in an absence of vegetation. Direct uptake of metals by plants creates a route of exposure for wildlife. However, impacts are less evident for terrestrial wildlife than for the aquatic resources (Appendix J).

In those areas not covered by discrete mine-waste deposits, surficial floodplain soils may have elevated metals concentrations due to deposition of fine-grained sediments or by adsorption of dissolved metals in flood and/or irrigation waters originating from California Gulch and the Arkansas River. No direct effects on soil function or plant productivity were identified for these agricultural areas. This is most likely due to the low plant-available fraction of the metals. However, elevated metals concentrations in plant tissue were measured, and concerns have been raised over the potential effects of these metals on livestock.

Metals in mine-waste deposits and floodplain soils are available for transport through surface and groundwater pathways. Evidence of erosion of streamside deposits was observed at a number of locations. Shallow wells (1-10 ft deep) placed in and adjacent to the deposits demonstrated increased metals concentrations in the shallow water table in the immediate vicinity of the deposits due to leaching. However, the potential for these deposits to influence metals concentrations in surface water is limited by the typical deposit thickness of less than 2 feet and the correspondingly small loading potential relative to the large volume of surface and groundwater moving through the valley. Stream bank deposits of mine-waste comprise a small portion of the total length of banks in the 11-mile reach (8.5 percent). Because the deposits are generally shallow and are located at the top of the bank profile, the potential for erosion is greatest at bankfull conditions, when the dilution potential is large.

The combination of numerous shallow monitoring wells within and adjacent to fluvial deposits and data from a small number of domestic water supplies located in Reaches 0, 1, 2, and 3 provide good information to characterize the condition of the groundwater resource within the 11-mile reach. Local groundwater effects appear to be linked to a combination of infiltration from snowmelt and an interaction with a high water table during spring runoff. Again, the setting minimizes the potential for measurable concentration effects on the Arkansas River and the valley aquifer. This interpretation is supported by surface water data collected throughout the 11-mile reach and by USGS studies of individual mine-waste deposits, examining metals loading to side channel flow and shallow groundwater. These data are also consistent with an analytical model of the potential for mine-waste deposits to influence Arkansas River metal concentrations (see Appendix G) within the 11-mile reach. Using conservative assumptions, this analysis demonstrated that the cumulative effect of mine-waste erosion on instream metals concentrations could not be detected. Groundwater of the valley fill aquifer underlying the mine-waste deposits provides a domestic water supply to a number of private residences within/adjacent to the 500-year floodplain. Sampling of water from the wells and springs on these properties show that concentrations are below the maximum contaminant level (MCLs) defining injury. In combination, these data indicate that although metal levels are elevated in shallow groundwater in and near mine-waste deposits, injuries to surface water or the domestic water supply are not occurring via this pathway.

Instream sediment metal concentrations within the 11-mile reach are elevated relative to areas above California Gulch. However, the coarse cobble and gravel riverbed and relatively steep gradient has little fine-grained sediments. Although sediments may provide a point of exposure for benthic organisms, the lack of fine-grained sediment substrate limits the importance of this pathway.

As noted above, within the 500-year floodplain of the 11-mile reach, the level of injury varies with distance from California Gulch. Metals concentrations in the Arkansas River are many times the TVSs immediately below the confluence and over the length of Reach 1. Impacts to the biological resources are correspondingly greatest in this river reach as well. The reduced abundance and diversity of benthic macroinvertebrates have been linked to the elevated concentrations of dissolved metals from California Gulch through laboratory and field toxicity tests. The greatly reduced abundance and biomass of resident trout within Reach 1 is also consistent with acutely and chronically toxic concentrations of dissolved metals.

Approximately two miles downstream from California Gulch, at the confluence with Lake Fork, water quality is substantially improved due to the dilution effects of tributary flow. Although Lake Fork can also be a source of metals loading, on average, cadmium, lead, and zinc concentrations in Reach 2 are reduced by one-half, relative to concentrations just below California Gulch. The benefits of dilution and attenuation of metals with downstream distance can be seen in stream productivity below the Lake Fork confluence. Over Reaches 2 and 3, a reduction in the impacts to both benthic macroinvertebrates and fish was observed. Additional dilution and attenuation results in continued improvements in water quality. However, metals concentrations are still above TVSs at this point. Although the abundance of benthic macroinvertebrates increases, the recovery is still not consistent with reference conditions upstream of California Gulch. Movement of metals through the food chain is documented within Reach 3, and the current level of injury to aquatic resources is expected to persist until further reductions in metals loading from California Gulch are achieved.

Mine-waste deposits follow a similar pattern of downstream improvements; however, river hydraulics have resulted in discontinuous patterns of deposition. Mine-waste deposits near the confluence have higher metals concentrations than those further downstream. This is most likely due to older, coarser, and less refined river wastes being deposited near the mouth of California Gulch. Although on average metals concentrations in mine-waste deposits generally decrease with distance from California Gulch, the relative abundance of mine-waste is much larger in Reach 3 than in Reach 2. This appears to be due to the historic aggradation of the river over this reach (most likely from deposition of coarse hydraulic mining spoils prior to the turn of the century) and the resultant reduced flow capacity of the channel, resulting in a greater frequency of overbank flow.

Another factor influencing the current channel morphology in Reach 3 is a high level of historic flow augmentation. Transfer of west slope water to the Arkansas through Lake Fork appears to have further increased channel width. Large flows in combination with the deposited hydraulic mine-wastes have resulted in a broad, shallow channel particularly in Reach 3. Although not a concern in terms of metals related injury to the resources, the shallow channel configuration and variability of the flow regime due to augmentation represents an additional limiting factor for fish.

Just downstream of the County Road 55 Bridge, the floodplain of the Arkansas River narrows and the bankfull capacity of the channel increases. This, in combination with greater distance from California Gulch, has limited the deposition of mine-waste. Only a few very small deposits of mine-waste were visually identified. Water quality data for Reach 4 are absent; however, tributary inflows are present within this reach. Given the lack of mine-waste, additional dilution, and continued opportunity for attenuation, it is expected that resource conditions in Reach 4 will be as good or better than in Reach 3. As discussed in Chapter 6, the observation of improving downstream trends within the 11-mile reach is consistent with the pattern of aquatic resource conditions further downstream.

Much of the historic injury identified in the characterization process originates with the poor quality water flowing from the LMDT and California Gulch. Since the onset of treatment of the LMDT and Yak Tunnel flows in 1992, injuries are primarily due to the continuing metals load from California

Gulch. The site characterization effort indicates that current surface and shallow groundwater flows from California Gulch greatly exceed the TVSs. Flow of contaminated water from California Gulch is the primary pathway responsible for elevated metals concentrations in the surface water of the 11-mile reach of the Arkansas River. Metals loading from California Gulch can be linked to decreased stream productivity for all forms of aquatic organisms and the transfer of metals through the food chain, resulting in injury to terrestrial species.

The following provides an integration, distillation, and assessment of the data/information presented in Chapter 2. The focus of the following sections is to characterize the current level of injury within the 11-mile reach and to provide a practical basis for the identification of restoration needs presented in Chapter 4. The narrative presents a summary discussion of the overall conditions of the resources within each reach, which is then followed by key findings for the soils, surface water, groundwater, and biological resources. Where appropriate and where information allows, the cause and level of injury is assessed. An assessment of the level of injury is based on comparison with the definitions of injury discussed in Section 1.0, comparison with reference conditions, and the experience of the consulting team. In those cases where the assessment is not solely based upon a comparison of the data to relevant definition of injury, the logic supporting the consulting team's view is expressed. Because the most appropriate point of comparison for mining impacts to the 11-mile reach is the Arkansas River upstream of California Gulch, a similar discussion for Reach 0 is provided along with Reaches 1-4. In addition to the narrative, a matrix summarizing injury determination findings by resource is provided at the end of this section as a quick reference.

3.1 Reach 0: Above California Gulch

The Arkansas River above California Gulch has been identified by the consulting team as a point of reference for assessing downstream mining impacts. The primary consideration for use of this upstream reach as a reference has been the recovery of the aquatic ecosystem since 1992, when treatment of the LMDT resulted in a dramatic decrease in metals concentrations in that portion of the river. Mining influences from the Climax Mine on the East Fork of the Arkansas and St. Kevins Gulch continue to contribute metals to the Arkansas upstream from Reach 0. However, the ongoing contribution of metals from these sources does not appear to impact the productivity of the aquatic and near-stream biological resources in Reach 0. Another important consideration is the absence of mine-waste deposits along Reach 0. Although elevated levels of dissolved metals had historically been an issue, the direct disposal of mine-waste in tributary drainages was relatively insignificant upstream of California Gulch, thereby limiting the potential for deposition in this area.

Baseline conditions (i.e., non-mining influences) for this area were also given consideration when evaluating the appropriateness of Reach 0 as a control; however, only the key findings are presented here. Additional information can be found in Chapter 1 and the literature review in Appendix F. Some flow augmentation occurs on the Arkansas River above California Gulch. On average, 15-20 percent of the flow in the Arkansas through Reach 0 during spring runoff is due to trans-mountain flow augmentation; during all other times of the year, this reach is not augmented. Grazing is another baseline consideration. Although it does not appear that the extent of grazing through Reach 0 is as great as for some areas of the 11-mile reach, some grazing has occurred within portions of the Reach 0 floodplain.

3.1.1 Hydrology/Geomorphology

- Reach 0 is upstream of California Gulch. It contains no observable deposits of mine-waste, and therefore, provides a basis for comparison of the impact of mine-waste on downstream Reaches 1-4. However, Reach 0 is morphologically somewhat different from the downstream reaches. It is marshy, contains dense willow growth, beaver dams, and multiple channels that appear to be in transition to a single channel. The CR 300 bridge may also cause a backwater effect on this reach.

3.1.2 Surface Water

- Reach 0 is not being evaluated to assess injury. Rather, it is serving as the baseline control and, therefore, as a benchmark for downstream reaches. It incorporates several small upstream sources of metals outside the influence of California Gulch, and receives treated discharge from the LMDT. Period 3 data indicates that Reach 0 is periodically affected by elevated metals concentrations that exceed TVSs for all the metals evaluated.

- Generally, more stringent controls implemented as part of the Clean Water Act (CWA), and treatment at the LMDT have decreased metals concentrations significantly. For example, dissolved zinc measured downstream of the East Fork and Tennessee Creek confluence in spring and fall of 1999 was less than the acute and chronic TVS.

- Based on the temporal distribution of total metals data across the three time periods, cadmium, copper, lead, and zinc concentrations show decreasing trends in concentrations during both the high and lows flow conditions.

- Because neither productivity nor diversity of aquatic life is impacted by metals, Reach 0 provides a suitable point of comparison for downstream reaches.

3.1.3 Sediments

- Instream sediments concentrations of metals are lower than in downstream reaches, but are elevated compared to sediments collected from other Colorado streams not influenced by mining. Elevated levels could be reflective of some historic mining impacts and the result of natural conditions (i.e., mineralization) representative of the Colorado Mineral Belt.

3.1.4 Groundwater

- Limited groundwater data are available for Reach 0. However, these data are representative of the aquifer and show that groundwater along the stream corridor is suitable for domestic water supply.

- Reach 0 groundwater is not influenced by mine-waste and is of good quality, therefore, Reach 0 provides a suitable point of comparison for downstream reaches.

3.1.5 Floodplain Soils

- Soil sampling was conducted in Tennessee Park (on a tributary to the Arkansas River) by Sommers et al. (1991) and Levy et al. (1992). The highest concentrations of metals were found in the 0-1 inch depth. This finding was consistent for all metals reported. The maximum concentration of total cadmium found in samples collected from Tennessee Park was 13 mg/Kg. This exceeds the concentration reported to be toxic or excessive (8 mg/Kg) for agronomic species (Kabata-Pendias 2001). However, this concentration is not considered to be toxic to perennial species that would commonly be found growing in the area of Tennessee Park (Redente and Baker 1996; Paschke et al. 2000; Paschke and Redente 2002). All other soil metal concentrations (copper, lead, and zinc) were below levels considered to be phytotoxic, even for agronomic species. It is important to note that phytotoxicity thresholds are commonly quoted for agronomic species because the vast majority of toxicity testing has been with annual crop plants. However, those toxicity studies that have been conducted with perennial species consistently show that these species are more tolerant to metals than agronomic plants.

- Keammerer (1987) reported that total and plant-available (bioavailable) cadmium, copper, and lead were well below phytotoxic concentrations for agronomic species. Total zinc concentrations were in the toxic range for agronomic species, but plant-available zinc concentrations were well below concentrations considered toxic to agronomic plants (Kabata-Pendias 2001) (Table 3-1). This more extensive sampling by Keammerer provides good baseline data to compare to concentrations reported for soils and mine-waste deposits along the 11-mile reach because of the physical locations of the sample sites and the relatively low metal concentrations in the soil medium. Keammerer (1987), Sommers et al. (1991), and Levy et al. (1992) did not identify any areas of mine-waste deposits on Tennessee Creek, the East Fork, and the mainstem of the Arkansas River upstream of California Gulch. It appears that the concentrations of metals are primarily the result of natural conditions and any effects of mining, milling, or smelting on floodplain soils are limited.

- Reach 0 provides a suitable baseline for downstream reaches because metal concentrations in floodplain soils are not in a toxic range for plants or high enough to inhibit normal soil functions.

3.1.6 Biota

3.1.6.1 Terrestrial Vegetation

- Reach 0 is the benchmark for cover, biomass, and species diversity. Keammerer (1987) reported plant cover, production, and species diversity data for 9 sites he sampled upstream of the California Gulch confluence. Plant cover is a measure of the percent of the ground surface covered with live vegetation. Production is the measure of plant mass within a specified area. Species diversity is a measure of the number of species encountered during the sampling activity. Average plant canopy cover was 52 percent ($\underline{+}$3.7), with a range of 38-68 percent. Average production was 137 g/m^2 ($\underline{+}$21.5), with a range of 43 to 244 g/m^2. Total plant diversity was 16 species. Cover, production, and species diversity values reflect past grazing activity in the majority of sample locations. 0 to 35 percent of the vegetation has been removed by grazing.

- Willows are the dominant riparian shrub, and are interspersed with open water wetlands and grasses. The uplands are dominated by herbaceous riparian vegetation consisting of sedges, rushes, and mesic grasses representative of moist soils. These areas are interspersed with upland grasses (CDOW 1988).

- Recently, habitat within Reach 0 has not had as high a level of agricultural use as areas within the 11 mile reach; however, overall habitat within Reach 0 provides a reasonable point of comparison for downstream reaches.

- Keammerer (1987) also reported plant tissue metal concentrations for these 9 sites (Table 3-2). Metal concentrations in shoot material were far below concentrations that might be considered toxic, even for the most sensitive agronomic species.

- Reach 0 provides a suitable baseline for downstream reaches because plant tissue metal concentrations are in a normal range for plant function and plant communities have cover and production levels that are representative of non-metal impacted sites in this environment that have been subjected to some domestic grazing.

3.1.6.2 Aquatic Community

3.1.6.2.1 Benthic Community

- Total species richness, species richness of mayflies, total abundance of mayflies, and density of metal-sensitive Heptageniidae in Reach 0 are typical of what would be expected in similar size reference streams. Thus, Reach 0 provides appropriate benchmarks for benthic macroinvertebrates for the 11-mile reach of the Arkansas River.

- Benthic communities in Reach 0 sampled prior to remediation of the LMDT were characterized by relatively low species richness and reduced abundance of metal sensitive species. Long-term (10-year) analysis of benthic communities from Reach 0 following remediation of the LMDT has shown dramatic improvements in richness and abundance of sensitive taxa and are comparable to measures observed at locations not influenced by mining.

- Although studies conducted prior to 1992 showed significant toxicity of water collected from Reach 0, subsequent studies reported less acute toxicity to fish and invertebrates. These results reflect the improvement in water quality and reduced metal concentrations following remediation.

- Field collections of caddisflies from Reach 0 showed that metal levels in these organisms declined over time, reflecting improvements in water quality. A short-term (9 day) field experiment showed that caddisflies placed at Reach 0 did not significantly bioaccumulate heavy metals.

3.1.6.2.2 Fish Populations

- Chadwick Ecological Consultants (1998) found that Reach 0 sites were dominated by low gradient riffles and/or runs. Cobble substrate and willow were the dominant instream substrate and near stream vegetation was present at all sites. Their inventory of the habitat indicated that pool habitat is lacking, substrate is uniform, and undercut banks are substantially lacking. Woodling (1990) scored the habitat as good using RBPS while Chadwick (1998) scored the habitat as good to excellent/optimal during 1994 and 1998 surveys. HQI ratings indicate that annual stream flow variation, nitrate, cover, and substrate were all factors limiting brown trout biomass productivity. Predicted trout biomasses ranged from 62 to 97 lbs/acre. These results are presented only for a relative comparison of the habitat quality among reaches. Combined, these data indicate that there are some components of the aquatic physical habitat that are limiting to trout in Reach 0. Specifically limiting factors include the lack of cover along streambanks and habitat diversity (e.g., pools were infrequent), as well as limitations due to the existing flow regime.

- Although some aspects of the aquatic habitat may be better than for downstream reaches, overall Reach 0 provides a reasonable point of comparison.

- Abundance, biomass, and length-frequency distributions of brown trout in Reach 0 are typical of what would be expected in similar size reference streams. Thus, Reach 0 is a reasonable benchmark for brown trout populations in the 11-mile reach of the Arkansas River.

- Brown trout surveyed in the fall showed temporal (annual) variation in population abundance (fish/acre), biomass (lbs/acre), and length-frequency distributions. Data collected from 1979 to 1999 showed that brown trout population estimates were variable over the time period, but do not appear to be significantly different before and after the LMDT treatment plant began operation. For the most recent years, after treatment began at the LMDT, abundance (number of fish per acre) was lower in 1999 compared to 1994 (Figure 3-2). Biomass did not follow a similar trend (Figure 3-3). It is likely that the decrease in brown trout abundance between 1994 and 1999 is a sampling artifact and/or related to factors other than water quality. The largest contributor of metals, the LMDT, has been undergoing treatment since 1992.

- Based on the quality of the habitat and other characteristics (excluding water quality), the HQI model predicted from about 62 to 97 lbs/acre as a carrying capacity for trout in Reach 0. Post 1992 biomass data fall within and exceed the upper predicted range of trout biomass for this reach, which may indicate that the reduced influence of metals from the LMDT has allowed for greater trout productivity.

- Davies and Brinkman (1990, 1994, 1999) evaluated the toxicity of several metals to brown trout. These observations, combined with those of fish abundance and density, indicate that, although metals concentrations in the Arkansas River are elevated above TVSs, they are clearly not elevated for sufficient duration and magnitude to cause widespread impacts to the brown trout population in Reach 0.

- A recently published report by Nehring & Policky (2002) evaluates trends in trout populations over the last 16 years. In recent years it appears brown trout density and biomass are improving in this Reach.

3.1.6.3 Terrestrial Vertebrates

3.1.6.3.1 Small Mammals

- Based on the habitat present and the low metals exposure represented by soils and vegetation, Reach 0 is expected to support a healthy small mammal community. Small mammal trapping by Woodward Clyde resulted in the capture of five species of small mammals in Reach 0.

- Average metal concentrations in kidney and liver of voles were below No Observed Effect Levels (NOELS) and other benchmark values reported in the literature (Appendix J).

- Examination of microscopic level changes in tissue structure (histopathology) from voles collected in Reach 0 showed no effects associated with metals exposure.

- For all metals of concern, the tissue residue data from Reach 0 are considered representative of the baseline conditions for metal concentrations in voles and other herbivorous small mammals.

3.1.6.3.2 Large Mammals

- Because the riparian corridor is fairly narrow, the majority of large mammals spend only a limited amount of time feeding in these areas. However, there are probably few individuals that favor riparian habitat and the dense vegetation may provide cover for fawns and calves.

- There are no injury specific data for large mammals from Reach 0, therefore, vegetation and soils data from Reach 0 were used to characterize injury following a risk assessment approach (Appendix J).

- Except for cadmium, mean metal concentrations for grasses and forbs in Reach 0 were below recommended dietary levels for ruminants.

- Mean cadmium concentrations in Reach 0 vegetation (0.8 and 3.8 mg/Kg for grasses and forbs respectively) exceeded the recommended dietary level for ruminants (0.5 mg/Kg), but concentrations were within the range of maximum acceptable exposure without effect (NOEL) (3-5 mg/Kg) (Appendix J).

- Estimates of metals intake from ingestion of vegetation and soils from Reach 0 do not exceed NOEL-based Toxicity Reference Values (Appendix J). Therefore, Reach 0 is a suitable benchmark for characterizing injury to large mammals in the 11-mile reach.

3.1.6.3.3 Birds

- The presence of healthy riparian habitat and aquatic invertebrate community indicates that Reach 0 should support a migratory bird community similar to non-mining impacted streams.

- Because surface water is the most significant metals source in the 11-mile reach, food-borne exposure represented by aquatic invertebrates is a significant route of exposure to migratory birds. Evaluation of water-dependant birds (American dipper and tree swallow) represents a possible worst-case scenario for migratory birds in the Upper Arkansas River Basin.

- Blood and liver metal concentrations in American dippers and tree swallows from Reach 0 were below literature-based benchmarks and were not significantly different than out-of-basin Study References.

- ALAD in American dippers and tree swallows was reduced by 39 percent and 36 percent respectively when compared to the Study Reference for each species. This degree of ALAD suppression is representative of low-level lead exposure, but is not associated with actual effects (Beyer and Storm 1995; Pain 1995; Franson 1996).

- Lead and zinc concentrations in invertebrates (dietary items for dippers and swallows) collected from Reach 0 are slightly elevated above literature-based dietary benchmarks, but not abnormally high. Cadmium in invertebrates was below dietary benchmarks and there were no copper dietary benchmarks identified for birds.

- Based on the condition of the habitat, Reach 0 provides a representative baseline for migratory birds. However, because of the migratory nature of birds and because some dietary exposure to lead and zinc may occur in Reach 0, out-of-basin Study References will be used for evaluating injury as well as Reach 0.

3.1.7 Baseline Considerations

- Stream flow in this reach is augmented by water imported to both Tennessee Creek and the Upper East Fork. Flow augmentation to Tennessee Creek occurs via the Ewing Ditch, Wurtz Ditch, and Wurtz Ditch Extension, while the Upper East Fork receives flow augmentation from the Columbine Ditch (URS 1998). These ditches generally augment flows into the Upper Arkansas River by as much as 15-20 percent of the total streamflow during spring runoff. The most significant impact of flow regulation on natural river hydrology is as much a result of patterns of release as the volume of water released. Rapid fluctuations in flows, for example, will disrupt natural hydrological and geomorphological processes causing riverbank instability and substantial sedimentation. However, over the past 70 years, flow augmentation in this reach has likely had (not continuously, but on various occasions) a significant impact on hydrological and geomorphological processes in the Upper East Fork and Tennessee Creek.

- Flow regulation can impact aquatic habitat conditions for both fish and invertebrates, and can exert negative direct and indirect effects on their populations and communities. In terms of Tennessee Creek and the Upper East Fork, aquatic biota may have been sporadicly impacted by flow regulation, but not on a continuous basis. There is no evidence to indicate flow regulation has had a detrimental effect during Period 3.

- It is unclear whether or not livestock grazing had significantly impacted the Upper East Fork and Tennessee Creek. The current vegetation community structure, dense willow thickets mixed with open grassy areas, suggests that grazing had minimal impacts within the reach.

3.2 Reach 1: California Gulch Confluence to Lake Fork Confluence

The surface water, groundwater, soils, and biological natural resources of Reach 1 are impacted by the effects of mining. Surface water quality is heavily impacted by dissolved and total metals loads from California Gulch. Even though there has been substantial improvement since 1992 when the LMDT and Yak Tunnel treatment facilities came on-line, the current metals load from California Gulch results in large exceedances of the chronic and acute TVSs and is damaging the biological productivity of Reach 1 compared to upstream. For the length of Reach 1, there is a lack of diversity and productivity for benthic organisms. Although no fish kills due to metals discharge have been documented, resident fish populations in this reach have historically been greatly reduced and have only slightly recovered. Numerous site specific and laboratory studies have been conducted supporting the acute and chronic effects that have been observed for both direct exposure and food chain pathways. Based on field observations and considering the high dissolved zinc concentrations, populations of brown trout would currently only be present in this reach seasonally as they migrate to and from headwater spawning areas.

Soils have been directly impacted by the historic deposition of mine-wastes. In combination, the relative volume of mine-wastes and the toxicity of those wastes are higher than for downstream reaches. These conditions are consistent with the presence of older deposits of less refined mine-waste. The concentrations of metals measured in these deposits inhibit or preclude normal soil function/biological activity (soil microflora and fauna) and are phytotoxic. The result is floodplain deposit areas that are barren or have low vegetation cover.

Reach 1 surficial floodplain soils not associated with distinct mine-waste deposits have elevated metals concentrations due to historic irrigation activities where very fine-grained mine-wastes and/or both total and dissolved metals present in the irrigation waters have adsorbed to the soil. Historic flood events have also contributed to the general contamination of surficial soils in areas away from mine-waste deposits. The concentrations of metals in these surficial soils are less than for the mine-waste deposits and, although elevated, do not appear to be impacting plant growth. This is most likely due to the low plant-available fraction of the soil metal content.

Metals are being contributed from mine-waste deposits along the Arkansas River, both in dissolved and total form. Erosion of bank deposits of mine-waste occurs during high flow, and infiltration through these deposits and/or seasonal contact with a rising water table result in leaching to shallow groundwater. However, recent surface water data and more detailed studies on individual deposits further downstream (Walton-Day et al. 2000) indicate that the ability of these deposits to influence overall surface and groundwater quality is small.

Limited shallow groundwater data for Reach 1, within and adjacent to mine-waste deposits, show localized increases in certain metals concentrations due to leaching of these materials. At the confluence, observed elevated metals levels in shallow groundwater may also be in part due to shallow groundwater flowing from the California Gulch drainage. Given that shallow monitoring well data available for Reach

1 are from wells adjacent to the stream corridor downstream from California Gulch, therefore, certain of these shallow groundwater data also reflect the influence of Arkansas River water.

Limited data are available for domestic water supply wells in Reach 1. However, the location of the available wells allows for a valuable comparison of the water quality of the valley fill aquifer with data from domestic and monitoring wells in lower California Gulch. The domestic water supply wells in Reach 1 are located at and just downstream of the confluence with California Gulch. Even though groundwater quality within California Gulch is poor, the Reach 1 wells are below the MCLs that define injury. Consistent with the findings of USEPAs 1983 study, rapid dilution and attenuation of metals from California Gulch and Reach 1 floodplain mine-waste deposits results in acceptable groundwater quality within the valley fill aquifer.

This assessment of the impacts of mine-waste deposits on surface and groundwater is consistent with a practical examination of the setting. Available data indicate that the mine-waste deposits generally reside within the upper two feet of floodplain soils, and are generally not in contact with the water table under average or low-flow conditions. Correspondingly, the contribution of metals to surface and groundwater would be greatest at bankfull stage, which is also when the dilution effects would be greatest. In addition, overall erosion rates appear to be low because the surface area of the deposits in contact with the high flow channel is a relatively small portion of overall bank length. Because spatially detailed synoptic surface water sampling events were not available to do fine-scale loading analysis over the 11-mile reach, an analytical model was used to evaluate the potential for direct loading from deposits to the river. An analysis of the potential effects of mine-waste erosion on surface water quality supports the view that, even under accelerated rates of erosion/runoff, the change in concentration associated with these deposits would be small (Appendix G).

Metals in Reach 1 of the Arkansas River move through the aquatic food chain and can be linked to injury for both aquatic and terrestrial species. Within Reach 1, metals in the water column are accumulated by stream periphyton, which is a food source for grazing benthic macroinvertebrates. The periphyton metals are transferred to the benthic macroinvertebrate grazers and are then available to predatory macroinvertebrates. In turn, both types of macroinvertebrates are a food source to brown trout and aquatic dependant birds, such as American dippers, and therefore provide a pathway for additional exposure to metals. Although dipper data are not available for Reach 1, in downstream reaches with lower metals concentrations in the food source, dippers were found to have elevated blood-lead and depressed ALAD levels. Fine-grained sediments containing elevated metals concentrations can also contribute to these pathways. However, in the case of Reach 1, the river bed is primarily comprised of gravel to cobble sized material.

Adult winged forms of benthic macroinvertebrates are food for terrestrial species. Metals in the adult forms of these insects influence enzyme production in tree swallows in downstream reaches, a defined injury. Custer et al. (2003 In Press) conducted studies by placing a series of nesting boxes along the river at various points and collecting nesting birds for sampling. The studies confirmed that the tree swallows were exhibiting depressed ALAD due to elevated blood lead concentrations. Again, specific data for Reach 1 are not available. However, given the fact that metals concentrations in all environmental media are higher in Reach 1 than in downstream reaches, these injuries are concluded to be present in Reach 1 as well.

Elevated metals levels in plant tissue and soils within the Reach 1 floodplain also provide a potential pathway of exposure to other terrestrial organisms. Most highly exposed species would be those such as rodents, who have a small home range and spend a majority of their time collecting food in or around mine-waste deposits. While there are small mammal data for Reach 1, evaluation of data from Reach 0, Reach 2, and the NPL site, representing environmental exposures higher and lower than those expected in Reach 1, indicate that there is no small mammal injury occurring in Reach 1 (Appendix J). Larger grazing species, such as deer and elk, would spend less time residing in the area of mine-waste deposition and would be less likely to be injured by elevated metals in the soil and plants because exposure is significantly reduced. No information directly documenting injury to terrestrial herbivores was identified. However, a risk-assessment approach was used to characterize potential injury to large mammals. Based on potential exposure represented by vegetation and soils data, it does not appear that large mammals in Reach 1 are being injured (Appendix J).

3.2.1 Hydrology/Geomorphology

- The river within Reach 1 is best characterized by a series of smaller reaches (Figure 2-49). Subreach 1A is a steep reach (Table 2-3) that was very active in the past. It contains a relatively large amount of mine-waste (Table 2-30), but only 13 percent of the banks expose mine-wastes that are subject to erosion. Subreach 1B is steep (Table 2-3) and contains a relatively small amount of mine-waste that is exposed in only 5 percent of the banks. Subreach 1C is less steep than the upstream reach, and is located upstream of the confluence of Lake Fork. It contains a very large amount of mine-waste (Table 2-30), but only 15 percent of the banks contain exposed mine-waste.

- Agricultural irrigation occurs in the valley bottom below the river terrace. Existing maps of the irrigation ditch system in Reach 1 suggest that, by numbers of ditches alone, the east side of the river is more heavily irrigated than the west side of the river (Figure 1-6).

3.2.2 Surface Water

- Surface water resources in Reach 1 are injured by elevated concentrations of cadmium, copper, lead, and zinc during high flow, and cadmium, lead, and zinc during low flow. Metals concentrations and overall water quality in Reach 1 is dominated largely by discharge from California Gulch. Exceedances of TVSs defining injury are prevalent, although somewhat improved from 1992 when both the LMDT and Yak Tunnel facilities began treatment. However, the net effect of treatment is not fully evident due to several factors, including: 1) discharges of water from lower California Gulch source areas, such as Stray Horse Gulch and Oregon Gulch (Star Ditch); 2) ongoing disturbances associated with remediation activities upstream; 3) spring runoff that results in elevated concentrations predominantly due to California Gulch discharge, and to a much lesser extent the East Fork and Tennessee Creeks. California Gulch is considered to be the primary metals source to Reach 1 surface waters (Table 3-3).

- During high flows, dissolved cadmium, copper, and zinc exceeded the acute TVSs several times while dissolved lead exceeded the acute TVS once. During low flows, only cadmium and zinc exceeded the acute TVSs, copper did not exceed the TVSs, and lead only exceeded the chronic TVS. On average, dissolved cadmium, copper, and lead concentrations were very similar during high and lows flows, whereas mean zinc was considerably greater during low flows. For both flow conditions, zinc exhibited the largest increase in exceedances of TVSs relative to the other three metals. The percentage of zinc concentrations exceeding the TVSs was only slightly greater for high flow samples compared to low flows samples. The large increase in concentrations of zinc and exceedances of the TVSs for zinc indicates that California Gulch is a significant source. Data evaluated during period 3 may also reflect disturbances from ongoing remediation in California Gulch.

- Based on the evaluation of total metals concentrations and their distribution through time in Reach 1, no clear trends were noted for cadmium and copper, but it appears that lead and zinc show decreasing trends with slightly lower concentrations observed in more recent years when compared to previous years.

- Compared to Reach 0, mean concentrations of all metals increased in Reach 1 during both high and low flows, with zinc exhibiting the highest increases. During high flows, increases in cadmium, copper, and lead are small. Unlike Reach 0 where mean dissolved zinc concentrations were higher during high flows, in Reach 1 mean dissolved zinc was higher during low flows suggesting greater influence of metals loading due to California Gulch during the low flow period. Average zinc in Reach 1 represents a 4-fold increase during high flows and a 5 to 6-fold increase during low flows relative to Reach 0 (Figure 3-4 and Figure 3-5).

3.2.3 Sediments

- Injury to sediments can best be determined from benthic invertebrates. The mass and concentration of instream sediments are not sufficient to result in injury to surface water in this reach.

- Concentrations of copper, lead, and zinc in sediments from Reach 1 are elevated over those found in Reach 0. Mean concentrations of copper, lead, and zinc are, 1.9, 5.9, and 3.6 times greater, respectively, in Reach 1 compared to Reach 0.

3.2.4 Groundwater

- Well UMW19, located in the shallow groundwater system on the California Gulch side of the Arkansas River just downstream from the confluence, demonstrates the potential for impacts from the California Gulch system on main valley shallow sub-surface flow. The maximum concentration of zinc measured in UMW19 was 55.9 mg/L in 1999 during high flows in the Arkansas River.

- The deeper valley fill groundwater currently used as a domestic water supply within Reach 1 is below the MCLs and is therefore not injured (Table 2-9).

- Concentrations in shallow groundwater (0-10 ft) measured in and adjacent to near-bank mine-waste deposits are reflective of the water quality of the Arkansas River or represent the influence of individual mine-waste deposits, depending upon placement. Table 3-4 provides a summary of shallow monitoring well sampling results for Reach 1 wells during Period 3. Although values measured at these wells exceed the TVs defining injury to surface water, there is no reasonable expectation that shallow groundwater is causing injury to surface water.

- Concentrations of metals in shallow ground water show seasonal changes in concentrations much the same as the river with increased concentrations during high flows and decreased concentrations during low flows, indicating the hydraulic connectivity of these shallow alluvial wells to the river.

3.2.5 Floodplain Soils

- A total of 24 mine-waste deposits were identified and characterized by EPA in 1996 and 1997 (URS 1997 and 1998) (Table 3-5 and Appendix D). There is a total of approximately 887,000 ft^3 of mine-waste, covering a surface area of approximately 785,364 ft^2 in Reach 1. The average depth of the mine-waste deposits was 1.1 feet; no deposits that averaged greater than 2 feet in depth were found. Soils where mine-waste deposits occur are considered injured. Total metal concentrations exceed phytoxicity thresholds and plant growth has been substantially impacted on most sites where mine-waste deposits have been identified. Of the 24 mine-waste deposits identified in this reach, 23 deposits have poor to fair vegetation cover (0 to 15 percent plant cover) using aerial photographs to judge plant cover (Section 3.2.6.1).

- Compared to Reach 0, total metals concentrations in floodplain (riparian) soils (not including data for mine-waste deposits) along Reach 1 are substantially higher. Plant-available metals concentrations in Reach 1 are also higher than Reach 0, but the concentrations are in a similar range. Based on concentrations in the literature considered to induce a phytotoxic response in plants, the plant-available concentrations in Reach 1 are well below levels reported to be phytotoxic.

- Keammerer (1987) reported total and plant-available (bioavailable) metal concentrations in soils not directly impacted by mine-waste deposition between the confluence of California Gulch and the Lake Fork confluence (Table 3-1). Keammerer's data showed total metal concentrations for cadmium to be somewhat lower than Swyers (1990) and Levy et al. (1992). However, the total metal concentrations reported by Keammerer for copper, lead, and zinc were markedly higher than the concentrations reported by Levy and Swyers. What is most significant about Keammerer's data are that the plant-available metal concentrations for cadmium, copper, lead, and zinc were very low (Table 3-1).

- Plant-available concentration of metals is the best measure for injury determination because the bioavailable fraction of the metal is what determines biotic responses. Metal threshold concentrations from the literature are primarily from hydroponic and sand culture experiments, where plant-available metal concentrations are the same as total metal concentrations. Thus, comparing plant-available metal concentrations from the Upper Arkansas River to total metal concentrations from the literature is an acceptable comparison. Therefore, based on plant-available concentrations, floodplain soils are not considered to be injured.

3.2.6 Biota

3.2.6.1 Terrestrial Vegetation

- Vegetation is considered injured in this reach where most mine-waste deposits occur. Of the 24 mine-waste deposits identified along Reach 1, 23 deposits have poor to fair vegetation cover based on evaluations of aerial photographs of the deposits.

- Cover, biomass, and number of species in Reach 1 are equal to or greater than Reach 0 (Tables 2-11 and 2-36). All tissue metal concentrations are below thresholds considered to be toxic to perennial species. There is no evidence of metal-induced injury in Reach 1 for vegetation growing in riparian areas.

- Reach 1 is characteristically similar to Reach 0, with willows dominating the riparian shrub community, open water wetlands, sedges and rushes in the waterlogged soils, and uplands being dominated by herbaceous riparian vegetation. The primary difference is the presence of unvegetated mine-waste deposits and sandbars. Agricultural activities currently occur in Reach 1.

- Some individual plant samples had zinc tissue concentrations that were in the toxic range for some species (Tables 2-35, 2-36, and 3-2). It is important to note that toxicity thresholds vary among plant species and perennial species are generally more metal-tolerant than annual agronomic species that are more commonly cited in the toxicity literature. Work by Paschke et al. (2000) on zinc toxicity in native perennial species established zinc toxicity thresholds for perennial grasses. Toxicity was not reported for zinc until plant tissue concentrations exceeded 2,000 mg/Kg. This is two to four times higher than the concentrations found on the Seppi Ranch (Reach 1).

- Sommers et al. (1991) reported that elevated zinc concentrations in soils can induce chlorosis, an iron deficiency. This condition was evident on the Seppi Ranch (Reach 1). However, data on plant cover and production were not collected in a way to determine if this chlorosis has resulted in a significant reduction in plant growth. Field observations in 2000 and 2001 along Reach 1 provide supporting evidence that plant communities are healthy and similar in productivity and cover to Reach 0.

3.2.6.2 Aquatic Community

3.2.6.2.1 Benthic Community

- Benthic communities in Reach 1 are injured due to elevated metals levels in surface water. Benthic communities in Reach 1 were characterized by reduced abundance and richness and a shift in community composition from metal-sensitive taxa to metal-tolerant taxa relevant to Reach 0. Inspection of long-term variation in benthic communities showed relatively little change in macroinvertebrate abundance between 1989 and 1999. In contrast, measures of species richness showed some evidence of improvement following remediation of the Yak Tunnel in California Gulch; in particular, mayfly richness increased from 3.2 species per sample in fall 1989 to 6.0 species per sample in fall 1998.

- Concentrations of cadmium and zinc in *Arctopsyche grandis* were consistently higher in Reach 1 than in Reach 0, the upstream reference. There was relatively little evidence of reduced metal uptake by caddisflies in Reach 1 following remediation of California Gulch. Results of field experiments measuring metal uptake by *Brachycentrus* in Reach 1 showed that caddisflies readily accumulated heavy metals during the 9-day exposure. Concentrations of cadmium and zinc in *Brachycentrus* in Reach 1 increased over time and were two to six times greater compared to Reach 0.

- Results of acute toxicity tests conducted with *Ceriodaphnia dubia* consistently showed significant mortality of organisms exposed to water from Reach 1, indicating injury to the benthic community.

- The lowest genetic diversity for the mayfly *Baetis tricaudatus* in the Arkansas River was detected in Reach 1. These results support the hypothesis that long-term exposure of *Baetis* to heavy metals has resulted in a population "bottleneck" and that sensitive genotypes have been eliminated. Loss of these sensitive genotypes indicate injury and will reduce the ability of Reach 1 populations to respond to other natural and anthropogenic stressors.

- Concentrations of cadmium and zinc in sediment and periphyton collected from Reach 1 were greatly elevated compared to samples collected from Reach 0. Cadmium and zinc levels were between 5 and 7 times greater in periphyton than in sediment and are a significant route of metal exposure. Results of toxicity tests showed that sediments were acutely toxic to invertebrates and that chironomids bioaccumulated significant concentrations of cadmium, copper, lead, and zinc from sediments. However, because fine sediments comprise a small portion of the streambed substrate, it is unlikely that sediments are a major source of metal exposure in Reach 1.

- Results of these analyses indicate that benthic macroinvertebrates in Reach 1 were injured by exposure to metals. Microcosm experiments show that aqueous metal levels in Reach 1 are sufficient to cause significant mortality to most macroinvertebrate taxa. Significant effects of Reach 1 sediments on growth and survivorship of chironomids were also observed.

- Figure 3-1 shows the most likely pathways for exposure to metals within the benthic community. This analysis is based on known relationships between metal levels in water and periphyton and feeding habits of dominant macroinvertebrates. Although exposure to metals in water is important for some groups, metals in periphyton, a food source for benthic macroinvertebrates, is a major route of exposure for many taxa. In particular, metal uptake by grazing mayflies and caddisflies most likely occurred through exposure to periphyton. The importance of periphyton and sediments as a route of exposure to benthic macroinvertebrates was supported by laboratory experiments. Significant accumulation of metals by chironomids exposed to sediment collected from Reach 1 and by mayflies exposed to periphyton was observed in the laboratory.

3.2.6.2.2 Fish Populations

- Field surveys of brown trout from 1979 to 1999 showed both spatial (upstream versus downstream) and temporal variation in population abundance and biomass (Figures 3-2 and 3-3). Compared to Reach 0, fish survey results showed significantly reduced abundance and biomass of brown trout collected from Reach 1 for all years surveyed (Table 2-18).

- For the years 1979, 1985, and 1987, both abundance and biomass were severely depressed in Reach 1 below California Gulch. Surveys in 1989 showed high numbers at all stations sampled including Reach 1, but suppressed biomass continued in Reach 1. Examination of the full record prior to treatment in 1992 indicates a steady increase in the number of trout and biomass. In 1992, the YAK and the LMDT treatment plants went online and began removing metals from California Gulch and the LMDT. Surveys in 1994 and 1997 show a continued pattern of suppressed abundance and biomass, but are improved compared to the 1979-1985 period. Data from 1999 reveal increased numbers similar to those observed in 1989, as well as increased biomass.

- Fish habitat in Reach 1 as inventoried by Chadwick Ecological Consultants (1999) was dominated by runs and low gradient riffles. Pool habitat is clearly lacking, substrate is uniform and not diverse, and undercut banks are substantially lacking. Woodling (1990) scored habitat using the RBPs and scored Reach 1 habitat ranging from 70 to 74 out of the possible 135, with both scores falling between the good and fair ratings. Chadwick (1999) assessed a location in Reach 1 and scored it at 105 (good) out of the possible 135 in 1994, while in 1998 the habitat at this location was similarly scored in the good range. HQI ratings indicate that annual stream flow variation, nitrate, cover, and substrate are limiting brown trout biomass productivity. Combined, these data indicate that there are components of the aquatic physical habitat that are limiting to trout in Reach 1. Compared to Reach 0, predicted trout biomass was considerably lower, RBP scores were similar, and similar habitat features such as those limiting brown trout were also observed, and found to be more pronounced in Reach 1.

- Based on the quality of the habitat and other characteristics (excluding water quality), the HQI model predicted 49 lbs/acre as a carrying capacity for trout in Reach 1. This estimate indicated that the quality of the habitat in Reach 1 is not capable of supporting a large quantity of trout. Biomass measured during the fish surveys at sites in Reach 1 from 1985 to 1999 ranged from as low as 0.8 to 31 lbs/acre. Of the pre-1992 data, biomass estimates from 1985 and 1986 are extremely low compared to the predicted estimates, whereas 1989 estimate is considerably higher. Post-1992 biomass estimates are still less than predicted (Figure 2-14).

- Results of laboratory experiments conducted by Davies and Brinkman (1999) show that the high concentrations of metals immediately downstream from California Gulch are likely to cause direct toxic effects on brown trout. Metal levels in water immediately downstream from California Gulch were generally 2-4 times greater than the concentrations known to be toxic to brown trout.

- Toxicity tests conducted with cladocerans and fathead minnows showed that water from California Gulch, the Yak Tunnel, and Reach 1 was acutely toxic (Tables 2-38 and 2-39). Mean LC_{50} values for invertebrates measured in Reach 1 ranged from 40-47 percent (Table 2-38). Experiments conducted by ENSR Consulting, Inc. (Weston 1994) reported LC_{50} values for invertebrates and fish exposed to water collected from California Gulch and the Arkansas River (Table 2-39). Results showed that water from California Gulch and stations in Reach 1 was highly toxic to invertebrates (LC_{50} = 1-5 percent).

- Results of field surveys in the Arkansas River and laboratory toxicity experiments indicate that brown trout in Reach 1 are injured by exposure to heavy metals. Metal concentrations in water exceed established chronic values for brown trout and are sufficient to cause significant acute and chronic effects on resident populations. Surveys of brown trout populations conducted by the CDOW showed large reductions in abundance (80 percent) and biomass (79 percent) compared to Reach 0 across all sampling dates. In addition, length-frequency distributions indicate poor recruitment of juvenile brown trout in this reach.

- A recently published report by Nehring & Policky (2002) evaluates trends in trout populations over the last 16 years. This report indicates continued improvement in brown trout fishery. It states that if this trend continues over the next several years, it may be strong empirical evidence that the efforts at ameliorating heavy metal pollution are beginning to have a positive effect on the trout population.

3.2.6.3 Terrestrial Vertebrates

3.2.6.3.1 Small Mammals

- There are no injury-specific data for small mammals from Reach 1, however, potential exposure from vegetation and soils is higher in Reach 1 than in Reach 0.
- Metals concentrations in small mammal tissue samples from the NPL site, Reach 0, and Reach 2, representing a gradient of metals exposures that are higher and lower than the exposure expected in Reach 1, did not exceed benchmarks nor did they exhibit pathological changes associated with metals effects (Appendix J). Therefore, it is not expected that the metals exposure in Reach 1 is at levels that cause injury to small mammals.
- Species with more insectivorous diets such as shrews may have higher exposures than rodents, but data are not available for direct evaluation of these species. Scientific literature indicates that insectivores may be more tolerant of increased metals exposures and benchmarks used for herbivorous rodents may not be appropriate for insectivores (Shore and Douben 1994; Cooke and Johnson 1996; Eisler 2000; and Ma and Talmage; 2001) (Appendix J).

3.2.6.3.2 Large Mammals

- Habitat in Reach 1 is characteristically similar to Reach 0; the primary difference is the presence of un-vegetated mine-waste deposits. Because there are no injury specific data for large mammals from Reach 1, vegetation and soils data were used to characterize injury following a risk assessment approach (Appendix J).
- Mean cadmium concentrations in grasses and forbs (2.2 and 4.6 mg/Kg), but are within the range of maximum acceptable exposure with no observed effect (NOEL) (3-5 mg/Kg) (Church 1988). All other metals of concern are below the recommended dietary levels for ruminants.
- Estimation of metals intake from ingestion of vegetation and soils from Reach 1 do not exceed NOEL-based Toxicity Reference Values indicating very low potential for injury to large mammals in Reach 1 (Appendix J).

- Zinc levels in grasses and forbs from Reach 1 are near the lower limit associated with copper deficiency in ruminants. Elevated dietary zinc levels (300-1,000 mg/Kg) can result in zinc induced copper deficiency in cattle (Hambidge et al. 1986). Subsequently, copper deficiency creates an iron deficiency in cattle because a copper-containing protein, ceruplasmin, is needed for iron transportation and utilization in the bloodstream (Davis and Mertz 1987). However, effects resulting from these dietary deficiencies are not obvious and cannot be determined without a detailed study of the animal's diet along with corresponding physiological/pathological tests.

3.2.6.3.3 Birds

- There are no specific bird injury data from Reach 1, however, metals concentrations are elevated in water, invertebrates, and sediments compared to Reach 0 and most downstream reaches. Because injury to birds (American dipper and tree swallows) was documented in downstream reaches where exposure concentrations were lower and because birds move between reaches, injury is also expected in Reach 1.

3.2.7 Baseline Considerations

- The effects of flow regulation for this reach will be very similar to Reach 0 since there are no additional sources of water augmentation below that for Tennessee Creek. Because this reach of the river is further downstream, effects should be somewhat reduced compared with Reach 0. Therefore, it seems unlikely that flow regulation exerts any significant influence on this portion of the Arkansas River beyond that mentioned for Reach 0.

- Klima and Scherer (2000) noted that Mexican settlers maintained cattle and sheep ranches on the Arkansas River as early as the 1830s, and that Colorado experienced a livestock boom as ranching became a formidable industry throughout the 19th century. As late as 1929 there were 8,800 cattle and horses and 102,328 sheep grazing on National Forests in the Leadville area; these numbers dropped to 758 cattle and 11,000 sheep in 1944 in the Leadville District of the San Isabel National Forest (Klima and Scherer 2000). Klima and Scherer (2000) further note that during the 1800s to the early 1900s overgrazing by livestock had occurred over much of the grass-shrub area. Ranching continues over much of Reach 1 today.

- Plant communities in Reach 1 have been impacted by agricultural practices, and native plant communities have been displaced or modified by the creation of pasture lands and grazing in and along the stream corridors. These agricultural activities have contributed to changes in the composition and diversity of the riparian zone, and have affected its overall condition.

3.3 Reach 2: Lake Fork Confluence to Highway 24 Bridge

The surface water, groundwater, soils, and biological natural resources within Reach 2 have been injured by the impacts of mining. The same pathways and exposure points exist within Reach 2 as within Reach1; however, the level of injury for certain resources within Reach 2 is not as great. This is due to two distinguishing factors: 1) substantial tributary inflow occurs in Reach 2 and results in dilution of metals concentrations in surface and groundwater; and 2) the volume per stream length and average metals concentration of mine-waste deposits are less than Reach 1 due to greater distance from the source and the hydraulic characteristics for the reach.

The diluting effects of tributary waters and some level of attenuation of dissolved metals results in roughly half of the dissolved instream zinc concentration over the length of Reach 2, as well as reductions in the concentrations of other metals. Metals concentrations in Reach 2 are still in excess of the TVSs and, although lower than in Reach 1, there is still a lack of diversity and productivity for benthic organisms. Even though recovery is evident, fish populations are still somewhat reduced relative to upstream areas and appear to vary between years and seasons. Instream metals concentrations play the largest role in the decreased productivity of the Arkansas River through Reach 2. However, non-mining influences such as the effects of flow augmentation can be substantial, further contributing to depressed stream productivity.

Soils within Reach 2 have been impacted by the historic deposition of mine-waste. As discussed for Reach 1, injuries caused by mine-waste are inhibition or absence of normal soil functions at the location of the deposits and related impacts to vegetation. The frequency of deposits and relative volume of mine-waste over this reach is less than in Reach 1. Total metals concentrations of the deposits are also substantially less than in Reach 1.

Floodplain soils within Reach 2 not directly impacted by mine-waste deposits have also been affected by historic mining. Metals concentrations of floodplain soils not associated with discrete mine-waste deposits are elevated relative to Reach 0, but are less than in Reach 1. Plant-available concentrations also further decrease relative to Reach 1. Historic flooding and irrigation of bottomlands are the pathways for surficial contamination of these soils. Irrigation activity within Reach 2 appears to have been higher than in other reaches and is likely a factor in the extent of surficial soil contamination (Figure 1-6).

Although some contribution of metals from mine-waste deposits to surface and groundwater is occurring, an increase in Arkansas River metals loading attributable to mine-waste deposits is not perceptible over this reach. The large inflows from Lake Fork, even though reduced from pre-1982 flows, have a strong dilution effect, resulting in substantial improvement in water quality relative to Reach 1.

Impacts to aquatic biota are still evident within Reach 2. However, the biotic community does show a noticeable improvement compared to Reach 1. The recovery correlates with improving surface water concentrations. Density and diversity of benthic macroinvertebrates improved from Reach 1 and, for certain sampling events (e.g., September 1994 and September 1999), trout populations in Reach 2 were similar to those observed for Reach 0. Although toxicity of surface water appears to have decreased from Reach 1, toxic effects were still observed in the laboratory for C*eriodaphnia* and fathead minnows. Food chain transfer of metals (e.g., periphyton, benthic macroinvertebrates, fish) is still evident in Reach 2; however, sampling was not spatially detailed enough to assess differences from Reach 1.

Assessing the level of hazardous substance-related injury to the aquatic community in Reach 2 is more difficult than Reach 1. Although flow augmentation from Lake Fork has a beneficial effect in terms of the water quality within Reach 2, flow augmentation may affect stream productivity. Increased peak flows and unseasonal peak flows have been observed to impact stream productivity by flushing the young-of-the-year trout and by altering instream habitat. Prior to 1981, when the Mt. Elbert Tunnel came on line, peak flows were greatly increased and extended. Pre-1982 peak flows appear to have altered the condition of the channel downstream from Lake Fork. Recently, the level of augmentation appears to have been better managed with respect to fishery concerns. Although it is not possible to sort the benefits of dilution from the negative influences of increased flow and habitat alteration, further improvements in managing flow augmentation would most likely benefit stream productivity.

Metals accumulation by vegetation was specifically identified as a concern to ranchers within Reach 2. Observations of a bone formation disease, osteochondrosis, in the late 1980s led to investigations of the metals concentration in a foal with this disease. Elevated levels of zinc were observed in organ tissue. Available data do not allow for a determination as to whether soil, water, or forage was primarily responsible for the elevated zinc concentration in the foal's liver tissue, and it is not possible to discern if zinc was the primary cause of the observed osteochondrosis, or if elevated cadmium levels were also involved. However, using standard risk assessment methodology, the probability that mammalian wildlife experience injury in Reach 2 is low (Appendix J).

3.3.1 Hydrology/Geomorphology

- Reach 2 begins at the confluence of Lake Fork with the Arkansas River. Substantially increased flows are evident downstream of Lake Fork. Trans-mountain diversions further increased the discharge of Lake Fork and the Arkansas River until 1981, when much of the increased flow was diverted to Twin Lakes Reservoir through the Mount Elbert conduit, thereby reducing the flow in the upstream portion of the Arkansas River. However, during extreme events significant amounts of water are released through Lake Fork. East side ephemeral stream tributaries Iowa Gulch and Thompson Gulch provide snowmelt runoff and storm runoff to the Arkansas River. Irrigation water is diverted on the west side for the Derry No. 1 Ditch, which conveys water to Box Creek, which in turn delivers water to Reach 4.

- Subreach 2A is less steep than the upstream reaches (Table 2-3) and contains considerable mine-waste (Table 2-30), but only 14 percent of the banks contain exposed mine-waste. Subreach 2B consists of two channels, and contains significantly less mine-waste than Subreaches 1C and 2A. InterFluve (1999) indicates that bankfull discharge is large, as is the bankfull recurrence interval. Width and depth are larger than Subreach 2A, and mine-waste has probably moved through this channel to Subreach 3A. Only 1 percent of the banks expose mine-waste (Table 2-30).

- The railroad track first enters the designated 500-year floodplain approximately 3 miles downstream of the confluence with California Gulch, where it cuts almost due south through the middle of the floodplain. For about 2000 feet, while traveling within the designated floodplain, it appears that the railroad track has acted as a hydrological barrier, constricting the path of the river to the western side along the track. Although the track travels within the designated floodplain for 0.5 miles, it travels along the eastern edge for about 0.33 miles before entering at the north, and travels along the western edge of the marked floodplain boundary for approximately 0.66 miles after exiting the marked floodplain boundary just south of the Highway 24 Bridge. Because the marked boundary is an arbitrary designation with the floodplain extending well beyond this conservatively marked perimeter along much of its length, this entire length (0.5 + 0.33 + 0.66 miles) was included in the distance the track travels within the designated 500-year flood plain. The railroad right-of-way is not viewed to be a significant baseline factor in terms of stream productivity.

3.3.2 Surface Water

- Surface water resources in Reach 2 are injured by elevated concentrations of cadmium, copper, lead, and zinc during high flows. During low flows, surface waters are injured due to elevated concentrations of zinc. Only single exceedances of TVSs for cadmium, copper, and lead were noted during low flows (Table 3-6).

- Based on the distribution of total metals over the entire POR, cadmium, copper, and lead, show decreasing trends in concentrations during both the high and low flow condition. Zinc shows a decreasing trend only during the low flow condition.

- Compared to Reach 0, mean concentrations of all metals increased in Reach 2 during high flow while copper and zinc increased during low flows. However, during both high and low flows, increases in cadmium, copper, and lead were small. Similar to Reach 0, mean dissolved zinc concentrations were higher during high flows. Average zinc in Reach 2 represents a 2- to 3-fold increase during high flows and a 2-fold increase during low flows relative to Reach 0 average zinc concentrations (Figure 3-4 and Figure 3-5).

- The sources for metals in Reach 2 are concentrations from Reach 0 and California Gulch, with California Gulch being the primary source for zinc in this reach. Mining activities in the Lake Fork drainage and Iowa Gulch may contribute some quantities of metals, but the largest proportion of metals is due to discharge from California Gulch.

- Inflows from the Lake Fork tributary provide dilution that generally results in decreased metal concentrations. Based on the mean concentrations of dissolved metals, Reach 2 had lower concentrations of cadmium, lead, and zinc during both high and low flows relative to Reach 1. Copper was, on average, slightly greater in Reach 2 during both flow conditions. Dilution from Lake Fork reduced hardness values thereby reducing TVSs. Despite this decrease in Reach 2 TVSs, the ratio of TVS exceedances to the total number of samples for a parameter showed relatively similar percentages of exceedances between Reaches 1 and 2. Cadmium, copper, and zinc exceeded the acute TVSs and lead exceeded the chronic TVS during high flow. Only copper and zinc exceeded the acute TVSs during low flow, while cadmium and lead only exceeded the chronic TVSs during low flows. The percentage of samples exceeding the chronic TVSs for all four metals was greater during high flows relative to low flows.

3.3.3 Sediments

- Concentrations of metals in sediments from Reach 2 are elevated over those found in Reach 0. Mean concentrations of cadmium, copper, lead, and zinc are 2.8, 7.2, 9.7, and 7.7 times greater, respectively, in Reach 2 compared to Reach 0.

- Compared to Reach 1, Reach 2 sediment metals concentrations are greater. Given the small sample size, difference in sediment concentrations from Reach 1 may be explained by the expected range of variability in mine-waste. Elevated sediment metals concentrations may also reflect precipitation/settling of metals concentrations from surface waters given the change in water quality and discharge that occurs due to Lake Fork inflows (McCulley, Frick, & Gilman, Inc. 1990).

- The mass and concentration of instream sediments are not sufficient to result in injury to surface water.

3.3.4 Groundwater

- Mean concentrations of cadmium, copper, and zinc decreased in shallow groundwater wells located in Reach 2 compared to mean concentrations observed in Reach 1 wells (Table 3-4). For example, mean dissolved zinc in Reach 2 wells averaged 3.13 mg/L, whereas in Reach 1 wells dissolved zinc averaged 4.36 mg/L. Mean lead concentrations increased in Reach 2 wells (0.011 mg/L) when compared to Reach 1 wells (0.006 mg/L). These differences in shallow groundwater quality reflect differences in mine-waste deposits and well positions rather than general trends in groundwater.

- Although metals concentrations in shallow groundwater are elevated there are no data and no expectations that shallow groundwater is causing Reach 2 surface water to be injured. This conclusion is based upon a review of the surface water data and shallow and deeper groundwater data. In total, these data indicate that dilution and attenuation quickly overwhelm the localized impacts of mine-waste deposits on shallow groundwater. Impacts to surface water are immeasurable and groundwater concentrations decrease rapidly with distance from mine-waste deposits along the horizontal and vertical flow paths.

- Water collected from domestic water supply wells in Reach 2 are well below the MCLs used to define injury.

3.3.5 Floodplain Soils

- A total of 35 mine-waste deposits were identified and characterized by USEPA in 1996 and 1997 (URS 1997 and 1998) (Table 3-5 and Appendix D). There is a total of approximately 233,389 ft^3 of mine-waste, covering a surface area of approximately

405,936 ft^2 in Reach 2. The average depth of the deposits was 0.6 feet; no deposit was found to be greater than 1.5 feet in average depth.

- Soils where mine-waste deposits occur are considered injured. Total metal concentrations exceed toxicity thresholds and plant growth has been substantially impacted on most sites where mine-waste deposits have bee identified. Of 35 deposits along Reach 2, two deposits have poor vegetation cover (<10 percent cover), 19 deposits have fair vegetation cover (10-15 percent cover), and 14 deposits have good vegetation cover (>50 percent cover), using aerial photographs to judge plant cover (Section 3.3.6.1).

- Compared to Reach 0, total metals concentrations in floodplain (riparian) soils along Reach 2 are substantially higher. Plant-available metals concentrations in Reach 2, however, are similar to Reach 0. Based on concentrations in the literature considered to induce a phytotoxic response in plants, the plant-available concentrations in Reach 2 are well below levels reported to be phytotoxic. Therefore, based on plant-available concentrations, floodplain soils are not considered to be injured.

- Keammerer (1987) reported on total and plant-available (bioavailable) metal concentrations in soils not directly impacted by mine-waste deposition along this reach of river (Table 3-1). Keammerer's data showed total metal concentrations for all metals to be substantially lower than those reported by Levy et al. (1992) and Sommers et al (1991). Keammerer sampled at eight different locations and presented what is believed to be a more representative view of the soil metal regime in this area. Data from Keammerer (1987) revealed low plant-available metals concentrations at the sample locations used in this study (Table 3-1).

- Plant tissue concentrations of zinc are in the phytotoxic range for some samples collected by Keammerer (1987). See section 3.3.6.1 (Vegetation) for further discussion of injury.

3.3.6 Biota

3.3.6.1 Terrestrial Vegetation

- Vegetation is considered injured where most mine-waste deposits occur. Of the 35 mine-waste deposits identified along Reach 2, 21 deposits have poor to fair vegetation cover based on evaluations of aerial photographs of the deposits.

- Cover, biomass, and number of species in Reach 2 are equal to or grater than Reach 0. Average zinc concentrations in grasses and forbs are below phytotoxicity thresholds (Table 3-2), but some individual plant samples had tissue concentrations that were in the toxic range for agronomic species (Table 2-45). It is important to note that toxicity thresholds vary among plant species and perennial species are generally much more metal tolerant that annual agronomic species that are more commonly cited in the toxicity literature. Work by Paschke et al. (2000) on zinc toxicity in native perennial species established zinc toxicity thresholds for perennial grasses. Toxicity was not reported for zinc until plant tissue concentrations exceeded 2,000 mg/Kg. This is two times higher than the tissue concentrations found in Reach 2. The USEPA study on irrigated soils planned for 2001-02 should provide additional data to answer the question of phytotoxicity. Currently, there is not evidence of metal-induced injury in Reach 2 for vegetation growing in riparian areas.

- Sommers et al. (1991) reported zinc-induced iron deficiency/chlorosis on the Smith Ranch. However, data on plant cover and production were not collected in a way to determine if this chlorosis has resulted in a significant reduction in plant growth. Field observations in 2000 and 2001 along Reach 2 provide supporting evidence that plant communities are healthy and similar in productivity and cover to Reach 0.

- Reach 2 exhibits a shift in the terrestrial habitat. The upgradient half of Reach 2 is similar to Reach 1. Along the riparian corridor, the lower half of this reach is dominated by riparian herbaceous vegetation consisting primarily of sedges and rushes indicative of waterlogged soils. Similar to upstream reaches, the uplands are dominated by herbaceous riparian vegetation consisting of sedges, rushes, and mesic grasses representative of moist soils. The area is interspersed with unvegetated mine-waste deposits and sandbars.

- Tissue metal concentrations of cadmium are high enough to potentially pose a problem for ruminants; however, toxicity cannot be determined without a detailed study of an animal’s diet along with corresponding animal physiological/pathological tests (Section 3.3.6.2.1).

3.3.6.2 Aquatic Community

3.3.6.2.1 Benthic Community

- Microcosm experiments show that aqueous metal levels in Reach 2 are sufficient to cause significant mortality to most macroinvertebrate taxa. Field sampling showed a large reduction in total mayfly abundance (43 percent) and density of metal-sensitive Heptageniidae (73 percent). The species richness of mayflies was reduced by 23 percent. There was some indication of improvement in benthic communities in Reach 2 compared to Reach 1. This improvement most likely resulted from reduced metal levels in water and periphyton, primarily due to dilution from Lake Fork.

- Total macroinvertebrate abundance in Reach 2 was greater than abundances at either Reach 0 or Reach 1. However, total mayfly abundance and number of heptageniid mayflies were reduced compared to Reach 0. Similar patterns were observed for species richness of macroinvertebrates in Reach 2. Total species richness in Reach 2 was similar to that observed in Reach 0; however, species richness of mayflies was lower than Reach 0.

- Results of acute toxicity tests conducted with water collected from Reach 2 in 1987 (e.g., prior to treatment at both the LMDT and Yak Tunnel) showed 100 percent mortality to *Ceriodaphnia*. However, experiments conducted in subsequent years (after 1994) reported less mortality (LC50 values ranged from 37-56 percent).

3.3.6.2.2 Fish Populations

- Results of field surveys in the Arkansas River and experiments indicate that brown trout in Reach 2 are injured by exposure to heavy metals. Metal concentrations are sufficient to cause acute and chronic effects on resident populations. In addition, length-frequency distributions of brown trout populations suggest relatively poor recruitment. Although these data indicate that brown trout populations are reduced in Reach 2, there is some evidence of increased abundance and biomass compared to Reach 1. Increased biomass and abundance in Reach 2 are most likely a result of both lower metal levels and improvements in overall habitat quality.

- Chadwick (1998) site AR-4 falls within Reach 2, which is dominated by runs and low gradient riffles, with willows along the banks. Physical habitat inventory indicates that pool habitat is present although in reduced amounts, substrate is predominantly cobble, and undercut banks are substantially greater than in upstream reaches. RBPs used to rate habitat quality categorized the habitat as good in 1994 and optimal during 1998.

- Surveys of brown trout populations in Reach 2 were conducted by the CDOW and others between 1985 and 1999. Prior to 1992, brown trout abundance and biomass were slightly higher in Reach 2 than in Reach 1, but reduced overall compared to Reach 0. In 1994 abundance and biomass were significantly higher than Reach 1 and similar to Reach 0, but in 1997 and 1999 abundance and biomass were similar to Reach 1. Both abundance and biomass were reduced compared to Reach 0 (Figures 3-2, 3-3, and 3-6).

- Based on the quality of the habitat and other characteristics (excluding water quality), the HQI model predicted 180 lbs/acre as a carrying capacity for trout in Reach 2. Such a high standing stock estimate indicates that habitat quality in this Reach is good. Pre-1992 standing stock estimates ranged from 0.88 to 43 lbs/acre. More recently (1994, 1997, and

1999) measured biomass of brown trout to range from 44 to 102 lbs/acre. Reduced measured biomass as compared to the predicted biomass suggests that limiting factors exist causing continued depressed productivity of brown trout in Reach 2, although better than observed in Reach 1.

- The primary change in Reach 2 is the augmentation of flows from Lake Fork. Although much of the trans-basin water that used to be discharged via Lake Fork is now conveyed via the Mt. Elbert Conduit, flows in Lake Fork are still augmented and, as such, increase flows in the Arkansas River and result in unnatural flow patterns. Dilution from Lake Fork is likely the primary influence causing increased biomass measured for Reach 2. However, the potentially negative role of regulated flows on trout populations within Reach 2 cannot be separated from that of metals. Therefore, although increased abundance would be expected, the level of recovery expected from further water quality improvements, cannot be quantified. No reach specific toxicity data were available for Reach 2. However, metal levels in this reach exceed concentrations known to be toxic to brown trout (Davies and Brinkman 1999).

- A recently published report by Nehring & Policky (2002) evaluates trends in trout populations over the last 16 years. This report indicates continued improvement in brown trout fishery. It states that if this trend continues over the next several years, it may be strong empirical evidence that the efforts at ameliorating heavy metal pollution are beginning to have a positive effect on the trout population.

3.3.6.3 Terrestrial Vertebrates

3.3.6.3.1 Small Mammals

- Small mammals were collected in Reach 2 from irrigated pasturelands and near fluvial mine-waste deposits. Neither liver nor kidney metal concentrations from Reach 2 exceed literature-based benchmarks associated with physiological and histopathological effects, but most liver and kidney metal concentrations from Reach 2 were higher than Reach 0 (Appendix J).

- Tissues from eight voles and two short-tailed weasles were evaluated for microscopic-level effects (histopathology) and none of the tissues showed effects associated with metals exposure.

- Small mammal tissue samples from the NPL site (representing areas of higher exposure) and Reach 0 (representing areas of lower exposure) did not exceed literature-based benchmarks nor did they exhibit histopathological effects.

- Based on direct measure of injury in Reach 0 and 2 and indirect measures (comparisons with the NPL site data) there is no injury to small mammals in Reach 2.

3.3.6.3.2 Large Mammals

- There are no injury-specific large mammal data from Reach 2, therefore, vegetation and soils data were used to characterize injury following a risk assessment approach (Appendix J).

- Mean cadmium concentrations in grasses and forbs (1.6 and 3.4 mg/Kg for grasses and forbs respectively) reported by Keammerer (1987) exceed the recommended dietary levels for ruminants (0.5 mg/Kg), but are within the range of maximum acceptable exposure with no observed effect (NOEL) (3-5 mg/Kg) (Church 1988). Levy et al. (1992) reported cadmium concentrations of 13.2 mg/Kg in willow (one sample from Reach 1), 21 mg/Kg in iris (one sample from Reach 2), and 7.3 mg/Kg in Yarrow (one sample from Reach 2). These values exceed the 10 mg/Kg associated with mild renal dysfunction, but neither iris nor willow are primary dietary components of ungulates occurring in this area.

- Estimation of metals intake from ingestion of vegetation and soils from Reach 1 do not exceed NOEL-based Toxicity Reference Values indicating very low potential for injury to large mammals in Reach 1 (Appendix J).

- Average zinc concentrations in vegetation are below the limit associated with copper deficiency, but some individual samples exceeded the lower limit. Reports of iron and copper deficiencies on the Smith Ranch may be attributed to elevated zinc levels in both soils and vegetation. Elevated zinc levels in forage (3,000-1,000 mg/Kg) can result in zinc induced copper deficiency in cattle (Hambidge et al. 1986). Because livestock are known to ingest soils during grazing (1-20 percent of dry matter intake), soil may be a significant route of zinc exposure for livestock.

- Beginning in the 1930s, cases of foals exhibiting lameness and swelling of joints have been reported in the UARB, in the Leadville area (Farrington 1985). In 1986, a foal from the Smith Ranch exhibiting these symptoms was necropsied by veterinarians at Colorado State University and a diagnosis of osteochondrosis was made (Norrdin 1987). Osteochondrosis is a bone formation disease where cartilage does not turn to bone as normally occurs during the time of bone formation. Because cartilage is retained, the shape of the forming bone may be altered, and the joints become swollen, culminating in slight to severe lameness and, in further stages, complete debilitation (PRC Environmental Management 1992). With respect to the foal from the Smith Ranch, cause and effect of the osteochondrosis could not be established because background levels of metals in organs of non-clinical foals from the area were not determined. However, this foal had a zinc concentration of 900 ppm in its liver (Smith 1992) (normal range in horses is 40 to 125 ppm, with a high range of 160 to 500 ppm), which is a level consistent with the toxic signs of stiffness, lameness, and osteochondrosis. Foals are naturally susceptible to osteochondrosis because of their high growth rate and long bones. The lesions associated with this disease develop during the third to sixth month after birth (Rooney 1975).

- As noted earlier, cadmium is elevated in forage species in this area, and cadmium toxicosis affects bones and kidneys. It has been suggested that zinc can partially offset the toxic effects of cadmium (Amdur et al. 1991) and high zinc intake can actually provide some protection from cadmium toxicosis in horses (PRC Environmental Management 1992). However, cadmium or zinc can antagonize copper metabolism in horses by displacing copper from sulfhydryl-binding sites (Evans et al. 1970). Copper deficiency on these binding sites can result in abnormal collagen formation and weak bones. It is therefore possible that the osteochondrosis in foals can be associated with elevated cadmium or zinc interfering with copper metabolism, or with the more direct effect of excessive zinc exposure. Any cause of osteochondrosis must remain circumstantial at this point because no study has demonstrated a cause and effect between the disease and metal concentrations in forage. A conclusion as to injury to livestock cannot be made without further analysis.

3.3.6.3.3 Birds

- Metal concentrations in aquatic invertebrates were higher than Reach 0 and the Study Reference indicating increased metals exposure. Although there was a significant increase in metals exposure in Reach 2 compared to Reach 0, overall neither blood nor liver metal concentrations were significantly higher for Reach 2 compared to Reach 0 and only slightly higher than the Study Reference.

- ALAD for both dippers and swallows was significantly reduced compared to the Study References, but was not significantly different than Reach 0 and ALAD was not reduced by > 50 percent for either species.

- Dipper metallothionein levels in Reach 2 were 50 percent higher than Reach 0 and 82 percent higher than the Study Reference indicating increased exposure, but not necessarily injury.

- Tree swallow nest success in Reach 2 was lower than the nationwide average (Robertson et al. 1992) and significantly less than nest success in Reach 0. Nest success in Reach 2 was the lowest of any colony sampled on the Arkansas River.

- Based on the reduced nest success in Reach 2 compared to Reach 0, there is injury occurring to migratory birds.

3.3.7 Baseline Considerations

- In addition to flow augmentation mentioned above for Reach 0, substantial flow augmentation to the Arkansas River occurs via Lake Fork Creek south of Turquoise Lake. Turquoise Lake is augmented by water transported from the Colorado River Basin by the Homestake Tunnel, the Boustead Tunnel, and the Busk-Ivanhoe Tunnel.

  From 1976 to 1983, flows measured upstream and downstream of the Lake Fork influence depict a significant influence of flow augmentations when both native and augmented flows were conveyed down Lake Fork. During this time frame, there were numerous events where flows as measured at the USGS gage near Malta experienced inordinately higher discharges of longer durations and unique hydrologic events relative to the reach upstream of California Gulch. Mean daily flow data from 1976 to 1983 indicate that augmentations via Lake Fork affected the shape and magnitude of the Arkansas River hydrograph at Malta. Since 1981, nearly all imported and native inflow to Turquoise Reservoir has been conveyed through the Mt. Elbert Conduit. BOR compared native inflows into Turquoise Reservoir with measured reservoir outflows from 1992 to 1998. During this time period the volume of water released from the reservoir was from 25 percent to 84 percent less than native inflows to the reservoir. These data indicate that the effects of flow diversions through the Mt. Elbert conduit on the native inflow hydrograph range from an almost complete diversion of runoff (1992), to a postponement of the peak runoff event (1993), to a combined increase and postponement of peak discharge (1998).

  Data received from BOR making similar comparisons indicates that prior to the Mt. Elbert conduit coming on line, from 1970 to 1981, differences in native inflows versus reservoir outflows ranged from 136 to 292 percent as increased discharge from the reservoir and water discharged to Lake Fork. In 1982, there was a net reduction of 87 percent between inflows and outflows. In 1983 there was a 179 percent increase, and from 1984 to 1996 there was an 18 percent to 88 percent reduction in flows. In 1994, 1995, and 1996 there was a 79 percent, 75 percent, and 18 percent reduction in outflows compared to native inflows. Timing and magnitude of these events are similar to that described for 1993 where there was a combined increase and postponement of peak discharges (InterFluve 1999).

In summary, the flow differences between upstream and downstream of Lake Fork have been erratic due to increases and decreases of reservoir releases. From 1984 to 1996 there was a net reduction in outflows from the reservoir. Augmentation has occurred by increases in flows following normal peak discharge periods. The effects are not only a function of net increase or decrease in flows but also a function of timing.

- It is difficult to separate this reach from that of Reach 1 in terms of impacts due to livestock grazing. Based on historical accounts of livestock grazing in the Arkansas River valley in the Leadville area in general (Klima and Scherer 2000), this reach was likely occupied by large cattle and/or sheep ranches and experienced overgrazing not significantly different from Reach 1. This area currently experiences low high-density cattle grazing. Uncontrolled grazing coupled with flow augmentation and the presence of mine-waste deposits has led to eroding streambanks in some reaches of this section. However, in 1999, the Lake County Soil Conservation District and the Natural Resource Conservation Service initiated a riparian fencing and rotational grazing program on portions of this reach.

3.4 Reach 3: Highway 24 Bridge to Narrows Below CR 55 Bridge

Reach 3 of the Arkansas River generally continues to show improvements in surface water quality relative to upstream sampling locations. Improvements can be linked to dilution from additional inflows and, most likely, some level of attenuation. However, although improvements in surface water zinc concentrations are observed, cadmium, copper, and lead do not always follow that pattern.

Mine-waste deposits are prevalent along Reach 3. The channel morphology of the river through this reach has resulted in an increase of mine-waste deposits per river mile compared to Reach 2 (Table 2-30). Reach 3 has a low bankfull capacity and, therefore, has probably experienced more historical overbank flow, resulting in deposition of more mine waste. The shallow channel morphology appears to be due to deposition of coarse spoils from early hydraulic mining activities followed years later by increased flows from trans-mountain diversions through Lake Fork. On average, concentrations of metals in the mine-waste deposits are less than Reach 1, but slightly higher than Reach 2. Total and plant-available metals concentrations in soils are similar to Reach 2, as are plant tissue concentrations of metals. Consistent with Reaches 1 and 2, injuries related to soil function and vegetation cover at the locations of mine-waste deposits are present along Reach 3.

Several USGS studies have been conducted within Reach 3 to look at the effects of mine-waste deposits on metals concentrations in shallow groundwater and flow in the Arkansas River. Shallow wells were completed within and adjacent to mine-waste deposits, and surface water samples were collected from a side channel of the Arkansas River in contact with a mine-waste deposit, and at locations immediately upstream and downstream of the deposit. Localized influence on metal concentrations in groundwater within the deposit was observed, but elevated concentrations dissipated rapidly with distance, most likely due to the larger flows and strong interaction of surface and groundwater in and along the channel. Direct metals loading to the Arkansas River could not be measured in the surface water samples. As for upstream reaches, this is due both to a low potential for the shallow mine-waste deposits to contribute a significant mass of metals and to the dilution effects of the large volume of surface and groundwater flows in the system. Groundwater from domestic water supply sources in Reach 3 does not exceed the MCLs.

Data indicate that injuries to aquatic organisms due to elevated metals concentrations are lessened, but still evident in this reach. In general, it is expected that productivity in Reach 3 would increase with improvements in water quality. Correspondingly, overall abundance of benthic organisms including sensitive species is similar to Reach 0. However, the long, straight, and shallow channel configuration that exists over much of Reach 3 offers little fish holding habitat for periods of runoff/augmented flow. The presence of a large number of mine-waste deposits, and possibly grazing, has reduced the quality of riparian habitat along the banks of this reach and, in turn, influences instream habitat. These factors, when coupled with elevated metals concentrations, likely contribute to reduced trout populations and carrying capacity within Reach 3.

Recent acquisition of a large portion of the land adjacent to Reach 3 by the State and County should allow for reduction or elimination of the current level of grazing activity along Reach 3. Management of instream fish habitat, along with improvements in the riparian habitat, will now be achievable, and the further resource recovery in this area should benefit accordingly.

3.4.1 Hydrology/Geomorphology

- The channel in Subreach 3A was active in the past, but is less so presently, and the floodplain contains a relatively large amount of mine-waste, but only 15 percent of the banks expose mine-waste. The large quantity of mine-waste in Subreach 3A is probably related to the high frequency of overbank flooding, the wide floodplain, and the relatively low gradient of this subreach. The east side tributaries of Empire Gulch and Dry Union Gulch provide ephemeral flows during snowmelt and summer storms. Subreach 3B is steep and this channel was also more active in the past than in the present (Table 2-3). This reach contains less mine-waste than Subreach 3A (Table 2-30), probably because of its steep gradient (Table 2-3). Only 9 percent of the banks in Subreach 3B expose mine-waste. Big Union Creek is perennial and contributes flow to the southernmost part of Subreach 3B.

- Approximately 1,500 feet south of the Highway 24 Bridge, the highway exits the 500-year flood plain and extends southward for approximately 2 miles before re-entering the western edge of the floodplain. It then runs parallel to the western edge of the floodplain for approximately 4,500 feet, but does not appear to have any constraining influence. Approximately 0.5 miles south of county road 55 at Kobe, Highway 24 re-enters the floodplain on the western edge and could act as a hydraulic barrier constraining the river. At this point, natural topography forces the highway and river close together for a few hundred feet, after which the flood plain re-opens.

3.4.2 Surface Water

- Based on the concentrations of cadmium, copper, lead, and zinc in surface water resources in Reach 3, surface waters in this reach are injured during both high and low flows (Table 3-7).

- The distribution of total metals across all time periods for Reach 3 shows no clear trends in concentrations increasing or decreasing for any of the four metals evaluated. The evaluation is limited by a small set of data in the early 1970s followed by no data available until about 1990. Focusing on Period 3, cadmium, copper, and lead concentrations remain relatively static, but zinc shows a distinct decrease in total concentrations.

- During high and low flows, mean concentrations of cadmium, copper, and lead increased in Reach 3, compared to Reach 2, and mean zinc was lower. During high flows, cadmium, copper, and zinc exceeded the acute TVSs and lead exceeded the chronic TVS. During low flow, copper and zinc exceeded the acute TVSs, and cadmium and lead exceeded only the chronic TVSs. During high and low flows, there was a substantial increase in the number of exceedances of the TVS for copper in Reach 3 when compared to Reach 2. The percentage of samples exceeding the chronic TVSs was greater during high flows relative to low flows. Elevated copper concentrations were noted to occur between 1995 and 1997 and then decline to a level more consistent with the data collected prior to this time. Continued decline of mean zinc concentrations in Reach 3 during both the high and low flow periods suggests that upstream sources are controlling water quality.

- Compared to Reach 0, mean dissolved concentrations of all metals increased in Reach 3 during high and low flows. However, during high and low flows, increases in cadmium, copper, and lead are small. Mean zinc concentrations exhibited substantially larger concentrations relative to Reach 0. Mean dissolved zinc concentrations were higher during high flows in Reach 3. Average zinc in Reach 3 represents about a 2-fold increase during high and low flows relative to Reach 0 mean zinc concentrations (Figure 3-4 and Figure 3-5).

3.4.3 Sediments

- Concentrations of metals in sediments from Reach 3 are elevated over those sediments found in Reach 0; however, metals in sediments from Reach 3 are not as elevated as those in Reach 2. Mean concentrations of cadmium, copper, lead, and zinc are 1.3, 1.2, 4.4, and 3.3 times greater, respectively, in Reach 3 compared to Reach 0.

- The mass and concentration of instream sediments are not sufficient to result in injury to surface water.

3.4.4 Groundwater

- Mean concentrations of cadmium, copper, and lead increased in shallow monitoring wells located in Reach 3 compared to mean concentrations observed in Reach 2 shallow monitoring wells (Table 3-4). Mean dissolved zinc in Reach 3 wells averaged 2.35 mg/L whereas in Reach 2 wells, dissolved zinc averaged 3.13 mg/L. This difference is more likely due to the nature of the specific mine-waste deposits where wells were constructed and the screened intervals than to the general conditions of groundwater. A significant number of samples in a distributary channel that bisects mine-waste deposits were collected, resulting in the above reported observations. However, although concentrations of shallow groundwater are elevated, Reach 3 specific studies do not indicate that discharging shallow groundwater is resulting in injury to the surface water resources.

- Sampling of a domestic water supply within Reach 3 indicates concentrations below levels indicative of injury.

3.4.5 Floodplain Soils

- Soil where mine-waste deposits occur are considered to be injured. Total metal concentrations exceed toxicity thresholds and plant growth has been substantially impacted on most sites where mine-waste deposits have been identified. Of 94 deposits along Reach 3, 26 deposits have poor vegetation cover (<10 percent cover), 56 deposits have fair vegetation cover (10-50 percent cover), and 12 deposits have good vegetation cover (>50 percent cover), using aerial photographs to judge plant cover.

- A total of 94 mine-waste deposits were identified and characterized by EPA in 1996 and 1997 (URS 1997 and 1998) (Table 3-5 and Appendix D). There is a total of approximately 1,578,311 ft^3 of mine-waste covering a surface area of approximately 1,638,612 ft^2 in Reach 3. The average depth of the deposits was 1 foot. Seven deposits were found to be over 2 feet in average depth, with one deposit having an average depth of 3 feet.

- Compared to Reach 0, total metals concentrations in floodplain (riparian) soils along Reach 3 are substantially higher. Plant-available metals concentrations in Reach 3, however, are similar to Reach 0. Based on concentrations in the literature considered to induce a phytotoxic response in plants, the plant-available concentrations in Reach 3 are well below levels reported to be phytotoxic.

- Keammerer (1987) sampled soils at seven locations along the portion of the Arkansas River between Highway 24 and the confluence with the narrows (Table 3-1). Total and plant-available (bioavailable) soil metal concentrations were similar to concentrations reported for portions of the river upstream of this river reach. Total metal concentrations for cadmium, lead, and zinc were within the toxic range for agronomic species, but all plant-available concentrations (cadmium, copper, lead, and zinc) were well below concentrations considered to be phytotoxic. As reported for the other river reaches, the soil metals in this reach between Highway 24 and the Narrows have low bioavailability.

3.4.6 Biota

3.4.6.1 Terrestrial Vegetation

- Vegetation is considered injured where most mine-waste deposits occur. Of the 94 mine-waste deposits identified along Reach 3, 82 deposits have poor to fair vegetation cover based on evaluations of aerial photographs of the deposits.

- Cover in Reach 3 is greater than Reach 0. Biomass is the same and number of species in Reach 3 is slightly less than Reach 0. All tissue metal concentrations are below thresholds considered to be toxic to perennial species. There is no evidence of metal-induced injury in Reach 3 for vegetation growing in riparian areas.

- Reach 3 terrestrial habitat is similar to the lower segment of Reach 2, with the riparian area dominated by herbaceous vegetation indicative of saturated soils (e.g., sedges and rushes), with areas of open standing water. The upland is interspersed with riparian shrub vegetation consisting of willow species. The primary difference in Reach 3 is the presence of large areas of unvegetated mine-waste deposits and unvegetated sandbars.

- Keammerer (1987) reported that average concentrations of all metals in grasses and forbs were below concentrations considered to be excessive or toxic to agronomic plants (Table 3-2). But some individual plant samples had zinc tissue concentrations that were in the toxic range for agronomic plants (Table 2-55). It is important to note that toxicity thresholds vary among plant species and perennial species are generally much more metal tolerant than annual agronomic species that are more commonly cited in the toxicity literature. Work by Paschke et al. (2000) on zinc toxicity in native perennial species established zinc toxicity threshold for perennial grasses. Toxicity was not reported for zinc until plant tissue concentrations exceeded 2,000 mg/Kg. This is two times higher than the tissue concentrations found in Reach 3.

- Plant tissue metal concentrations of cadmium are high enough to potentially pose a problem for ruminants; however, toxicity cannot be determined without a detailed study of an animal's diet along with corresponding animal physiological/pathological tests (Section 3.3.6.2.1).

3.4.6.2 Aquatic Community

3.4.6.2.1 Benthic Community

- Results of analyses indicate that benthic macroinvertebrates in Reach 3 were injured by exposure to metals. Microcosm experiments show that aqueous metal levels are sufficient to cause significant mortality to most macroinvertebrate taxa. In laboratory experiments, sediments from Reach 3 reduced growth and survivorship of chironomids. Significant loss of genetic diversity in mayflies was also observed. A reduction in mayfly richness (46 percent) and total abundance (40 percent) of mayflies was observed in Reach 3 compared to Reach 0. Metal-sensitive Heptageniidae were reduced by 76 percent and highly elevated metal levels were measured in most dominant taxa. Concentrations of cadmium and zinc were 2-2.5 times greater in the caddisfly *Arctopsyche* compared to Reach 0. Surface water is a major pathway for metal exposure of benthic macroinvertebrate. However, elevated metal concentrations in periphyton, a food source for many species, also contribute to the level of exposure. Accumulation of metals by chironomids exposed to sediment collected from Reach 3 was observed.

- Results of acute toxicity tests conducted with water collected from Reach 3 in 1987 showed 100 percent mortality to *Ceriodaphnia*; however, subsequent experiments showed considerably less acute toxicity to invertebrates. Experiments conducted with fathead minnows in 1991 showed that exposure to water from Reach 3 at concentrations exceeding 50 percent were acutely toxic. Chronic toxicity tests conducted in fall 1990 and spring 1991 with *Ceriodaphnia dubia* showed that organisms exposed to water from Reach 3 were affected by metals. Significant seasonal variation in metal toxicity was also observed, reflecting seasonal differences in total zinc concentrations. However, toxicity testing for this reach has not been conducted since the onset of treatment at the Yak Tunnel and the LMDT in 1992.

- Recent total macroinvertebrate abundance generally exceeded 700 individuals per 0.1 m^2 and was greater at this reach compared to other upstream reaches. Increased abundance in this section of the Arkansas River resulted primarily from a large increase in abundance of caddisflies and dipterans, which accounted for greater than 50 percent of the benthic community. Recent data (1999-2000) show that total abundance of mayflies and stoneflies was similar to Reach 0. Temporal patterns of benthic community structure in Reach 3 reflect improvements in water quality following remediation of California Gulch. Several metal sensitive species, which were either rare or absent before 1992, were collected in benthic samples in subsequent years.

- Concentrations of cadmium, copper, and zinc were significantly elevated in benthic macroinvertebrates collected in Reach 3 compared to Reach 0. Large differences among species were also reported, with highest levels of metals measured in grazing mayflies. Long-term analyses of metal concentrations in *Arctopsyche grandis* showed that levels of cadmium and zinc were lower in Reach 3 compared to Reach 1; however, metal levels in organisms remained elevated compared to Reach 0. There was also some evidence of reduced metal uptake by caddisflies following remediation of California Gulch and the LMDT.

- Metal concentrations measured in benthic macroinvertebrates collected from AR-5 in Reach 3 in the Arkansas River (Kiffney and Clements 1993) are illustrated in Figure 2-85. For cadmium and zinc, concentrations ranged from higher to lower for the following species: *Baetis*, *Pteronarcella*, *Arctopsyche*, *Skwala*, and *Rhyacophila*.

- Genetic diversity of mayflies increased dramatically in Reach 3 as a result of dilution of metals and immigration of new individuals (and new genotypes) from local tributaries. The highest genetic diversity measured in the Arkansas River was recorded in Reach 3.

- Elevated levels of metallothionein in mayflies indicated that mayflies from Reach 3 were exposed to heavy metals. Despite significantly greater concentrations of total cadmium, total Metallothionein in mayflies was less in Reach 3 compared to Reach 0.

- Concentrations of cadmium and zinc in sediment and periphyton collected from Reach 3 remained elevated compared to samples collected from Reach 0. Cadmium and zinc levels were between 3-4 times greater in periphyton than in sediment. Sediment toxicity tests showed that acute toxicity was reduced in Reach 3 compared to Reach 1. Chironomids exposed to sediments from Reach 3 accumulated cadmium, copper, lead, and zinc. In contrast to the spatial pattern of decreasing concentrations with downstream distance observed for sediments, metal levels in chironomids did not follow a similar pattern. These results suggest that factors other than bulk metal concentration influenced metal bioavailability to benthic organisms.

3.4.6.2.2 Fish Populations

- Results of field surveys in the Arkansas River and experiments indicate that brown trout in Reach 3 are injured by exposure to heavy metals. Metal concentrations in water exceed criterion values and are sufficient to cause acute and chronic effects on resident populations. Field surveys conducted by the CDOW showed large reduction in abundance (75 percent) and biomass (46 percent) at Reach 3 compared to Reach 0 across all dates. Surprisingly, reductions in biomass and abundance of brown trout were greater in Reach 3 than in Reach 2, despite slightly improved water quality. Length-frequency distributions of brown trout populations suggest poor recruitment of juveniles. Feeding habits of brown trout are shifted to include a greater proportion of metal-tolerant taxa (chironomids and caddisflies).

- Although no studies assessing effects of water from Reach 3 on brown trout have been conducted, zinc levels in this reach exceed concentrations known to be toxic to brown trout (Davies and Brinkman 1999).

- Surveys of brown trout populations in Reach 3 conducted from 1994 to 1999 by CDOW and others generally showed that population abundance and biomass were reduced compared to Reach 0. Although surveys conducted in August 1997 showed some evidence of recovery in Reach 3, abundance and biomass were considerably less than those in Reach 0 (Figures 3-2, 3-3, and 3-6). Furthermore, during all four years that the biomass estimates were made, the biomass at Reach 3 was always greater than measured in Reach 1.

- Age 2 trout were the most common age class in Arkansas River samples, but also varied in abundance among stations. Age 2 trout were present at all sampling stations during all years and seasons. However, their abundance was consistently reduced downstream from California Gulch. Age 3 trout were most common in sites downstream and at stations AR-4 and AR-1. This age class was generally absent from fall samples, except for a few individuals downstream and at station AR-4.

- Chadwick (1998) site AR-5 falls within Reach 3, which was dominated by runs and low gradient riffles, cobble substrates, and willow along the stream banks. Inventory of the habitat revealed that pool habitat is not present, substrate is uniform and not diverse, and undercut banks are substantially reduced. RBP ratings conducted by Chadwick (1998) indicate excellent habitat for reach AR-5 during 1994 and optimal habitat during 1998. These scores are not at all consistent with the more quantitative data of the habitat inventory. HQI ratings indicate that cover, stream bank erosion, and water velocity are limiting the potential carrying capacity. Predicted trout biomass for AR-5 was 82 lbs/acre. Combined, these data indicate that there are components of the aquatic physical habitat that are limiting to trout in Reach 3, specifically, reduced cover along streambanks, poor habitat diversity (e.g., pools were very infrequent), and timing and magnitude of water velocities.

- Based on the quality of the habitat and other characteristics (excluding water quality), the HQI model predicted 82 lbs/acre as a carrying capacity for trout in Reach 3. Biomass measured during the fish surveys at sites in Reach 3 from 1991 to 1999 ranged from 40 to 59 lbs/acre. Reduced measured biomass, as compared to the predicted biomass, suggests that limiting factors exist causing continued depressed productivity of brown trout in Reach 3, although better than observed in Reach 1. Continued effects of water quality are present, albeit not as great, and there is a reduced availability of high quality habitat.

- Clements and Rees (1997) found that brown trout from Reach 3 consumed greater numbers of chironomids and caddisflies in Reach 3, because these were the dominant prey species available. Concentrations of heavy metals in dominant prey taxa and brown trout stomach contents were greater at Reach 3 compared to Reach 0.

- Nehring (1986) compared tissue metal levels in age 1, 2, and 3 brown trout collected from Reach 3 (Figure 2-46). Results showed that cadmium concentrations were generally greater compared to Reach 0, and that levels increased with fish age. Based on these early studies, Nehring (1986) concluded that long-term exposure to metals in the Arkansas River, particularly cadmium, has had a significant detrimental impact on brown trout populations.

- Metal levels were significantly elevated in brown trout gill and gut tissue collected from Reach 3, indicating greater metal exposure. However, metal levels in liver and kidney tissue, the primary organs of metal storage and regulation, were either similar or greater at the upstream reach. In addition, brown trout size and condition factors (weight x 100/length^3) were significantly reduced at Reach 0 compared to Reach 3. Finally, although condition factors were significantly correlated with metal levels in liver tissue of fish collected from Reach 0, there was no relationship at Reach 3 (Figure 2-83). Clements and Rees (1997) hypothesized that greater prey abundance and slightly warmer water temperature in Reach 3 influenced fish condition and metal regulation in brown trout.

- A recently published report by Nehring & Policky (2002) evaluates trends in trout populations over the last 16 years. This report indicates continued improvement in brown trout fishery. It states that if this trend continues over the next several years, it may be strong empirical evidence that the efforts at ameliorating heavy metal pollution are beginning to have a positive effect on the trout population.

3.4.6.3 Terrestrial Vertebrates

3.4.6.3.1 Small Mammals

- There are no injury-specific data for small mammals from Reach 3, however, potential exposure from vegetation and soils is similar to Reach 2 and higher than in Reach 0.

- Metals concentrations in small mammal tissue samples from the NPL site, Reach 0, and Reach 2, representing a gradient of metals exposures that are higher and lower than the exposure expected in Reach 3, did not exceed benchmarks nor did they exhibit pathological changes associated associated with metals effects (Appendix J). Therefore, it is not expected that the metals exposure in Reach 3 is at levels that cause injury to small mammals.

3.4.6.3.2 Large Mammals

- Because there are no injury specific data for large mammals from Reach 1, vegetation and soils data were used to characterize injury following a risk assessment approach (Appendix J).

- Mean cadmium concentrations in grasses and forbs (1.6 and 6.4 mg/Kg for grasses and forbs respectively) exceed the recommended dietary levels for ruminants (0.5 mg/Kg). Cadmium concentrations in forbs exceed the upper limit for the range of maximum acceptable exposure with no observed effect (NOEL) (3-5 mg/Kg) (Church 1988).

3.4.6.3.3 Birds

- Average blood lead in American dippers from Reach 3 was significantly higher than in Reach 0. Reach 3 had the highest blood lead concentration in the 11-Mile Reach and the average concentration exceeded the literature-based benchmark.

- ALAD in American dippers and tree swallows was significantly reduced compared to the Study References, but was not significantly different than Reach 0 for either species. This may be due to low-level lead exposure in Reach 0. American dipper ALAD was reduced by 67 percent compared to the Study Reference and tree swallow ALAD was reduced by 39 percent compared to the Study Reference.

- Dipper metallothionein levels in Reach 3 were 17 percent higher than Reach 0 and 70 percent higher than the Study Reference indicating a possible increased metals exposure, but not necessarily injury.

- Aquatic invertebrates from Reach 3 had significantly higher lead (21.9 mg/Kg) and zinc (279.5 mg/Kg) compared to Reach 0 (2.5 mg/Kg Pb and 119.7 mg/Kg Zn).

- Based on the ALAD suppression and blood lead concentrations, there is injury occurring to migratory birds in Reach 3.

3.4.7 Baseline Considerations

- As mentioned under Reach 2, substantial flow augmentation to the Arkansas River occurs south of Turquoise Lake via Lake Fork Creek. There is no additional source of flow augmentation between Highway 24 Bridge and County Road 55. Therefore, this reach should not significantly differ from Reach 2 with respect to impacts of flow regulation.

- It is difficult to differentiate this reach from that of Reaches 1 or 2 in terms of impacts due to livestock grazing. Historical accounts of livestock grazing in the Arkansas River valley in the Leadville area in general suggest that this reach was likely occupied by large cattle and sheep ranches and experienced substantial overgrazing not significantly different from Reaches 1 and 2. In recent history, this reach has received moderate to high intensity grazing. Much of this reach is currently under a riparian fencing and rotational grazing program. Unrestricted livestock grazing, augmented flows, and mine-waste-deposits have created highly erodible banks in some portions of this reach.

3.5 Reach 4: Narrows Below CR 55 Bridge to Two-Bit Gulch Confluence

Additional flow from tributaries and increased channel and valley constriction set Reach 4 apart from Reaches 1-3. These changes in hydrology and morphology likely reduce impacts from historic mining activity. Water quality continues to improve due to further dilution from high-quality tributaries such as Big Union, Box, and Spring Creeks. The narrowing of the floodplain, coupled with increasing flow, has resulted in only a few small deposits of mine-waste. These deposits had not previously been mapped or sampled by USEPA or by others, most likely due to their small size. Evidence of historic hydraulic mining can be seen along Box Creek. Deposition of spoils is evident on the west side of the railroad right-of-way as Box Creek enters the valley floor.

Data on environmental conditions within Reach 4 are sparse. Recent data from the river downstream of Reach 4 suggest continued improvements in water quality. These few downstream data are consistent with the practical view that numerous tributaries of high quality water join the Arkansas River within Reach 4.

Near-stream and instream physical habitat also appear to improve over the length of Reach 4. Data are not available to directly assess the level of injuries present in Reach 4. However, data from Reach 3 and downstream of Reach 4 provide a general understanding of the nature of mining related injuries within this reach.

3.5.1 Hydrology/Geomorphology

- Reach 4 has a relatively gentle slope (Table 2-3), and should be the repository of large amounts of mine-waste from steep Subreach 3B. It contains no mapable mine-waste deposits, and apparently acts as a conduit of upstream sediment that is delivered to the canyon downstream. As in Subreach 2B, the channel capacity is large and overbank flooding is less frequent than in Subreaches 1A, 1B, 1C, 2A, 3A, and 3B. Therefore, Reach 4 has been able to convey mine-waste downstream, and contains little or no mine-waste.

- East side tributaries, Sawmill Gulch and Two-Bit Gulch, contribute ephemeral flows to the Arkansas River during snowmelt and summer storms. Historically, the large west side tributary Box Creek drains an area of dredge tailings, that probably delivered increased amounts of sediment to the downstream reaches of Box Creek and to the Arkansas River at the south end of Reach 4 during the dredging operation.

3.5.2 Surface Water

Surface water data for Reach 4 are not available; however, it is expected that surface water quality will be similar to Reach 3. Slight improvements are expected due to additional clean tributary inflows and continuing attenuation of metals. This is consistent with data collected downstream of Reach 4. Correspondingly, the level of injury is expected to be slightly less than for Reach 3.

3.5.3 Sediments

No data are available for sediments in Reach 4. However, it is expected that sediment metal concentrations will be similar to Reaches 1, 2, & 3, as Reach 4 exhibits the same cobble/boulder channel bottom as upstream reaches and accumulation of fine-grained sediments is limited.

3.5.4 Groundwater

No groundwater data are available for Reach 4. Lack of mine-waste deposits lessens concerns of impacts to shallow groundwater. Adequate upgradient simply indicates Reach 4 would be suitable for domestic water supply use.

3.5.5 Floodplain Soils

- With respect to mine-waste deposits, not enough information exists to draw direct conclusions about injury to vegetation at locations where deposits occur. However, only a few small barren or sparsely vegetated areas consistent with mine-waste deposits could be identified.

- There are no floodplain soils (riparian) or mined-waste data available to make comparisons to Reach 0.

- There is no evidence to indicate injury to floodplain (riparian) soils in Reach 4. Soils metal concentrations decline in each subsequent reach below Reach 0. It is assumed that soil metal concentrations in Reach 4 are lower than in Reach 3. Since floodplain soils are not considered to be injured in reaches upstream of Reach 4, there is no reason to infer that floodplain soils along Reach 4 are injured.

3.5.6 Biota

3.5.6.1 Terrestrial Vegetation

- Evidence of injury to vegetation along Reach 4 is uncertain because no plant cover or chemical data exists for mine-waste deposits. Field observations along Reach 4 confirm that vegetation is productive in floodplain soils. Only a few areas of sparse vegetation coincident with mine-wastes have been observed.

3.5.6.2 Aquatic Community

3.5.6.2.1 Benthic Community

Although surveys of benthic macroinvertebrate communities in Reach 4 have not been conducted, based on metal levels in water it is likely that these organisms are injured by exposure to metals. Metal concentrations in water in Reach 4 are similar to those in Reach 3. Exposure of benthic macroinvertebrates to metals in microcosms at concentrations similar to those observed in Reach 4 caused significant reductions in total macroinvertebrate abundance and abundance of metal-sensitive organisms. However, as noted for Reach 3, observed macroinvertebrate abundance and sensitive species abundance is expected to be similar to Reach 0.

3.5.6.2.2 Fish Populations

- Data on brown trout populations in Reach 4 are very limited. Because metal levels in water can be inferred to exceed those known to cause acute and chronic effects in brown trout, it is likely that populations in Reach 4 are injured by exposure to metals.

- Only a small data set is available for Reach 4 in 1999. Abundance and biomass are much less than Reach 0, and are the lowest of all reaches sampled in 1999 (Figures 3-2 and 3-3). Data collected just downstream of Reach 4 are available for 1985, 1988, and 1994. The data for 1985 and 1988 show relatively low numbers and biomass compared to Reach 0. Data for 1994 show higher numbers and biomass compared to Reach 3, and significantly increased numbers and biomass compared to previous years. It is difficult to compare these data to the upstream reaches based on a single sample period in 1999 supplemented by downstream data from previous years. Based on these data, it is difficult to determine whether there could be some marked recovery or some other disturbance that may depress populations.

- A recently published report by Nehring & Policky (2002) evaluates trends in trout populations over the last 16 years. This report indicates continued improvement in brown trout fishery. It states that if this trend continues over the next several years, it may be strong empirical evidence that the efforts at ameliorating heavy metal pollution are beginning to have a positive effect on the trout population.

3.5.6.3 Terrestrial Vertebrates

3.5.6.3.1 Small Mammals

- The presence of mine waste in Reach 4 creates the potential for metals exposure to small mammals. However there are fewer mine-waste deposits and only a few areas that are void of vegetation. Based on the trend of declining metals concentrations in soil and vegetation from Reach 1 to Reach 3, it is assumed that concentrations in Reach 4 would continue to decline and would not exceed NOELs. Small mammal injury is not expected to occur in Reach 4.

3.5.6.3.2 Large Mammals

- There are no data for large mammals nor are there soils or vegetation data for Reach 4. With the exception of mine-waste deposits, Reach 4 is well vegetated with only a few areas of sparse vegetation. Declining metals concentrations in soils and plants suggests that intake rates for the metals of concern would be reduced in Reach 4 compared to upstream reaches and large mammals would not be injured.

3.5.6.3.3 Birds

- There are no data for birds from Reach 4 nor are there aquatic invertebrate data to evaluate exposure. However, there are no known loading sources in Reach 4, therefore, exposure in Reach 4 is expected to be similar to Reach 3 and Reach 5. Invertebrate and dipper blood samples from Reach 5 have similar metal concentrations as Reach3 and cadmium, copper, lead, and zinc in dipper blood from Reach 5 are in the same range as in Reach 3. Liver cadmium and lead increase slightly from Reach 3 to Reach 5. In both Reach 3 and Reach 5, injury to birds was documented based on >50 percent ALAD suppression and liver and blood lead concentrations exceeding those in Reach 0, thus injury is assumed to be occurring at similar levels in Reach 4.

3.5.7 Baseline Considerations

- It is likely that this reach experienced historical livestock grazing impacts similar to Reach 1-3. In recent history, this reach has received moderate to high intensity grazing. Much of this reach is currently under a riparian fencing and rotational grazing program.

3.6 Data Gaps

Consistent with the Work Plan tasks, the SCR is to identify data gaps that limit or preclude aspects of the characterization. For the purpose of this report, data gaps fall into two categories:

- Injury Determination: Information that would help better define the presence or absence of injury and/or the nature and extent of an identified injury.

- Restoration Planning: Information necessary to better define the need for restoration and/or to better evaluate a range of alternatives.

With regard to injury determination there is an overwhelming amount of contemporary information on the chemical and biological condition of the resources of the 500-year floodplain of the UARB. Although the spatial and temporal distribution of the available information is not as dense for some areas as for others, overall it provides the basis for a very reasonable characterization of injury for the surface water, groundwater, and soil resources.

Spatial gaps in information were often resolved through an understanding of the physical parameters. For example, concerns regarding spotty data for surface water quality at a particular location along the UAR were resolved through a review of upstream and downstream data and an understanding of the interim tributary inflows and/or presence of source materials. This example holds true for groundwater, fluvial mine-waste deposits, and soils as well. Similar inferences were also made for biological resources in terms of spatial gaps. A correlation with the level of injury to the water or geologic resources provided a basis for concluding whether a biological resource would be expected to have a greater or lesser degree of injury potential than upstream or downstream areas.

Another consideration in identifying data gaps was the level of completeness required and/or the level of importance of certain information. For example, the range of individual species that could be considered for injury is extensive. However, the use of indicator species allowed a general understanding of the other species that may be injured, making information on other individual species less important. With regard to biological resources, additional insight was also gained at the habitat level. The chemical quality and condition of the environmental media comprising a range of species habitat were considered to be critical information for both injury determination and for restoration planning. An understanding of the condition of the fundamental resources that comprise important habitat was given far greater importance than data on injury to a specific species.

The following areas have been identified as possible data gaps. Discussion on the roles of additional data are provided relative to the characterization effort and the next effort, which is evaluation of restoration alternatives and restoration planning. Where possible, the type and amount of information to be collected is also discussed.

- Additional objective information on the quality of stream physical habitat for fish is necessary. A more detailed habitat inventory over the 11-mile reach would provide the necessary information to begin to examine relationships between habitat and water quality on trout productivity and to identify areas suitable for restoration. This information would need to be paired with long-term comprehensive monitoring of flow, water quality, and aquatic biota to be of value.

- Soils located in the floodplain along the 11-mile reach, that have not been directly impacted by mine-waste material, are known to have elevated concentrations of metals because of flooding and irrigation practices. However, it does not appear that the plant community or soil microbial community is negatively impacted by these metals, and generally, transfer of metals to higher trophic levels does not appear to be problematic. There is no data gap with respect to characterizing the condition of the soil natural resource. The potential for harm to livestock has been identified because of elevated concentrations of cadmium and zinc in vegetation. Further study of agricultural practices and livestock diet are recommended, but these studies go beyond the characterization of natural resource conditions.

- Data were not found describing the conditions of the resources within Reach 4 beyond observations by USEPA and site reconnaissance in conjunction with the development of this report. This information indicates that there is no significant accumulation of mine-waste within Reach 4. Surface water quality sampling conducted upstream and downstream of Reach 4 are consistent with the inference that water quality continues to improve over the course of Reach 4. With additional clean tributary inflow and additional opportunity for attenuation, it is expected that exceedances of the TVSs will be further diminished relative to upstream reaches.

Because the extent of mine-waste in Reach 4 is known to be limited, additional information is not required for development of restoration alternatives. However, since data describing water quality within Reach 4 are not available, it is not possible to directly document if exceedances of the TVSs are occurring and, if they are, the level of any exceedances.

Considering that water quality data for Reach 4 would primarily be useful to confirm the extent of injury and that such data would best be collected in the context of a multi-station synoptic sampling effort, a separate effort is not recommended. Rather, it is recommended that a water quality and biological monitoring station be included in future sampling work conducted by USEPA, Colorado Department of Health, USGS, USFWS, the Bureau of Reclamation, or any other upcoming government of private party sampling effort. A combined water quality, flow, and biological monitoring effort would be optimal.

- An abundance of USEPA data are available characterizing the individual mine-waste deposits within the 11-mile reach. Additional data are not required for characterization efforts. Data on the acid generating potential of the deposits and more representative sampling of metals concentrations for certain deposits would be useful for any restoration design efforts. Although not critical, they would also be useful for the evaluation of restoration alternatives. If USEPA is contemplating additional sampling efforts, input into the Work Plan regarding these issues can be provided. An independent effort prior to the restoration alternatives reporting requirement; however, is not recommended at this time.

TABLES

Table 3-1

Total and Plant-Available Soil Metal Concentrations for Sites Sampled along the Arkansas River [1]

Reach	Cadmium (mg/kg)		Copper (mg/kg)		Lead (mg/kg)		Zinc (mg/kg)		n [3]
	Total	**PA [2]**	**Total**	**PA**	**Total**	**PA**	**Total**	**PA**	
0	3.3 (±0.57)	1.4 (±0.25)	29.9 (±7.3)	3.9 (±1.1)	238 (±45)	23.7 (±7.3)	428 (±75)	73.9 (±16)	9
1	13.5 (±5.7)	2.9 (±1.1)	192 (±115)	12.7 (±5.3)	3,990 (±1,212)	51.4 (±21)	3,142 (±2,385)	158 (±74)	7
2	15.4 (±3.9)	2.6 (±1.2)	51.4 (±15)	2.5 (±0.6)	675 (±241)	24.5 (±9.3)	1180 (±451)	121 (±67)	8
3	7.4 (±2.9)	3.1 (±1.4)	58.5 (±31)	8.6 (±5.1)	626 (±435)	11.8 (±2.9)	959 (±407)	175 (±71)	8

[1] Means and standard errors (±1 s.e.) for sites sampled in 1987 by Keammerer.

[2] PA = Plant Available Using DTPA Soil Extract

[3] n = number of samples

Table 3-2

Plant-Tissue Metal Concentrations for Grasses and Forbs (reported on a dry-weight basis) from Sites Sampled along the Arkansas River [1]

Reach	Cadmium (mg/kg)		Copper (mg/kg)		Lead (mg/kg)		Zinc (mg/kg)		n[3]
	Grasses[2]	Forbs[2]	Grasses	Forbs	Grasses	Forbs	Grasses	Forbs	
0	0.8 (±1.3)	3.8 (±0.87)	5.1 (±0.6)	11.2 (±3.9)	0.1 (±0)	2.9 (±1.6)	82 (±17.3)	255 (±72)	9
1	2.2 (±0.2)	4.6 (±1.4)	4.6 (±0.4)	10.3 (±2)	12.2 (±5.2)	19.8 (±8.3)	153 (±71)	248 (±74)	7
2	1.6 (±0.9)	3.4 (±3.5)	4.9 (±1.8)	7.7 (±4.8)	9.0 (±7)	13.1 (±24)	147 (±223)	186 (±315)	8
3	1.6 (±0.4)	6.4 (±1.1)	6.4 (±0.6)	18.9 (±1.6)	4.5 (±2.8)	0.1 (±0)	239 (±79)	394 (±98)	8

[1] Means and standard errors (±1 s.e.) for sites sampled in 1987.

[2] The dietary concentration of cadmium that has been set as the maximum tolerable level for ruminants is 0.5 mg/kg (Church 1988). This concentration is exceeded for both grasses and forbs. This is most likely a result of the generally higher mineralization and metal content associated with soils in this region and does not translate to an injury to terrestrial trust resources. True toxicity to ruminants can only be determined with diet, physiological, and pathological studies of grazing animals.

[3] n = number of samples

Table 3-3

Mean Metal Concentrations (mg/L) in Reach 1 during Period 3 and Exceedances of Chronic TVSs (number exceeding TVS/ total number of samples)

	Flow	Dissolved Cadmium	Dissolved Copper	Dissolved Lead	Dissolved Zinc
Chronic TVS[1]	High	0.002	0.0077	0.0021	0.1011
	Low	0.003	0.0127	0.0039	0.1664
Mean (min, max) Concentrations	High	0.0017 (0.00006, 0.014)	0.0052 (0.0005, 0.036)	0.0037 (0.0001, 0.14)	0.403 (0.005, 2.15)
	Low	0.0018 (0.00005, 0.0124)	0.0029 (0.0005, 0.0124)	0.0031 (0.0001, 0.05)	0.559 (0.005, 2.23)
Exceedances	High	23/125	21/130	16/121	112/126
	Low	14/98	0/100	11/88	81/96

[1] Calculated at the mean reach hardness during high flows in Period 3 (Hardness = 83.5 mg/L) and during low flows in Period 3 (Hardness = 150.3 mg/L).

Table 3-4

Summary of Shallow Groundwater Quality Characteristics for Period 3 (Dissolved Metals)

Metal	Reach	Number of Samples (n)	Number of Stations (StaCnt)	Mean Dissolved Concentration (mg/L)	Minimum Dissolved Concentration (mg/L)	Maximum Dissolved Concentration (mg/L)	Standard Deviation (mg/L)
Cadmium	1	91	8	0.0099	0.0001	0.187	0.023
	2	44	4	0.0092	0.0001	0.036	0.01
	3	155	26	0.0184	0.0001	0.249	0.036
Copper	1	91	8	0.003	0.0003	0.084	0.009
	2	44	4	0.0017	0.0003	0.011	0.002
	3	153	26	0.0331	0.0003	0.442	0.066
Lead	1	89	8	0.0056	0.0005	0.016	0.006
	2	44	4	0.0106	0.0005	0.096	0.02
	3	154	26	0.016	0.0005	0.476	0.052
Zinc	1	91	8	4.36	0.00045	29.7	6.59
	2	45	4	3.13	0.00045	9.82	3.44
	3	158	26	2.35	0.00045	16.203	3.01

Table 3-5

Physical and Chemical Characteristics of the Mine-Waste Deposits along the Arkansas River

Reach	Surface Area (ft^2)	Volume (ft^3)	Average Depth (ft)	Total Cadmium (mg/kg)	Total Copper (mg/kg)	Total Lead (mg/kg)	Total Zinc (mg/kg)
1	785,364	886,814	1.1	117	446	4,228	7,271
2	405,936	233,389	0.6	153	200	3,266	3,438
3	1,638,612	1,578,311	1.0	129	258	3,069	4,926

Table 3-6

Mean Metal Concentrations (mg/L) in Reach 2 during Period 3 and Exceedances of Chronic TVSs (number exceeding TVS/ total number of samples)

	Flow	Dissolved Cadmium	Dissolved Copper	Dissolved Lead	Dissolved Zinc
Chronic TVS[1]	High	0.0016	0.0061	0.0015	0.0799
	Low	0.002	0.0079	0.0022	0.1043
Mean (min, max) Concentrations	High	0.0016 (0.00015, 0.0068)	0.0068 (0.0005, 0.025)	0.0028 (0.0001, 0.0171)	0.313 (0.05, 1.15)
	Low	0.00059 (0.0001, 0.0025)	0.00349 (0.0005, 0.025)	0.00064 (0.0001, 0.0025)	0.187 (0.005, 0.63)
Exceedances	High	8/28	9/28	11/28	25/29
	Low	1/27	1/28	1/27	21/28

[1] Calculated at the mean reach hardness during high flows in Period 3 (Hardness = 63.3 mg/L) and during low flows in Period 3 (Hardness = 86.6 mg/L).

Table 3-7

Mean Metal Concentrations (mg/L) in Reach 3 during Period 3 and Exceedances of Chronic TVSs (number exceeding TVS/ total number of samples)

	Flow	Dissolved Cadmium	Dissolved Copper	Dissolved Lead	Dissolved Zinc
Chronic TVS[1]	High	0.0017	0.0066	0.0017	0.0865
	Low	0.0023	0.009	0.0025	0.1186
Mean (min, max) Concentrations	High	0.00182 (0.0002, 0.006)	0.01305 (0.0005, 0.025)	0.00314 (0.00015, 0.027)	0.24038 (0.026, 1.04)
	Low	0.00113 (0.0001, 0.0025)	0.00769 (0.0005, 0.025)	0.00194 (0.00015, 0.045)	0.17186 (0.005, 0.637)
Exceedances	High	42/76	41/77	44/72	56/84
	Low	23/71	17/72	2/63	46/77

[1] Calculated at the mean reach hardness during high flows in Period 3 (Hardness = 69.5 mg/L) and during low flows in Period 3 (Hardness = 100.8 mg/L).

FIGURES

Food Chain Transfer of Zinc in Reach 3

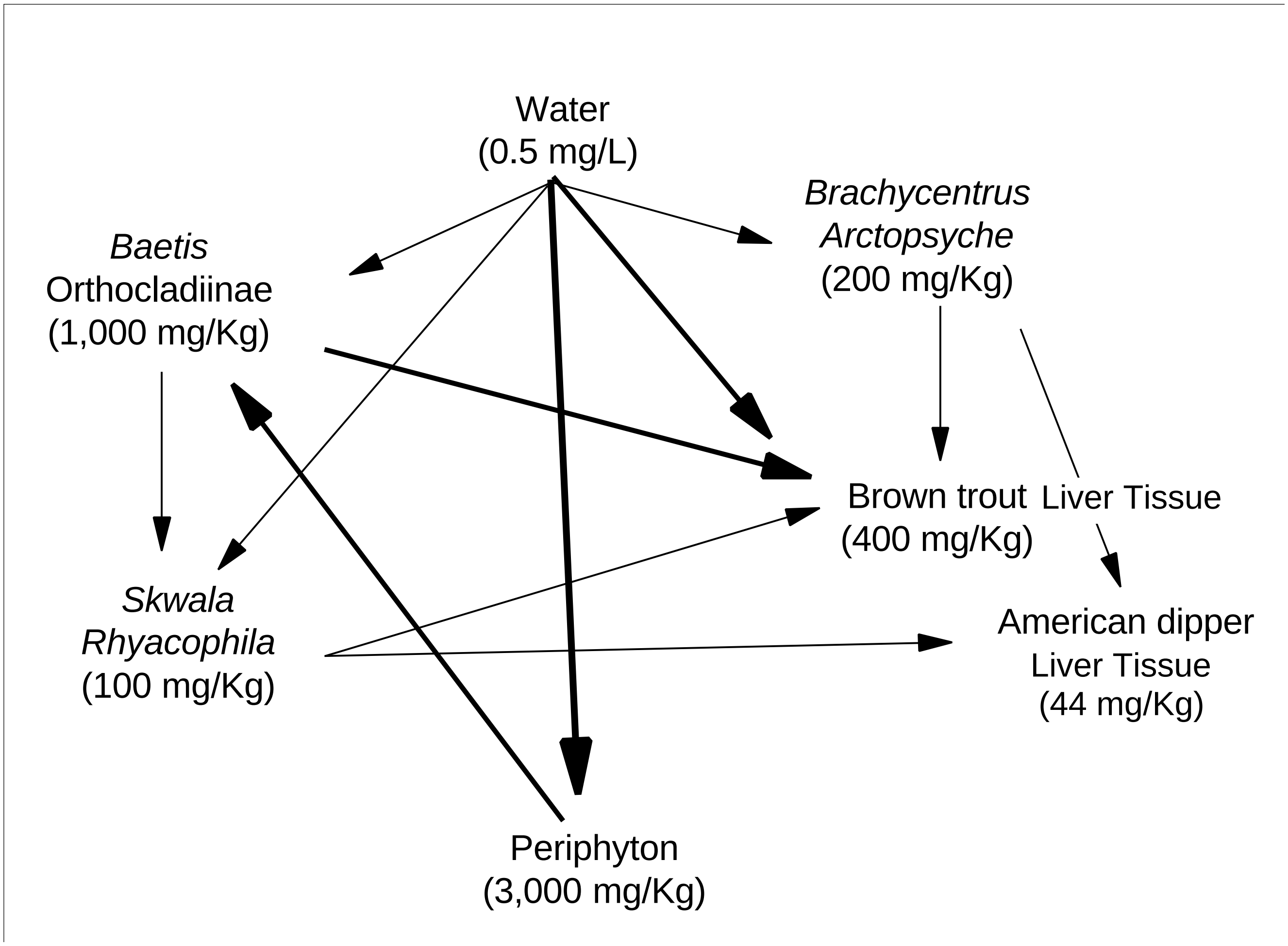

Figure 3-1

Conceptual Model Showing Food Chain Transport of Zinc in Reach 3 of the Arkansas River [1]

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[1] The model is based on known feeding relationships and zinc concentrations in important prey items. The size of the arrows reflects the significance of each pathway. Values shown reflect mean zinc concentrations measured in each compartment in Reach 3 (Arkansas Station AR-5).

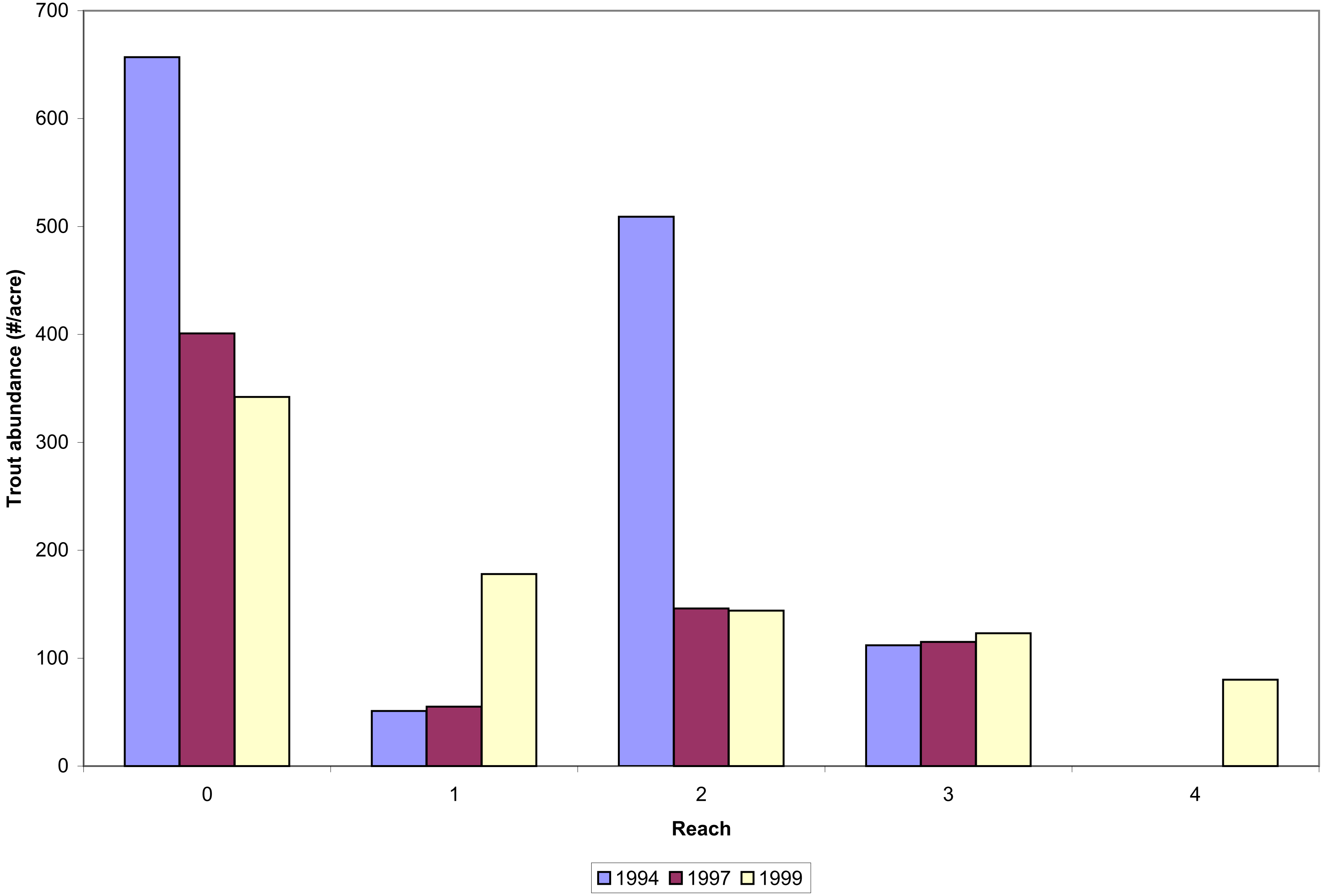

Figure 3-2

Brown Trout Abundance at Arkansas River Reaches After Treatment of the Yak and LMDT Discharges Began

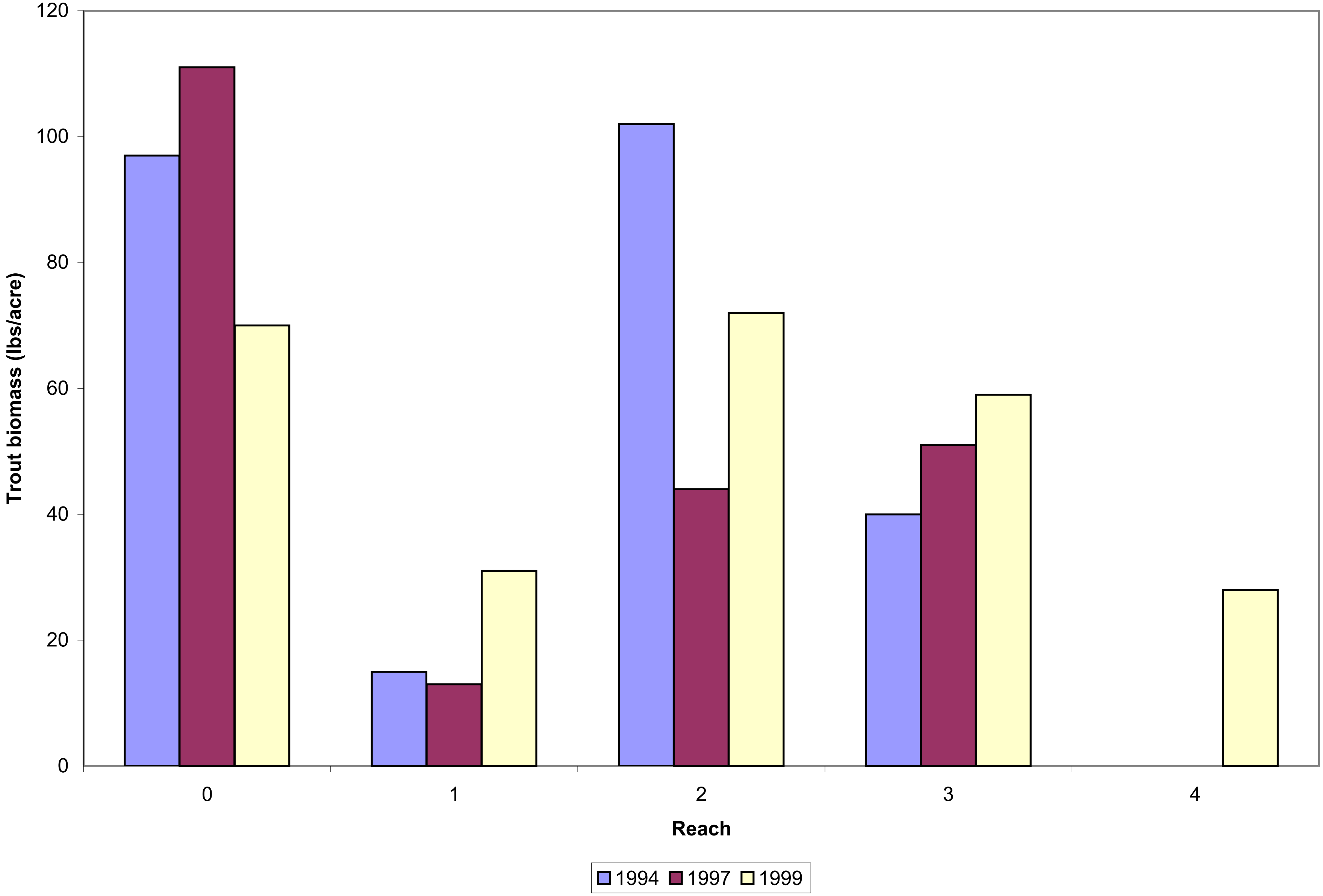

Figure 3-3
Brown Trout Biomass at Arkansas River Reaches After Treatment of the Yak and LMDT Discharges Began

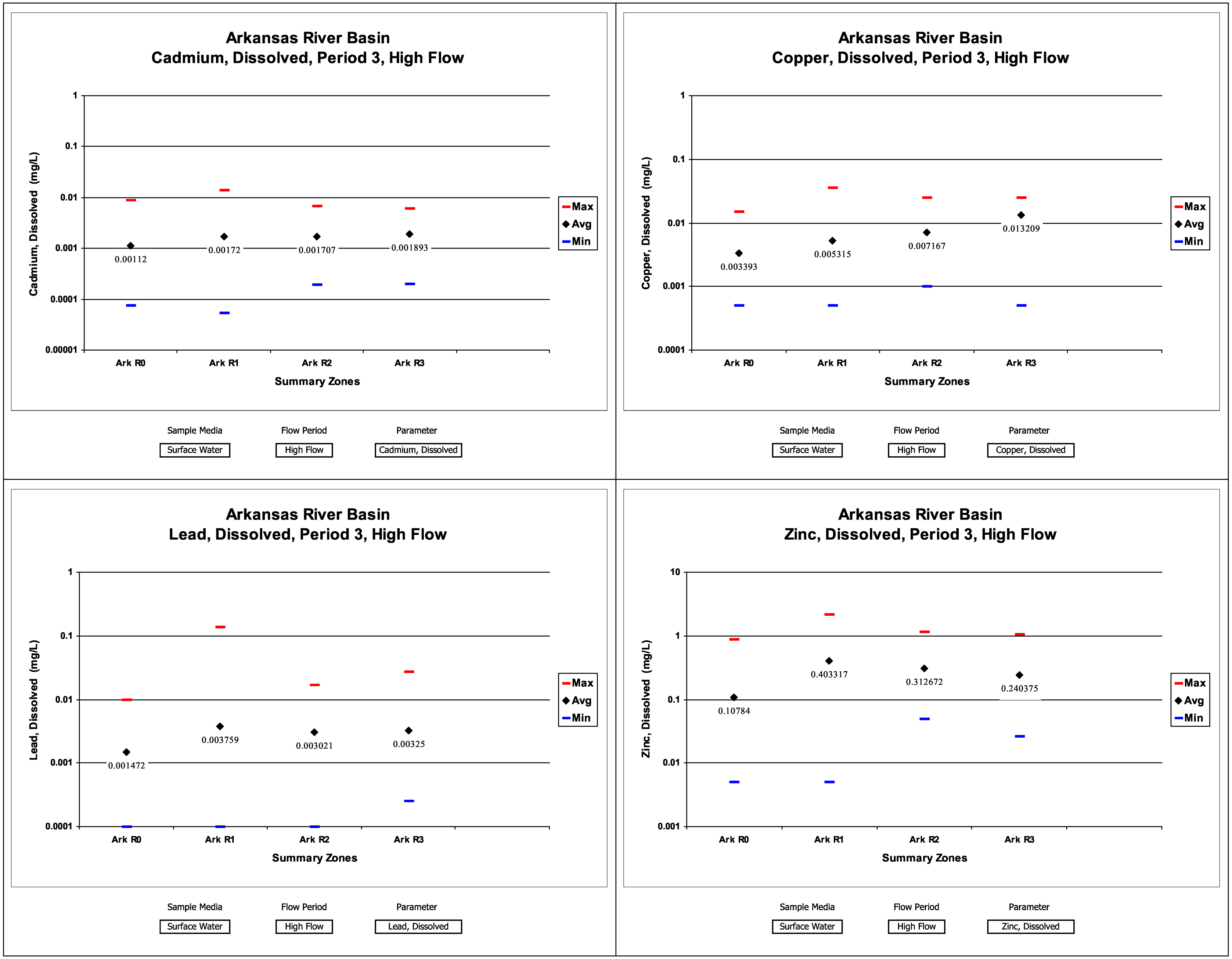

Figure 3-4

Spatial Summary for Water Quality (High Flow) for Reaches 0, 1, 2 and 3 (No data are available for Reach 4)

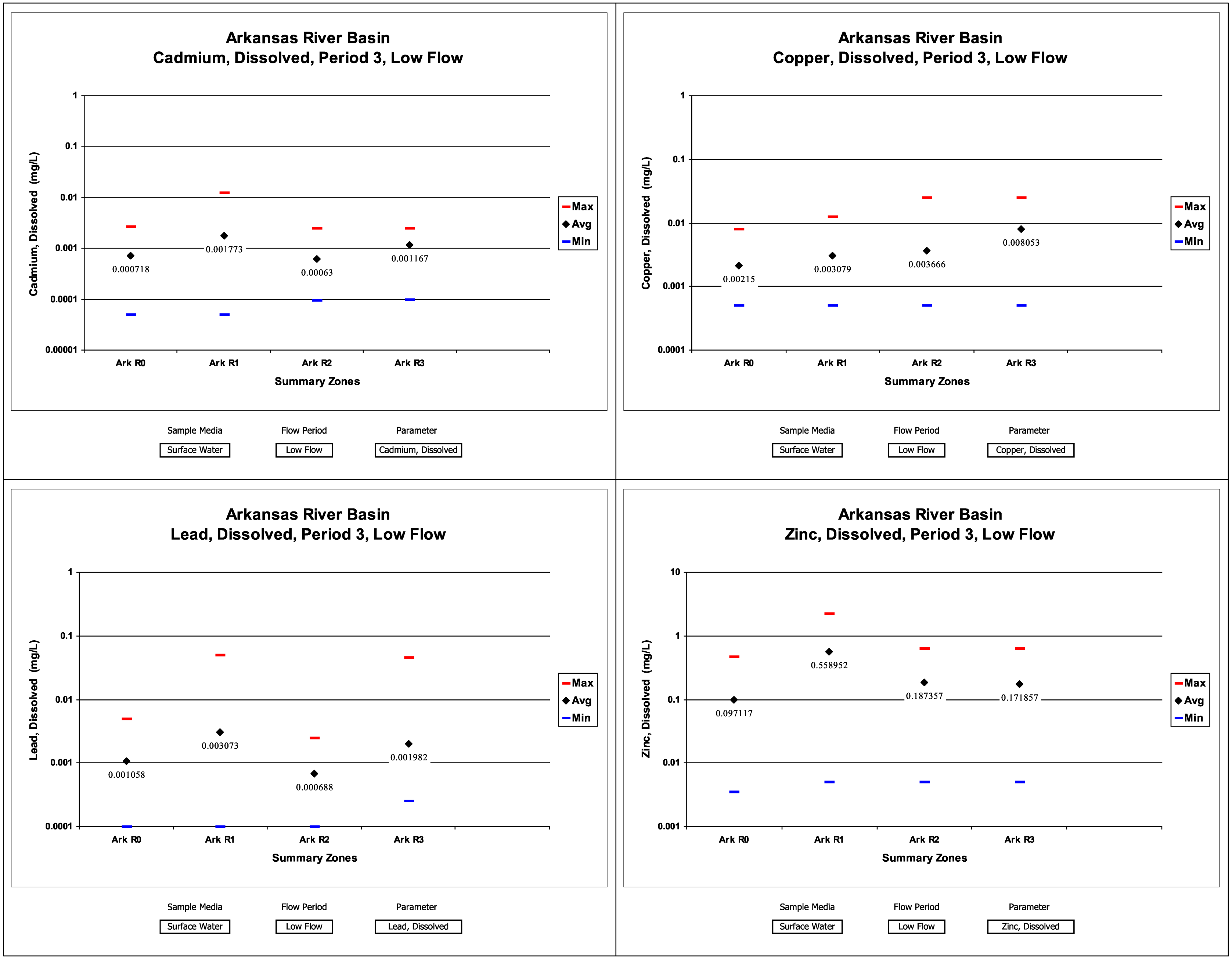

Figure 3-5

Spatial Summary for Water Quality (Low Flow) for Reaches 0, 1, 2 and 3 (No data are available for Reach 4).

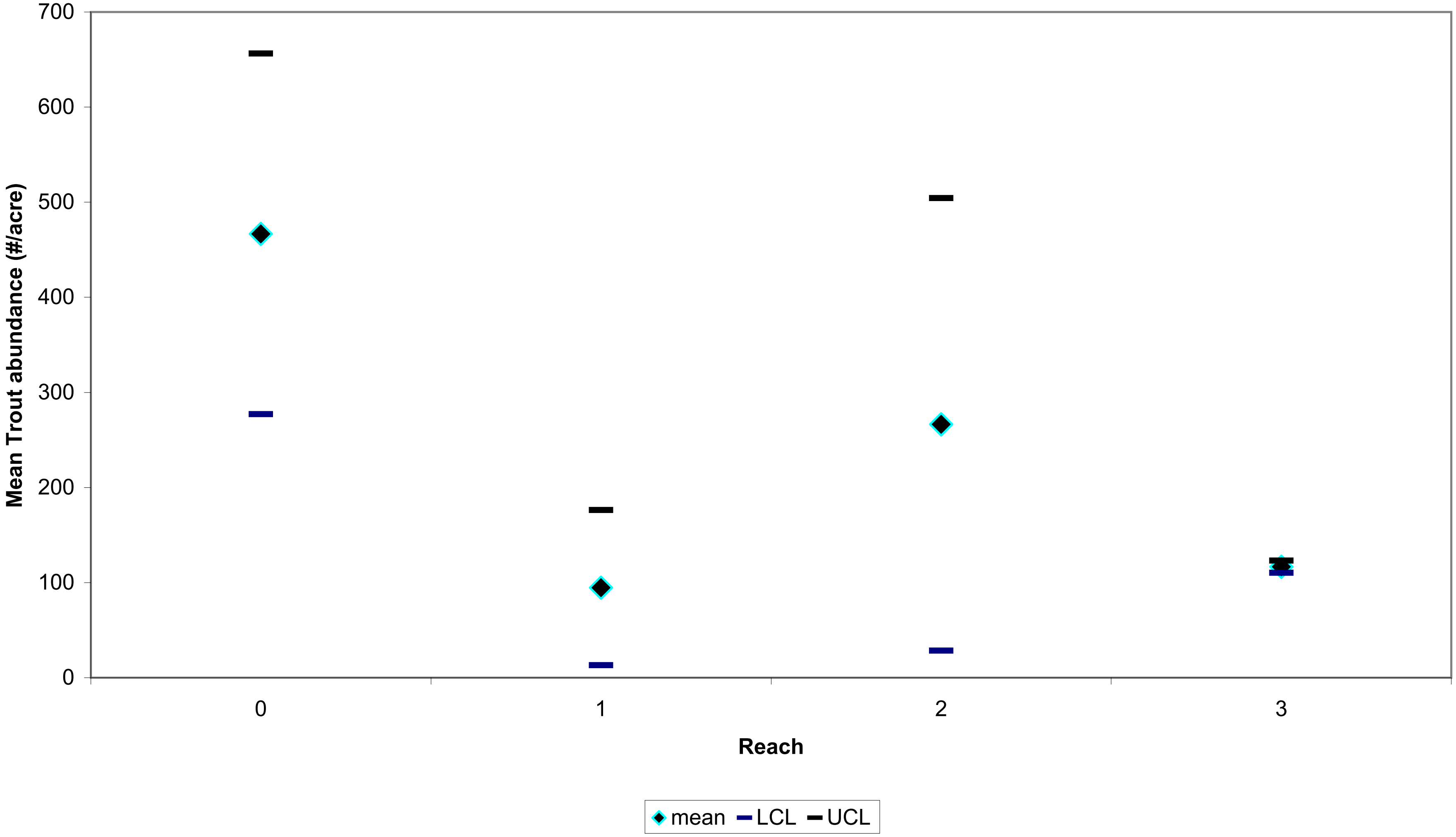

Figure 3-6
Brown Trout Mean Abundance (95% Confidence Limits) at Arkansas River Reaches After Treatment of the Yak and LMDT Discharges Began.

MATRIX SUMMARIZING INJURY CHARACTERIZATION FOR THE 11-MILE REACH OF THE UPPER ARKANSAS RIVER BASIN

1. Surface Water Resources:

- **A. Surface Water**
- **B. Sediments**

Surface Water 1992 to 2001 (Period 3)

Reach 0 – Confluence of Tennessee Creek and East Fork Arkansas River to County Road 300 [2.8 river miles (RM)]

Control Site Conditions

High Flow	Low Flow
Summary Data - Mean (min,max) mg/L Diss Cd = 0.0011 (0.00008, 0.009)(stations=5, n=49) Diss Cu = 0.0034 (0.0005, 0.015)(stations=5, n=48) Diss Pb = 0.0015 (0.0001, 0.01)(stations=5, n=42) Diss Zn = 0.108 (0.005, 0.87)(stations=5, n=50) Average hardness 57.6 mg/L as $CaCO_3$	Summary Data - Mean (min,max) mg/L Diss Cd = 0.00072 (0.00005, 0.0027)(stations=6, n=90) Diss Cu = 0.0022 (0.0005, 0.008)(stations=6, n=88) Diss Pb = 0.00106 (0.0001, 0.005)(stations=6, n=79) Diss Zn = 0.097 (0.0035, 0.47)(stations=6, n=89) Average hardness 100.1 mg/L as $CaCO_3$

Commentary: Concentrations of all four metals sometimes exceed the TVSs upstream of California Gulch during high flow. Copper is the only metal that has not exceeded the TVSs during low flows. In recent years, zinc concentrations upstream of California Gulch have consistently been declining. Although treatment of the Leadville Tunnel drainage has greatly improved water quality, Reach 0 metals concentrations are influenced by sources in both the East Fork of the Arkansas River and Tennessee Creek drainage.

Representativeness of Data: With the exception noted above, the data are considered to be representative of actual field conditions in Reach 0. Sample locations are distributed throughout the reach with several locations just downstream of the confluence of the East Fork Arkansas River and Tennessee Creek, and several more just upstream of the confluence of California Gulch with the Arkansas River, providing good spatial coverage. The data are well distributed over the 8-year period and across the flow conditions present.

Data Gaps: None

Related Text: Sections 2.1.2; 3.1.2

<table>
<tr><th colspan="3">Surface Water 1992 to 2001 (Period 3)</th></tr>
<tr><th colspan="3">Reach 1 – Downstream of California Gulch Confluence to Upstream of Lake Fork Confluence (1.6 RM)</th></tr>
<tr><th></th><th>High Flow</th><th>Low Flow</th></tr>
<tr><td><i>Regulatory Thresholds For Injury</i></td><td>1. Acute and chronic TVSs based on mean hardness for each reach for cadmium, copper, lead and zinc [43 CFR 11.62(b)].</td><td>1. Acute and chronic TVSs based on mean hardness for each reach for cadmium, copper, lead and zinc [43 CFR 11.62(b)].</td></tr>
<tr><td></td>
<td><u>Summary Data – Mean (min,max) mg/L</u>
Diss Cd = 0.0017 (0.00006, 0.014)
Diss Cu = 0.0053 (0.0005, 0.036)
Diss Pb = 0.0038 (0.0001, 0.14)
Diss Zn = 0.403 (0.005, 2.15)

Regulatory Thresholds for Injury (mg/L)
<table>
<tr><th>Analyte</th><th>Acute</th><th>Chronic</th><th>Hardness</th></tr>
<tr><td>Cadmium</td><td>0.003</td><td>0.002</td><td>83.54</td></tr>
<tr><td>Copper</td><td>0.0113</td><td>0.0077</td><td>83.54</td></tr>
<tr><td>Lead</td><td>0.0531</td><td>0.0021</td><td>83.54</td></tr>
<tr><td>Zinc</td><td>0.1006</td><td>0.1011</td><td>83.54</td></tr>
</table>
Exceedence Data (# exceeding Regulatory Thresholds)
<table>
<tr><th>Analyte</th><th>Total n</th><th>Stations</th><th>> Acute</th><th>> Chronic</th></tr>
<tr><td>Cadmium</td><td>125</td><td>7</td><td>17</td><td>24</td></tr>
<tr><td>Copper</td><td>130</td><td>8</td><td>20</td><td>22</td></tr>
<tr><td>Lead</td><td>121</td><td>7</td><td>1</td><td>18</td></tr>
<tr><td>Zinc</td><td>126</td><td>7</td><td>112</td><td>112</td></tr>
</table></td>
<td><u>Summary Data - Mean (min,max) mg/L</u>
Diss Cd = 0.0018 (0.00005, 0.0124)
Diss Cu = 0.0031 (0.0005, 0.0124)
Diss Pb = 0.0031 (0.0001, 0.05)
Diss Zn = 0.559 (0.005, 2.23)

Regulatory Thresholds for Injury (mg/L)
<table>
<tr><th>Analyte</th><th>Acute</th><th>Chronic</th><th>Hardness</th></tr>
<tr><td>Cadmium</td><td>0.0058</td><td>0.003</td><td>150.3</td></tr>
<tr><td>Copper</td><td>0.0197</td><td>0.0127</td><td>150.3</td></tr>
<tr><td>Lead</td><td>0.1003</td><td>0.0039</td><td>150.3</td></tr>
<tr><td>Zinc</td><td>0.1655</td><td>0.1664</td><td>150.3</td></tr>
</table>
Exceedence Data (# exceeding Regulatory Thresholds)
<table>
<tr><th>Analyte</th><th>Total n</th><th>Stations</th><th>> Acute</th><th>> Chronic</th></tr>
<tr><td>Cadmium</td><td>98</td><td>7</td><td>5</td><td>14</td></tr>
<tr><td>Copper</td><td>101</td><td>7</td><td>0</td><td>0</td></tr>
<tr><td>Lead</td><td>90</td><td>7</td><td>0</td><td>11</td></tr>
<tr><td>Zinc</td><td>96</td><td>7</td><td>81</td><td>81</td></tr>
</table></td></tr>
<tr><td><i>Related Benchmark Comparisons</i></td><td colspan="2">Compared to Reach 0, mean concentrations of all metals increased in Reach 1 during both high and low flows, with zinc exhibiting the highest increases. During high flows, increases in cadmium, copper, and lead are small. Unlike Reach 0 where mean dissolved zinc concentrations were higher during high flows, in Reach 1 mean dissolved zinc was higher during low flows. Average zinc in Reach 1 represents a 4-fold increase during high flows and a 5 to 6-fold increase during low flows relative to Reach 0 mean zinc concentrations.</td></tr>
<tr><td></td><td colspan="2"><u>Statement of Injury</u>: Surface water resources in Reach 1 are injured by elevated concentrations of cadmium, copper, lead, and zinc during high flow, and cadmium, lead, and zinc during low flow.

<u>Commentary</u>: During high flows, cadmium, copper, and lead exceeded the acute TVSs several times while lead exceeded the acute TVS once. During low flows, only cadmium and zinc exceeded the acute TVSs, copper did not exceed the TVSs, and lead only exceeded the chronic TVS. On average, dissolved cadmium, copper, and lead concentrations were very similar during high and lows flows, whereas mean zinc was considerably greater during low flows. For both flow conditions, zinc exhibited the largest increase in exceedences of TVSs relative to the other three metals. The percentage of zinc concentrations exceeding the TVSs was only slightly greater for high flow samples compared to low flows samples. The large increase in concentrations of zinc and exceedences of the TVSs for zinc indicates that California Gulch is a significant source. Data evaluated during this period may also reflect ongoing remediation in California Gulch. California Gulch is considered to be the primary metals source to Reach 1 surface waters.

<u>Representativeness of Data</u>: The data are considered to be representative of actual field conditions in Reach 1. Sample locations are primarily located just downstream of California Gulch, but there are a few locations distributed throughout the reach which provide good spatial coverage. Temporally, the data are well distributed over the 8-year period and across the flow conditions present. There may be episodes of source area runoff that result in larger exceedences of the criteria than shown in this analysis. However, given the temporal and spatial coverage of the metals data for Reach 1, the data are considered sufficient for injury characterization.

<u>Data Gaps</u>: None

<u>Is current information sufficient for restoration planning</u>? The data compiled for Period 3 provide an adequate base of information for restoration planning.

<u>Related Text</u>: Sections 2.2.2; 3.2.2</td></tr>
</table>

Surface Water 1992 to 2001 (Period 3)

Reach 2 – Downstream of Lake Fork Confluence to Upstream of Highway 24 Bridge (3.3 RM)

	High Flow	Low Flow
Regulatory Thresholds For Injury	1. Acute and chronic TVSs based on mean hardness for each reach for cadmium, copper, lead and zinc [43 CFR 11.62(b)].	1. Acute and chronic TVSs based on mean hardness for each reach for cadmium, copper, lead and zinc [43 CFR 11.62(b)].

High Flow

Summary Data - Mean (min,max) mg/L

Diss Cd = 0.0017 (0.00019, 0.0068)
Diss Cu = 0.0072 (0.001, 0.025)
Diss Pb = 0.0030 (0.0001, 0.0171)
Diss Zn = 0.313 (0.05, 1.15)

Regulatory Thresholds for Injury (mg/L)

Analyte	Acute	Chronic	Hardness
Cadmium	0.0023	0.0016	63.26
Copper	0.0087	0.0061	63.26
Lead	0.0391	0.0015	63.26
Zinc	0.0795	0.0799	63.26

Exceedence Data (# exceeding Regulatory Thresholds)

Analyte	Total n	Stations	> Acute	> Chronic
Cadmium	28	3	8	10
Copper	28	3	6	9
Lead	28	3	0	13
Zinc	29	3	25	25

Low Flow

Summary Data - Mean (min,max) mg/L

Diss Cd = 0.00063 (0.00001, 0.0025)
Diss Cu = 0.00367 (0.0005, 0.025)
Diss Pb = 0.00069 (0.0001, 0.0025)
Diss Zn = 0.187 (0.005, 0.63)

Regulatory Thresholds for Injury (mg/L)

Analyte	Acute	Chronic	Hardness
Cadmium	0.0032	0.002	86.62
Copper	0.0117	0.0079	86.62
Lead	0.0552	0.0022	86.62
Zinc	0.1038	0.1043	86.62

Exceedence Data (# exceeding Regulatory Thresholds)

Analyte	Total n	Stations	> Acute	> Chronic
Cadmium	27	3	0	1
Copper	28	3	1	1
Lead	27	3	0	1
Zinc	28	3	21	21

Related Benchmark Comparisons

Compared to Reach 0, mean concentrations of all metals increased in Reach 2 during high flow, while copper and zinc increased during low flows. However, during both high and low flows, increases in cadmium, copper, and lead were small. Similar to Reach 0, Reach 2 mean dissolved zinc was also higher during high flows. Average zinc in Reach 2 represents a 2- to 3-fold increase during high flows and a 2-fold increase during low flows relative to Reach 0 average zinc concentrations.

Statement of Injury: Surface water resources in Reach 2 are injured by elevated concentrations of cadmium, copper, lead, and zinc during high flows. During low flows, surface waters are injured due to elevated concentrations of zinc. Only single exceedances of TVSs for cadmium, copper, and lead were noted during low flows.

Commentary: Based on the mean concentrations of dissolved metals, Reach 2 had lower concentrations of cadmium, lead, and zinc during both high and low flows relative to Reach 1. Copper was, on average, slightly greater in Reach 2 during both flow conditions. Dilution from Lake Fork reduced hardness values thereby reducing TVSs. Despite this decrease in Reach 2 TVSs, the ratio of TVS exceedances to the total number of samples for a parameter showed relatively similar percentages of exceedances between Reaches 1 and 2, although the average magnitude of exceedence was lower for Reach 2. Cadmium, copper, and zinc exceeded the acute TVSs and lead exceeded the chronic TVS during high flow. Only copper and zinc exceeded the acute TVSs during low flow, while cadmium and lead only exceeded the chronic TVSs during low flows. The percentage of samples exceeding the chronic TVSs for all four metals was greater during high flows relative to low flows. The primary sources for metals in Reach 2 are upstream sources. Mining activities in the Lake Fork drainage and Iowa Gulch may contribute some metals, but the larger proportions of metals (zinc) is due to discharge from California Gulch.

Representativeness of Data: Although fewer samples are available for Reach 2 than for the previous two reaches, the temporal and spatial distribution of the data during both flow conditions provides representative coverage for Reach 2. These data are also considered adequate for injury determination.

Data Gaps: None

Is current information sufficient for restoration planning? Given that the expected source of metals in Reach 2 is largely due to upstream sources, these data are considered adequate for restoration planning.

Related Text: Sections 2.3.2; 3.3.2

Surface Water 1992 to 2001 (Period 3)

Reach 3 – Downstream of Highway 24 Bridge to Narrows near Kobe (3.5 RM)

	High Flow	Low Flow
Regulatory Thresholds For Injury	1. Acute and chronic TVSs based on mean hardness for each reach for cadmium, copper, lead and zinc [43 CFR 11.62(b)].	1. Acute and chronic TVSs based on mean hardness for each reach for cadmium, copper, lead and zinc [43 CFR 11.62(b)].

High Flow

Summary Data - Mean (min,max) mg/L
Diss Cd = 0.00189 (0.0002, 0.006)
Diss Cu = 0.01321 (0.0005, 0.025)
Diss Pb = 0.00325 (0.00025, 0.027)
Diss Zn = 0.24038 (0.026, 1.04)

Regulatory Thresholds for Injury (mg/L)

Analyte	Acute	Chronic	Hardness
Cadmium	0.0025	0.0017	69.5
Copper	0.0095	0.0066	69.5
Lead	0.0434	0.0017	69.5
Zinc	0.0861	0.0865	69.5

Exceedence Data (# exceeding Regulatory Thresholds)

Analyte	Total n	Stations	> Acute	> Chronic
Cadmium	76	7	5	44
Copper	77	7	39	42
Lead	72	7	0	46
Zinc	84	7	56	56

Low Flow

Summary Data - Mean (min,max) mg/L
Diss Cd = 0.00117 (0.0001, 0.0025)
Diss Cu = 0.00805 (0.0005, 0.025)
Diss Pb = 0.00198 (0.00025, 0.045)
Diss Zn = 0.17186 (0.005, 0.637)

Regulatory Thresholds for Injury (mg/L)

Analyte	Acute	Chronic	Hardness
Cadmium	0.0037	0.0023	100.79
Copper	0.0135	0.009	100.79
Lead	0.0651	0.0025	100.79
Zinc	0.118	0.1186	100.79

Exceedence Data (# exceeding Regulatory Thresholds)

Analyte	Total n	Stations	> Acute	> Chronic
Cadmium	72	7	0	24
Copper	73	7	18	18
Lead	64	7	0	2
Zinc	77	7	46	46

Related Benchmark Comparisons

Compared to Reach 0, mean concentrations of all metals increased in Reach 3 during high and low flows. However, during high and low flows, increases in cadmium, copper, and lead are small. Mean zinc concentrations exhibited substantially larger concentrations relative to Reach 0. Similar to Reach 0 mean dissolved zinc concentrations were higher during high flows in Reach 3 than during low flows. Average zinc in Reach 3 represents about a 2-fold increase during high and low flows relative to Reach 0 mean zinc concentrations.

Statement of Injury: Surface water resources in Reach 3 are injured by concentrations of cadmium, copper, lead, and zinc during both high and low flows.

Commentary: During high and low flows, mean concentrations of cadmium, copper, and lead increased in Reach 3, and mean zinc was lower compared to mean zinc in Reach 2. Cadmium, copper, and zinc exceeded the acute TVSs and lead only exceeded the chronic TVS during high flow, while during low flow only copper and zinc exceeded the acute TVSs, and cadmium and lead exceeded only the chronic TVSs. During high and low flows, there was a substantial increase in the number of exceedences of the TVSs for copper in Reach 3 when compared to Reach 2. The percentage of samples exceeding the chronic TVSs was greater during high flows relative to low flows. The increased concentrations of copper and exceedences of the TVSs during high flow suggests that there may be additional sources of copper in or just upstream of this reach, or that samples were collected during some type of disturbance. Elevated copper concentrations were noted to occur between 1995 and 1997 and then decline to a level more consistent with the data collected prior to this time. Continued decline of mean zinc concentrations in Reach 3 during both the high and low flow periods suggests that the primary sources are still those located upstream.

Representativeness of Data: The data are considered to be representative of actual field conditions in Reach 3. The temporal and spatial distribution of the data indicates that samples are distributed throughout the time period and the distance of the reach. Given the temporal and spatial coverage of the metals data for Reach 3, the data are considered sufficient for injury characterization.

Data Gaps: None

Is current information sufficient for restoration planning? There is an unexplained increase in copper and cadmium during a short time period of high flows in Reach 3. While the source or cause of this increase is unknown, the temporal and spatial scale of the data is adequate for restoration planning.

Related Text: Sections 2.4.2; 3.4.2

<table>
<tr><th colspan="3">Surface Water 1992 to 2001 (Period 3)</th></tr>
<tr><th colspan="3">Reach 4 – Downstream of Narrows near Kobe to Two Bit Gulch (1.6 RM)</th></tr>
<tr><th></th><th>High Flow</th><th>Low Flow</th></tr>
<tr><td><i>Regulatory Thresholds For Injury</i></td><td>1. Acute and chronic TVSs based on mean hardness for each reach for cadmium, copper, lead and zinc [43 CFR 11.62(b)].</td><td>1. Acute and chronic TVSs based on mean hardness for each reach for cadmium, copper, lead and zinc [43 CFR 11.62(b)].</td></tr>
<tr><td></td><td><u>Summary Data - Mean (min,max) mg/L</u>
No data available for this reach.</td><td><u>Summary Data - Mean (min,max) mg/L</u>
No data available for this reach.</td></tr>
<tr><td><i>Related Benchmark Comparisons</i></td><td colspan="2">No data available for comparisons.</td></tr>
<tr><td></td><td colspan="2"><u>Statement of Injury</u>: Based on water quality upstream and downstream of Reach 4, injury to surface water as determined by exceedances of TVSs for zinc and other metals is occurring.
<u>Commentary</u>: There are two tributaries to Reach 4, however, neither is expected to dramatically influence water quality, therefore, water quality in Reach 4 is expected to be very similar to quality found in Reach 3.
<u>Representativeness of Data</u>: Due to the lack of sample data in Reach 4, representative conditions of the reach cannot be assessed.
<u>Data Gaps</u>: None
<u>Is current information sufficient for restoration planning</u>? There are no sample data for the metals of interest in Reach 4. However, the anticipated lack of other influences that could increase or decrease metals concentrations suggests that additional data collection would provide no additional benefit for the purpose of restoration planning.
<u>Related Text</u>: Sections 2.5.2; 3.5.2</td></tr>
</table>

Instream Sediment 1992 to 2000 (Period 3)

Reach 0 – Confluence of Tennessee Creek and East Fork Arkansas River to County Road 300 (2.8 RM)

Control Site Conditions

Summary Data – Dry Weight (mg/kg)

Analyte	Stations	Total n	Min	Max	Ave	StdDev
Cadmium	2	6	1	23	6.2	8.5
Copper	2	13	3.18	170	24.7	44.5
Lead	1	10	24	510	88.9	152.0
Zinc	2	17	25	2500	345.0	646.7

Commentary: Sediment concentrations in Reach 0 are controlled by releases of metals from historic mining activities and natural mineralization.

Representativeness of Data: Although the temporal and spatial distribution of the data are limited, additional data would likely be similar to the current range of concentrations. Geomorphological assessment indicates that the Upper Arkansas is a sediment-poor system due to its high gradient, elevation in the watershed, and high flow runoff events, which results in a large-sized bed substrates. Fines are quickly transported down river and deposit only in areas where water velocities are slow, allowing these materials to settle out of the water column.

Data Gaps: None

Related Text: Sections 2.1.3; 3.1.3

Instream Sediment 1992 to 2000	
Reach 1 – Downstream of California Gulch Confluence to Upstream of Lake Fork Confluence (1.6 RM)	
Regulatory Thresholds For Injury	1. Concentrations and duration of substances sufficient to have caused injury as defined in paragraphs (c), (d), (e), or (f) of this section to groundwater, air, geologic, or biological resources when exposed to surface water, suspended sediments, or bed, bank, or shoreline sediments [43 CFR 11.62(b)(v)].
	Summary Data – Dry Weight (mg/kg)
Related Benchmark Comparisons	Concentrations of copper, lead, and zinc in sediments from Reach 1 are elevated over those found in Reach 0. Mean concentrations of copper, lead, and zinc are 1.9, 5.9, and 3.6 times greater, respectively, in Reach 1 compared to Reach 0.

Summary Data – Dry Weight (mg/kg)

Analyte	Stations	Total n	Min	Max	Ave	StdDev
Cadmium	3	6	1.96	11.1	6.0	3.1
Copper	3	6	15.83	131	46.8	42.5
Lead	2	3	291	922	521.0	348.5
Zinc	3	6	239.7	2,072	1,251.2	651.4

Statement of Injury: No definitive criteria are available for sediments in the regulations. Copper, lead, and zinc in sediments from Reach 1 are elevated when compared to Reach 0. For additional information about the potential for injury, see the surface water and/or biological sections of the matrix.

Commentary: Sources of metals enriched sediments are primarily related to precipitation and snowmelt runoff that erodes sediments from the various types of mining wastes in California Gulch, upstream, and naturally mineralized deposits. For a more complete understanding of sediment injury, the reader is referred to the surface water and biological sections of the matrix.

Representativeness of Data: There is a limited amount of sediment data for this reach. Although the temporal and spatial distribution of the data is limited, additional data would likely be similar to the current range of concentrations. Geomorphological assessment indicates that the Upper Arkansas is a sediment-poor system due to its high gradient, elevation in the watershed, and high flow runoff events due to snowmelt, which results in a large-sized bed substrates. 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. Sources of sediment in Reach 1 include overland runoff and erosion of historical mining areas higher up in the watershed.

Data Gaps: Although the data are sparse, they do meet the acceptance criteria for injury determination.

Is current information sufficient for restoration planning? Yes

Related Text: Sections 2.2.3; 3.2.3

Instream Sediment 1992 to 2000

Reach 2 – Downstream of Lake Fork Confluence to Upstream of Highway 24 Bridge (3.3 RM)

Regulatory Thresholds For Injury

1. Concentrations and duration of substances sufficient to have caused injury as defined in paragraphs (c), (d), (e), or (f) of this section to groundwater, air, geologic, or biological resources when exposed to surface water, suspended sediments, or bed, bank, or shoreline sediments [43 CFR 11.62(b)(v)].

Summary Data – Dry Weight (mg/kg)

Analyte	Stations	Total n	Min	Max	Ave	StdDev
Cadmium	5	5	1	33	17.6	13.0
Copper	5	5	10	610	177.7	247.4
Lead	5	5	63	1,900	862.8	764.3
Zinc	5	5	180	5,200	2,669.8	1,930.8

Related Benchmark Comparisons

Concentrations of metals in sediments from Reach 2 are elevated over those found in Reach 0. Mean concentrations of cadmium, copper, lead, and zinc are 2.8, 7.2, 9.7, and 7.7 times greater, respectively, in Reach 2 compared to Reach 0.

Statement of Injury: No definitive criteria are available for sediments in the regulations. All four metals are elevated when compared to Reach 0. For additional information about the potential for injury see the surface water and/or biological sections of the matrix.

Commentary: Sources of metal-enriched sediments are largely from upstream areas such as California Gulch and tributary streams.

Representativeness of Data: Although the temporal and spatial distribution of the data is limited, additional data would likely be similar to the current range of concentrations. Geomorphological assessment indicates that the Upper Arkansas is a sediment-starved system due to its high gradient, elevation in the watershed, and high flow runoff events due to snowmelt, which results in a large sized bed substrates. 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. Sources of sediment in Reach 2 include overland runoff and erosion of historical mining areas higher up in the watershed.

Data Gaps: None

Is current information sufficient for restoration planning? Yes

Related Text: Sections 2.3.3; 3.3.3

Instream Sediment 1992 to 2000

Reach 3 – Downstream of Highway 24 Bridge to Narrows near Kobe (3.5 RM)

Regulatory Thresholds For Injury

1. Concentrations and duration of substances sufficient to have caused injury as defined in paragraphs (c), (d), (e), or (f) of this section to groundwater, air, geologic, or biological resources when exposed to surface water, suspended sediments, or bed, bank, or shoreline sediments [43 CFR 11.62(b)(v)].

Summary Data – Dry Weight (mg/kg)

Analyte	Stations	Total n	Min	Max	Ave	StdDev
Cadmium	4	6	3.27	14	8.2	3.9
Copper	4	6	14.24	52.19	30.5	17.5
Lead	3	3	104	601.9	394.0	258.9
Zinc	4	6	398.7	2,079	1,148.6	783.6

Related Benchmark Comparisons

Concentrations of metals in sediments from Reach 3 are elevated over those sediments found in Reach 0; however, metals in sediments from Reach 3 are not nearly as elevated as those in Reach 2. Mean concentrations of cadmium, copper, lead, and zinc are 1.3, 1.2, 4.4, and 3.3 times greater, respectively, in Reach 3 compared to Reach 0.

Statement of Injury: No definitive criteria are available for sediments in the regulations. All four metals evaluated in sediments are elevated when compared to the upstream location. For additional information about the potential for injury see the surface water and/or biological sections of the matrix.

Commentary: Sources of metal enriched sediments are largely believed to be from upstream areas such as California Gulch and tributary streams.

Representativeness of Data: Although the temporal and spatial distribution of the data is limited, additional data would likely be similar to the current range of concentrations. Geomorphological assessment indicates that the Upper Arkansas is a sediment-starved system due to its high gradient, elevation in the watershed, and high flow runoff events due to snowmelt, which results in a large sized bed substrates. 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. Sources of sediment in Reach 3 include overland runoff and erosion of historical mining areas higher up in the watershed.

Data Gaps: None

Is current information sufficient for restoration planning? Yes

Related Text: Sections 2.4.3; 3.4.3

Instream Sediment 1992 to 2000

Reach 4 – Downstream of Narrows near Kobe to Two Bit Gulch (1.6 RM)

Regulatory Thresholds For Injury

1. Concentrations and duration of substances sufficient to have caused injury as defined in paragraphs (c), (d), (e), or (f) of this section to groundwater, air, geologic, or biological resources when exposed to surface water, suspended sediments, or bed, bank, or shoreline sediments [43 CFR 11.62 (b)(v)].

Summary Data – Dry Weight (mg/kg)

Analyte	Stations	Total n	Value
Cadmium	1	1	9
Copper	1	1	56
Lead	1	1	610
Zinc	1	1	1,500

Related Benchmark Comparisons

Only a single measurement value for each metal is available from Reach 4, and comparisons of these single measurements to mean data should be used with caution. Concentrations of metals in sediments from Reach 4 are elevated over those found in Reach 0; however, metals in sediments from Reach 4 are not nearly as elevated as those in Reach 2. Mean concentrations of cadmium, copper, lead, and zinc are 1.5, 2.3, 6.9, and 4.3 times greater, respectively, in Reach 4 compared to Reach 0.

Statement of Injury: No definitive criteria are available for sediments in the regulations. All four metals evaluated in sediments are elevated when compared to the upstream location. For additional information about the potential for injury see the surface water and/or biological sections of the matrix.

Commentary: Sources of metal enriched sediments are largely believed to be from upstream areas such as California Gulch and tributary streams.

Representativeness of Data: Although the temporal and spatial distribution of the data is limited, additional data would likely be similar to the current range of concentrations. Geomorphological assessment indicates that the Upper Arkansas is a sediment-starved system due to its high gradient, elevation in the watershed, and high flow runoff events due to snowmelt, which results in a large sized bed substrates. 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. Sources of sediment in Reach 4 include overland runoff and erosion of historical mining areas higher up in the watershed.

Data Gaps:

Is current information sufficient for restoration planning?

Related Text: Sections 2.5.3; 3.5.3

2. Groundwater Resources:

A. Groundwater

Groundwater 1992 to 2000

Reach 0 – Confluence of Tennessee Creek and East Fork Arkansas River to County Road 300 (2.8 RM)

Control Site Conditions

Summary of DWS Groundwater Quality Characteristics (mg/L) – Dissolved Metals

Analyte	MCL	Total n	Stations	Mean	Min	Max	Std Dev
Cadmium	0.005	1	1	0.0025	0.0025	0.0025	0
Copper	1.3[1]	1	1	0.007	0.007	0.007	0
Lead	0.015[2]	1	1	0.015	0.015	0.015	0
Zinc	5.0	1	1	0.02	0.02	0.02	0

Commentary: Groundwater within Reach 0 is suitable for domestic water supply. There are no shallow monitoring well data available for Reach 0.

Representativeness of Data: The well is representative of groundwater available for a domestic supply. Although shallow data are absent, there are no observable surficial deposits of mine-waste.

Data Gaps: None

Related Text: Sections 2.1.4; 3.1.4

[1] There is no MCL for copper, but it has a drinking water supply standard of 1.3 mg/L in Colorado.

[2] There is no MCL for lead, but it has an action level of 0.015 mg/L in Colorado.

Groundwater 1992 to 2000

Reach 1 – Downstream of California Gulch Confluence to Upstream of Lake Fork Confluence (1.6 RM)

Regulatory Thresholds For Injury

1. Exceedence of the Maximum Contaminant Levels [43CFR11.62(c)].

Summary of SMW Groundwater Quality Characteristics (mg/L) – Dissolved Metals

Analyte	Total n	Stations	Mean	Min	Max	Std Dev
Cadmium	91	8	0.0099	0.0001	0.187	0.023
Copper	91	8	0.003	0.0003	0.084	0.009
Lead	89	8	0.0056	0.0005	0.016	0.006
Zinc	91	8	4.36	0.00045	29.7	6.59

Summary of DWS Groundwater Quality Characteristics (mg/L) – Dissolved Metals

Analyte	MCL	Total n	Stations	Mean	Min	Max	Std Dev
Cadmium	0.005	3	3	0.0033	0.0025	0.005	0.0014
Copper	1.3[1]	3	3	0.0005	0.0025	0.01	0.0043
Lead	0.015[2]	3	3	0.0067	0.0025	0.015	0.0072
Zinc	5.0	3	3	0.598	0.063	1.1	0.519

Related Benchmark Comparisons

No shallow monitoring well data for benchmark comparison with Reach 0. Shallow groundwater data from the area of mine-waste deposits generally exceed more stringent surface water criteria. Domestic water supply well quality is similar to Reach 0.

Statement of Injury: Concentrations in DWS wells in Reach 1 are below the MCLs defining injury. Although shallow groundwater exceeds both the surface water criteria (ALC) and MCLs at certain locations, this water is not causing injury to the surface water or domestic water supply resources.

Commentary: Most of these wells are very shallow and are completed within or adjacent to mine-waste deposits. A focused study by USGS in Reach 3 shows the range of impact from mine-waste deposits limited due to the large volume of surface and groundwater flow when compared to the relatively small volume of wastes in the valley fill aquifer system. Based on USGS findings, localized contamination from mine-waste deposits is expected. Current surface water data do not indicate a significant groundwater/surface water pathway. This may again be due to the large volumes of flow in both the ground and surface water systems. Deeper groundwater providing the domestic water supply is suitable for such use.

Representativeness of Data: The combination of SMW and DWS data are considered to be representative of the condition of the groundwater resource.

Data Gaps: None.

Is current information sufficient for restoration planning? Yes

Related Text: Sections 2.2.4; 3.2.4

[1] There is no MCL for copper, but it has a drinking water supply standard of 1.3 mg/L in Colorado.
[2] There is no MCL for lead, but it has an action level of 0.015 mg/L in Colorado.

Groundwater 1992 to 2000

Reach 2 – Downstream of Lake Fork Confluence to Upstream of Highway 24 Bridge (3.3 RM)

Regulatory Thresholds For Injury

1. Exceedence of the Maximum Contaminant Levels [43CFR11.62(c)].

Summary of SMW Groundwater Quality Characteristics (mg/L) – Dissolved Metals

Analyte	Total n	Stations	Mean	Min	Max	Std Dev
Cadmium	44	4	0.0092	0.0001	0.036	0.01
Copper	44	4	0.0017	0.0003	0.011	0.002
Lead	44	4	0.0106	0.0005	0.096	0.02
Zinc	45	4	3.13	0.00045	9.82	3.44

Summary of DWS Groundwater Quality Characteristics (mg/L) – Dissolved Metals

Analyte	MCL	Total n	Stations	Mean	Min	Max	Std Dev
Cadmium	0.005	2	1	0.0015	0.0005	0.0025	0.0014
Copper	1.3[1]	2	1	0.0023	0.002	0.0025	0.0004
Lead	0.015[2]	2	1	0.01	0.005	0.015	0.007
Zinc	5.0	2	1	0.193	0.0022	0.383	0.269

Related Benchmark Comparisons

No shallow monitoring well data for benchmark comparison with Reach 0. Shallow groundwater data generally exceed more stringent surface water criteria. Domestic water supply well water quality is similar to Reach 0.

Statement of Injury: Concentrations in DWS wells in Reach 1 are below the MCLs defining injury. Although shallow groundwater exceeds both the surface water criteria (ALC) and MCLs at certain locations, this water is not causing injury to the surface water or domestic water supply resources.

Commentary: Most of the wells are very shallow and are completed within or adjacent to mine-waste deposits. A focused study by USGS in Reach 3 shows the range of impact from mine-waste deposits limited due to the large volume of surface and groundwater flow when compared to the relatively small volume of wastes in the valley fill aquifer system. Based on USGS findings, localized contamination from mine-waste deposits is expected. Current surface water data do not indicate a significant groundwater/surface water pathway. This may again be due to the large volumes of flow in both the ground and surface water systems. Deeper groundwater providing the domestic water supply is suitable for such use.

Representativeness of Data: The combination of SMW and DWS data are considered to be representative of the condition of groundwater resources.

Data Gaps: None.

Is current information sufficient for restoration planning? Yes

Related Text: Sections 2.3.4; 3.3.4

Groundwater 1992 to 2000

Reach 3 – Downstream of Highway 24 Bridge to Narrows near Kobe (3.5 RM)

Regulatory Thresholds For Injury

1. Exceedence of the Maximum Contaminant Levels [43CFR11.62(c)].

Summary of SMW Groundwater Quality Characteristics (mg/L) – Dissolved Metals

Analyte	Total n	Stations	Mean	Min	Max	Std Dev
Cadmium	155	26	0.0184	0.0001	0.249	0.036
Copper	153	26	0.0331	0.0003	0.442	0.066
Lead	154	26	0.016	0.0005	0.476	0.052
Zinc	158	26	2.35	0.00045	16.203	3.01

Summary of DWS Groundwater Quality Characteristics (mg/L) – Dissolved Metals

Analyte	MCL	Total n	Stations	Mean	Min	Max	Std Dev
Cadmium	0.005	1	1	0.0025	0.0025	0.0025	0
Copper	1.3[1]	1	1	0.0025	0.0025	0.0025	0
Lead	0.015[2]	1	1	0.015	0.015	0.015	0
Zinc	5.0	2	2	0.081	0.032	0.13	0.069

Related Benchmark Comparisons

No shallow monitoring well data for benchmark comparison with Reach 0. Shallow groundwater data generally exceed more stringent surface water criteria. Domestic water supply well water quality is similar to Reach 0.

Statement of Injury: Concentrations in DWS wells in Reach 1 are below the MCLs defining injury. Although shallow groundwater exceeds both the surface water criteria (ALC) and MCLs at certain locations, this water is not causing injury to the surface water or domestic water supply resources.

Commentary: Most of the wells are very shallow and are completed within or adjacent to mine-waste deposits. A focused study by USGS in Reach 3 shows the range of impact from mine-waste deposits limited due to the large volume of surface and groundwater flow when compared to the relatively small volume of wastes in the valley fill aquifer system. Based on USGS findings, localized contamination from mine-waste deposits is expected. Current surface water data do not indicate a significant groundwater/surface water pathway. This may again be due to the large volumes of flow in both the ground and surface water systems. Deeper groundwater providing domestic water supply is suitable for such use.

Representativeness of Data: The combination of SMW and DWS data are considered to be representative of the condition of groundwater resources.

Data Gaps: See Reach 1.

Is current information sufficient for restoration planning? Yes

Related Text: Sections 2.4.4; 3.4.4

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[1] There is no MCL for copper, but it has a drinking water supply standard of 1.3 mg/L in Colorado.

[2] There is no MCL for lead, but it has an action level of 0.015 mg/L in Colorado.

Groundwater 1992 to 2000	
Reach 4 – Downstream of Narrows near Kobe to Two Bit Gulch (1.6 RM)	
Regulatory Thresholds For Injury	1. Exceedence of the Maximum Contaminant Levels [43CFR11.62(c)].
	Summary Data There are no SMW or DWS summary data available for this reach.
Related Benchmark Comparisons	No data for benchmark comparison with Reach 0. Groundwater data generally exceed more stringent surface water criteria.
	Statement of Injury: There are no significant mine-waste deposits within Reach 4. It is expected that the water quality in the shallow groundwater system immediately adjacent to the river would be comparable to that of the river and domestic water supplies would not be injured. Commentary: Given the constriction of the valley at Reach 4, some shallow groundwater probably reports to the river (i.e., a gaining reach). It is expected that metals loading from groundwater would be insignificant compared to the large flow in the Arkansas River under all conditions. Representativeness of Data: Data Gaps: Any collection of groundwater data would be more appropriate for upstream reaches given the lack of mine-waste deposits in this reach. Is current information sufficient for restoration planning? Yes Related Text: Sections 2.5.4; 3.5.4

3. Geologic Resources:

A. Floodplain Soils

Floodplain Soils

Reach 0 – Confluence of Tennessee Creek and East Fork Arkansas River to County Road 300 (2.8 RM)

Control Site Conditions

Summary Data

Total Metal Concentrations of Floodplain Soils

Analyte	Mean Concentrations (mg/kg)
Cadmium	3.3
Copper	29.9
Lead	238
Zinc	428

Plant-Available Metal Concentrations of Floodplain Soils

Analyte	Mean Concentrations (mg/kg)
Cadmium	1.4
Copper	3.9
Lead	23.7
Zinc	73.9

Literature Threshold Concentrations of Total Metals
in Soils for Toxicity to Vegetation (Kabata-Pendias 2001)

Analyte	Literature Threshold Concentrations (mg/kg)
Cadmium	8
Copper	125
Lead	400
Zinc	400

Commentary: The only metal in soil reported to be in a toxic range was total zinc. However, the toxic threshold is specifically for agronomic species such as lettuce, beans, and corn. Native perennial species have been shown to be more tolerant of metals than agronomic species (Paschke et al. 2000). Plant-available zinc concentrations are well below levels considered to be toxic to native plants (Paschke et al. 2000). This assessment is supported by the Reach 0 vegetation data.

Representativeness of Data: The data are considered to be representative of actual field conditions in Reach 0. Sample locations are well distributed within riparian zones along the East Fork of the Arkansas River and Tennessee Creek. Samples along St. Kevins Gulch have not been included in the summary data because of potential impacts from previous mining in that area. There are no identified fluvial mine-waste deposits in Reach 0. There are no identified mine-waste deposits in Reach 0.

Data Gaps: No data gap is identified.

Related Text: Sections 2.1.5; 3.1.5

Floodplain Soils

Reach 1 – Downstream of California Gulch Confluence to Upstream of Lake Fork Confluence (1.6 RM)

Regulatory Thresholds For Injury

1. Concentrations of metals in soils sufficient to cause a phytotoxic response [43 CFR11.62(e)(10)].
2. Soil pH [43 CFR11.62(e)(2)].

Summary Data

Total Metal Concentrations of Floodplain Soils (mg/kg)

Analyte	Mean Concentrations	
	Reach 0	Reach 1
Cadmium	3.3	13.5
Copper	29.9	192
Lead	238	3,990
Zinc	428	3,142

Plant Available Metal Concentrations of Floodplain Soils (mg/kg)

Analyte	Mean Concentrations	
	Reach 0	Reach 1
Cadmium	1.4	2.9
Copper	3.9	12.7
Lead	23.7	51.4
Zinc	73.9	158

Total Metal Concentrations of Mine-Waste Deposits (mg/kg)

Analyte	Mean Concentrations
Cadmium	177
Copper	446
Lead	4,228
Zinc	7,271

Soil pH above injury level of 4.0. No regulatory injury due to pH.

Related Benchmark Comparisons

Compared to Reach 0, total metals concentrations in floodplain (riparian) soils along Reach 1 are substantially higher. Plant-available metals concentrations in Reach 1 are also higher than Reach 0, but the concentrations are in a similar range. Based on concentrations in the literature considered to induce a phytotoxic response in plants, the plant-available concentrations in Reach 1 are well below levels reported to be phytotoxic. Total metals concentrations in mine-waste deposits along Reach 1 are substantially higher than floodplain soils in Reach 0.

Statement of Injury: Soils where mine-waste deposits occur are considered to be injured. Total metal concentrations exceed toxicity thresholds and plant growth has been substantially impacted on most sites where mine-waste deposits have been identified. Of 24 deposits along Reach 1, 14 deposits have poor vegetation cover (<10% cover), 9 deposits have fair vegetation cover (10-50% cover), and 1 deposit has good vegetation cover (>50% cover), using aerial photographs to judge plant cover. Based on plant-available concentrations, floodplain soils are not considered to be injured.

Commentary: Mine-waste deposits in Reach 1 cover a surface area of approximately 18 acres, with a volume of approximately 887,000 ft^3. These deposits are distributed in close proximity to the Arkansas River throughout the reach. Of the 24 deposits in this reach, 11 are ranked as a high priority for restoration, 11 are ranked as moderate priority, and 2 are ranked as low priority (Section 4.0 and Appendix 6). The potential for these deposits to influence metals concentrations in both surface water and groundwater is limited by the shallow thickness of the deposits and the corresponding small loading potential relative to the large volume of surface and groundwater moving through the valley. Stream bank deposits of mine waste comprise a small portion of the total length of the banks along Reach 1.

Floodplain (riparian) soils include non-mine waste soils within and adjacent to the 500 year floodplain of the Arkansas River. The fact that total metals concentrations along Reach 1 are substantially higher than concentrations found in floodplain soils in Reach 0 is evidence that these soils have been impacted by water from the Arkansas River; from past irrigation and flooding. Vegetation along this reach is productive and all data reviewed indicate that plant tissue concentrations of heavy metals are below concentrations considered to by phytotoxic.

Plant-available concentrations of metals are the best measure of injury determination because the bioavailable fraction of the metal is what determines biotic responses. In addition, threshold concentrations from the literature are primarily from hydroponic and sand culture experiments, where plant-available metal concentrations are the same as total metal concentrations. Thus, comparing plant-available metal concentrations from the Upper Arkansas River to total metal concentrations from the literature is an acceptable comparison.

Representativeness of Data: The data are considered to be representative of actual field conditions in Reach 1, and believed to be adequate to characterize injury. Sample locations are well distributed along Reach 1 and located within riparian zones associated with the Arkansas River.

Data Gaps: More pH data and acid-generating potential of mine-waste deposits would be valuable in restoration planning but is not needed for injury assessment. Plant-available metal concentrations of mine-waste deposits would be valuable for injury assessment.

Is current information sufficient for restoration planning? Yes. However, this answer depends on the level of detail required for the restoration alternatives. If design includes amendment rates, then data on pH and acid-generating potential of mine-waste deposits is needed. It would take approximately 3 to 6 months to generate these data at a cost of approximately $15,000.

Related Text: Sections 2.2.5; 3.2.5

Floodplain Soils

Reach 2 – Downstream of Lake Fork Confluence to Upstream of Highway 24 Bridge (3.3 RM)

Regulatory Thresholds For Injury

1. Concentrations of metals in soils sufficient to cause a phytotoxic response [43 CFR11.62(e)(10)].
2. Soil pH [43 CFR11.62(e)(2)].

Summary Data

Total Metal Concentrations of Floodplain Soils (mg/kg)

Analyte	Mean Concentrations	
	Reach 0	Reach 2
Cadmium	3.3	15.4
Copper	29.9	51.4
Lead	238	675
Zinc	428	1,180

Plant Available Metal Concentrations of Floodplain Soils (mg/kg)

Analyte	Mean Concentrations	
	Reach 0	Reach 2
Cadmium	1.4	2.6
Copper	3.9	2.5
Lead	23.7	24.5
Zinc	73.9	121

Total Metal Concentrations of Mine-Waste Deposits (mg/kg)

Analyte	Mean Concentrations
Cadmium	153
Copper	200
Lead	3,266
Zinc	3,438

Soil pH above injury level of 4.0. No regulatory injury due to pH.

Related Benchmark Comparisons

Compared to Reach 0, total metals concentrations in floodplain (riparian) soils along Reach 2 are substantially higher. Plant-available metals concentrations in Reach 2, however, are similar to Reach 0. Based on concentrations in the literature considered to induce a phytotoxic response in plants, the plant-available concentrations in Reach 2 are well below levels reported to be phytotoxic. Total metals concentrations in mine-waste deposits along Reach 2 are substantially higher than floodplain soils in Reach 0.

Statement of Injury: Soils where mine-waste deposits occur are considered injured. Total metal concentrations exceed toxicity thresholds and plant growth has been substantially impacted on most sites where mine-waste deposits have been identified. Of 35 deposits along Reach 2, 2 deposits have poor vegetation cover (<10% cover), 19 deposits have fair vegetation cover (10-50% cover), and 14 deposits have good vegetation cover (>50% cover), using aerial photographs to judge plant cover. Based on plant-available concentrations, floodplain soils are not considered to be injured.

Commentary: Mine-waste deposits in Reach 2 cover a surface area of approximately 9 acres, with a volume of approximately 233,000 ft^3. These deposits are distributed in close proximity to the Arkansas River, throughout the reach. Of the 35 deposits in this reach, 3 are ranked as high priority for restoration, 27 are ranked as moderate priority, and 5 are ranked as low priority (Section 4.0 and Appendix 6). The potential for these deposits to influence metals concentrations in both surface water and groundwater is limited by the shallow thickness of the deposits and the corresponding small loading potential relative to the large volume of surface and groundwater moving through the valley. Stream bank deposits of mine waste comprise a small portion of the total length of the banks along Reach 2.

Floodplain (riparian) soils include non-mine waste soils within and adjacent to the 500 year floodplain of the Arkansas River. The fact that total metals concentrations along Reach 2 are substantially higher than concentrations found in floodplain soils in Reach 0 is evidence that these soils have been impacted by water from the Arkansas River; from past irrigation and flooding. Vegetation along this reach is productive and all data reviewed indicate that plant tissue concentrations of heavy metals are below concentrations considered to by phytotoxic, with the exception of zinc, which is in the toxic range for agronomic species. Recent work by Paschke et al. (2000) on zinc toxicity in native perennial species established toxicity thresholds that are two times higher than the tissue concentrations found in Reach 2. The EPA study on irrigated soils planned for 2001-02 should provide additional data to answer the question of phytotoxicity.

Plant-available concentrations of metals are the best measure for injury determination because the bioavailable fraction of the metal is what determines biotic responses. In addition, threshold concentrations from the literature are primarily from hydroponic and sand culture experiments, where plant-available metal concentrations are the same as total metal concentrations. Thus, comparing plant-available metal concentrations from the UAR to total metal concentrations from the literature is an acceptable comparison.

Representativeness of Data: The data are considered to be representative of actual field conditions in Reach 2, and believed to be adequate to characterize injury. Sample locations are well distributed along Reach 2 and located within riparian zones associated with the Arkansas River. See vegetation matrix for Reach 2 for discussion of plant tissue concentrations as related to above comments under commentary.

Data Gaps: More pH data and acid-generating potential of mine-waste deposits would be valuable in restoration planning but is not needed for injury assessment. Plant-available metal concentrations of mine-waste deposits would be valuable for injury assessment.

Is current information sufficient for restoration planning? Yes. However, this answer depends on the level of detail required for the restoration alternatives. If design includes amendment rates, then data on pH and acid-generating potential of mine-waste deposits is needed. It would take approximately 3 to 6 months to generate these data at a cost of approximately $9,000.

Related Text: Section 2.3.5; 3.3.5

Floodplain Soils

Reach 3 – Downstream of Highway 24 Bridge to Narrows near Kobe (3.5 RM)

Regulatory Thresholds For Injury

1. Concentrations of metals in soils sufficient to cause a phytotoxic response [43 CFR11.62(e)(10)].
2. Soil pH [43 CFR11.62(e)(2)].

Summary Data

Total Metal Concentrations of Floodplain Soils (mg/kg)

Analyte	Mean Concentrations	
	Reach 0	Reach 3
Cadmium	3.3	7.4
Copper	29.9	58.5
Lead	238	626
Zinc	428	959

Plant Available Metal Concentrations of Floodplain Soils (mg/kg)

Analyte	Mean Concentrations	
	Reach 0	Reach 3
Cadmium	1.4	3.1
Copper	3.9	8.6
Lead	23.7	11.8
Zinc	73.9	175

Total Metal Concentrations of Mine-Waste Deposits (mg/kg)

Analyte	Mean Concentrations
Cadmium	153
Copper	301
Lead	3,517
Zinc	5,212

Soil pH above injury level of 4.0. No regulatory injury due to pH.

Related Benchmark Comparisons

Compared to Reach 0, total metals concentrations in floodplain (riparian) soils along Reach 3 are substantially higher. Plant-available metals concentrations in Reach 3, however, are similar to Reach 0. Based on concentrations in the literature considered to induce a phytotoxic response in plants, the plant-available concentrations in Reach 3 are well below levels reported to be phytotoxic. Total metals concentrations in mine-waste deposits along Reach 3 are substantially higher than floodplain soils in Reach 0.

Statement of Injury: Soil where mine-waste deposits occur are considered to be injured. Total metal concentrations exceed toxicity thresholds and plant growth has been substantially impacted on most sites where mine-waste deposits have been identified. Of 94 deposits along Reach 3, 26 deposits have poor vegetation cover (<10% cover), 56 deposits have fair vegetation cover (10-50% cover), and 12 deposits have good vegetation cover (>50% cover), using aerial photographs to judge plant cover. Based on plant-available concentrations, floodplain soils are not considered to be injured.

Commentary: Mine-waste deposits in Reach 3 cover a surface area of approximately 37 acres, with a volume of approximately 1,578,300 ft^3. These deposits are distributed in close proximity to the Arkansas River, throughout the reach. Of the 94 deposits in this reach, 13 are ranked as high priority for restoration, 69 are ranked as moderate priority, and 12 are ranked as low priority (Section 4.0 and Appendix 6). The potential for these deposits to influence metals concentrations in both surface water and groundwater is limited by the shallow thickness of the deposits and the corresponding small loading potential relative to the large volume of surface and groundwater moving through the valley. Stream bank deposits of mine waste comprise a small portion of the total length of the banks along Reach 3.

Floodplain (riparian) soils include non-mine waste soils within and adjacent to the 500 year floodplain of the Arkansas River. The fact that total metals concentrations along Reach 3 are substantially higher than concentrations found in floodplain soils in Reach 0 is evidence that these soils have been impacted by water from the Arkansas River; most likely from past irrigation and flooding. Vegetation along this reach is productive and all data reviewed indicate that plant tissue concentrations of heavy metals are below concentrations considered to by phytotoxic.

Plant-available concentrations of metals are the best measure for injury determination because the bioavailable fraction of the metal is what determines biotic responses. In addition, threshold concentrations from the literature are primarily from hydroponic and sand culture experiments, where plant-available metal concentrations are the same as total metal concentrations. Thus, comparing plant-available metal concentrations from the UAR to total metal concentrations from the literature is an acceptable comparison.

Representativeness of Data: The data are considered to be representative of actual field conditions in Reach 3, and believed to be adequate to characterize injury. Sample locations are well distributed along Reach 3 and located within riparian zones associated with the Arkansas River.

Data Gaps: More pH data and acid-generating potential of mine-waste deposits would be valuable in restoration planning but is not needed for injury assessment. Plant-available metal concentrations of mine-waste deposits would be valuable for injury assessment.

Is current information sufficient for restoration planning? Yes. However, there is not adequate data for design. If design includes amendment rates, then data on pH and acid-generating potential of mine-waste deposits is needed. It would take approximately 3 to 6 months to generate these data at a cost of approximately $23,000.

Related Text: Sections 2.4.5; 3.4.5

Floodplain Soils	
Reach 4 – Downstream of Narrows near Kobe to Two Bit Gulch (1.6 RM)	
Regulatory Thresholds For Injury	1. Concentrations of metals in soils sufficient to cause a phytotoxic response [43 CFR11.62(e)(10)]. 2. Soil pH [43 CFR11.62(e)(2)].
	Summary Data No data are available for floodplain soils in Reach 4. Some small deposits of mine-waste exist in Reach 4; however, they have not been quantified with respect to surface area, volume, and chemical properties.
Related Benchmark Comparisons	No floodplain soils or mine-waste data to make comparisons with Reach 0
	Statement of Injury: There is no evidence to indicate injury to floodplain (riparian) soils in Reach 4. Soil metal concentrations decline in each subsequent reach below Reach 0. It is assumed that soil metal concentrations in Reach 4 are lower than in Reach 3. Since floodplain soils are not considered to be injured in reaches upstream of Reach 4, there is no reason to believe that floodplain soils along Reach 4 are injured. With respect to mine-waste deposits, not enough information exists to draw direct conclusions about injury. However, only a few small barren or sparsely vegetated areas consistent with mine-waste deposits could be identified. It is inferred that soils in those small areas are injured due to the presence of mine-waste. Commentary: Field observations indicate that vegetation along this reach is productive. The potential for mine-waste deposits to influence metals concentrations in both surface water and groundwater is limited by the corresponding small loading potential relative to the large volume of surface and groundwater moving through the valley. Representativeness of Data: No data available. Data Gaps: Soil data are not available for this reach, but collection of this data is not necessary. Data on physical and chemical properties of mine-waste are needed. Is current information sufficient for restoration planning: Based on data from reaches upstream of Reach 4, extrapolations can be made to Reach 4 that would be adequate for restoration planning. pH data and acid-generating potential of mine-waste deposits would be valuable in restoration planning. Metal concentrations of mine-waste deposits would be valuable for injury assessment, along with an assessment of plant cover. It would take approximately 3 to 6 months to generate these data at a cost of approximately $4,000. Related Text: Sections 2.5.5; 3.5.5

4. Biological Resources:

- **A. Vegetation**
- **B. Benthic Organisms**
- **C. Brown Trout**
- **D. Terrestrial Wildlife – Small Mammals**
- **E. Terrestrial Wildlife – Migratory Birds**

Vegetation

Reach 0 – Confluence of Tennessee Creek and East Fork Arkansas River to County Road 300 (2.8 RM)

Control Site Conditions

Summary Data

Total Plant Cover = 52.4%; Total Biomass = 137 g/m^2; Species Diversity = Average of 14 Species

Plant Tissue Metal Concentrations for Grasses and Forbs (mg/kg)

Analyte	Grasses (mg/kg)	Forbs (mg/kg)
Cadmium	0.8	3.8
Copper	5.1	11.2
Lead	0.1	2.9
Zinc	82	255

Literature Thresholds for Tissue Metal Concentrations Considered to be Toxic to Vegetation (Kabata-Pendias 2001)

Analyte	Literature Threshold Concentrations (mg/kg)
Cadmium	30
Copper	100
Lead	300
Zinc	400

Physiological/Morphological Effects: No data available.

Commentary: All tissue metal concentrations are well below thresholds considered to be toxic to perennial species. Plant communities have cover and production levels that are representative of non-metal impacted sites in this environment that have been subjected to domestic livestock grazing.

Representativeness of Data: Data are considered to be representative of actual field conditions in Reach 0. Sample locations are well distributed within riparian zones along the East Fork of the Arkansas River and Tennessee Creek. Samples along St. Kevins Gulch have not been included in the summary data because of potential impact from previous mining in this area.

Data Gaps: No data gaps identified.

Related Text: Sections 2.1.6.1; 3.1.6.1

Vegetation

Reach 1 – Downstream of California Gulch Confluence to Upstream of Lake Fork Confluence (1.6 RM)

Regulatory Thresholds For Injury

1. Concentrations of metals in soils sufficient to cause a phytotoxic response [43 CFR11.62(e)(10)].

Summary Data

Plant Tissue Metal Concentrations for Grasses and Forbs (mg/kg)

Analyte	Reach 0		Reach 1	
	Grasses	Forbs	Grasses	Forbs
Cadmium	0.8	3.8	2.2	4.6
Copper	5.1	11.2	4.6	10.3
Lead	0.1	2.9	12.2	19.8
Zinc	82	255	153	248

Comparison with Reach 0

Vegetation Measure	Reach 0	Reach 1
Total Biomass (g/m^2)	137	256
Total Plant Cover (%)	52.4	63.4
Avg. Species Diversity	14	16

Physiological/Morphological Effects: No data available.

Related Benchmark Comparisons

For cover, biomass, and species diversity comparison, see table above.

Statement of Injury: Cover, biomass, and number of species in Reach 1 are equal to or greater than Reach 0. All tissue metal concentrations are below thresholds considered to be toxic to perennial species. There is no evidence of metal induced injury in Reach 1 for vegetation growing in riparian areas. However, vegetation is injured where most mine-waste deposits occur (see floodplain soils matrices).

Commentary: Out of 24 mine-waste deposits, 22 are ranked as high or moderate priority for restoration. 23 of these deposits have poor to fair vegetation cover.

Cadmium concentrations in grasses and forbs are in a range considered to be toxic to ruminants (0.5 mg/kg). Therefore, there is a potential problem for ruminants along this portion of the Arkansas River. In addition, sampling by Levy et al. (1992) found one sample of lousewort (*Pedicularis* spp.) with zinc concentrations high enough (>500 mg/kg) to be problematic to ruminants. Elevated concentrations of zinc in forage (>300 mg/kg) can result in zinc induced copper deficiency in cattle. It is important to note, however, that actual toxicity cannot be determined without a detailed study of an animal's diet and corresponding animal physiological tests. An exposure assessment is needed to determine injury to large mammals.

Representativeness of Data: Data are considered to be representative of actual field conditions in Reach 1, and believed to be adequate to characterize injury. Sample locations are well distributed along Reach 1 and located within riparian zones associated with the Arkansas River.

Data Gaps: No ground-collected data are available for plant cover and production on mine-waste deposits. No data are available for tissue metal concentrations of vegetation growing on mine-waste deposits. Although these data would be informative, they are not essential for defining injury or for restoration planning. An exposure assessment would be valuable in determining injury to large mammals.

Is current information sufficient for restoration planning? Yes.

Related Text: Sections 2.2.6.1; 3.2.6.1

Vegetation

Reach 2 – Downstream of Lake Fork Confluence to Upstream of Highway 24 Bridge (3.3 RM)

Regulatory Thresholds For Injury

1. Concentrations of metals in soils sufficient to cause a phytotoxic response [43 CFR11.62(e)(10)].

Summary Data

Plant Tissue Metal Concentrations for Grasses and Forbs (mg/kg)

Analyte	Reach 0		Reach 2	
	Grasses	Forbs	Grasses	Forbs
Cadmium	0.8	3.8	1.6	3.4
Copper	5.1	11.2	4.9	7.7
Lead	0.1	2.9	9.0	13.1
Zinc	82	255	147	186

Comparison with Reach 0

Vegetation Measure	Reach 0	Reach 2
Total Biomass (g/m^2)	137	242
Total Plant Cover (%)	52.4	77.0
Avg. Species Diversity	14	14

Physiological/Morphological Effects: Evidence of iron deficiency and iron chlorosis in pastures on Smith Ranch (Sommers et al. 1991) caused by excess zinc in the plant tissue.

Related Benchmark Comparisons

For cover, biomass, and species diversity comparison, see table above.

Statement of Injury: Cover, biomass, and number of species in Reach 2 are equal to or greater than Reach 0. There is no evidence of metal-induced injury in Reach 2 for vegetation growing in riparian areas. Vegetation is injured where most mine-waste deposits occur (see floodplain soils matrices).

Commentary: Average zinc concentrations in grasses and forbs are below phytotoxicity thresholds (Table 3-2), but some individual plant samples had tissue concentrations that were in the toxic range for agronomic species. It is important to note that toxicity thresholds vary among plant species and perennial species are generally much more metal tolerant that annual agronomic species that are more commonly cited in the toxicity literature. Work by Paschke et al. (2000) on zinc toxicity in native perennial speices established zinc toxicity thresholds for perennial grasses. Toxicity was not reported for zinc until plant tissue concentrations exceeded 2,000 mg/kg. This is two times higher than the tissue concentrations found in Reach 2. The EPA study on irrigated soils planned for 2001-02 should provide additional data to answer the question of phytotoxicity. Currently, there is no evidence of metal-induced injury in Reach 2 for vegetation growing in riparian areas.

Sommers et al. (1991) reported zinc-induced iron deficiency/chlorosis on the Smith Ranch. However, data on plant cover and production were not collected in a way to determine if this chlorosis has resulted in a significant reduction in plant growth. Field observations in 2000 and 2001 along Reach 2 provide supporting evidence that plant communities are healthy and similar in productivity and cover to Reach 0.

Tissue metal concentrations of Cd are high enough to potentially pose a problem for ruminants, however toxicity cannot be determined without detailed study of an animal's diet. In addition, reports of iron and copper deficiencies in cattle may be attributed to elevated zinc levels in soils and vegetation along this reach. An exposure assessment is needed to determine injury to large mammals.

With respect to mine-waste deposits, 30 out of 35 deposits are ranked as high or moderate priority for restoration. 21 of these deposits have poor to fair vegetation cover.

Representativeness of Data: Existing data may be representative of actual field conditions but are not adequate to determine geographic extent or degree of zinc toxicity to vegetation.

Data Gaps: No ground-collected data are available for plant cover and production on mine-waste deposits. No data are available for tissue metal concentrations of vegetation growing on mine-waste deposits. Although these data would be informative, they are not essential for defining injury or for restoration planning. If zinc induced iron deficiency/chlorosis still exists along Reach 2, the literature indicates that plant production would be affected (based on greenhouse study conducted by Sommers et al 1991). However, no data exists to quantify the level of reduction, and no data exists to describe the geographical extent of this zinc effect.

An exposure assessment would be valuable in determining injury to large mammals.

Is current information sufficient for restoration planning? No. Additional data on zinc concentrations in vegetation are needed, in order to determine if some restoration is actually needed. It would take approximately 3 months to generate this data and the cost would be approximately $15,000. However, the treatment of zinc induced iron deficiency/chlorosis can be easily accomplished with foliar application of $FeSO_4$. Foliar applied $FeSO_4$ has been demonstrated to increase plant yield, increase Cu concentration, increase Fe concentration and reduce zinc concentration in plant tissue.

Related Text: Sections 2.3.1.6; 3.3.6.1

Vegetation

Reach 3 – Downstream of Highway 24 Bridge to Narrows near Kobe (3.5 RM)

Regulatory Thresholds For Injury

1. Concentrations of metals in soils sufficient to cause a phytotoxic response [43 CFR11.62(e)(10)].

Summary Data

Plant Tissue Metal Concentrations for Grasses and Forbs (mg/kg)

Analyte	Reach 0		Reach 3	
	Grasses	Forbs	Grasses	Forbs
Cadmium	0.8	3.8	1.6	6.4
Copper	5.1	11.2	6.4	18.9
Lead	0.1	2.9	4.5	0.1
Zinc	82	255	239	394

Comparison with Reach 0

Vegetation Measure	Reach 0	Reach 3
Total Biomass (g/m^2)	137	136
Total Plant Cover (%)	52.4	65.2
Avg. Species Diversity	14	11

Physiological/Morphological Effects: No data available.

Related Benchmark Comparisons

For cover, biomass, and species diversity comparison, see table above.

Statement of Injury: Cover in Reach 3 is greater than Reach 0. Biomass is the same and number of species in Reach 3 is slightly less than Reach 0. All tissue metal concentrations are below thresholds considered to be toxic to perennial species. There is no evidence of metal-induced injury in Reach 3 for vegetation growing in riparian areas. However, vegetation is injured where most mine-waste deposits occur (see floodplain soil matrices).

Commentary: Available data do not indicate injury to vegetation growing on riparian soils in Reach 3. However, out of 94 mine-waste deposits, 72 are ranked as high or moderate priority for restoration. 82 of these deposits have poor to fair vegetation cover.

Keammerer (1987) reported that average concentrations of all metals in grasses and forbs were below concentrations considered to be excessive or toxic to agronomic plants (Table 3-2). But some individual plant samples had zinc tissue concentrations that were in the toxic range for agronomic plants (Table 2-61). It is important to note that toxicity thresholds vary among plant species and perennial species are generally much more metal tolerant that annual agronomic species that are more commonly cited in the toxicity literature. Work by Paschke et al. (2000) on zinc toxicity in native perennial species established zinc toxicity thresholds for perennial grasses. Toxicity was not reported for zinc until plant tissue concentrations exceeded 2,000 mg/kg. This is two times higher than the tissue concentrations found in Reach 3.

Tissue metal concentrations of cadmium are high enough to pose a problem for ruminants; however, toxicity cannot be determined without a detailed study of an animal's diet along with corresponding animal physiological/pathological tests. An exposure assessment is needed to determine injury to large mammals.

Representativeness of Data: Data are considered to be representative of actual field conditions in Reach 3. Sample locations are well distributed along Reach 3 and located within riparian zones associated with the Arkansas River.

Data Gaps: No ground-collected data are available for plant cover and production on mine-waste deposits. No data are available for tissue metal concentrations of vegetation growing on mine-waste deposits. Although these data would be informative, they are not essential for defining injury or for restoration planning. See Appendix J.

Is current information sufficient for restoration planning? Yes.

Related Text: Sections 2.4.6.1; 3.4.6.1

Vegetation

Reach 4 – Downstream of Narrows near Kobe to Two Bit Gulch (1.6 RM)

Regulatory Thresholds For Injury

1. Concentrations of metals in soils sufficient to cause a phytotoxic response [43 CFR11.62(e)(10)].

Summary Data

No data are available regarding plant tissue concentrations for Reach 4.

Plant Tissue Metal Concentrations for Grasses and Forbs (mg/kg)

Analyte	Reach 0	
	Grasses	Forbs
Cadmium	0.8	3.8
Copper	5.1	11.2
Lead	0.1	2.9
Zinc	82	255

Physiological/Morphological Effects: No data available.

Related Benchmark Comparisons

1. Reach 0 is the benchmark for cover, biomass, and species diversity. Total plant cover in Reach 0 = 52.4%, total biomass = 137 g/m^2, species diversity = average of 14 species.
2. No data are available for vegetation cover, production, or tissue metal concentrations.

Statement of Injury: Evidence of injury to vegetation along Reach 4 is uncertain because no plant cover or chemical data exists for mine-waste deposits. However, small barren or sparsely vegetated mine-waste deposits indicate injury to vegetation.

Commentary: Field observations along Reach 4 confirm that vegetation is productive in floodplain soils.

Representativeness of Data: No quantitative data available.

Data Gaps: No data are available for plant cover, production, or species diversity. No data are available for tissue metal concentrations of vegetation growing on riparian soils or mine-waste deposits.

Is current information sufficient for restoration planning: Yes. Data on mine-waste deposits, as noted earlier, would be adequate for restoration planning.

Related Text: Sections 2.5.6.1; 3.5.6.1

Benthic Organisms

Reach 0 – Confluence of Tennessee Creek and East Fork Arkansas River to County Road 300 (2.8 RM)

Control Site Conditions

Summary Data

Reach 0	
Number of Macroinvertebrate Taxa	24.4
Species Richness of Mayflies	6.4
Total Abundance of Mayflies	184.8
Total Abundance of Heptageniidae	75.1

Commentary: Dramatic improvements in benthic communities have been observed since remediation of Leadville Mine Drainage Tunnel. Currently, benthic communities in Reach 0 are diverse and dominated by several metal sensitive groups. Communities are similar to those observed in other reference streams in the mineralized region of Colorado.

Representativeness of Data: Data used for this analysis were collected from station AR1, immediately downstream from the confluence of Tennessee Creek and the East Fork of the Arkansas River. Community structure data are based on 11 years of monitoring benthic macroinvertebrates in the Arkansas River. Metal concentrations in caddisflies have been measured during this same period.

Data Gaps: None

Related Text: Sections 2.1.6.3.1; 3.1.6.2.1

Benthic Organisms

Reach 1 – Downstream of California Gulch Confluence to Upstream of Lake Fork Confluence (1.6 RM)

Regulatory Thresholds For Injury

1. Metal concentrations considered toxic to benthic macroinvertebrates [43 CFR 11.62(f)(1)(i)];
2. See Surface Water;
3. Genetic diversity; and
4. Microcosm experiments.

Summary Data

	Reach 0	Reach 1
Number of Macroinvertebrate Taxa	24.4	18.9
Species Richness of Mayflies	6.4	3.1
Total Abundance of Mayflies	184.8	48.7
Total Abundance of Heptageniidae	75.1	2.7

Related Benchmark Comparisons

1. Comparisons to benchmark (Reach 0):
   a. Community structure;
   b. Metal levels in dominant taxa; and
   c. Metal levers in periphyton.

Statement of Injury: Benthic organisms are injured due to elevated metals concentrations in surface water. Results of microcosm experiments show that aqueous metal levels are sufficient to cause significant mortality to most macroinvertebrate taxa. Significant effects of sediments collected from Reach 1 were observed on growth and survivorship of chironomids. Significant loss of genetic diversity in mayflies was observed in Reach 1. Moderate reduction in total species richness was observed. Large reduction in mayfly richness and total abundance of mayflies was observed. Metal-sensitive Heptageniidae were virtually eliminated. Highly elevated metal levels were observed in most dominant taxa and concentrations of cadmium and zinc were 2-3 times greater in *Arctopsyche grandis*. Rapid uptake of cadmium and zinc by the caddisfly *Brachycentrus* was measured in field experiments. Significant accumulation of metals by chironomids exposed to sediment and by mayflies exposed to periphyton was measured. Highly elevated levels of metals in periphyton were measured.

Commentary: The primary pathway for benthic macroinvertebrate exposure is surface water quality. However, elevated metals concentrations in periphyton, a food source for portions of the community, contribute to the level of exposure. Although the periphyton structure (e.g., number of species and community composition) does not appear to be injured due to elevated metals, it provides an indirect exposure pathway for metals in the surface water system.

Representativeness of Data: Community structure data in Reach 1 are based on 11 years of monitoring the Arkansas River at station AR3, 0.5 km downstream from California Gulch. Metal levels in caddisflies and other dominant taxa have been measured over the same period.

Data Gaps: None

Is current information sufficient for restoration planning? Yes

Related Text: Sections 2.2.6.3.1; 3.2.6.2.1

Benthic Organisms

Reach 2 – Downstream of Lake Fork Confluence to Upstream of Highway 24 Bridge (3.3 RM)

Regulatory Thresholds For Injury

1.Metal concentrations considered to be toxic to macroinvertebrates [43 CFR 11.62(f)(1)(i)];
2. See Surface Water; and
3. Microcosm experiments.

Summary Data

	Reach 0	**Reach 2**
Number of Macroinvertebrate Taxa	24.4	25.2
Species Richness of Mayflies	6.4	4.8
Total Abundance of Mayflies	184.8	103.0
Total Abundance of Heptageniidae	75.1	18.6

Related Benchmark Comparisons

1. Comparisons to benchmark:
   a. Community structure.

Statement of Injury: Benthic organisms are injured due to elevated metals concentrations in surface water. Results of microcosm experiments show that aqueous metal levels in Reach 2 are sufficient to cause significant mortality to most macroinvertebrate taxa, especially mayflies. Metal levels in sediments are sufficient to cause mortality to benthic organisms. No difference in total species richness was observed; however, a large reduction in mayfly abundance and density of metal-sensitive Heptageniidae was measured. Mayfly richness was reduced by 23 percent.

Commentary: The primary pathway for benthic macroinvertebrate exposure is surface water quality. However, elevated metals concentrations in periphyton, a food source for portions of the community, contribute to the level of exposure. Although periphyton structure does not appear to be injured due to elevated metals, it provides an indirect exposure pathway for metals in the surface water system.

Representativeness of Data: Community structure data are based on 6 years of monitoring the Arkansas River.

Data Gaps: None

Is current information sufficient for restoration planning? Yes

Related Text: Sections 2.3.6.3.1; 3.3.6.2.1

Benthic Organisms

Reach 3 – Downstream of Highway 24 Bridge to Narrows near Kobe (3.5 RM)

Regulatory Thresholds For Injury

1. Metal concentrations considered to be toxic to macroinvertebrates [43 CFR 11.62(f)(1)(i)].
2. See Surface Water.
3. Results of microcosm and field experiments showing:
   a. Increased sensitivity to novel stressors; and
   b. Direct effects of metals on macroinvertebrates.

Summary Data

	Reach 0	Reach 3
Number of Macroinvertebrate Taxa	24.4	22.8
Species Richness of Mayflies	6.4	3.6
Total Abundance of Mayflies	184.8	95.8
Total Abundance of Heptageniidae	75.1	13.6

Related Benchmark Comparisons

1. Comparisons to benchmark:
   a. Community structure;
   b. Elevated metal levels in dominant taxa; and
   c. Elevated metal levels in periphyton.

Statement of Injury: Benthic organisms are injured due to elevated metals concentrations in surface water. Results of microcosm experiments show that aqueous metal levels are sufficient to cause significant mortality to most macroinvertebrate taxa. Significant effects of sediments on growth and survivorship of chironomids were observed. Mayflies from this reach were more sensitive to novel stressors (e.g., acidification; UV-B radiation) compared to organisms from the reference reach. Large reductions in mayfly richness and abundance were observed in Reach 3. Abundance of metal-sensitive Heptageniidae was reduced by 76 percent, but there was no difference in total species richness. Metal levels in most dominant taxa were significantly elevated and concentrations of cadmium and zinc were 2-2.5 times greater in *Arctopsyche grandis*. Significant accumulation of metals by chironomids exposed to sediment from Reach 3 was observed. Metal levels in periphyton were greatly elevated.

Commentary The primary pathway for benthic macroinvertebrate exposure is surface water quality. However, elevated metals concentrations in periphyton, a food source for portions of the community, contribute to the level of exposure. Although the periphyton structure does not appear to be injured due to elevated metals, it provides an indirect exposure pathway for metals in the surface water system.

Representativeness of Data: Community structure data are based on 11 years of monitoring the Arkansas River at station AR5, located at the lower portion of Reach 3. Metal levels in caddisflies and other dominant taxa have been measured over the same period.

Data Gaps: None

Is current information sufficient for restoration planning? Yes

Related Text: Sections 2.4.6.3.1; 3.4.6.2.1

Benthic Organisms	
Reach 4 – Downstream of Narrows near Kobe to Two Bit Gulch (1.6 RM)	
Regulatory Thresholds For Injury	1. Metal concentrations considered to be toxic to macroinvertebrates [43 CFR 11.62(f)(1)(i)]; and 2. See Surface Water.
	Summary Data
Related Benchmark Comparisons	Benthic macroinvertebrate data are unavailable from this reach.
	Statement of Injury: Injury cannot be directly determined in this reach because of the lack of data. However, based on metal levels measured in Reach 4 and results of microcosm experiments, it is likely that benthic communities are injured. Commentary: n/a Representativeness of Data: n/a Data Gaps: Yes, because there are no data available from this reach. Is current information sufficient for restoration planning? Yes, data not necessary for restoration planning. Source area contributions are from upstream. Related Text: Sections 2.5.6.3.1; 3.5.6.2.1

Brown Trout

Reach 0 – Confluence of Tennessee Creek and East Fork Arkansas River to County Road 300 (2.8 RM)

Control Site Conditions

Summary Data

Reach 0	
Abundance (#/acre)	466.7[1]
Biomass (lbs/acre)	92.7

Commentary: Brown trout populations in Reach 0 are characterized by relatively high abundance and biomass. Length frequency distributions indicate a healthy population with significant recruitment of juvenile fish.

Representativeness of Data: Data from Reach 0 are based on collections of brown trout by the CDOW conducted in 1994, 1997 & 1999, and are used as a benchmark for downstream reaches. Data from spring 1998 are not included because they are not representative.

Data Gaps: None

Related Text: Sections 2.1.6.3.2; 3.1.6.2.2

[1] Mean for three years – 1994, 1997, and 1999

Brown Trout

Reach 1 – Downstream of California Gulch Confluence to Upstream of Lake Fork Confluence (1.6 RM)

Regulatory Thresholds For Injury

1. Metal concentrations considered to be toxic to fish [43 CFR 11.62(f)(1)(i)].
2. See Surface Water.
3. Results of acute and chronic toxicity tests.

Summary Data

	Reach 0	**Reach 1**
Abundance (#/acre)	466.7[1]	94.7
Biomass (lbs/acre)	92.7	19.7

Related Benchmark Comparisons

1. Comparisons to benchmark:
   a. Abundance (number per acre) and biomass (pounds per acre); and
   b. Length-frequency distributions.

Statement of Injury: Brown trout within Reach 1 are injured due to elevated metal levels. Aqueous metal concentrations are sufficient to cause acute mortality to brown trout. Large reduction in mean abundance (80%) and biomass (79%) across all sampling occasions. Length-frequency distributions suggest very poor recruitment and survival of juveniles.

Commentary: Exposure of brown trout to metals occurs from water and diet. Although the relative importance of these pathways is unknown, metal levels in both compartments are sufficiently elevated to result in significant bioaccumulation.

Representativeness of Data: Abundance and biomass data were obtained from extensive CDOW surveys conducted from 1994, 1997 & 1999. Numerous experiments have been conducted measuring the chronic and acute effects of metals on brown trout in the laboratory.

Data Gaps: None

Is current information sufficient for restoration planning? Yes

Related Text: Sections 2.2.6.3.2; 3.2.6.2.2

[1] Mean for three years – 1994, 1997, and 1999

Brown Trout

Reach 2 – Downstream of Lake Fork Confluence to Upstream of Highway 24 Bridge (3.3 RM)

Regulatory Thresholds For Injury

1. Metal concentrations considered to be toxic to fish [43 CFR 11.62(f)(1)(i)].
2. See Surface Water.
3. Results of acute and chronic toxicity tests.

Summary Data

	Reach 0	Reach 2
Abundance (#/acre)	466.7[1]	279.7
Biomass (lbs/acre)	92.7	72.7

Related Benchmark Comparisons

1. Comparisons to benchmark:
   a. Abundance (number per acre) and biomass (pounds per acre); and
   b. Length-frequency distributions.

Statement of Injury: Brown trout within Reach 1 are injured due to elevated metal levels. Aqueous metal concentrations are sufficient to cause chronic and some acute toxicity to brown trout. Large reduction in mean abundance (40%) and biomass (21%) across all dates; length-frequency distributions suggest poor recruitment

Commentary: Exposure of brown trout to metals occurs from water and diet. Although the relative importance of these pathways is unknown, metal levels in both compartments are sufficiently elevated to significantly affect bioaccumulation.

Representativeness of Data: Abundance and biomass data were obtained from extensive CDOW surveys conducted from 1994, 1997 & 1999. Numerous experiments have been conducted measuring the chronic and acute effects of metals on brown trout in the laboratory.

Data Gaps: None

Is current information sufficient for restoration planning? Yes

Related Text: Sections 2.3.6.3.2; 3.3.6.2.2

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[1] Mean for three years – 1994, 1997, and 1999

Brown Trout

Reach 3 – Downstream of Highway 24 Bridge to Narrows near Kobe (3.5 RM)

Regulatory Thresholds For Injury

1. Metal concentrations considered to be toxic to fish [43 CFR 11.62(f)(1)(i)].
2. See Surface Water.
3. Results of acute and chronic toxicity tests.

Summary Data

	Reach 0	Reach 3
Abundance (#/acre)	466.7[1]	116.7
Biomass (lbs/acre)	92.7	50.0

Related Benchmark Comparisons

1. Comparisons to benchmark:
   a. Abundance (number per acre) and biomass (pounds per acre);
   b. Length-frequency distributions; and

Statement of Injury: Brown trout within Reach 1 are injured due to elevated metal levels. Aqueous metal concentrations are sufficient to cause chronic and some acute mortality to brown trout. Large reduction in mean abundance (75%) and biomass (46%) across all dates relative to Reach 0. Length-frequency distributions suggest poor recruitment. Elevated metal levels were measured in dominant prey species, gill, and gut tissue; however, metals were not elevated in kidney and liver tissue.

Commentary: Exposure of brown trout to metals occurs from water and diet. Although the relative importance of these pathways is unknown, metal levels in both compartments are sufficiently elevated to significantly affect bioaccumulation. Reductions in abundance and biomass are greater than in Reach 2. However, differences in habitat quality and timing of sampling may be reflected in these comparisons.

Representativeness of Data: Abundance and biomass data were obtained from extensive CDOW surveys conducted from 1994, 1997 & 1999. Numerous experiments have been conducted measuring the chronic and acute effects of metals on brown trout in the laboratory. Studies of feeding habits and metal bioaccumulation were based on a survey conducted over several seasons in 1993.

Data Gaps: None

Is current information sufficient for restoration planning? Yes

Related Text: Sections 2.4.6.3.2; 3.4.6.2.2

[1] Mean for three years – 1994, 1997, and 1999

Brown Trout

Reach 4 – Downstream of Narrows near Kobe to Two Bit Gulch (1.6 RM)

Regulatory Thresholds For Injury

1. Metal concentrations considered to be toxic to fish [43 CFR 11.62(f)(1)(i)];
2. See Surface Water; and
3. Results of chronic and acute toxicity tests.

Summary Data:

	Reach 0	**Reach 4**
Abundance (#/acre)	466.7[1]	80.0
Biomass (lbs/acre)	92.7	28.0

Related Benchmark Comparisons

1. Comparisons to benchmark:
   a. Abundance (number per acre) and biomass (pounds per acre); and
   b. Length-frequency distributions.

Statement of Injury: Aqueous metal concentrations are sufficient to cause chronic and some acute toxicity to brown trout. Large reduction in mean abundance (82%) and biomass (70%) compared to reach 0.

Commentary: Exposure of brown trout to metals occurs from water and diet. Although the relative importance of these pathways is unknown, metal levels in water are sufficiently elevated to significantly affect bioaccumulation. Differences in habitat quality and timing of sampling make direct comparisons between reaches questionable.

Representativeness of Data: Brown trout data from Reach 4 are very limited and are restricted to a single sampling event in 1999. Data collected immediately downstream from Reach 4 in 1994 show some improvement in biomass and abundance.

Data Gaps: Additional data on brown trout abundance and biomass from Reach 4 would be useful for determining injury.

Is current information sufficient for restoration planning? Yes

Related Text: Sections 2.5.6.3.2; 3.5.6.2.2

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[1] Mean for three years – 1994, 1997, and 1999

Terrestrial Wildlife – Small Mammals

Reach 0 – Confluence of Tennessee Creek and East Fork Arkansas River to County Road 300 (2.8 RM)

Control Site Conditions

Summary Data

Average Liver Concentrations (mg/kg wet weight) in Voles from Reach 0, Tennessee Park, and Threshold Values Reported in the Literature

Analyte	Reach 0	Threshold Values
Cadmium	2.6	13-15
Copper	5.9	N/R
Lead	0.7	2.5
Zinc	28.2	N/R

N/R – Not Reported

Average Kidney Concentrations (mg/kg wet weight) in Voles from Reach 0, Tennessee Park, and Threshold Values Reported in the Literature

Analyte	Reach 0	Threshold Values
Cadmium	5.3	30 - 100
Copper	6.4	N/R
Lead	0.5	7.0
Zinc	24.8	N/R

N/R – Not Reported

Commentary: Data from Tennessee Park are included here as another point for comparison. All data are from voles, which are primarily herbivores.

Representativeness of Data: Data were collected from riparian areas along the Arkansas River and Tennessee Creek and are representative of existing conditions. A histopathological evaluation was done in conjunction with the metals analyses and there were no overt signs of metals poisoning in small mammals from this reach (Control Site) or Tennessee Park. Pathologists stated that based on the metals concentrations in the kidney, he did not expect to see any pathological changes.

Data Gaps: None

Related Text: Sections 2.1.6.4.1; 3.1.6.3.1

Terrestrial Wildlife – Small Mammals	
Reach 1 – Downstream of California Gulch Confluence to Upstream of Lake Fork Confluence (1.6 RM)	
Regulatory Thresholds For Injury	1. Histopathological lesions [43 CFR 11.62(f)].
	<u>Summary Data</u>: There are no small mammal data for Reach 1.
Related Benchmark Comparisons	1. Metal tissue concentrations reported in the literature. 2. Comparison of tissue metal concentrations within Reach 0.
	<u>Statement of Injury</u>: <u>Commentary</u>: Based upon soils, vegetation, and fluvial tailings data, Reaches 1 and 3 have similar conditions and would result in similar injuries. <u>Representativeness of Data</u>: Because small mammals move within and between reaches, it is assumed that small mammals throughout the 11-mile reach would receive similar exposure to that in Reach 2. <u>Data Gaps</u>: No. Data are available for upstream and downstream reaches and for the NPL site. <u>Is current information sufficient for restoration planning</u>? Yes <u>Related Text</u>: Sections 2.2.6.4.1; 3.2.6.3.1

Terrestrial Wildlife – Small Mammals

Reach 2 – Downstream of Lake Fork Confluence to Upstream of Highway 24 Bridge (3.3 RM)

Regulatory Thresholds For Injury

1. Histopathological lesions [43 CFR 11.62(f)].

Summary Data:

Average Liver and Kidney Concentrations (mg/kg wet weight) in Voles from Reach 2

Analyte	**Kidney**		**Liver**	
	Reach 0	**Reach 2**	**Reach 0**	**Reach 2**
Cadmium	5.3	11.1	2.6	4.3
Copper	6.4	6.7	5.9	7.9
Lead	0.5	2.0	0.7	0.5
Zinc	24.8	48.7	28.2	29.6

Related Benchmark Comparisons

1. Metal tissue concentrations reported in the literature.
2. Comparison of tissue metal concentrations within Reach 0.

Statement of Injury: No injury based on histopathological evaluation. No injury based on comparison of tissue concentrations to literature threshold values.

Commentary: The vole liver and kidney cadmium concentrations from this reach are approximately 2 times that from Reach 0.

Representativeness of Data: The data are representative of existing conditions and are a good evaluation of herbivorous small mammals. Metals exposure to insectivores is generally higher and can result in higher tissue concentrations. Extrapolation to other feeding guilds based on literature values is suggestive of probable injury.

Data Gaps: None

Is current information sufficient for restoration planning? Yes

Related Text: Sections 2.3.6.4.1; 3.3.6.3.1

Terrestrial Wildlife – Small Mammals	
Reach 3 – Downstream of Highway 24 Bridge to Narrows near Kobe (3.5 RM)	
Regulatory Thresholds For Injury	1. Histopathological lesions [43 CFR 11.62(f)].
	Summary Data: There are only small mammal data for Reach 0 and Reach 2. Based upon soils, vegetation, and fluvial tailings data, Reach 1 and 3 have similar conditions and would result in similar injuries. Additional data would not necessarily affect restoration planning.
Related Benchmark Comparisons	1. Metal tissue concentrations reported in the literature. 2. Comparison of tissue metal concentrations within Reach 0.
	Statement of Injury: See Reaches 1 and 2. Commentary: See Reaches 1 and 2. Representativeness of Data: See Reaches 1 and 2. Data Gaps: No Is current information sufficient for restoration planning? Yes Related Text: Sections 2.4.6.4.1; 3.4.6.3.1

<table>
<tr><th colspan="2">Terrestrial Wildlife – Small Mammals</th></tr>
<tr><td colspan="2">Reach 4 – Downstream of Narrows near Kobe to Two Bit Gulch (1.6 RM)</td></tr>
<tr><td><i>Regulatory Thresholds For Injury</i></td><td>1. Histopathological lesions [43 CFR 11.62(f)].</td></tr>
<tr><td></td><td><u>Summary Data</u>: There are no small mammal data for Reach 4.</td></tr>
<tr><td><i>Related Benchmark Comparisons</i></td><td>1. Metal tissue concentrations reported in the literature.
2. Comparison of tissue metal concentrations within Reach 0.</td></tr>
<tr><td></td><td><u>Statement of Injury</u>: See Reaches 1 and 2.
<u>Commentary</u>: See Reaches 1 and 2.
<u>Representativeness of Data</u>: See Reaches 1 and 2.
<u>Data Gaps</u>: No
<u>Is current information sufficient for restoration planning</u>? Yes
<u>Related Text</u>: Sections 2.5.6.4.1; 3.5.6.3.1</td></tr>
</table>

Terrestrial Wildlife – Migratory Birds

Reach 0 – Confluence of Tennessee Creek and East Fork Arkansas River to County Road 300 (2.8 RM)

Control Site Conditions

Summary Data

Average Blood Metal Concentrations (µg/mL wet weight) in American Dippers from Reach 0, Poudre River, and Benchmarks Reported in the Literature

Analyte	Reach 0	Poudre River	Benchmarks
Cadmium	0.036	0.010	N/R
Copper	0.220	0.16	N/R
Lead	0.102	0.037	0.2-3.0
Zinc	10.458	4.089	60.0

N/R – Not Reported

Average Liver Concentration (mg/kg wet weight) in Tree Swallows from Reach 0, and Benchmarks Reported in the Literature

Analyte	Reach 0 (Upper East Fork)		Study Reference	Benchmarks
	Colorado Belle Cabins	LMDT		
Cadmium	0.06	0.04	<D/L	40.0
Copper	6.9	4.3	<17.71	N/R
Lead	0.03	0.04	<D/L	2.0-6.0
Zinc	21.18	21.07	70.8	60.0

D/L – Detection Limit

Average Liver Metal Concentrations (mg/kg wet weight) in American Dippers from Reach 0, Poudre River, and Benchmarks Reported in the Literature

Analyte	Reach 0	Poudre River	Benchmarks
Cadmium	0.619	0.213	40.0
Copper	4.626	6.898	N/R
Lead	0.203	0.011	2.0-6.0
Zinc	45.567	21.384	60.0

N/R – Not Reported

Average American Dipper ALAD Activity for Reach 0 and the Study Reference1

Location	n	ALAD Activity
Study Reference[2]	23	1,203
Reach 0	10	735

[1] From Archuleta et al. 2000

[2] Study Reference: Poudre River, Colorado

Average Tree Swallow ALAD Activity for Reach 0 and the Study Reference[1]

Location	n	ALAD Activity
Study Reference[2]	20	74
Reach 0	22	47

[1] From Custer and Custer 2000, USFWS 2000

[2] Study Reference: Casper WY, Pueblo, CO and Agassiz National Wildlife Refuge, MN

Commentary: The data used to represent Reach 0 for the American dipper study include samples from the Upper East Fork. There was no significant difference between American dipper blood metal and ALAD levels from the Upper East Fork compared to the Poudre River. There was a significant difference between American dipper liver lead and zinc levels from the Upper East Fork and the Poudre River.

Representativeness of Data: Both of the reported bird studies were conducted to evaluate metals exposure and measure ALAD suppression. The American dipper data for the Upper East Fork is represented by 10 ALAD samples and 13 metals samples collected over a 5-year period. The American dipper study Reference Area is represented by 23 ALAD samples and 27 metals samples collected over a 5-year period. The swallow study is represented by 13 liver samples from the Upper East Fork and 25 ALAD samples collected over a two-year period. Both bird species are representative of water dependant passerine birds. Clutch size and nest success were measured in the tree swallow study but not the dipper study. There are no known toxicological studies of terrestrial dependant passerine birds.

Data Gaps: None

Related Text: Sections 2.1.6.4.3; 3.1.6.3.3

Terrestrial Wildlife – Migratory Birds	
Reach 1 – Downstream of California Gulch Confluence to Upstream of Lake Fork Confluence (1.6 RM)	
Regulatory Thresholds For Injury	1. ALAD activity in assessment area is significantly less (alpha <0.05) than mean values for the control area and ALAD suppression of at least 50% was measured [43 CFR 11.62(f)]. 2. Reduced reproduction [43 CFR 11.62(f)].
	Summary Data: Neither of the migratory bird studies had sample locations within this reach.
Related Benchmark Comparisons	1. Metal concentrations in organs and blood reported in the literature; 2. Metal concentrations in organs and blood from the Control Area; and 3. Metal concentrations in organs and blood from the study Reference Area (i.e. Poudre River)
	Statement of Injury: Neither of the migratory bird studies had sample locations within this reach. Commentary: American dippers were sampled at nest sites along the Arkansas River. While there is a nest site just upstream of the California Gulch confluence, birds nesting here were seen foraging both up- and downstream of California Gulch. Therefore, these samples were not included in the analyses. The next known nest site is in Reach 2. Tree swallows were sampled from nest sites along the Arkansas River that were established by the placement of nest boxes. There were no suitable locations for nest box placement in Reach 1. Representativeness of Data: Because the birds move within and between reaches, it is assumed that the exposure in Reaches 2 and 3 is representative of the entire 11-mile reach. Data Gaps: None Is current information sufficient for restoration planning? Yes Related Text: Sections 2.2.6.4.3; 3.2.6.3.3

Terrestrial Wildlife – Migratory Birds

Reach 2 – Downstream of Lake Fork Confluence to Upstream of Highway 24 Bridge (3.3 RM)

Regulatory Thresholds For Injury

1. ALAD activity in assessment area is significantly less (alpha <0.05) than mean values for the control area and ALAD suppression of at least 50% was measured [43 CFR 11.62(f)].
2. Reduced reproduction [43 CFR 11.62(f)].

Summary Data: ALAD is suppressed in both swallows (38%) and in American dippers (37%) compared to the study Reference Areas, but not at the 50% level.

Average Metals Concentrations in American Dipper Blood and Liver samples From Reach 2 (ppm wet weight) [1]

Blood	n	Cadmium	Copper	Lead	Zinc
Reach 2	17	0.01	0.13	0.16	4.15
Reach 0	14	0.04	0.23	0.11	13.93
Study Reference[2]	27	0.01	0.16	0.04	4.09
Benchmark	--	NR[3]	NR	0.20	60.00
Liver	**n**	**Cadmium**	**Copper**	**Lead**	**Zinc**
Reach 2	6	0.23	5.04	0.53	39.85
Reach 0	4	0.84	5.39	0.19	34.31
Study Reference	14	0.21	6.90	0.01	21.38
Benchmark	--	40.00	NR	2.00	60.00

[1] From: Archuleta et al. 2000
[2] Study Reference: Poudre River, Colorado
[3] NR=Benchmark not reported

Average Metals concentration in Tree Swallow Livers from Reach 2 (ppm, wet weight)[1]

Location	n	Cadmium	Copper	Lead	Zinc
Reach 2	10	0.06	4.55	0.18	20.99
Reach 0	13	0.05	5.16	0.06	21.09
Study Reference[2]	30	<dl[3]	17.71	<dl	70.8
Benchmark	--	40.00	NR[4]	2.00	60.00

[1] From: Custer and Custer 2000
[2] Study Reference: Agassiz NWR Minnesota
[3] <dl=less than detection limit
[4] NR=Benchmark not reported

Average American Dipper ALAD Activity for Reach 0, Reach 2, and the Study Reference[1]

Location	N	ALAD Activity	%ALAD Reduction Compared to Study Reference	% ALAD Reduction Compared to Reach 0
Study Reference[2]	23	1,203		
Reach 0	10	735	39	
Reach 2	15	639	47	13

[1] From Archuleta et al. 2000
[2] Study Reference Site: Poudre River, Colorado

Average Tree Swallow ALAD Activity for Reach 0, Reach 2, and the Study Reference[1]

Location	N	ALAD Activity	%ALAD Reduction Compared to Study Reference[2]	% ALAD Reduction Compared to Reach 0
Study Reference	20	74		
Reach 0	22	47	36	
Reach 2	32	48	35	0

[1] From: Custer and Custer 2000, USFWS 2000
[2] Study Reference sites are: Casper, WY, Pueblo, CO, and Agassiz National Wildlife Refuge, Minnesota

Related Benchmark Comparisons

1. Metal concentrations in organs and blood reported in the literature.
2. Metal concentrations in organs and blood from the Control Area.
3. Metal concentrations in organs and blood from the study Reference Area (i.e., Poudre River).

Statement of Injury: No injury based on ALAD suppression or reduced reproduction. No injury based on comparison of blood and liver metal (Pb) concentrations to threshold values. However, these concentrations are lower than literature-based benchmarks and not indicative of injury.

Commentary: Liver and blood lead concentrations are significantly higher in this reach than Reach 0 and the study Reference Area (i.e., Poudre River). Both birds are exposed to metals via their food source; aquatic macroinvertebrates for dippers and emergent aquatic invertebrates for tree swallows.

Representativeness of Data: The American dipper data are represented by 4 different sample sites in this reach. There were 20 ALAD samples and 25 metals samples taken over a 5-year period. The swallow study is represented by one nesting colony in this reach. There were 10 liver samples and 40 ALAD samples collected from this reach.

Data Gaps: None

Is current information sufficient for restoration planning? Yes

Related Text: Sections 2.3.6.4.3; 3.3.6.3.3

Terrestrial Wildlife – Migratory Birds

Reach 3 – Downstream of Highway 24 Bridge to Narrows near Kobe (3.5 RM)

Regulatory Thresholds For Injury

1. ALAD activity in assessment area is significantly less (alpha <0.05) than mean values for the control area and ALAD suppression of at least 50% was measured [43 CFR 11.62(f)].
2. Reduced reproduction [43 CFR 11.62(f)].

Summary Data:

Average Metals Concentrations in American Dipper Blood and Liver Samples from Reach 3 (ppm wet weight) [1]

Blood	n	Cadmium	Copper	Lead	Zinc
Reach 3	11	0.06	0.15	0.22	5.96
Reach 2	17	0.01	0.13	0.16	4.15
Reach 0	14	0.04	0.23	0.11	13.93
Study Reference[2]	27	0.01	0.16	0.04	4.09
Benchmark	--	NR[3]	NR	0.20	60.00

Liver	n	Cadmium	Copper	Lead	Zinc
Reach 3	5	0.80	7.30	0.58	33.31
Reach 2	6	0.23	5.04	0.53	39.85
Reach 0	4	0.84	5.39	0.19	34.31
Study Reference	14	0.21	6.90	0.01	21.38
Benchmark	--	40.00	NR	2.00	60.00

[1] From: Archuleta et al. 2000

[2] Study Reference: Poudre River, Colorado

[3] NR=Benchmark not reported

Average Metals Concentration in Tree Swallow Livers from Reach 3 (ppm, wet weight)[1]

Location	n	Cadmium	Copper	Lead	Zinc
Reach 3	6	0.08	4.16	0.05	22.93
Reach 2	10	0.06	4.55	0.18	20.99
Reach 0	13	0.05	5.16	0.06	21.09
Study Reference[2]	30	<dl	17.71	<dl	70.8
Benchmark	--	40.00	NR	2.00	60.00

[1] From: Custer and Custer 2000

[2] Study Reference: Agassiz NWR Minnesota

Average American Dipper ALAD Activity for Reaches 0, 2, 3,and the Study Reference[1]

Location	n	ALAD Activity	%ALAD Reduction Compared to Study Reference[2]	% ALAD Reduction Compared to Reach 0
Study Reference	23	1,203	--	--
Reach 0	10	735	39	
Reach 2	15	639	47	13
Reach 3	06	452	62	39

[1] From Archuleta et al. 2000

[2] Study Reference Site: Poudre River, Colorado

Average Tree Swallow ALAD Activity for Reaches 0, 2, 3, and the Study Reference [1]

Location	n	ALAD Activity	%ALAD Reduction Compared to Study Reference[2]	% ALAD Reduction Compared to Reach 0
Study Reference	20	74	--	--
Reach 0	22	47	36	
Reach 2	32	48	35	0
Reach 3	8	45	39	4

[1] From: Custer and Custer 2000, USFWS 2000

[2] Study Reference sites are: Casper, WY, Pueblo, CO, and Agassiz National Wildlife Refuge, Minnesota

Related Benchmark Comparisons

1. Metal concentrations in organs and blood reported in the literature.
2. Metal concentrations in organs and blood from the Control Area.
3. Metal concentrations in organs and blood from the study Reference Area (i.e., Poudre River).

Statement of Injury: Injury based on ALAD suppression but none based on reduced reproduction. No injury based on comparison of concentrations to literature threshold values. However, these concentrations are lower than literature-based benchmarks and not indicative of injury.

Commentary: ALAD activity was reduced in tree swallows by 49% and in American dippers by 62% compared to the study Reference Areas.

Representativeness of Data: The American dipper data are represented by 2 sample sites in this reach. There were 6 ALAD samples taken and 11 metals samples taken over a 5-year period. The tree swallow data are represented by 1 nesting colony located at 1 site in this reach. There were 6 liver samples and 10 ALAD samples.

Data Gaps: None

Is current information sufficient for restoration planning? Yes

Related Text: Section 2.4.6.4.3; 3.4.6.3.3

Terrestrial Wildlife – Migratory Birds	
Reach 4 – Downstream of Narrows near Kobe to Two Bit Gulch (1.6 RM)	
Regulatory Thresholds For Injury	1. ALAD activity in assessment area is significantly less (alpha <0.05) than mean values for the control area and ALAD suppression of at least 50% was measured [43 CFR 11.62(f)]. 2. Reduced reproduction [43 CFR 11.62(f)].
	Summary Data: Neither of the migratory bird studies had sample locations within this reach.
Related Benchmark Comparisons	1. Metal concentrations in organs and blood reported in the literature. 2. Metal concentrations in organs and blood from the Control Area. 3. Metal concentrations in organs and blood from the study Reference Area (i.e., Poudre River).
	Statement of Injury: Injury is occurring to migratory birds in Reach 4 based on likelihood of suppressed ALAD and elevated lead in blood and liver of American dippers and tree swallows. Commentary: While there are no data specific to this reach, data from Reaches 3 and 5 are representative of the likely conditions in Reach 4. Representativeness of Data: Because there are no major loading sources in Reach 4, data from Reach 3 and Reach 5 are representativeof the likely conditions in Reach 4. Data Gaps: None Is current information sufficient for restoration planning? Yes Related Text: Sections 2.5.6.4.3; 3.5.6.3.3