6.0 UPPER ARKANSAS RIVER BASIN DOWNSTREAM OF THE 11-MILE REACH

Consistent with the Work Plan and the Scope of Work, this chapter reviews the existing literature and data sources in order to examine the adequacy of information available for assessing potential natural resource injuries for the upper Arkansas River downstream of the 11-mile reach (Downstream Area). The Downstream Area is defined as the 500-year floodplain below the 11-mile reach, beginning with the confluence of Two-Bit Gulch and continuing for 125 miles to and including Pueblo Reservoir (Figure 6-1).

To accomplish the above-stated objectives, the consulting team developed the following questions about the data in each resource category that would ultimately allow them to make a determination about whether more data might be necessary:

- How much data are available, including spatial and temporal coverages?
- Is additional information needed in order to make a determination about (1) injury characterization, and/or (2) restoration planning?
- If yes to the above question, then what are the types, amounts, and costs of data required to make a determination about injury characterization and restoration planning?

The information/data were compiled, reviewed, and evaluated in detail with these questions in mind. Responses to the above questions reflect the consensus views of the consulting team and are based upon the information reviewed, as well as on the experience of the team. Using such an approach it is possible to evaluate whether more data might be of use in making informed decisions about the Downstream Area. In assessing if more data are needed, the consulting team considered the formal definitions of what constitutes injury under the Department of Interior Natural Resource Damage Assessment regulations.

In consideration of the high level of review that had occurred, the MOU Parties requested that this chapter also present a characterization of the conditions of the Downstream Area resources and an identification of any injuries that may be attributable to mine-waste. The characterization follows the approach utilized for the 11-mile reach. Given this additional request, the text has been divided to provide an overview of the levels of information available and the relevance of that information to determining injury. This section is followed by a more detailed discussion of that information as it relates to a characterization of injury. A matrix summarizing findings with regard to injury for the Downstream Area is presented at the end of this chapter.

Based on the characterization for the 11-mile reach, surface water was identified as the fundamental contaminant transport mechanism and exposure pathway for the Downstream Area. The Downstream Area of the Arkansas River undergoes significant physical and chemical changes from the bottom of the 11-mile reach to Pueblo Reservoir. The obvious impacts associated with deposition of historic mine-waste, diminish over this same distance. The river system is influenced by changes in climate, geology, land-use and resource management. These changes affect water quality characteristics, flow regimes, and river morphology. In turn, the biological communities and their condition can be different based on these characteristics alone, making it difficult to determine what, if any, natural resource injury has occurred as a result of exposure to metals. There are also major changes in the geomorphology of the river that could influence how mine-wastes are distributed.

6.1 Adequacy of Available Information

The following generally describes the nature and extent of information available to characterize conditions and potential injuries for the natural resources comprising the Downstream Area. The range of information for each resource category was reviewed relative to the Work Plan objectives and specific questions discussed above. Additional supporting information (including specific study/data references) is presented on a reach-by-reach basis in Section 6.2 in conjunction with a characterization of injury.

Surface Water Resources

Review of the literature and the electronically compiled data shows that a substantial amount of surface water quality data are available for most reaches in the Downstream Area. The data were determined to be sufficient to characterize the level of natural resource injury. The review indicates that the data are well distributed spatially and temporally, including before and after treatment at the Yak Tunnel and LMDT. Most importantly, sufficient data exists to assess conditions of the surface water within the last few years. Data are available from both the seasonal high and low flow periods at many of the reaches. While the data over the 125-mile section of the Downstream Area are not as extensive as those for the 11-mile reach, the level of resolution provided is consistent with major changes in flow rates and setting.

Available historical and recent data were compared to Colorado’s TVSs for the Arkansas River. This comparison showed exceedances of the TVSs for cadmium, copper, lead, and zinc within the Downstream Area, which defines a natural resource injury based on the regulations. On average, concentrations of dissolved metals decrease from Leadville to Pueblo Reservoir, with the majority of TVS exceedances occurring primarily upstream of Lake Creek and prior to the treatment of mine drainage in the Leadville area. It is evident that median concentrations of most metals have decreased significantly since water treatment began. More recent exceedances of TVSs are infrequent and of a lower magnitude than historical exceedances. Comparison of the recent data against the State's TVSs provides a conservative estimate of the potential for aquatic community-level effects. This comparison to the TVSs along with current biological conditions and further comparision to Reach 0, suggests that acute toxicity is not occurring in the 125-mile Downstream Area. Based on review of both sediment and water quality studies, it appears that the most significant source of metals (primarily cadmium, copper, iron, lead, manganese, and zinc) to the Upper Arkansas River has been, and continues to be, the Leadville Mining District. Current levels of dissolved metals in the Downstream Area can primarily be related to water quality in California Gulch.

As stated above, the record of water quality data spans the dynamics of high and low flows across several years. Some reaches contain more data than others. Comparisons between data sets for upstream and downstream locations were conducted to observe if changes in water quality occurred within intermediate reaches. Given the amount of data, as well as its spatial and temporal resolution, it is not expected that additional surface water quality data would provide any new or different information than those already available for the purpose of injury determination. Likewise, additional information for water quality is not expected to provide new thoughts on how restoration might need to proceed. Based on this evaluation, no additional surface water quality data are recommended for collection to assess injury or for restoration planning in the Downstream Area.

Sediment Resources

Spatially, the coverage of sediment quality data for the 125-mile Downstream Area is adequate considering the large distance. Kimball et al. (1995) sampled twice (fall 1988 and spring 1989) at 12 sites from downstream of the 11-mile reach to just upstream of Canon City. Church et al. (1994) collected several sediment quality samples during February 1994, including 15 samples from the end of the 11-mile reach to Pueblo Reservoir. McCulley Frick and Gilman, Inc. (1990) collected 10 samples on one occasion during April 1989, ranging from the bottom of the 11-mile reach to Florence. Ruse (2000) sampled one time during fall 1989, sampling 11 sites from the bottom of the 11-mile reach to Portland. Based on the review of available sediment quality data, the locations where samples were collected suggest that spatially, a reasonable amount of sediment quality data are available, while temporally, the amount of data are more limited. More recent sediment quality data (e.g., within the last two years) were not found. However, the temporal span of the data brackets the period before and after treatment at the

Yak Tunnel and LMDT, which has been shown to be an important transition in the basin relative to changes in metals concentrations (Figure 6-2). Generally, sediment metal concentrations show decreasing trends from upstream to downstream. With respect to Reach 0, concentrations are elevated for most of the metals to about Reach 6 and from there through Reaches 7 and 8, only zinc is elevated above those concentrations in Reach 0. By Reach 9, all four metals concentrations in sediments are lower than those observed in Reach 0.

Kimball et al. (1995) data provide evidence that the current sediment quality is largely a function of colloidal deposition and resuspension and can therefore be tied to current water quality. California Gulch is currently the largest source of metals, and sources in that drainage have not yet been fully remediated. Clearly, mine-wastes have been transported to and within the river to varying downstream locations, but most all of these (i.e., identifiable deposits) are located within the 11-mile reach (URS 1998). However, overall (and particularly above Canon City), the Arkansas River is a low sediment-transport system.

Evaluation of available sediment data in terms of their usefulness for defining injury is not as straightforward as for surface water. Although the regulations do not provide numerical criteria, sediment concentrations found in the control area (Reach 0) provide a point of reference. However, in a setting like the Arkansas River, consideration must be given to the fact that large portions of the system with the greatest potential for elevated sediment concentrations are of high gradient and have limited capacity to store sediment; therefore, the importance of this pathway is limited. The work of Kimball et al. (1995) and others is another consideration when evaluating the need for additional sediment data. It is important to recognize that future sediment contamination is more likely a function of water quality rather than erosion of any mine-wastes within and below the 11-mile reach. Releases of metals from the California Gulch Superfund Site will have the greatest influence on future sediment concentrations. Correspondingly, water quality monitoring within the 11-mile reach would provide the greatest level of information on downstream sediment injury potential, as well as on the need for restoration. Given the present amount of information and its utility in assessing injury and planning for restoration, no additional sediment quality data are needed.

Groundwater Resources

Limited data were found in the open literature and in the compiled electronic database. Thus, the spatial and temporal coverages of data are sparse. The Safe Drinking Water Information System (SDWIS) database contains information that States must report to USEPA as required by the Safe Drinking Water Act. These requirements take three forms: maximum contaminant levels (the maximum level of a specific contaminant that can occur in drinking water), treatment techniques (specific methods facilities must follow to remove certain contaminants), and monitoring and reporting requirements (schedules utilities must follow to report testing results). States report any violations of these three types to USEPA.

Based on knowledge of the hydrology of the 11-mile reach, the lack of significant mine-waste deposits downstream, and the fact that drinking water supply wells within the 11-mile reach meet MCLs, groundwater is not a concern for injury in the Downstream Area. The SDWIS database along with information from the 11-mile reach confirms that groundwater resources have not been injured. Groundwater data may also be available from other regulatory programs, such as the CERCLA smelter sites in Salida and Canon City. However, it is not expected that these or any other additional data are needed for injury determination or restoration planning.

Geologic Resources

The BLM sampled soils in the Downstream Area in July 2000 along transects at 18 separate locations (Figure 6-3). Total metal concentrations were determined for lead and zinc at all sites and for cadmium and copper for a subset of these sites. Plant-available metal concentrations were not determined for soils in the Downstream Area. However, total metal concentration is below levels of concern. The BLM soils data are limited spatially, since only 18 locations were sampled along 125 miles of river between Two-Bit Gulch and Pueblo Reservoir. However, it is unlikely that additional soil sampling would yield different results. Additional soils data are therefore not needed for injury assessment or restoration planning, except where mine-waste deposits occur in Reach 5.

Vegetation

There are no spatial or temporal data for vegetation. For similar reasons as stated for wildlife below, there is no realistic concern about injury to this resource. The limited areas for recent deposition of mine-waste indicate that the potential for storage of metals-enriched soils/sediments is low, hence no significant pathway for metals transfer to vegetation exists. Additional information is not required for injury determination or restoration planning.

Benthic Macroinvertebrates

There are no individual macroinvertebrate surveys for the Downstream Area that are both spatially and temporally comprehensive. The available studies either focus on long term data from a specific station (e.g., station AR-8 in Buena Vista) or were conducted at numerous locations over a limited time period. Long term monitoring at station AR-8 (Reach 6) near Buena Vista showed dramatic improvements in benthic macroinvertebrate communities over the past 10 years, corresponding to significant reductions in metal concentrations (Clements et al. 2002). These data suggest that injury to benthic macroinvertebrates occurred in the past, but that the system has since recovered with improvements in water quality. Recent surveys show that community composition and abundance of sensitive species in Reach 6 are similar to those observed in Reach 0, the control area. Because this station is located at the upper end of the Downstream Area, it is unlikely that additional monitoring would detect significant impacts further downstream.

Although several spatially extensive surveys conducted in the Downstream Area showed differences in community composition as far downstream as Salida, these differences are unlikely due to metals exposure. Compared to the 11-mile reach, spatially and temporally extensive benthic macroinvertebrate data in the Downstream Area are limited. Despite these limited data, additional benthic macroinvertebrate monitoring in the Downstream Area is not required to further define injury or plan for restoration.

Fish

There are fish population data for various sites in the Downstream Area dating back to 1981, but not all stations have been sampled consistently, making it difficult to evaluate temporal trends. The most consistent fish population data have been collected at the Wellsville station below Salida. Evaluation of population data for the Wellsville station does not show statistically significant differences in total biomass relative to control values both “before” and “after” water treatment. However, comparisons among age classes were not done, and further analyses of existing data may be warranted. Based on the improvements seen in water quality and the potentially confounding influence of regulated flows and other factors, collecting additional fish population or community data in the Downstream Area would not be helpful for injury characterization or restoration planning. A general understanding of the ongoing potential for injury to fish can be derived from comparisons of water quality data to toxicity values from the published literature. From a restoration perspective, it is quite clear that addressing the large issues of source control in California Gulch would have the largest potential for restoration benefits in the Downstream Area.

Wildlife Resources

Assessment of the existing literature revealed that two bird studies have been conducted for the Downstream Area. Both studies focused on evaluating metals exposure and potential injury. The tree swallow study data shows that the birds are being exposed to lead and that ALAD suppression is occurring, but not to the extent of defined injury. Based on ALAD suppression, injury was documented in American dippers from Balltown to Granite. At all other sites downstream of Granite, ALAD suppression is occurring but not to the extent of defined injury.

At present, the only substantive wildlife data available are for birds. Spatially, there is enough data to define the effect of metals on birds in the Downstream Area. There are one to three years worth of data, which are expected to be adequate for characterizing current injuries. Based on more detailed sampling within and above the 11-mile reach, injury to the most sensitive species such as dippers can be linked to water quality. Additional exposure data would not be more helpful for injury determination or restoration planning.

No mammalian toxicological data are presently available in the Downstream Area. In addition, very little data exists that could be used to determine possible exposure and the potential for injures using a risk-based approach (i.e., soils and vegetation). Additional data are not necessary to assess potential injury due to the fact that potential for injury in the 11-mile reach is linked to the presence of mine-waste deposits. The Downstream Area has a lower potential for injury to wildlife resources based on its distance from the primary source area in Leadville, limited areas of deposition, and diminishing concentrations in media of concern.

There are many sources of information that are relevant to characterizing the past and present level of injury in the Downstream Area. As would be expected, the spatial and temporal coverages of the data vary between resources. Knowledge gained through a detailed characterization of the 11-mile reach and upstream areas helps to put the question of injury in the Downstream Area into perspective. Available information for the 11-mile reach indicates that, other than in discrete areas where relatively undiluted mine-waste deposits have resulted in high floodplain soil/sediment metals concentrations, the primary potential for injury is to the aquatic system. Absence of significant deposits of mine-waste in the Downstream Area limits the potential for injury beyond the aquatic system. Available information indicates that present injuries within the aquatic system would most likely be linked to metals emanating from the California Gulch Superfund Site and that dilution and attenuation greatly limit the potential for injury below the confluence with Lake Creek. Therefore, although additional detailed studies in the Downstream Area may provide some refinement as to the potential for injury, such information would not enhance the level of understanding and would not be useful for restoration planning. For these reasons, additional studies are not recommended. This view is also based on the practical perspective that for such studies to be of any additional value, they would have to be conducted at a very fine spatial scale over many years. Even then the ability to place such study results into the overall context of basin conditions is questionable. The relationship of California Gulch to downstream water quality makes consideration of long-term monitoring of water quality, a more insightful approach than near-term efforts focused on defining the potential for a specific injury.

6.2 Characterization of Injury

This section presents a summary of the information available to characterize injury within the Downstream Area. A determination of injury is first discussed by resource followed by an evaluation of injury for that resource. Specific studies discussed in this chapter are cited throughout and a bibliography that provides a complete listing of relevant information is included as Appendix A, Appendix C_1 and Appendix C_2.

Approach

This characterization was conducted using the available literature as well as the composite of chemical and physical data to assess the nature and extent of contamination. Correspondingly, this characterization builds upon the detailed base of knowledge developed for the 11-mile reach. In terms of injury to natural resources, information on downstream conditions is considered in conjunction with findings of injury and the cause of any injuries within the 11-mile reach. Within the 11-mile reach, the primary cause of any identified injuries are poor water quality attributable to metals from upstream (e.g., California Gulch) and fluvial mine-waste deposits. These causes diminish with distance downstream within and below the 11-mile reach. Consistent with these findings, the primary focus for the Downstream Area is on water quality and the presence of fluvial mine-waste deposits. These two resource characteristics provide a fundamental means of assessing the potential for downstream injury. However, as discussed in the following text, information on related biological resources are considered. Given the differences in setting, Pueblo Reservoir is discussed separately.

In order to better understand the various environmental settings and flow regimes along the length of the UARB and as a means of recognizing the areas with larger potential for injury, the geomorphology of the river was characterized. The characterization focuses on identifying changes in stream flow and the morphology types that have the highest potential for storing sediments and mine-wastes (i.e., significant depositional areas). This approach is based on the findings for the 11-mile reach, where metals loading from upstream sources and fluvial mine-waste deposits were identified as the primary pathway for injury. At the same time, the existing literature and supporting data were evaluated by natural resource category, paying special attention to water quality and aquatic biological resources.

To better characterize surface water quality (cadmium, copper, lead, and zinc concentrations) in the Downstream Area, the river was divided into reaches based on major changes in hydrology and geomorphology (Figure 6-1). Based on these attributes, the following reaches were defined:

- **Reach 5** – Reach 5 extends from the confluence of Two-Bit Gulch, which is the downstream limit of the 11-mile reach, to the confluence of Lake Creek. Lake Creek delivers a large amount of trans-basin water to the Arkansas River. The river in Reach 5 is in a narrow valley that is flanked by high terraces.

- **Reach 6** – Reach 6 extends from the junction of Lake Creek to the junction of Chalk Creek at the upstream extent of Browns Canyon. The upstream limit of this reach is determined by the large discharge contributions from Lake Creek, and the downstream limit is based upon the geomorphic change from open valley with terraces to a canyon. From the Lake Creek confluence to Princeton (Harvard Lakes quadrangle), the river is in a canyon, but from Princeton to Chalk Creek, it flows in an open valley with terraces.

- **Reach 7** – Reach 7 extends from Chalk Creek to the junction of the South Fork Arkansas River. The upstream limit is determined by the geomorphic control of Browns Canyon, and the downstream limit is determined by the discharge contribution of South Fork Arkansas River. The river is in a deep canyon (Browns Canyon) from about 2 miles south of Chalk Creek to about Browns Canyon (Salida West quadrangle), where it is confined by terraces to about Squaw Creek, where it then flows in an open valley with a floodplain to Salida and to the confluence of South Fork Arkansas River.

- **Reach 8** – Reach 8 extends from the confluence of the South Fork Arkansas River to Canon City. The reach is primarily a canyon composed of the Arkansas River and Royal Gorge, but the valley widens at Wellsville, between Howard and Coaldale and at Parkdale. In the wide sections, the river is flanked by terraces.

- **Reach 9** – Reach 9 extends from Canon City to Pueblo Reservoir. This reach is characterized by an open valley with a floodplain. The change from canyon to open valley at Canon City is dramatic.

- **Reach 10** –Pueblo Reservoir including the Arkansas River downstream of the reservoir to approximately 1.5 miles downstream of Pueblo Dam. (This additional area was included due to the limited amount of data found for the reservoir and to assess if metals appear to be transported from the reservoir.)

Using the surface water data compiled into the database and the reaches described above, summary statistics and graphics were developed to aid in assessing the temporal and spatial trends.

6.3 Geomorphology

The morphology of the Downstream Area is highly variable over it's 125-mile length. However, based upon study of U.S. Geological Survey (USGS) topographic maps, soil survey maps (Wheeler et al. 1995; Fletcher 1975), and field observations, it was possible to identify different valley types for which a characterization could be made of the potential for mine-waste storage in each. The river flows through three diverse valley types:

1. Canyons (Browns Canyon, Arkansas River Canyon, and Royal Gorge);

2. Open valleys with high terraces (north and south of Buena Vista); and

3. Open valleys with floodplains (downstream of Canon City) (the 11-mile reach is of this type).

Available information and field observations indicate the following:

- Canyons: Resistant bedrock is the dominant factor controlling channel characteristics in the canyons. Nevertheless, the channel may be flanked by a narrow high terrace and a low discontinuous bench, and vegetated islands may be present in the channel. However, the confined channel is an efficient conduit of sand-size and finer sediment, and the potential for mine-waste storage is low. Of the approximately 125 miles of the Downstream Area, about 47 miles or 38 percent of linear channel is canyon-bound. Canyon valley types were identified in the Downstream Area at the following locations:

    - Granite Quadrangle, downstream from 1 mile below Kobe;
    - South Peak Quadrangle;
    - Nathrop Quadrangle, Browns Canyon Quadrangle;
    - Salida East Quadrangle, from Cleora downstream;
    - Howard Quadrangle, downstream to T49N, R10E, Sec 34;
    - Cotopaxi Quadrangle, downstream from Gobblers Knob;
    - Arkansas Mountain Quadrangle;

- Echo Quadrangle, downstream from 1 mile below Texas Creek;
- McIntyre Hills Quadrangle, downstream to Parkdale Siding; and
- Royal Gorge Quadrangle.

- Open Valleys with High Terraces: Canyons lead to broad basins, which contain alluvium that forms high terraces that confine the river. As in the canyons, discontinuous benches and islands formed of modern alluvium exist. However, the confined channel is an efficient conduit of sand and finer sediments, and the potential for mine-waste storage is low. Of the approximately 125 miles of channel in the Downstream Area, about 45 miles or 36 percent of linear channel is confined by high terraces. Locations where high terraces are present are identified below:

    - Harvard Lake Quadrangle;
    - Buena Vista West Quadrangle;
    - Buena Vista East Quadrangle, downstream to T145, R78W, Sec 33;
    - Nathrop Quadrangle, downstream to Browns Canyon;
    - Salida West Quadrangle, downstream to T50N, R8E, Sec 22;
    - Salida East Quadrangle, downstream to Cleora;
    - Howard Quadrangle, downstream from T49N R10E Sec 34;
    - Coaldale Quadrangle;
    - Cotopaxi to Cobblers Knob Quadrangle;
    - Echo Quadrangle, downstream to 1 mile below Texas Creek;
    - McIntyre Hills Quadrangle, downstream of Parkdale Siding; and
    - Royal Gorge Quadrangle, downstream to Parkdale.

- Open Valleys with Floodplains: In open valleys, where the channel has a floodplain and the potential for mine-waste storage is high, the channel is adjustable and capable of shifting laterally. Locations where floodplains are present are identified below:

    - Buena Vista East Quadrangle, T14S, R78W, Secs. 33, 34 and T15S, R78W, Secs. 4, 3;
    - Salida West Quadrangle from T50N, R8E, Sec. 22 downstream;
    - Canon City Quadrangle;
    - Florence Quadrangle;
    - Pierce Gulch Quadrangle; and
    - Hobson Quadrangle.

As described above, of the approximately 125 miles of channel in the Downstream Area, about 33 miles or 26 percent of the distance has a potential for mine-waste storage. These areas include:

- A 1.6-mile reach downstream of Buena Vista;
- A 5-mile reach upstream of Salida; and
- Downstream of Canon City into Pueblo Reservoir.

The potential for mine-waste storage is greatest in the lower downstream portion of the 125-mile reach, including Pueblo Reservoir. With the exception of approximately 1.6 miles of river downstream of Buena Vista and approximately 5 miles of river upstream of Salida, mine-wastes released from the 11-mile reach are most likely flushed through the canyon- and terrace-bound reaches of the river to the wide, alluvial reach downstream of Canon City and to Pueblo Reservoir.

The significant areas of potential sediment (and mine-waste) storage are as follows (Figure 6-4):

- Buena Vista East Quadrangle (Figure 6-5): T14S, R78W, Sec. 33; T15S, R78W, Secs. 3, 4 (Champion SWA - Cogan Property).

- Salida West Quadrangle (Figure 6-6): T50N, R8E, parts of Secs. 22, 23, 26, 25, 36, 31, 32 (From Spiral Drive upstream for approximately 5 miles).

- Canon City Quadrangle (Figure 6-7): A narrow floodplain flanks the channel from Canon City to the east.

- Florence Quadrangle (Figure 6-8): A narrow floodplain flanks the channel through T19S, R69W, Sec. 9, 16, 15, 14. In Section 13, the floodplain widens significantly, and it continues to be wide across the Pierce Gulch and Hobson Quadrangles to the Pueblo Reservoir.

6.4 Surface Water

According to NRDA regulations (43 CFR 11), surface water, suspended sediments, and bed, bank, and shoreline sediments comprise the surface water natural resource. Although part of the surface water resource, instream sediments are discussed separately. To the extent possible, water quality data from the individual studies cited are included in the electronic database and are combined with the data from other sources (e.g., STORET, CDPHE, and other state and regional data sources) to assess the spatial attributes and temporal dynamics of the resource.

Summary statistics were calculated and are summarized in Tables 6-1 through 6-6 for dissolved and total metals to assess the spatial and temporal trends of metals in Arkansas River surface waters.

These summary statistics are divided by metal, form of the metal, reach, and flow condition. Metal concentrations measured during Period 3 were used to assess recent conditions as well as to evaluate injury potential to surface waters due to exceedances of TVSs. Based on this assessment, the following trends emerged:

- When data from all time periods for a metal are considered, it appears that seasonal high flows are accompanied by higher concentrations of metals in Reaches 5 to 9 than those observed during low flows. When data from all time periods are considered, dissolved cadmium, copper, and zinc show a steady decline in concentration from upstream to downstream to Reach 8, followed by an increase in Reach 9. Dissolved lead decreases from Reach 5 to 6, then it gradually increases from Reach 6 to 9.

- In contrast, when only Period 3 (1992-present) data are considered, all high-flow mean concentrations show a steady decrease in concentration from Reaches 5 to 9.

- Based on the mean concentrations of metals, the frequency and magnitude of TVS exceedances for all metals generally declines in the Downstream Area reaches when compared to those exceedances observed in Reaches 1 to 4. No samples for any metal exceed their respective TVSs in Reach 9 upstream of Pueblo Reservoir during Period 3 (1992 to present) and, likewise, no exceedances occurred in the Reservoir after 1992. Thus, it appears that the combination of attenuation, dilution due to tributary inflows, increased hardness that increases TVSs, and treatment at the Yak Tunnel and LMDT have all positively affected the Upper Arkansas River.

6.4.1 Supporting Information

The U.S. Geological Survey conducted a water quality assessment of the Arkansas River Basin that described spatial and temporal variations in water quality during the period 1990-1993 (Ortiz et al. 1998). The data for this assessment are reported separately in Dash and Ortiz (1996). They collected water quality data between the LMDT and Pueblo Reservoir at 10 mainstem sites, 12 tributaries, and 2 mine drainage sites. Samples were analyzed for dissolved solids, major ions, trace elements, nutrients, and suspended sediments. Based on previous water quality data, they selected cadmium, copper, iron, lead, manganese, and zinc as the primary trace elements of concern. In addition, water samples collected five times at four sites were analyzed for arsenic, chromium, mercury, nickel, selenium, and silver. The investigators reported that drainage from abandoned mines and mine tailings was the primary cause of elevated trace element concentrations in the Upper Arkansas River Basin. They concluded that dissolved trace element concentrations in the upper basin generally decreased from Leadville to Portland. Following the completion of the water treatment facilities at the LMDT and Yak Tunnel, a statistically significant decrease in concentrations of cadmium, copper, manganese, and zinc was observed at several downstream mainstem sites. Tributaries sampled did not provide significant metals loads to the Arkansas River. Water quality standards for trace elements were exceeded in several water samples, but the majority of exceedances occurred prior to water treatment. Other studies reviewed reported water quality data that generally supported the conclusion of Ortiz et al. (1998). They include Crouch et al. (1984), McCulley, Frick and Gilman Inc. (1990), Wetherbee et al. (1991), Clark and Lewis (1997), and Ruse et al. (2000).

Review of the available literature suggests the following:

- Cadmium, copper, iron, lead, manganese, and zinc have been identified as exceeding either acute or chronic aquatic life standards at one or more locations over the entire period of record (Dash and Ortiz 1996; Ortiz et al. 1998).

- The Leadville Mining District is the primary source of metals affecting water quality and sediments in the Downstream Area. While there are local sources contributing metals loads to tributaries of the Arkansas River, none of the tributaries are currently a significant source of metals to the mainstem (McCulley, Frick and Gilman Inc.1990; Church et al. 1994; Kimball et al. 1995; Ortiz et al.1998; Church et al. 2000).

- The majority of aquatic life water quality standard exceedances occurred prior to water treatment at the LMDT and Yak tunnel (Dash and Ortiz 1996; Ortiz et al.1998).

- Partitioning of metals in the water column from the aqueous dissolved phase to particulate phase actively occurs, especially within the first 10-20 miles downstream of the 11-mile reach, thus decreasing the bioavailability of metals in the water column (McCulley, Frick and Gilman Inc.1990; Kimball et al. 1995).

- During high flow, colloids are resuspended and transported downstream and contribute to the elevated dissolved metals concentrations observed during high flow and storm events. Colloidal-size particles pass through the filter size, 0.45 µm, used for dissolved metals samples, but they are not necessarily considered to be bioavailable (Kimball et al. 1995; Ortiz et al.1998).

- When compared to aquatic life standards, arsenic, chromium, mercury, nickel, and selenium do not occur in significant concentrations in the Downstream Area (Dash and Ortiz 1996; Ortiz et al. 1998).

Review of the surface water data compiled in the database for the four metals for Reaches 5 through 9 are shown below (Tables 6-1 through 6-3).

Reach 5

Given the small size of the reach, limited data are available. Available data were collected from 1975 to 1999 for all four metals from two stations. This represents all of the data available in the database for cadmium, copper, lead, and zinc regardless of the time period considered. Based on the mean dissolved metal concentration data for all Periods combined, metals in Reach 5 remain higher than in the downstream reaches, yet generally remained similar or decreased in concentration compared to upstream concentrations (measured in Reach 3).

During Period 3, mean concentrations of all dissolved metals were greater during high flow relative to low flow concentrations. Dissolved cadmium exceeded the TVSs only once during high flow, and dissolved copper exceeded the chronic TVS in this reach once during low flow. Lead exceeded the chronic TVS during high flow only, while zinc exceeded acute TVSs during both high and low flows. Compared to Reach 0 during Period 3, mean dissolved cadmium was lower, copper and lead were slightly elevated, and zinc was considerably higher in Reach 5 during both flow conditions.

Reach 6

Water quality data were abundant for Reach 6. Almost all the data available in the database for cadmium, copper, and lead were collected between 1986 and 2000. Zinc data were found as far back as 1968, extending to 2000. A small amount of data are available from 1968 to 1975 and the concentrations are variable, whereas the largest proportion of the data for zinc were collected between 1986 and 1999. While no clear trends are observable for zinc, the highest zinc concentrations were collected in 1968-1969.

Across all time periods and flow conditions, dissolved cadmium, copper, and lead averaged less than concentrations measured in Reach 5, while zinc averaged slightly greater in Reach 6 relative to Reach 5.

During Period 3, dissolved concentrations of all four metals exceeded TVSs during both high and low flows. Copper and lead primarily exceeded the acute TVSs, while cadmium and zinc exceeded the acute TVSs during high and low flows. Compared to Reach 0 mean dissolved metals concentrations during Period 3, cadmium, copper, lead, and zinc were lower in Reach 6 during both flow conditions. Due to inflows from Lake Creek, hardness is reduced during both high and low flows relative to the higher hardness values observed in Reach 0 and other upstream reaches, which results in lower TVSs in Reach 6.

Reach 7

Across all time periods and flow conditions, data for cadmium, copper, and lead were collected primarily from 1986 to 2000, while for zinc the same time span applies with additional samples being collected 1968, 1969, and 1975. Considering all the data, mean dissolved cadmium, copper and lead were slightly higher in Reach 7 compared to Reach 6, while zinc was slightly lower.

During Period 3, dissolved concentrations of copper, lead, and zinc exceeded TVSs during both high and low flows on more than one occasion. Cadmium exceeded the TVSs only once during low flows. Copper exceeded the acute TVSs during both flow conditions, while lead only exceeded the chronic TVSs during both flow conditions. Zinc exceeded the acute TVSs during high and low flows.

Reach 8

For dissolved cadmium, data were collected from 1981 to 1998. For dissolved copper, lead, and zinc, data were collected from 1975 to 1998. Across all flow conditions and periods, average dissolved cadmium, copper, lead, and zinc were lower in Reach 8 than average concentrations in Reach 7.

During Period 3, dissolved concentrations of copper, lead, and zinc exceeded TVSs during high flows on more than one occasion, while only lead and zinc exceeded TVSs more than once during low flows. Copper exceeded the acute TVSs during high flow, but only exceeded the chronic TVS once during low flows. Lead exceeded the chronic TVS during both flow conditions. Zinc exceeded the acute TVSs during high and low flows.

Reach 9

For all metals, dissolved data were collected from 1979 to 1997. Across all flow conditions and periods, average dissolved metals concentrations in Reach 9 were higher than metal concentrations in Reach 8.

During Period 3, dissolved concentrations of cadmium, copper, lead, and zinc did not exceed TVSs during either high or low flows. Higher hardness values in Reach 9 (resulting in higher TVSs) and some lower metal concentrations, result in no exceedances.

6.4.2 Summary of Injury Findings: Analysis of Exceedances of Table Value Standards (TVSs) during Period 3

- Surface water resources in Reach 5 are injured primarily due to concentrations of dissolved lead and zinc during high flows and zinc during low flows.
- The December 2000 CDPHE Status of Water Quality Report indicates that the Arkansas River from Lake Fork to Lake Creek is fully supporting its designated recreational and agricultural uses and partially supporting its aquatic life uses.
- Surface water resources in Reach 6 are injured due to concentrations of dissolved cadmium, copper, lead, and zinc during both high and low flow conditions.
- The December 2000 CDPHE Status of Water Quality Report indicates that the Arkansas River below Lake Creek is fully supporting its designated uses.
- Surface water resources in Reach 7 are injured due to concentrations of dissolved copper, lead, and zinc during both high and low flow conditions.
- Surface water resources in Reach 8 are injured due to concentrations of dissolved copper, lead, and zinc during high flows and lead and zinc during low flows.
- No surface water injury occurs in Reach 9 due to concentrations of cadmium, copper, lead, or zinc during either high or low flow conditions.
- The spatial extent of injury to surface water in the Downstream Area extends from Two-Bit Gulch to Canon City.

6.5 Instream Sediments

The evaluation of instream sediment information is relative to concentrations observed in the control area (Reach 0) as well as spatial trends with distance from the Leadville Mining District. Overall, instream sediments are not viewed to be a significant pathway for injury. The low potential for storage of instream sediments within Reaches 5, 6, 7, and 8 limits the potential for water quality effects and biological exposure. This is further supported by the general trend of decreasing metal concentrations with distance from sources and the good condition of the benthic macroinvertebrate communities.

6.5.1 Supporting Information

The most comprehensive sediment study was a three phased study conducted by the USGS. This study documented California Gulch as a metal source to the Arkansas River from Leadville to Pueblo Reservoir. It further determined that the California Gulch site was the primary metal source to Arkansas River sediments.

Phase I of this study was initiated in July 1993 to examine the distribution of elements in sediments from the Arkansas River Basin (Church 1993). The objective of the study was to determine the origin and time-of-deposition of fluvial mine-waste deposits in the Arkansas River immediately downstream of the confluence with California Gulch. They sampled the Arkansas River and its major tributaries to evaluate the contribution of lead from each of the potential sources. Cores of river sediments were taken at selected sites along the Arkansas River to provide sedimentological and geochronological control. They concluded that the mine-wastes in the Arkansas River below California Gulch are predominantly from California Gulch. Studies of lead in cores taken from this same area show sediment intervals beneath the mine-waste deposits that pre-date mining activity in the Leadville area.

In phase II of the study, geochemical data were retrieved from numerous geologic studies conducted over the last several decades in order to prepare geochemical maps showing the distribution of copper, lead, and zinc in the upper Arkansas River Basin (Smith 1994). As a result of this work, they identified ten additional lead source areas in the Arkansas River Basin which exceed the crustal abundance of lead by 8-30 times. Potential source areas include historic mining districts and milling and industrial sites. Using these geochemical maps, they selected seventeen sample sites along the Arkansas River from Leadville to Pueblo Reservoir for geochemical and lead-isotopic analysis (Church et al. 1994). They concluded that greater than 90 percent of the lead and zinc load in Arkansas River sediments between Leadville and the Chalk Creek confluence are from California Gulch NPL site. Lead, zinc, copper, arsenic, and cadmium were elevated from Leadville to the Chalk Creek confluence compared to sediments upstream of California Gulch. Lead and zinc are contributed to the Arkansas River by Chalk Creek, but the total additional metal load is small. Zinc became elevated downstream of Salida, suggesting an additional zinc source. However, Church (personal communication) later suggested that because of the lower gradient in the river at this site, the suspended colloidal load partially settles out and is incorporated into the river bed sediments. Data collected by Kimball et al. (1995) supports this conclusion.

In phase III of the study, tributaries to the Arkansas River were sampled to determine whether additional sources of metal released from historical mining activities elsewhere in the watershed contribute to the metals in streambed sediment in the mainstem of the Arkansas River. Whereas local anthropogenic sources were found in some of the tributaries, the measured chemical and lead-isotopic compositions determined at the mouths of these tributaries indicate that there are not substantial sources of metals from the tributaries that impact the streambed sediment in the Arkansas River (Church et al. 2000).

McCulley, Frick and Gilman, Inc. (1990) conducted a study in April 1989 of sediments and water to determine if trends in metal enrichment were consistent with loading from the Yak Tunnel/California Gulch mining area. They further evaluated the potential for metals to move between the water column and sediments. They determined that cadmium, copper, and zinc remain elevated in sediments (compared to Arkansas River sediments from upstream of California Gulch) downstream to about Granite. Lead concentrations remained elevated down to about Brown’s Canyon. They also noted elevated metals concentrations below Salida. Using sequential extractions of sediments and mass balance calculations, they determined that varying amounts of the aqueous trace metals discharged from California Gulch are partitioned from the liquid phase to the sediment phase, but that remobilization of trace metals from the sediment phase to the liquid phase was probably not significant.

Kimball et al. (1995) conducted studies in fall 1988 and spring 1989 to determine the effects of colloids on metal transport in the Arkansas River. They determined that iron colloids form in California Gulch and move downstream in suspension. While iron dominated the colloid composition, arsenic, cadmium, copper, manganese, lead, and zinc also occurred in the colloids. The colloidal load decreased by one half in the first 30 miles downstream from California Gulch due to aggregated colloids settling to the bed sediments. However, they determined that a substantial colloid load was transported through the entire study reach to Pueblo Reservoir. The dissolved metals were dominated by iron and zinc and the patterns of colloidal iron and zinc suggested that during low flow, dissolved and colloidal loads decrease downstream as metals partition to the colloidal fraction and the aggregated colloids settled to the stream. These colloids are resuspended during high flow at the same time that there is a flushing of metals with snowmelt runoff, creating the greatest metal loads of the year. This same flushing event could occur during thunderstorm runoff as was seen by Horowitz et al. (1990).

Kimball et al. (1995) suggest that some metals (cadmium, copper, iron, lead, and zinc) are remobilized as colloids into the aqueous phase during high flow and transported downstream as far as Pueblo Reservoir. This partitioning is also confirmed by CDOW water sampling reported by USFWS (1993) and is represented in the water quality data reported by McCulley, Frick and Gilman (1990). Ortiz et al. (1998) reported differences in cadmium, copper, lead, manganese and zinc, which can reasonably be explained by partitioning of colloids between bed sediments and the aqueous phase.

6.5.2 Summary of Injury Findings to Instream Sediments

- Sediment metals data were compiled and found to be present for each of the three periods of interest. Period 1 and 2 data were only available for Reaches 6-10, while Period 3 data were available for all of the downstream reaches (Table 6-7).

- Between Periods 1 and 2 there is a substantial shift in metals concentrations. Period 1 data suggest relatively low concentrations of metals compared to upstream concentrations observed in Reach 0 during the same period as well as during Period 3.

- During Period 2, the shift in metals concentrations, particularly for Reaches 6-8 shows a sharp increase. For example, Period 1 mean sediment zinc concentrations of 103.2, 195.8, and 98.3 mg/Kg were observed in Reaches 6, 7, and 8 respectively. During Period 2 mean sediment zinc concentrations of 2,813.3, 1,302.5, and 994.2 mg/Kg were observed in Reaches 6, 7, and 8, respectively. This shift is most likely due to differences in sampling and analytical techniques.

- Elevated levels of zinc in sediments in the reaches described above are present during Period 3, but not at the levels observed during Period 2. At Reaches 6, 7, and 8, zinc concentrations in sediments were 981.1, 469.8, and 459.5 mg/Kg, respectively during Period 3.

- During Period 3, the following observations were made for metals compared to those metals concentrations observed in Reach 0: cadmium, copper, lead, and zinc in sediment from Reach 5 are elevated over those concentrations found in Reach 0; copper, lead, and zinc in sediments from Reach 6 are elevated over those concentrations found in Reach 0, but are less than in Reach 5; zinc is the predominant metal in Reach 7 and 8 elevated over concentrations found in Reach 0, yet is lower than in each subsequent upstream reach; and by Reach 9 all mean metals concentrations are lower than concentrations observed in Reach 0.

- It is evident that the overall concentrations of cadmium, copper, lead, and zinc in sediments are declining, both temporally and spatially. This may be due to the importance of colloidal metal transport and deposition, which is largely a function of water quality (Kimball et al. 1995). Metals concentrations in surface waters were substantially decreased after 1992, due to the implementation of treatment at the LMDT and the Yak tunnel.

6.6 Groundwater

A query of all the available data in the database yielded a small amount of data for groundwater resources in the Downstream Area. Of the groundwater quality data found in the database, all were collected between 1970 and 2000 (or from Periods 1 and 3). There were no data available for period 2. There were no data available for Reach 5 or Reach 10. For Reaches 6, 7, 8, and 9 most data were collected from deep groundwater wells (40’–100’) that supply communities or groups of houses. The following provides a brief summary of the data available for Reaches 6, 7, 8, and 9.

6.6.1 Supporting Information

Summary data discussed for the following reaches, along with detailed information on well location and type, can be found in Table 6-8.

Reach 6

The data for Reach 6 includes statistical information for total concentrations of cadmium, copper and lead. There was a total of 12 sampling locations from this reach from which data was retrieved. There were no exceedances of the MCLs for any of the metals discussed. All data were retrieved from deep groundwater wells.

Reach 7

The data for Reach 7 includes statistical information for all four metals of concern, with data for both total and dissolved concentrations for copper and lead. Cadmium data only included total concentration, while zinc data only included dissolved concentrations. There were a total of 2 sampling locations in this reach from which data was retrieved. There were no exceedances of the MCLs for any of the metals discussed. All data were retrieved from deep groundwater wells.

Reach 8

The data for Reach 8 includes statistical information for all four metals of concern, with data for both total and dissolved concentrations for cadmium copper and lead with only dissolved concentrations for zinc. There were a total of three sampling locations in this reach from which data was retrieved. There were no exceedances of the MCLs for any of the metals discussed. Data for this reach were retrieved primarily from deep groundwater wells with the exception of some data being retrieved from wells of unknown depth or type.

<u>Reach 9</u>

The data for Reach 9 included statistical information for only copper, lead and zinc. Only dissolved concentrations were available for the three metals. All data was retrieved from three different sampling locations. There were no exceedances of the MCLs for the metals discussed. Data was retrieved from deep groundwater wells.

6.6.2 Summary of Injury Findings to Groundwater

Based on lack of injury to groundwater within the 11-mile reach and on confirming data for the Downstream Area, no injury to groundwater has occurred.

6.7 Floodplain Soils

Floodplain soils data (BLM 2000) provide a useful indicator of the impact of mine-wastes released from the 11-mile reach. Soil sampling in the control area (Reach 0) along with the 11-mile reach provide a basis for determining potential injury in the Downstream Area from mine-waste storage in the floodplain. Soils data currently available include total concentrations of cadmium, copper, lead and zinc at 18 separate locations between Two-Bit Gulch and Pueblo Reservoir.

6.7.1 Supporting Information

Limited soils data for the Downstream Area are available from BLM sampling in July 2000 (Figure 6-3). Soil samples were collected along 18 transects, with approximately 5 sites sampled along each transect. Soil samples were collected at multiple depths and depths varied with location. All samples were analyzed for lead, zinc, iron, and manganese. A subset of the samples were also analyzed for arsenic, cadmium, copper and silver. Samples were analyzed for total metals using XRF or a total digest procedure. There were no soil samples collected in Reach 5, two transects were sampled in Reach 6, one transect was sampled in Reach 7, nine transects were sampled in Reach 8, and six transects were sampled in Reach 9.

Table 6-9 presents a summary of the BLM (2000) floodplain soils data by reach for lead and zinc. These concentrations are compared to floodplain soils in the control area (Reach 0). The only reach where zinc concentrations are high enough to indicate the presence of mine-waste or some other anthropogenic influence is in Reach 6. There were two sample sites (CCT1B and CCT1C) where zinc concentrations were in the range of 2,000 to 4,000 mg/Kg. These sample sites are at the confluence of Clear Creek and not an area believed to represent a significant potential for mine-waste storage from the 11-mile reach. No other metal concentrations were high enough in any of the downstream reaches to indicate the possible presence of mine-waste material.

Reach 5

There are no data available for floodplain soils along Reach 5. Some small mine-waste deposits exist in Reach 5, but no data has been collected that characterizes the deposits with respect to surface area, depth, volume, and chemical properties.

Reaches 6-9

Soil chemistry data exists for floodplain soils along Reaches 6-9 (BLM 2000) (Table 6-9). This data includes total metal concentrations for lead and zinc for all sites sampled and cadmium and copper for a subset of these sites. There were approximately 17 transects where soils were sampled along these reaches.

6.7.2 Summary of Injury Findings to Soils

Although there are no floodplain soils data for Reach 5, field reconnaissance of this stretch of river confirm the presence of small deposits of mine-waste with low plant cover. It is assumed that soil metal concentrations and/or pH are affecting plant growth on these deposits, indicating injury to soils at locations where mine-waste deposits occur.

The elevated concentrations of zinc in floodplain soils at the confluence of Clear Creek (Reach 6) indicate the potential for injury in this location. The source of these metals may be from historical mining in the Clear Creek drainage. Total metal concentrations are potentially high enough to cause injury to soils at this location. However, this cannot be confirmed without further soil sampling and analysis.

Other than Reach 5 and two sample sites along Reach 6, there is no other evidence to indicate injury to floodplain soils in the remaining portions of Reach 6 and Reaches 7-9. Floodplain soils are not considered injured in most of Reach 6 and Reaches 7-9 because metal concentrations along these reaches are similar to Reach 0 and riparian vegetation does not show signs of metal toxicity.

6.8 Biological

Consistent with the findings for the 11-mile reach, the potential for mining-related injuries is greatest in aquatic organisms. Information presented in the following sections describes available information on fish, benthic macroinvertebrates, and two species of birds that depend upon macroinvertebrates as a food source, as well as considerations regarding vegetation and terrestrial wildlife.

6.8.1 Vegetation

Currently there is no quantitative vegetation data available for the Downstream Area. Large-scale vegetation mapping has been conducted but no sampling has been completed to describe plant cover, biomass, species composition, or metal tissue concentrations below the 11-mile reach.

6.8.1.1 Supporting Information

Information on vegetation in the Downstream Area is limited to field reconnaissance and large-scale habitat mapping. Inferences regarding injury are primarily based on an understanding of soil conditions within the 11-mile reach that cause injury to vegetation.

6.8.1.2 Summary of Injury Findings to Vegetation

Data are not available for vegetation cover, production or tissue metal concentrations along Reach 5. Field observations confirm that vegetation is healthy and shows no signs of injury that could be associated with elevated metal concentrations in floodplain soils. Mapping conducted by the Colorado Division of Wildlife also indicates that vegetation cover types are consistent with a floodplain setting for non-injured areas. However, plant growth has been observed to be limited in cover and production on several small mine-waste deposits along Reach 5. This limited plant cover and production indicates injury to vegetation at the few small areas where mine-waste deposits occur in this reach.

Data are not available for vegetation cover, production or tissue metal concentrations along Reach 6-9. However, injury to vegetation in upstream areas is limited to mine-waste deposits. Field reconnaissance and geomorphologic analyses indicate a lack of mine-waste deposits along Reach 6-9; therefore, there is no basis to conclude that injury exists to vegetation growing on floodplain soils along these reaches. Field observations confirm that vegetation is healthy and shows no signs of injury that could be associated with elevated metal concentrations in floodplain soils. Mapping conducted by the Colorado Division of Wildlife also indicates that vegetation cover types are consistent with a floodplain setting for non-injured areas.

6.8.2 Benthic Macroinvertebrates

Benthic macroinvertebrate data provide a useful indicator of the impact from metals in Upper Arkansas River water. Extensive work conducted in the control area (Reach 0) along with the 11-mile reach, provide a basis for understanding the relationship between water and the condition of benthic macroinvertebrate communities. This understanding enhances the value of the existing studies for the Downstream Area in terms of characterizing injury.

6.8.2.1 Supporting Information

A number of studies have examined the relationship between the abundance of macroinvertebrates and heavy metal concentrations in the Upper Arkansas River Basin. Additional studies have investigated the impacts of flow regime and other habitat characteristics on the abundance of macroinvertebrates.

Clements et al. (2002) conducted a long-term (10-year) research program investigating the impact of heavy metals on benthic macroinvertebrate communities in the Downstream Area at station AR-8 (Reach 6) from 1989-1999. This assessment included: 1) quantitative measurements of benthic community composition along a 70 km reach of the upper Arkansas River between Climax and Buena Vista; 2) measurements of heavy metal concentrations in water and other physicochemical characteristics; and 3) measurement of heavy metal concentrations in invertebrates. In addition, limited benthic macroinvertebrate data are available from several sampling occasions at station AR-7 in the upper section of Reach 6 at Granite.

Total macroinvertebrate abundance at station AR-8 in Reach 6 of the Downstream Area varied between 200 and 2000 individuals per 0.1 m^2 and was generally greater than in Reach 0 (Figure 2-15). Total species richness ranged from 11 to 26.6 species per sample and was similar to Reach 0 (Figure 2-18). Most other measures of benthic community composition, including abundance of metal-sensitive heptageniid mayflies, were either similar to or greater at station AR-8 compared to Reach 0. The only exception to this pattern was for species richness of mayflies, which did not recover downstream from California Gulch (Figure 2-18).

Temporal variation in benthic community composition was compared to changes in water quality over a ten-year period in order to assess the influence of improvements in water quality below LMDT and California Gulch. Metal concentrations at station AR-8 (Reach 6) were seasonally variable, with the highest concentrations measured in spring (Figure 6-13). Total zinc concentrations at this station were also significantly lower after remediation of California Gulch and LMDT (Figure 6-10). Abundance of dominant macroinvertebrate groups showed little seasonal or long- term variation (Figure 6-14). The only exception was total mayfly abundance and stonefly abundance, which gradually increased after 1995. The increase in abundance of mayflies was primarily a result of a steady increase in the number of metal-sensitive heptageniids (Figure 6-9), which were significantly greater after remediation in 1992 (Figure 6-10). The most consistent pattern in measures of species richness was a decrease in the seasonal variability in the later sampling periods (Figure 6-11).

Some evidence of recovery was also observed in the upper section of Reach 6 at Granite (stations AR-7). Prior to treatment of LMDT and California Gulch, benthic communities at AR-7 were comprised primarily of caddisflies and chironomids (Figure 6-15). Although these metal-tolerant groups dominated benthic communities after 1993, abundance of mayflies and stoneflies also increased. In particular, abundance of baetid mayflies increased by approximately 3 times after 1993 and approached densities observed in Reach 0. While density of heptageniid mayflies also increased during this period, these metal-sensitive organisms were much less abundant than in Reach 0 or in the lower section of Reach 6 (Buena Vista). Similar patterns in recovery were observed for measures of species richness (Figure 6-16). Total species richness and richness of most macroinvertebrate groups increased after treatment of LMDT and California Gulch. However, these values were significantly lower than those observed in Reach 0.

Exposure of benthic macroinvertebrates to heavy metals in the Downstream Area between 1990 and 1999 was assessed by measuring concentrations of zinc in the caddisfly *Arctopsyche grandis*

(Trichoptera: Hydropsychidae). Concentrations of zinc in *Arctopsyche* collected from Reach 6 (Buena Vista) generally declined over time (Figure 6-12). The only exception to this pattern was a large, unexplained peak in metal levels during spring 1999.

Statistical analyses of metal levels in *Arctopsyche* among all reaches before (1990-1992) and after (1993-2000) remediation of LMDT and California Gulch show highly significant spatial and temporal variation (Figure 6-17). Metal levels in caddisflies were significantly elevated in Reach 1 and declined downstream. However, metal concentrations at the two stations in Reach 6 (AR-7 and AR-8) were significantly greater than in Reach 0. In general, metal levels in caddisflies declined after 1992.

Kiffney and Clements (1993) carried out a one-year study to determine the extent of metal contamination (cadmium, copper, and zinc) in a benthic community from the Arkansas River. Elevated levels of metals in benthic organisms paralleled elevated concentrations of metals in the water. Levels of heavy metals in most dominant species of benthic macroinvertebrates were generally lower in Reach 6 compared to the 11-mile reach. For most species and most metals, concentrations in the Downstream Area were similar to those measured in Reach 0. The concentration of metals in aquatic macroinvertebrates was a better indicator of metal bioavailability in the Arkansas River than was the concentration of metals in the water.

Data collected by the U. S. Fish and Wildlife Service in October of 1995 showed that total abundance of benthic macroinvertebrates at all stations ranged from 176-1,209 individuals per Surber sample. Benthic communities at the six upstream stations (above Balltown, Granite Bridge, Fisherman’s Bridge, Highway 291 Bridge, and Stockyard Bridge) were dominated by caddisflies (primarily Brachycentridae and Hydropsychidae) and dipterans (primarily chironomids), which accounted for greater than 90 percent of total macroinvertebrate abundance. Mayfly and stonefly abundances were generally quite low at these upstream stations. In particular, heptageniid mayflies, organisms known to be sensitive to contaminants, were absent or greatly reduced at these upstream sites. There was a gradual shift in benthic community composition at the three furthest downstream stations (Valley Bridge, Lone Pine, Flood Plain), reflecting reduced abundance of caddisflies and increased abundance of mayflies. Stoneflies and mayflies at the three downstream stations accounted for 33-50 percent of total macroinvertebrate abundance. Mayfly assemblages at these downstream stations were dominated by Heptageniidae and Baetidae. The spatial patterns in abundance of dominant groups from upstream to downstream were similar to those reported by Clements et al. 2002 for Reach 6 (stations AR-7 at Granite and AR-8 in Buena Vista) and suggest that benthic communities were impacted by metals in 1995. The more recent data indicate that benthic communities are injured in the upper section of Reach 6, but that recovery has occurred in the lower section at Buena Vista.

In 1984-1985, Ruse et al. (2000a; 2000b) found that metal-tolerant species were common within the 11-mile reach. However, overall species composition at a larger spatial scale (Climax to Pueblo) was primarily influenced by variables related to the longitudinal gradient of the river (distance downstream, elevation, latitude, temperature). Species richness of chironomids, stoneflies, and caddisflies did not increase from upstream to downstream as predicted for Colorado streams. They attributed the lack of a downstream increase in species richness to the effects of heavy metals, flow regulation, and temperature. The results of this study are especially useful because of the large spatial scale (259 km). However, patterns observed at any particular location should be interpreted cautiously because these analyses were based on collections of exuviae, which may remain on the water surface for several days after emergence. As a consequence, organisms collected at any particular site may represent those that emerged from distant upstream locations.

Nelson and Roline (1996) investigated the relationship between benthic macroinvertebrate community composition and flow characteristics in the Arkansas River upstream and downstream from the confluence with Lake Creek. Results of an extensive literature review showed that most benthic macroinvertebrates are adapted to highly variable flow regimes and can tolerate a wide range of discharge. Results of field studies showed that flow augmentation as a result of trans-mountain diversions have increased stream discharge below Lake Creek. Although subtle differences in benthic communities between upstream and downstream sites were detected, most taxa were collected from both locations. However, these investigators reported that the distribution of one dominant species of caddisfly *(Brachycentrus occidentalis*) was closely related to streamflow. Because *Brachycentrus* is a major component of the diet of brown trout in the Arkansas River (Winters 1988), impacts of flow variation on this species may have significant consequences for brown trout growth and condition.

There is a limited amount of toxicological data available for the Downstream Area, most of which has been collected from the upper sections of the Arkansas River (e.g., Lake Creek to Buena Vista). Single species toxicity tests conducted with cladocerans (*Ceriodaphnia dubia*) and fathead minnows (*Pimephales promelus*) in 1991 showed some acute effects (for fathead minnows) and chronic effects of water collected from station AR-8 (Reach 6) in Buena Vista (Figure 2-36). In contrast, experiments conducted by U.S. EPA between 1991-1993 showed little acute toxicity of Arkansas River water (Table 2-21).

Frugis (1995) compared effects of heavy metals on chironomids exposed to sediments collected from a reference site (Cache la Poudre River) and station AR-8 in Buena Vista. Percent mortality of chironomids exposed to sediment from AR-8 (40 percent) was higher than control mortality (24.2

percent); however, this difference was not statistically significant. There was also no significant effect of metals in sediment on growth of chironomids.

Figure 2-33 shows results of a laboratory experiment in which chironomids (*Chironomus tentans*) were exposed to sediments collected from Reach 6. Despite the fact that metal concentrations in sediments from Reach 6 were similar to those in Reach 0, concentrations of cadmium, copper, lead, and zinc in chironomids exposed to these sediments were generally higher in the Downstream Area. These results indicate that physicochemical factors other than bulk metal concentrations (e.g., grain size, percent organic carbon) determined metal bioavailability in Reach 6.

6.8.2.2 Summary of Injury Findings to Benthic Macroinvertebrates

Available literature indicate the following regarding injury to benthic macroinvertebrates:

- Cadmium, copper, lead, and zinc concentrations in invertebrates have decreased in Reach 6 during the period 1995-1998, and concentrations decrease from upstream to downstream (Table 6-10) (Archuleta et al. 2000).

- Lead concentrations in invertebrates remained elevated in Reach 5 compared to concentrations in Reach 0 (Table 6-10, Table 2-27) (Archuleta et al. 2000).

- Total macroinvertebrate abundance in Reach 6 (Arkansas River at Granite) in the Downstream Area varied between 200 and 900 individuals per 0.1 m^2 and was similar to values observed in Reach 0. However, unlike Reach 0 benthic communities were dominated by caddisflies and chironomids (Clements, unpublished data).

- Total macroinvertebrate abundance at station AR-8 in the lower section of Reach 6 (Arkansas River at Buena Vista) in the Downstream Area varied between 200 and 2000 individuals per 0.1 m^2 and was generally greater than in Reach 0 (Figure 2-15) (CDOW 1998).

- There was a gradual increase in abundance of mayflies after 1995 at both downstream stations. In the downstream section of Reach 6 (Buena Vista) this was primarily a result of a steady increase in the number of metal-sensitive heptageniids (Figure 6-9), which were significantly greater after water treatment began upstream in 1992 (Figure 6-10) (Clements et al. 2002). In contrast, mayflies in the upstream section of Reach 6 (near Granite) were dominated by baetids. Although heptageniids increased in the upstream section of Reach 6 after remediation, abundance of these metal-sensitive species was relatively low compared to Reach 0 (Clements, unpublished data).

- Measures of species richness exhibited less seasonal variability in the later sampling periods (Figure 6-11) (Clements et al. 2002).

- Concentrations of zinc in *Arctopsyche* collected from Reach 6 generally declined over time and approached levels measured in organisms collected from Reach 0 (Figure 6-12) (Clements et al. 2002).

- Heptageniid mayflies, organisms known to be sensitive to contaminants, were absent or greatly reduced at six upstream site stations in Reaches 5, 6 and 7(above Balltown, Granite Bridge, Fisherman's Bridge, Highway 291 Bridge, and Stockyard Bridge) (USFWS 1995).

- Mayfly assemblages at three downstream stations in Reach 8 (Valley Bridge, Lone Pine, Flood Plain) were dominated by Heptageniidae and Baetidae (USFWS 1995).

- Levels of heavy metals in most dominant species of benthic macroinvertebrates were generally lower in Reach 6 (Buena Vista) compared to the 11-mile reach (Kiffney and Clements 1993).

- Species richness of chironomids, stoneflies, and caddisflies did not increase from upstream to downstream (i.e., from Tennessee Creek near the Leadville Mine Drainage Tunnel downstream to Pueblo Reservoir) as predicted for Colorado streams. This lack of a downstream increase in species richness may be attributable to the effects of heavy metals, flow regulation, or temperature (Ruse et al. 2000a; 2000b).

- Most benthic macroinvertebrates are adapted to highly variable flow regimes and can tolerate a wide range of discharge. However, the distribution of one dominant species of caddisfly *(Brachycentrus occidentalis*) was negatively affected by flow regulation.

Benthic macroinvertebrate data are lacking from Reach 5. However, because water quality in Reach 5 is similar to that observed in Reach 3 (where injury was observed) and because metal levels in Reach 5 exceed site-specific concentrations known to be toxic to metal-sensitive species, it is likely that benthic macroinvertebrates are injured in Reach 5.

Analysis of community structure for benthic macroinvertebrates collected at stations AR-7 (Granite) and AR-8 (Buena Vista) in Reach 6 shows significant improvement in species richness, diversity and abundance of some metal-sensitive species. In particular, abundance of Heptageniidae at station AR-8 in the lower section of Reach 6 increased 2-3 times since remediation of LMDT and California Gulch was initiated in 1992. Abundance of these organisms after 1996 was similar to that observed in Reach 0. Limited recovery of these metal-sensitive species was observed in the upper section of Reach 6. Metal concentrations in the caddisfly *Arctopsyche grandis* collected from Reach 6 have decreased since 1994 and are similar to those values measured in Reach 0. The only exception to this pattern is an unexplained spike in zinc concentration in 1999. Zinc levels in periphyton measured at the downstream portion of Reach 6 (1,031-1,273 µg/g) in 1995 and 1996 were also within the range of values observed in Reach 0 (409-4,200 µg/g). We conclude that there is no injury to benthic macroinvertebrates in Reach 6 near Buena Vista.

Despite improvements in water quality and macroinvertebrate communities over time, data collected from the upper section of Reach 6 near Granite suggest injury to benthic organisms. Abundance of metal-sensitive mayflies and species richness of mayflies and stoneflies are significantly lower at station AR-7 than in Reach 0. Based on a comparison of the upper and lower sections of Reach 6, we conclude that recovery of benthic macroinvertebrates occurs somewhere between Granite and Buena Vista.

Few data are available from Reaches 7 and 8 of the Arkansas River. However, microcosm experiments conducted in 1998 showed that exposure of benthic communities to a mixture of cadmium, copper, and zinc at concentrations similar to those measured at Reaches 7 and 8 had no effect on community composition, species richness of mayflies, or abundance of metal-sensitive species. Quantitative collections of benthic macroinvertebrates by the USFWS showed no spatial trends that could be related to heavy metals in Reaches 7 and 8, as well as further downstream. Based on these results, we conclude that there is no injury to benthic macroinvertebrates from heavy metals in Reaches 7 and 8. Furthermore, the dramatic recovery of benthic macroinvertebrates observed in Reach 6 (Buena Vista) following remediation of upstream metal sources suggests that injury to benthic macroinvertebrates below Reach 5 is unlikely.

6.8.3 Fish

The Downstream Area of the Arkansas River supports a naturally reproducing brown trout population and a growing rainbow trout population, which is supported by stocking (CDOW 1998). Neither brown nor rainbow trout are native to the Arkansas River Basin, but brown trout have been the primary fishery management focus for the CDOW. Other fish species present in the Arkansas River include Snake River cutthroat trout, brook trout, white suckers, and longnose suckers. Fishery related data currently available include population data based on electrofishing surveys, and limited laboratory toxicity testing.

6.8.3.1 Supporting Information

The CDOW has reported results of their population sampling efforts at various sampling stations since 1981. These data include number of each species captured and lengths and weights for each fish captured. Sampling stations have been located from just upstream of Granite to downstream at Coaldale. However, not every station has been sampled every year and some stations are sampled during spring while others are sampled during fall. The preferred approach to evaluating fish population data or natural resource injury is to compare total abundance, biomass, and length frequency distributions at downstream locations to a reference location. However, because the Arkansas River changes both physically and chemically from the bottom of the 11-mile reach to Pueblo Reservoir, it is difficult to compare populations upstream to those downstream over the 125-mile stretch. In addition, different sampling techniques were used upstream (backpack shocking) and downstream (boat shocking). Therefore, evaluation of temporal trends at each sampling station where sufficient data exists is presented. The most continuous and extensive data set is available for the Wellsville station, which begins at Wellsville and extends upstream to the Stockyard Bridge just below Salida. With the exception of 1987 and 1989, this location has been sampled yearly from 1981 to the present, representing the most continuous and extensive data set available (CDOW 1999). Additional survey sites include: above Granite, Tezak, Loma Linda, Coaldale, and Big Bend.

Historically, there was an absence of large brown trout in the Downstream Area, which was attributed to a variety of factors including metal toxicity, post spawning conditions, and the lack of forage fish (Nehring 1986). Winters (1988) conducted a detailed investigation of brown trout feeding habits, growth and condition at a single site approximately 30 km downstream from Salida. He reported that brown trout fry feed extensively on small, drifting invertebrates (especially *Baetis*), followed by a switch to caddisflies in older age classes. He characterized the general condition of brown trout in the Arkansas River as poor. The high rate of mortality observed in older fish and the absence of +4 age class in the Arkansas River was attributed to poor or unreliable food quality and the lack of forage fish.

More recently, Policky (1998) reported that brown and rainbow trout are living to an approximate age of 7 in the Downstream Area. Restrictive regulations (e.g., flies and lures only, 2 fish > 14 inches) and anglers practicing catch and release has maximized the brown trout population to carrying capacity of the habitat; therefore, some fish in the Wellsville area are in poor condition.

Based on Instream Flow Incremental Methodology analysis (BLM 2000), when optimum flows are reached at the Wellsville gage they will consistently protect habitat for all life stages and species of trout from Leadville to Canon City. Fish habitat has an optimum value at a certain velocity and depth. Trout habitat is optimized from 250 – 450 cfs (at Wellsville gage) throughout the year. Useable habitat rapidly decreases as flows exceed 550 cfs (BLM 2000), which frequently produce unfavorable habitat conditions for trout. In addition, macroinvertebrate densities are also influenced by high flows – optimum velocity values are exceeded above 500 cfs.

On 18 and 19 August 1988, a large fish kill occurred in the Arkansas River following water releases from Clear Creek Reservoir that had been treated with rotenone on 9 August 1988. Colorado Division of Wildlife personnel were treating the reservoir with rotenone to eliminate an over-population of suckers. The fish kill was estimated to have eliminated 100 percent of the fish community for 20 miles downstream and have significant effects for another 15 miles downstream (USFWS 1988). According to CDOW reports, brown trout recovered within 5 years and rotenone is not considered a limiting factor for downstream populations.

6.8.3.2 Summary of Injury Findings to Brown Trout

The following information is related to fish population data collected at the Wellsville station:

- Between 1982 and 1999, the number of fish per acre at the Wellsville station has remained at about 200 fish/acre (based on two-sample T-Test $\alpha = 0.05$ using data from CDOW 1999).

- There is no significant difference in the average number of fish per acre and average pounds per acre at the Wellsville station from 1992-1999 compared to 1981-1991 (based on two-sample T-Test $\alpha = 0.05$ using data from CDOW 1999).

- There is no significant difference in the average number of fish per acre greater than 14 inches at the Wellsville station during the period 1992-1998 compared to 1981-1991 (based on two-sample T-Test $\alpha = 0.05$ using data from CDOW 1999).

- Adult brown trout in the Wellsville area are in poor condition, probably due to overcrowding and a lack of sizable forage (Krieger 2000; Policky et al. 2000; Winters 1988).

Brown trout data from Reach 5 are lacking. However, because water quality in Reach 5 was similar to that measured in Reach 3 (where injury was observed), it is concluded that there is injury to brown trout in this downstream reach.

Metal concentrations decrease significantly downstream from Lake Creek, and mean values approach the regulatory threshold levels in Reach 6 and are consistent with concentrations measured in the control reach (Reach 0). Significant reduction in abundance (71 percent) and biomass (24 percent) of brown trout was observed in the upper section of Reach 6 (Granite) compared to Reach 0. Inspection of length frequency distributions of brown trout also showed relatively poor recruitment in Reach 6, with few juvenile fish present. The brown trout population in Reach 6 was characterized by reduced overall abundance but somewhat larger individuals compared to the reference reach.

Because of natural and anthropogenic changes in physical characteristics of the Arkansas River, particularly flow alterations associated with discharge from Lake Creek, it is possible that flow alterations immediately downstream from Lake Creek impact fish populations. However, there are no quantitative data showing direct effects of these flow modifications on brown trout. Although metals concentrations occasionally exceeded the TVSs downstream from Reach 6, there is no indication of injury to brown trout.

6.8.4 Terrestrial Wildlife

Information directly describing the potential for injury to terrestrial wildlife is not available for the Downstream Area. Any assessment for the potential for injury must be based upon a comparison to the 11-mile reach.

6.8.4.1 Supporting Information

Information describing the presence or absence of injury to terrestrial wildlife for the 11-mile reach is limited to small mammals. This information indicates that small mammals living in and around discrete deposits of mine waste may have exposure to elevated metals concentrations resulting in injury. Data for large mammals were not available, however, building upon the information available for small mammals, an exposure analysis for large mammals was conducted. As for small mammals, the potential for injury to large mammals is also linked to exposure in and around discrete floodplain deposits of mine waste.

6.8.4.2 Summary of Injury Findings to Terrestrial Wildlife

As mine-waste deposits are limited to a few small areas within the floodplain of Reach 5, the potential for injury to terrestrial wildlife is limited to small mammals residing in those areas. This is further supported by the fact that for most of the Downstream Area, water quality and floodplain soils metals concentrations are similar to Reach 0.

<u>Reach 5</u>

Due to the lack of small mammal data for Reach 5, it is not known if there is injury to this resource. Characterization of the metals concentrations in Reach 5 fluvial deposits, floodplain soils, vegetation, and terrestrial invertebrates would provide data to evaluate potential injury to small mammals.

<u>Reaches 6-9</u>

There are no small mammal data for Reaches 6-9. Because there are no known fluvial mine-waste deposits in Reaches 6-9 and because floodplain soils concentrations are relatively low, the potential for injury to terrestrial wildlife is not present.

6.8.5 Birds

Information on swallows and dippers from recent USFWS & USGS studies provide a basis for evaluating injury. These species are exposed due to their reliance on various life stages of benthic macroinvertebrates as a food source. Data from Reach 0 and the 11-mile reach enhance the understanding of data from the Downstream Area.

6.8.5.1 Supporting Information

The USFWS sampled blood and livers from American dippers at 12 sites in the Downstream area (Reaches 5-8) between 1995 and 1998 (Archuleta et al. 2000). Blood and liver samples were analyzed for metals and blood was also analyzed for ALAD. In addition, aquatic invertebrates (dipper food items) were collected from 19 sites and analyzed for metals. Aquatic invertebrate samples were generally comprised of one composite sample per nest site per year with the exception of 1998 when a composite sample was collected in April and a second composite sample collected in October from most sites. The

USGS sampled blood and liver from tree swallows at 4 locations (Reaches 6-9) in the Downstream Area between 1997 and 1998 (Custer et al. 2003 In Press). Tree swallow liver samples were analyzed for metals concentrations and blood was analyzed for ALAD activity. Swallow stomach contents were analyzed for metals and food boli were evaluated to determine diet composition. These are the only known bird studies that attempt to evaluate metals exposure and effects on migratory birds in the Downstream Area.

For all Downstream Reaches, dipper blood metal concentrations were similar to concentrations from Reach 0 with the exception of lead in Reach 5. Blood lead in Reach 5 was approximately two times the concentration in Reach 0 (Table 6-12). ALAD in dipper samples was reduced in Reaches 5-7 compared to Reach 0 by 17 percent, 28 percent, and 14 percent respectively. Compared to the Study Reference, ALAD was reduced by 49 percent, 56 percent, 48 percent, and 25 percent in Reaches 5-8 respectively (Table 6-13).

In dipper liver samples, copper concentrations were higher in Reaches 5-7 compared to Reach 0, but not abnormally high. Lead liver concentrations were significantly higher in Reaches 5 and 6 compared to Reach 0. However, none of the metals in any of the Downstream reaches exceeded literature-based benchmarks.

Average lead and zinc concentrations in aquatic invertebrate samples were much higher in Reaches 5 and 6 compared to Reach 0 (Table 6-10). In samples collected between 1995-1998, the highest average concentrations for each metal of concern occurred in Reach 6 in 1995. Generally, all metal concentrations decreased from 1995 to 1998 in all reaches. Averaged over all years, Reaches 5 and 6 had the highest average concentrations for all metals of concern. The most recent samples collected in 1998, show that lead in Reaches 7 and 8 and zinc in Reaches 5-8 exceed the dietary benchmark for birds (Tables 6-10 and 6-11).

In swallow liver samples, cadmium was at least two times higher in Reaches 6-8 compared to Reach 0. Copper and zinc concentrations for all reaches were similar to Reach 0 and lower than the study reference. Lead concentrations in Reach 8 were significantly higher than the other Reaches and Reach 0 (Table 6-15). None of the metals in any of the Downstream reaches exceeded literature-based benchmarks.

Compared to the Study Reference, ALAD was suppressed in tree swallows by 22 percent, 1 percent, and 35 percent respectively in Reaches 6-8 respectively. None of the Downstream reaches had suppressed ALAD compared to Reach 0.

Emergent adult aquatic invertebrates (swallow food items) had metal concentrations which were generally 2-3 times lower than nymph stage aquatic invertebrates for all metals of concern and only zinc exceeded the dietary threshold for birds (Custer et al. 2003 In Press).

6.8.5.2 Summary of Injury Findings to Birds

Findings of these studies and those of other investigators, related to the potential for injury, are presented below:

- Injury is occurring to American dippers from lead exposure in Reaches 5 & 6 (between Granite and Balltown). Levels of d-aminolevulinic acid dehydratase (ALAD) activity are suppressed in American dippers by approximately 50 percent compared to the reference area (Archuleta et al. 2000).

- At all other downstream sites, ALAD activity is suppressed in American dippers (25-48 percent compared to a reference area) indicating the birds are exposed to lead, but injury is not occurring (Archuleta et al. 2000).

- For all downstream sites, ALAD activity is suppressed in tree swallows (1-35 percent compared to reference area), indicating the birds are exposed to lead, but injury is not occurring (Custer et al. 2003 In Press).

- Migratory birds are exposed to metals (cadmium, lead, zinc) in the Downstream Area, but reported levels are typically below threshold values associated with lethal and sublethal (e.g., behavioral and/or physiological) effects (Archuleta et al. 2000; Custer et al. 2003 In Press).

Reaches 5-6

- Based on greater than 50 percent ALAD suppression, there is injury to American dippers when compared to Reach 0 (49 percent suppression for Reach 5 and 56 percent for Reach 6).

- There is no injury to tree swallows based on less than 50 percent ALAD suppression compared to Reach 0 (28 percent for Reach 6).

- Metal concentrations in liver, blood, and eggs of birds were all below benchmark values.

- No reproductive impairment (data for tree swallows only).

Reaches 7-8

- There is no injury to American dippers based on less than 50 percent ALAD suppression compared to Reach 0 (48 percent for Reach 7 and 25 percent for Reach 8).
- There is no injury to tree swallows based on less than 50 percent ALAD suppression compared to Reach 0 (1 percent for Reach 7).
- Metal concentrations in liver, blood, and eggs of birds were all below benchmark values.
- No reproductive impairment (data for tree swallows only).

Reach 9

- No data are available for migratory birds. However, downstream water and sediment quality continue to improve and metal concentrations in invertebrates are lower than Reach 0 (Table 6-11). Injury to migratory birds is not expected in Reach 9.

6.9 Pueblo Reservoir (Reach 10)

Pueblo Reservoir is discussed separately because of the many differences in physical setting from other upstream reaches. Overall, there are few metals data for Pueblo Reservoir relative to the amount of data collected from upstream sites. In the database, water quality data were found extending from about the mid 1980s to early in 1990. Most studies reviewed, investigated water and sediment quality, and a few of those included data on biota. None of the studies reviewed were specifically designed to determine if injuries to natural resources occur at Pueblo Reservoir. Assessment of injury over all time periods is limited by the paucity of data for all natural resource categories (per NRDA regulations) for Pueblo Reservoir. For example, the most recent water quality data are from 1989, and most biological data are from a reconnaissance study investigating irrigation drainage in 1988. However, limited data on the fundamental resources of surface water and sediments coupled with upstream data provide the basis for a reasonable assessment of the potential for injury.

6.9.1 Supporting Information

Surface Water

Herrmann and Mahan (1977) studied the concentration changes in inorganic chemicals pre- (1972-1974) and post- (1974-1976) impoundment of Arkansas River at Pueblo Reservoir. Dissolved and suspended levels of all inorganic constituents (Ag, Cu, Fe, Mn, Zn, Co, Pb, Cd, Li, Na, K, Ni, Mg, Ca, Hg) averaged less than recommended or maximum permissible limits for beneficial uses of reservoir water during this study. Seasonal, surface, and spatial trends were also observed for most constituents. Generally, constituents in water samples had higher winter concentrations and lower summer concentrations associated with high runoff. Based on spatial and surface trends, evaporation has somewhat of a concentrating effect on dissolved solids, and certain metals (iron, manganese, zinc and possibly copper, cadmium, and lead) appeared to be precipitating into the sediments. Although iron, manganese, and zinc did not follow the general trends, they showed depth profiles (samples taken at 3-5m intervals from the surface to the bottom) with higher dissolved concentrations in water near the bottom that indicate an exchange is taking place between the reservoir water and sediments. Additionally, dissolved oxygen tended to decrease with depth. Zinc concentrations were highly variable (range: 1– 38 µg/l) and may be related to the concentration of suspended matter carried into the reservoir by the Arkansas River (Herrmann and Mahan 1977).

Mueller et al. (1991) conducted a reconnaissance investigation of water quality, sediment, and biota associated with irrigation drainage in the middle Arkansas River Basin, which included a sample site at Pueblo Reservoir in the spring and fall of 1988. Water quality data show the same seasonal trend as Herrmann and Mahan (1977) observed, although zinc concentrations were not as variable.

McNight et al. (1991) examined the chemical characteristics of particulate organic carbon in water from one site in Pueblo Reservoir. Most major elements had comparable dissolved and colloid concentrations indicating they are primarily dissolved components. However, iron, manganese, and zinc had significantly greater concentrations in the organic colloid fraction indicating they are associated with that fraction in some way. Concentration ratios of the filtrate to the organic colloid for iron, manganese, and zinc exceed 500, 99, and 21 respectively (McNight et al. 1991), also indicating association with the organic colloid fraction. Based on this and other studies (e.g., Kimball et al. 1989), organic colloids may be important in the downstream transport of trace elements.

The recommended aquatic life criterion for total-recoverable iron (1,000 µg/l) (U.S. EPA 1986) near the reservoir bottom was exceeded in 12 samples during 1986-1989 (Lewis and Edelmann 1994).

All samples that exceeded water quality standards for iron were collected from June through September, and the authors attributed the iron concentrations to large concentrations of sediment and iron in the Arkansas River inflow. The sampling site where 11 exceedances were observed is located in a well-oxygenated area of the reservoir and it is unlikely that iron released from sediments contributed to the elevated iron concentrations (Lewis and Edelmann 1994).

The public water-supply standard for dissolved manganese (50 μg/l) (CDPHE 1990) near the reservoir bottom was exceeded in 26 samples during 1986-1989 (Lewis and Edelmann 1994). The authors attributed 14 of those exceedances to elevated concentrations of dissolved manganese in the Arkansas River during summer runoff and the other 12 exceedances were attributed to the mobilization of dissolved manganese from reservoir bottom sediments during periods of low dissolved-oxygen. Lewis and Edelmann (1994) reported that manganese releases from the sediments diminished after fall turnover mixes the deepest waters of the reservoir with well-oxygenated water from near the surface.

Generally, trace elements occur in relatively low concentrations in water (near surface and near bottom) of Pueblo Reservoir (Lewis and Edelmann 1994). A comparison of total-recoverable and dissolved concentrations of the predominant trace elements indicates that < 50 percent of the iron, manganese, and zinc concentrations are dissolved, which suggests that a large percentage of those elements in Pueblo Reservoir are sorbed to suspended sediment that is transported by the Arkansas River (Lewis and Edelmann 1994).

Reach 10 water quality data for cadmium, copper, lead, and zinc are limited to Periods 2 and 3. The data period of record (POR) is from 1982 to 1998, but is not consistent for each of the metals. Considering all of the available dissolved data for each metal over the POR, there is a clear decreasing trend of concentrations for cadmium, copper, and lead through time. No trends were obvious for zinc. Tables 6-2 and 6-3 show that all TVS exceedances occurred during Period 2 and no TVS exceedance occurred during Period 3. Cadmium and lead are the only metals that had exceedances of the TVSs during Period 2.

During Period 3, Reach 10 had not exceeded the TVSs for any of the four metals evaluated. Mean dissolved cadmium and lead are slightly elevated in Reach 10 compared to Reach 9, while copper is lower compared to Reach 9. Mean zinc concentrations are virtually identical between Reaches 9 and 10. Compared to Reach 0, mean dissolved concentrations of all four metals in Reach 10 are lower.

Available literature indicates the following:

- Overall, few exceedances of water quality standards have occurred (primarily during Period 2); however, standards were exceeded several times for two trace elements (iron and manganese) between 1986 and 1989 (Lewis and Edelmann 1994).

- Metals-contaminated sediment and water from the Upper Arkansas River Basin are being deposited in Pueblo Reservoir; however, concentrations are generally low (Herrmann and Mahan 1977; Callendar et al. 1988; Church et al. 1994; Lewis and Edelmann 1994).

- Metals concentrations (cadmium, lead, zinc) in water tend to be higher near the sediment – water interface (within 1m of the bottom) compared to surface samples (Herrmann and Mahan 1977; Lewis and Edelmann 1994).

- Average metals (cadmium, lead, and zinc) concentrations in tissues of birds tend to be below threshold values associated with lethal and sublethal (e.g., behavioral and/or physiological) effects (Mueller et al. 1991; Custer et al. 2003 In Press).

- Certain layers within sediment core samples from the reservoir show deposits that correspond to discharges from the Yak Tunnel (Callendar et al. 1988; Church et al. 1994).

- Iron, manganese, and zinc appear to be transported to and within the reservoir by colloids (McKnight et al. 1991).

- Based on the existing data, injuries to natural resources are not currently occurring at Pueblo Reservoir due to releases of hazardous substances from the Upper Arkansas River Basin (Herrmann and Mahan 1977; Mueller et al. 1991; Lewis and Edelmann 1994; Custer et al. 2003 In Press).

- Based on analyses of the data from the electronic database, as of 1990 no measured metals concentrations have exceeded their respective TVSs in the reservoir. Prior to 1990, TVS exceedances in the reservoir were rare.

Sediments

Callender et al. (1988) collected sediment cores from Pueblo Reservoir for metals analysis and, based on the vertical distribution of normalized metals data, interpreted the peaks of increased metals to represent the 1983 and 1985 Yak Tunnel surges. Church et al. (1994) analyzed specific core intervals from Callender et al.’s (1988) sediment samples and found lead-isotopic compositions that were similar to mineral deposits at Leadville. For lead, copper, and zinc there is a significant increase in total concentrations in specific intervals from 2 of 5 sediment cores from Pueblo Reservoir. Church et al.

(1994) concluded that those core intervals contained surge deposits formed as result of releases from the Yak Tunnel, supporting the interpretation made by Callender et al. (1988).

Herrmann and Mahan (1977) observed some metals (e.g., zinc, copper, cadmium, lead, manganese, iron) loading of the sediments in Pueblo Reservoir near the inlet. The average zinc concentration in the sediments was 3-4 times greater than the zinc content of pre-impoundment floodplain sediments (Table 6-16). Increased metals loading in Pueblo Reservoir was attributed to sediments from the Leadville Mining District (Herrmann and Mahan 1977). Mueller et al. (1991) collected sediment samples from one site near the inlet of Pueblo Reservoir. All metals concentrations except zinc were near pre-impoundment levels (Table 6-16). Lewis and Edelmann (1994) reported elevated lead and zinc concentrations in reservoir bottom sediments when compared to values from Shacklette and Boerngen (1984). Those elements are common constituents of mine drainage in the upper Arkansas River Basin. Weathering of sedimentary rock in the lower half of the Basin is another source of iron and manganese to the reservoir.

- Sediment metals data were compiled and found to be present for each of the three Periods of interest for Reach 10, Pueblo Reservoir (Table 6-7). Sediment data for Pueblo Reservoir were limited for Periods 1 and 3, with only a single sample collected during either period.

- Mean lead and zinc concentrations were higher in Period 2 over the single measurement point available for Period 1, while cadmium and copper are lower during Period 2.

- Compared to Period 2, mean concentrations of cadmium, copper, and lead are slightly greater during Period 3, while zinc was lower during Period 3.

- Compared to Reach 0, the single sediment sample collected for Reach 10 during Period 3 shows that concentrations of cadmium, lead, and zinc are lower in Reach 10 than the mean values observed for Reach 0.

Biological

Custer et al. (2003 In Press) sampled livers from barn and tree swallows from Pueblo Reservoir in 1997-98. They were able to sample only 3 birds in 1997 and 3 birds in 1998. Average concentrations for all metals were less than Reach 0 and all samples were less than the literature-based thresholds.

Mueller et al. (1991) sampled adult and juvenile waterfowl and shorebirds from Pueblo Reservoir and analyzed livers for metals. Only cadmium in adult birds exceeded the concentrations from Reach 0, but it did not exceed the literature-based benchmark. However, adult birds sampled from Pueblo Reservoir are not a valid indicator of exposure from Pueblo Reservoir as the birds may have been exposed at another site. Cadmium and lead in juvenile birds were all less than the detection limit. Some juvenile birds had zinc concentrations that were higher than Reach 0, but the average zinc concentration was less than the literature-based benchmark.

Mueller et al. (1991) also sampled fish in June and October from Pueblo Reservoir. They analyzed whole-body composite samples of several different species (bluegill, common carp, gizzard shad, channel catfish, and small mouth bass). Neither cadmium nor lead had detectable concentrations and zinc concentrations were below benchmark values.

6.9.2 Summary of Injury Findings for Pueblo Reservoir

- Available information on water quality indicates that injury to surface water is not present within Pueblo Reservoir. Surface water quality data do not show exceedances of the TVSs.

- The December 2000 CDPHE Status of Water Quality Report indicates that the Pueblo Reservoir and the Arkansas River downstream of the reservoir is fully supporting its designated uses.

- Sediment concentrations also indicate lack of injury. Although limited in numbers, data from about 20 years suggests that Pueblo Reservoir sediments are of similar or better quality than those found in the upstream reference, Reach 0.

- Corresponding to the lack of injury in surface water and sediment, no injuries were observed or are expected for aquatic or terrestrial biological resources within Pueblo Reservoir.

6.10 Baseline Considerations

There are many land use and resource management factors influencing the condition of the Downstream Area. This overview makes no attempt to characterize those influences. It should be noted that there are several historic mining districts located in the Downstream Area within the Arkansas River Basin. They include the Twin Lakes Mining District located above Twin Lakes, the Monarch Mining District located in the Chalk Creek area, the Rosita Hills Mining District located near Westcliff, and the Cripple Creek Mining District near Cripple Creek and Victor. In addition, there are three hazardous waste sites that are either on the National Priorities List or proposed for listing. They include Smeltertown located just North of Salida, Lincoln Park located southwest of Canon City, and College of the Canons located southwest of Canon City. The influences of any of these mining districts or sites on the condition of the UARB resources were not explored.

There have been numerous attempts by state and federal agencies to evaluate the role of non-mining impacts on the physical, chemical, and biological resources of the Upper Arkansas River. The Downstream Area is heavily managed, influenced by a variety of factors that have an effect on water quality, including:

- Trans-mountain diversions and flow augmentation from various tributaries;
- Urban development;
- Irrigation for agricultural uses;
- Hydroelectric power generation;
- Treatment of municipal and industrial waste;
- Recreational uses;
- Flood control; and
- Maintenance of the fishery.

Five major population centers are located in the Arkansas River Basin: Leadville; Colorado Springs; Pueblo; Las Animas; and Lamar. The Colorado Department of Public Health and Environment reported 88 permitted point source discharges in the Arkansas Basin, not including those covered by general permits: 55 domestic waste treatment facilities, twelve hardrock and mine dewatering permits, eleven industrial plants, six power plants, two hot springs pools, one water treatment plant, and two fish hatcheries (CDPHE 2002).

Particular emphasis has been placed upon flow regulation as it relates to recreation and influences on aquatic life (BLM 2000). The situation is then further complicated by the extensive use of the river between Buena Vista and the Pueblo Reservoir for recreational purposes. This stretch of the Arkansas River is reportedly the most widely used river in Colorado (CDPHE 2002). The main issue is how water delivery (scale and timing) influences recreational uses (i.e., rafting) versus the quality of the fishery. There is a difference between water releases to promote maintenance of the fishery versus flows appropriate for recreational rafting. A suitable hydrograph for brown trout was illustrated earlier in this report. The timing of peak flows and lower summer flows for fish does not necessarily correspond with those flows more suitable for good whitewater rafting in the mid to late summer. These are conflicting management issues that not only affect water quality due to dilution and flushing, but also the biological resources due to quality of water as well as quantity.

TABLES

Table 6-1

Summary Statistics for Dissolved Metals Concentrations in Surface Waters from the Downstream Area during Period 1, Table Value Standards (TVS), and Exceedences of TVSs for Each Metal during High and Low Flows

Reach	Analyte	Flow	Sta Cnt	n	Min	Max	Avg	Stdev	Avg Hard	Acute TVS	Chronic TVS	>Acute	>Chronic	By Flow Period		Across all Flows	
														%>Acute	%>Chronic	%>Acute	%>Chronic
5	Cd	H	1	8	0.0004	0.004	0.0015	0.0013	ND	ND	ND			ND	ND	ND	
		L	1	10	0.001	0.004	0.0025	0.0014	ND	ND	ND			ND	ND		
	Cu	H	1	6	0.0003	0.009	0.0052	0.0036	ND	ND	ND			ND	ND	ND	
		L	1	5	0.0003	0.244	0.0523	0.1072	ND	ND	ND			ND	ND		
	Pb	H	1	8	0.0002	0.00157	0.0008	0.0005	ND	ND	ND			ND	ND	ND	
		L	1	10	0.00013	0.00122	0.0006	0.0004	ND	ND	ND			ND	ND		
	Zn	H	1	8	0.00008	0.00025	0.0001	0.0001	ND	ND	ND			ND	ND	ND	
		L	1	11	0.00013	0.02	0.0021	0.0059	ND	ND	ND			ND	ND		
6	Cu	L	1	1	0.002	0.002	0.002		81.9	0.0111	0.0076	0	0	0	0		
	Zn	H	1	5	0.17	0.39	0.264	0.1108	44.95	0.0595	0.0598	5	5	100.00	100.00	100.00	100.00
		L	3	15	0.21	0.82	0.4387	0.2018	81.9	0.0989	0.0995	15	15	100.00	100.00		
7	Cu	L	1	1	0.002	0.002	0.002		103.98	0.0139	0.0093	0	0	0	0		
	Zn	L	2	3	0.11	0.19	0.14	0.0436	103.98	0.1211	0.1217	1	1	33.33	33.33		
8	Cd	H	1	1	0.00005	0.00005	0.0001		78.03	0.0028	0.0019	0	0	0	0	0	0
		L	1	1	0.001	0.001	0.001		133.93	0.0051	0.0028	0	0	0	0		
	Cu	H	1	1	0.0025	0.0025	0.0025		78.03	0.0106	0.0072	0	0	0	0	0	0
		L	1	1	0.002	0.002	0.002		133.93	0.0177	0.0115	0	0	0	0		
	Pb	H	1	1	0.0005	0.0005	0.0005		78.03	0.0492	0.0019	0	0	0	0	0	0
		L	3	3	0.002	0.002	0.002	0	133.93	0.0886	0.0035	0	0	0	0		
	Zn	H	1	1	0.033	0.033	0.033		78.03	0.095	0.0955	0	0	0	0	0	0
		L	1	2	0.08	0.11	0.095	0.0212	133.93	0.1501	0.1509	0	0	0	0		
9	Cd	H	1	2	0.0005	0.001	0.0008	0.0004	132.1	0.005	0.0027	0	0	0	0	0	0
		L	1	5	0.0005	0.001	0.0006	0.0002	248.11	0.0099	0.0044	0	0	0	0		
	Cu	H	1	2	0.004	0.011	0.0075	0.005	132.1	0.0175	0.0114	0	0	0	0	0	0
		L	1	3	0.002	0.003	0.0023	0.0006	248.11	0.0316	0.0195	0	0	0	0		
	Pb	H	1	2	0.001	0.069	0.035	0.0481	132.1	0.0873	0.0034	0	1	0	50	0	33.33
		L	1	1	0.001	0.001	0.001		248.11	0.171	0.0067	0	0	0	0		
	Zn	H	2	3	0.02	9.6	3.2133	5.531	132.1	0.1484	0.1491	1	1	33.33	33.33	30	30
		L	2	7	0.008	6.4	1.7869	3.017	248.11	0.2531	0.2544	2	2	28.57	28.57		

Note: Only reaches where data are available are shown.
ND-No data

Table 6-2

Summary Statistics for Dissolved Metals Concentrations in Surface Waters from the Downstream Area during Period 2, Table Value Standards (TVS), and Exceedences of TVSs for Each Metal during High and Low Flows

Reach	Analyte	Flow	Sta Cnt	n	Min	Max	Avg	Stdev	Avg Hard	Acute TVS	Chronic TVS	>Acute	>Chronic	By Flow Period		Across all Flows	
														%>Acute	%>Chronic	%>Acute	%>Chronic
5	Cd	H	1	5	0.0002	0.001	0.0008	0.0004	ND	ND	ND			ND	ND	ND	ND
		L	1	4	0.001	0.002	0.0013	0.0005	ND	ND	ND			ND	ND		
	Cu	H	1	3	0.0004	0.001	0.0008	0.0003	ND	ND	ND			ND	ND	ND	ND
		L	1	1	0.001	0.001	0.001		ND	ND	ND			ND	ND		
	Pb	H	1	5	0.00022	0.00056	0.0004	0.0001	ND	ND	ND			ND	ND	ND	ND
		L	1	4	0.00014	0.0003	0.0002	0.0001	ND	ND	ND			ND	ND		
	Zn	H	1	5	0.00005	0.00019	0.0001	0.0001	ND	ND	ND			ND	ND	ND	ND
		L	1	4	0.0001	0.00017	0.0001	0.00003	ND	ND	ND			ND	ND		
6	Cd	H	6	84	0.00005	0.00101	0.0004	0.0002	47.93	0.0017	0.0013	0	0	0	0	0.72	1.44
		L	7	55	0.00005	0.005	0.0005	0.0007	68.39	0.0025	0.0017	1	2	1.82	3.64		
	Cu	H	5	42	0.0003	0.032	0.0035	0.005	47.93	0.0067	0.0048	2	7	4.76	16.67	3.30	8.79
		L	6	49	0.0005	0.138	0.0046	0.0195	68.39	0.0094	0.0065	1	1	2.04	2.04		
	Pb	H	7	45	0.0001	0.014	0.0014	0.0025	47.93	0.0288	0.0011	0	8	0	17.78	0	15.31
		L	8	53	0.0005	0.006	0.0009	0.001	68.39	0.0426	0.0017	0	7	0	13.21		
	Zn	H	5	48	0.00001	0.17	0.0746	0.0368	47.93	0.0628	0.0632	26	26	54.17	54.17	52.13	50.00
		L	5	46	0.005	0.62	0.1114	0.0975	68.39	0.0849	0.0854	23	21	50.00	45.65		
7	Cd	H	4	38	0.00005	0.001	0.0003	0.0002	55.98	0.002	0.0015	0	0	0	0	0	0
		L	4	35	0.00005	0.001	0.0004	0.0003	92.9	0.0034	0.0021	0	0	0	0		
	Cu	H	4	18	0.001	0.049	0.0069	0.0112	55.98	0.0078	0.0055	2	4	11.11	22.22	6.25	10.42
		L	4	30	0.001	0.0175	0.0037	0.0031	92.9	0.0125	0.0084	1	1	3.33	3.33		
	Pb	H	4	21	0.0005	0.026	0.0036	0.0061	55.98	0.0342	0.0013	0	9	0	42.86	0	39.62
		L	4	32	0.0005	0.014	0.0026	0.003	92.9	0.0596	0.0023	0	12	0	37.50		
	Zn	H	4	20	0.023	0.091	0.0503	0.0184	55.98	0.0717	0.072	3	2	15.00	10.00	9.43	7.55
		L	4	33	0.019	0.19	0.066	0.0313	92.9	0.1101	0.1107	2	2	6.06	6.06		

ND-No data

Table 6-2 Continued

Reach	Analyte	Flow	Sta Cnt	n	Min	Max	Avg	Stdev	Avg Hard	Acute TVS	Chronic TVS	>Acute	>Chronic	By Flow Period		Across all Flows	
														%>Acute	%>Chronic	%>Acute	%>Chronic
8	Cd	H	8	60	0.00005	0.01	0.0007	0.0014	70.51	0.0025	0.0017	3	4	5.00	6.67	2.46	3.28
		L	10	62	0.00005	0.002	0.0004	0.0005	109.3	0.0041	0.0024	0	0	0.00	0.00		
	Cu	H	6	29	0.001	0.022	0.0047	0.0046	70.51	0.0097	0.0066	3	4	10.34	13.79	3.70	11.11
		L	8	52	0.0005	0.0141	0.0033	0.0034	109.3	0.0146	0.0097	0	5	0.00	9.62		
	Pb	H	9	50	0.0005	0.025	0.0027	0.0043	70.51	0.0441	0.0017	0	18	0.00	36.00	0.00	31.53
		L	10	61	0.0005	0.009	0.0019	0.0021	109.3	0.0711	0.0028	0	17	0.00	27.87		
	Zn	H	6	32	0.005	0.067	0.0301	0.0176	70.51	0.0872	0.0876	0	0	0.00	0.00	0.00	0.00
		L	8	54	0.006	0.115	0.0332	0.0234	109.3	0.1264	0.127	0	0	0.00	0.00		
9	Cd	H	2	37	0.00005	0.003	0.0006	0.0006	113.92	0.0043	0.0025	0	1	0.00	2.70	0.00	4.49
		L	3	52	0.00005	0.004	0.0007	0.001	189.94	0.0074	0.0036	0	3	0.00	5.77		
	Cu	H	2	39	0.0005	0.034	0.0077	0.0077	113.92	0.0152	0.01	4	7	10.26	17.95	5.32	9.57
		L	3	55	0.0005	0.028	0.0042	0.0045	189.94	0.0246	0.0155	1	2	1.82	3.64		
	Pb	H	2	37	0.00025	0.014	0.0024	0.0033	113.92	0.0744	0.0029	0	7	0.00	18.92	0.00	10.23
		L	3	51	0.00025	0.013	0.0013	0.0021	189.94	0.1289	0.005	0	2	0.00	3.92		
	Zn	H	2	38	0.001	0.16	0.0194	0.0262	113.92	0.1309	0.1315	1	1	2.63	2.63	1.14	1.14
		L	2	50	0.0015	0.12	0.024	0.0214	189.94	0.2018	0.2028	0	0	0.00	0.00		
10	Cd	H	4	96	0.00005	0.024	0.0016	0.0034	170.27	0.0066	0.0033	3	10	3.13	10.42	1.54	7.18
		L	4	99	0.00005	0.004	0.001	0.001	184.52	0.0072	0.0035	0	4	0.00	4.04		
	Cu	H	4	81	0.0005	0.009	0.0023	0.0015	170.27	0.0222	0.0141	0	0	0.00	0.00	0.00	0.00
		L	4	92	0.0005	0.013	0.0027	0.0021	184.52	0.0239	0.0151	0	0	0.00	0.00		
	Pb	H	4	95	0.00025	0.006	0.0018	0.0013	170.27	0.1147	0.0045	0	2	0.00	2.11	0.00	6.84
		L	4	95	0.00025	0.022	0.002	0.0029	184.52	0.125	0.0049	0	11	0.00	11.58		
	Zn	H	4	75	0.0005	0.06	0.0085	0.0108	170.27	0.184	0.1849	0	0	0.00	0.00	0.00	0.00
		L	4	91	0.0005	0.12	0.0094	0.0154	184.52	0.1969	0.1979	0	0	0.00	0.00		

Note: Only reaches where data are available are shown.

Table 6-3

Summary Statistics for Dissolved Metals Concentrations in Surface Waters from the Downstream Area during Period 3, Table Value Standards (TVS), and Exceedences of TVSs for Each Metal during High and Low Flows

Reach	Analyte	Flow	Sta Cnt	n	Min	Max	Avg	Stdev	Avg Hard	Acute TVS	Chronic TVS	>Acute	>Chronic	By Flow Period		Across all Flows	
														%>Acute	%>Chronic	%>Acute	%>Chronic
5	Cd	H	1	10	0.00015	0.00254	0.0008	0.0007	80.76	0.0029	0.0019	0	1	0.00	10.00	0.00	4.55
		L	1	12	0.00035	0.00107	0.0006	0.0003	109.58	0.0041	0.0024	0	0	0.00	0.00		
	Cu	H	1	10	0.0021	0.0073	0.0042	0.0017	80.76	0.011	0.0075	0	0	0.00	0.00	0.00	4.55
		L	1	12	0.0012	0.0127	0.0038	0.003	109.58	0.0146	0.0097	0	1	0.00	8.33		
	Pb	H	1	9	0.001	0.0035	0.0017	0.0009	80.76	0.0511	0.002	0	4	0.00	44.44	0.00	20.00
		L	1	11	0.001	0.001	0.001	0	109.58	0.0713	0.0028	0	0	0.00	0.00		
	Zn	H	1	10	0.059	0.568	0.2217	0.1632	80.76	0.0978	0.0983	6	6	60.00	60.00	50.00	50.00
		L	1	12	0.051	0.347	0.149	0.081	109.58	0.1266	0.1273	5	5	41.67	41.67		
6	Cd	H	9	212	0.00005	0.029	0.0006	0.0026	47.05	0.0016	0.0013	9	10	4.25	4.72	4.51	4.76
		L	9	187	0.00005	0.0025	0.0003	0.0005	62.79	0.0022	0.0016	9	9	4.81	4.81		
	Cu	H	9	210	0.0001	0.017	0.0027	0.0016	47.05	0.0066	0.0047	2	17	0.95	8.10	0.51	4.82
		L	9	184	0.0001	0.0079	0.0018	0.0014	62.79	0.0087	0.006	0	2	0.00	1.09		
	Pb	H	9	199	0.0005	0.031	0.0008	0.0022	47.05	0.0282	0.0011	1	13	0.50	6.53	0.26	3.94
		L	10	182	0.0005	0.007	0.0006	0.0005	62.79	0.0388	0.0015	0	2	0.00	1.10		
	Zn	H	8	213	0.005	0.64	0.0683	0.0729	47.05	0.0619	0.0622	67	66	31.46	30.99	31.15	30.89
		L	8	169	0.004	0.371	0.0762	0.0562	62.79	0.079	0.0794	52	52	30.77	30.77		
7	Cd	H	3	100	0.00005	0.0012	0.0002	0.0002	54.7	0.0019	0.0014	0	0	0.00	0.00	0.53	0.53
		L	3	89	0.00005	0.066	0.001	0.007	76.19	0.0028	0.0018	1	1	1.12	1.12		
	Cu	H	3	102	0.0001	0.041	0.0024	0.0044	54.7	0.0076	0.0053	2	4	1.96	3.92	1.60	3.21
		L	3	85	0.0001	0.0124	0.0018	0.002	76.19	0.0104	0.0071	1	2	1.18	2.35		
	Pb	H	3	101	0.0005	0.005	0.0008	0.0008	54.7	0.0333	0.0013	0	12	0.00	11.88	0.00	16.58
		L	3	86	0.0005	0.0253	0.0015	0.003	76.19	0.048	0.0019	0	19	0.00	22.09		
	Zn	H	3	103	0.004	0.137	0.0398	0.0273	54.7	0.0703	0.0706	12	12	11.65	11.65	7.57	7.57
		L	3	82	0.004	0.14	0.0396	0.0246	76.19	0.0931	0.0935	2	2	2.44	2.44		

ND-No data

Table 6-3 Continued

Reach	Analyte	Flow	Sta Cnt	n	Min	Max	Avg	Stdev	Avg Hard	Acute TVS	Chronic TVS	>Acute	>Chronic	By Flow Period		Across all Flows	
														%>Acute	%>Chronic	%>Acute	%>Chronic
8	Cd	H	6	194	0.00005	0.0009	0.0001	0.0001	75.72	0.0027	0.0018	0	0	0.00	0.00	0.00	0.00
		L	8	199	0.00005	0.0021	0.0001	0.0002	107.48	0.004	0.0024	0	0	0.00	0.00		
	Cu	H	6	187	0.0001	0.039	0.0019	0.0033	75.72	0.0103	0.0071	2	3	1.07	1.60	0.52	1.04
		L	7	197	0.0001	0.0101	0.0012	0.0013	107.48	0.0144	0.0095	0	1	0.00	0.51		
	Pb	H	6	196	0.0005	0.0131	0.0008	0.0014	75.72	0.0476	0.0019	0	12	0.00	6.12	0.25	4.25
		L	7	204	0.0005	0.1677	0.0017	0.012	107.48	0.0699	0.0027	1	5	0.49	2.45		
	Zn	H	6	191	0.003	0.226	0.0407	0.0343	75.72	0.0926	0.0931	16	15	8.38	7.85	5.42	5.15
		L	7	178	0.001	0.175	0.036	0.025	107.48	0.1246	0.1252	4	4	2.25	2.25		
9	Cd	H	2	12	0.00005	0.00025	0.0007	0.0001	118.61	0.0045	0.0025	0	0	0	0	0	0
		L	3	23	0.00005	0.0002	0.0006	0.00003	159.76	0.0062	0.0032	0	0	0	0		
	Cu	H	2	12	0.0003	0.004	0.0012	0.0012	118.61	0.0158	0.0104	0	0	0	0	0	0
		L	3	25	0.0001	0.0077	0.0013	0.0019	159.76	0.0209	0.0134	0	0	0	0		
	Pb	H	2	11	0.00025	0.002	0.0006	0.0005	118.61	0.0777	0.003	0	0	0	0	0	0
		L	3	28	0.00025	0.001	0.0005	0.0002	159.76	0.1071	0.0042	0	0	0	0		
	Zn	H	2	12	0.0015	0.061	0.0241	0.0192	118.61	0.1354	0.1361	0	0	0	0	0	0
		L	3	20	0.0015	0.05	0.0148	0.0133	159.76	0.1743	0.1752	0	0	0	0		
10	Cd	H	2	21	0.00005	0.0001	0.0001	0.00002	167.59	0.0065	0.0033	0	0	0	0	0	0
		L	2	20	0.00005	0.0003	0.0001	0.0001	200.38	0.0079	0.0037	0	0	0	0		
	Cu	H	2	21	0.0005	0.003	0.0007	0.0006	167.59	0.0219	0.0139	0	0	0	0	0	0
		L	2	20	0.0002	0.002	0.0007	0.0004	200.38	0.0259	0.0162	0	0	0	0		
	Pb	H	2	22	0.0005	0.002	0.0006	0.0004	167.59	0.1128	0.0044	0	0	0	0	0	0
		L	2	20	0.0005	0.0005	0.0005	0	200.38	0.1364	0.0053	0	0	0	0		
	Zn	H	2	18	0.003	0.047	0.0216	0.0155	167.59	0.1815	0.1824	0	0	0	0	0	0
		L	2	17	0.003	0.048	0.0143	0.0143	200.38	0.2112	0.2123	0	0	0	0		

Note: Only reaches where data are available are shown.
ND-No data

Table 6-4

Summary Statistics for Surface Water Concentrations of Total Cadmium, Copper, Lead, and Zinc in the Downstream Area during Period 1

Reach	Analyte	Flow	StaCnt	n	Min	Max	Avg	StdDev
7	Cd	H	1	2	0.001	0.009	0.005	0.0057
		L	1	10	0.0004	0.0014	0.0008	0.0003
	Cu	H	1	2	0.013	0.021	0.017	0.0057
		L	1	13	0.002	0.015	0.007	0.0033
	Pb	H	1	5	0.007	0.039	0.0226	0.0115
		L	1	10	0.004	0.04	0.0116	0.0115
	Zn	H	1	6	0.08	0.48	0.2017	0.1518
		L	1	26	0.05	0.22	0.1258	0.0451
8	Cd	H	3	9	0.00019	0.049	0.0079	0.0155
		L	2	16	0.0003	0.004	0.0013	0.0012
	Cu	H	2	7	0.0047	0.039	0.0137	0.0123
		L	1	18	0.002	0.046	0.0091	0.0096
	Pb	H	2	8	0.0005	0.14	0.0421	0.0528
		L	1	17	0.007	0.105	0.0205	0.0275
	Zn	H	2	11	0.059	0.86	0.2481	0.2508
		L	1	27	0.02	0.65	0.1341	0.1439
9	Cd	H	3	7	0.00015	0.0041	0.002	0.0016
		L	2	13	0.00015	0.01	0.0012	0.0027
	Cu	H	2	6	0.003	0.058	0.0225	0.0196
		L	2	18	0.0025	0.033	0.0073	0.0072
	Pb	H	2	6	0.0045	0.12	0.0579	0.0501
		L	2	18	0.002	0.094	0.0119	0.0215
	Zn	H	2	6	0.04	0.77	0.3483	0.269
		L	2	19	0.01	0.27	0.0826	0.065

ND-No data

Table 6-5

Summary Statistics for Surface Water Concentrations of Total Cadmium, Copper, Lead, and Zinc in the Downstream Area during Period 2

Reach	Analyte	Flow	StaCnt	n	Min	Max	Avg	StdDev
6	Cd	H	7	91	0.00005	0.01	0.0012	0.0017
		L	7	64	0.00005	0.01	0.0014	0.0024
	Cu	H	6	47	0.0005	0.064	0.0081	0.0107
		L	7	59	0.0005	0.175	0.006	0.0226
	Pb	H	4	39	0.0005	0.043	0.0085	0.0118
		L	5	53	0.0005	0.038	0.0043	0.0078
	Zn	H	6	51	0.019	0.84	0.1601	0.1714
		L	7	61	0.005	0.94	0.1329	0.1412
7	Cd	H	4	50	0.00005	0.005	0.001	0.0011
		L	4	64	0.00005	0.01	0.0009	0.0018
	Cu	H	4	23	0.0023	0.06	0.0133	0.0125
		L	4	51	0.0011	0.0158	0.0056	0.0027
	Pb	H	4	20	0.0005	0.05	0.0168	0.0156
		L	4	55	0.0005	0.021	0.0061	0.0048
	Zn	H	4	27	0.04	0.67	0.1901	0.1469
		L	4	58	0.045	0.27	0.1236	0.0506
8	Cd	H	7	64	0.00005	0.01	0.0015	0.0022
		L	9	79	0.00005	0.01	0.0011	0.0022
	Cu	H	6	38	0.0018	0.08	0.0126	0.0139
		L	9	70	0.0005	0.18	0.0107	0.0261
	Pb	H	6	35	0.0005	0.053	0.0149	0.0142
		L	9	74	0.0005	0.043	0.006	0.0073
	Zn	H	6	43	0.003	0.82	0.1879	0.1892
		L	8	76	0.02	0.3	0.0814	0.0549
9	Cd	H	3	24	0.00005	0.005	0.0025	0.0021
		L	4	43	0.00005	0.005	0.0016	0.0021
	Cu	H	3	20	0.005	0.07	0.0223	0.0178
		L	4	34	0.0022	0.026	0.0079	0.006
	Pb	H	3	19	0.004	0.098	0.0209	0.0213
		L	4	35	0.0005	1	0.0346	0.1681
	Zn	H	3	20	0.005	0.79	0.187	0.1642
		L	4	36	0.005	0.24	0.0682	0.0556
10	Cd	H	4	84	0.00005	0.01	0.0027	0.003
		L	4	85	0.00022	0.01	0.0031	0.0029
	Cu	H	4	88	0.001	0.43	0.0103	0.0455
		L	4	89	0.0012	0.048	0.0072	0.0072
	Pb	H	4	85	0.0005	0.025	0.0042	0.0039
		L	4	85	0.0005	0.08	0.0055	0.009
	Zn	H	4	92	0.001	0.515	0.0174	0.0535
		L	4	103	0.0025	0.1	0.0162	0.0169

Table 6-6

Summary Statistics for Surface Water Concentrations of Total Cadmium, Copper, Lead, and Zinc in the Downstream Area during Period 3

Reach	Analyte	Flow	StaCnt	n	Min	Max	Avg	StdDev
5	Cd	H	1	10	0.00034	0.00349	0.0013	0.0011
		L	1	12	0.00042	0.00119	0.0008	0.0002
	Cu	H	1	10	0.0028	0.015	0.0058	0.0038
		L	1	12	0.0014	0.0052	0.0029	0.001
	Pb	H	1	10	0.0038	0.045	0.0123	0.0125
		L	1	12	0.001	0.0074	0.0048	0.002
	Zn	H	1	10	0.082	0.692	0.2762	0.2092
		L	1	12	0.052	0.393	0.1813	0.0871
6	Cd	H	9	216	0.00005	0.028	0.0009	0.0024
		L	8	189	0.00005	0.008	0.0005	0.0008
	Cu	H	9	214	0.0005	0.075	0.0047	0.0057
		L	8	187	0.0005	0.0066	0.0023	0.0012
	Pb	H	9	204	0.0005	0.0408	0.0063	0.0088
		L	8	176	0.0005	0.013	0.0014	0.0022
	Zn	H	9	218	0.01	1	0.1226	0.1198
		L	8	189	0.005	0.461	0.0902	0.0718
7	Cd	H	2	100	0.00005	0.0055	0.0005	0.0008
		L	2	57	0.00005	0.001	0.0003	0.0003
	Cu	H	2	100	0.0005	0.055	0.0053	0.0092
		L	2	55	0.0005	0.0111	0.0029	0.0021
	Pb	H	2	100	0.0005	2.721	0.0307	0.2719
		L	2	57	0.0005	0.0264	0.0019	0.0048
	Zn	H	2	101	0.005	0.354	0.076	0.0689
		L	2	57	0.005	0.268	0.0587	0.045
8	Cd	H	6	220	0.00005	0.005	0.0004	0.0005
		L	6	207	0.00005	0.00218	0.0002	0.0004
	Cu	H	6	218	0.0005	0.089	0.0053	0.0078
		L	6	202	0.0005	0.045	0.0036	0.0047
	Pb	H	6	221	0.0005	0.0703	0.0069	0.0103
		L	6	205	0.0005	0.2	0.0029	0.0149
	Zn	H	6	218	0.005	0.482	0.102	0.0846
		L	6	200	0.005	0.45	0.0551	0.053

Table 6-6 Continued

Reach	Analyte	Flow	StaCnt	n	Min	Max	Avg	StdDev
9	Cd	H	2	14	0.00005	0.002	0.0004	0.0005
		L	3	28	0.00005	0.002	0.0003	0.0004
	Cu	H	2	14	0.0026	0.0293	0.0084	0.0074
		L	3	28	0.0015	0.034	0.0046	0.006
	Pb	H	2	13	0.0005	0.04	0.0081	0.0124
		L	3	29	0.0005	0.043	0.0033	0.008
	Zn	H	2	14	0.025	0.323	0.0976	0.0953
		L	3	28	0.011	0.14	0.0349	0.023
10	Cd	H	2	21	0.00005	0.001	0.0002	0.0003
		L	2	25	0.00005	0.001	0.0003	0.0004
	Cu	H	2	21	0.0005	0.0068	0.0023	0.0015
		L	2	25	0.0005	0.0041	0.0015	0.0009
	Pb	H	2	21	0.0005	0.0061	0.0013	0.0015
		L	2	25	0.0005	0.003	0.0007	0.0005
	Zn	H	2	21	0.005	0.06	0.0243	0.0155
		L	2	25	0.005	0.056	0.014	0.0127

Table 6-7

Concentrations of Cadmium, Copper, Lead, and Zinc (dry weight) in Reach 0 Sediments and the Downstream Area Sediments in Periods 1, 2, and 3

Period	Reach	Analyte	StaCnt	n	Min	Max	Avg	Stdev
1	0	Cadmium	1	1	18	18	18.0	
		Copper	1	1	73	73	73.0	
		Lead	1	1	162	162	162.0	
		Zinc	1	1	3,963	3,963	3,963.0	
	6	Cadmium	8	8	2.5	9	3.3	2.3
		Copper	8	8	16	46	30.6	10.1
		Lead	8	8	2.5	128	50.7	37.1
		Zinc	8	8	25	168	103.2	54.5
	7	Cadmium	5	5	2.5	2.5	2.5	0.0
		Copper	5	5	27	48	36.2	8.5
		Lead	5	5	27	105	63.6	32.2
		Zinc	5	5	33	533	195.8	199.1
	8	Cadmium	3	3	2.5	2.5	2.5	0.0
		Copper	3	3	34	41	37.7	3.5
		Lead	3	3	24	47	39.3	13.3
		Zinc	3	3	54	161	98.3	55.8
	9	Cadmium	3	3	2.5	6	3.7	2.0
		Copper	3	3	11	42	31.0	17.3
		Lead	3	3	9	30	18.0	10.8
		Zinc	3	3	28.5	157	103.2	66.7
	10	Cadmium	1	1	2.5	2.5	2.5	
		Copper	1	1	26	26	26.0	
		Lead	1	1	7	7	7.0	
		Zinc	1	1	99.5	99.5	99.5	
2	6	Cadmium	3	3	11	21	15.3	5.1
		Copper	3	3	65	121	87.3	29.7
		Lead	3	3	241	526	346.7	156.1
		Zinc	3	3	2,160	3,600	2,813.3	729.2
	7	Cadmium	1	2	5	9	7.0	2.8
		Copper	1	2	47	58	52.5	7.8
		Lead	1	2	143	221	182.0	55.2
		Zinc	1	2	925	1,680	1,302.5	533.9
	8	Cadmium	4	5	3	7	4.2	1.6
		Copper	4	5	40	52	44.0	4.7
		Lead	4	5	45	111	83.8	24.8
		Zinc	4	5	708	1,520	994.2	310.1
	9	Cadmium	11	20	0.13	5.9	1.1	1.4
		Copper	10	18	17	40	29.9	6.2
		Lead	11	20	11	93	44.9	23.3
		Zinc	11	20	83	863	309.9	168.1
	10	Cadmium	13	21	0.37	3.7	0.8	0.7
		Copper	13	21	11	36	23.6	7.4
		Lead	13	22	5.6	90	36.7	25.8
		Zinc	13	22	46	390	182.5	114.2

Table 6-7 Continued

Period	Reach	Analyte	StaCnt	n	Min	Max	Avg	Stdev
3	0	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	2,500	345.0	646.7
	5	Cadmium	3	5	5.48	16	10.4	4.6
		Copper	3	5	23.58	63	40.5	16.7
		Lead	2	2	602	770	686.0	118.8
		Zinc	3	5	310.85	2800	1,543.7	906.4
	6	Cadmium	11	17	1.35	15.4	4.8	3.5
		Copper	11	17	7.04	79.78	29.8	18.1
		Lead	8	8	67.6	550	287.3	142.8
		Zinc	11	17	238.39	2,559	981.1	559.4
	7	Cadmium	4	4	0.69	3.04	1.4	1.1
		Copper	4	4	8.74	32	20.3	9.5
		Lead	4	4	38.5	127	89.4	38.7
		Zinc	4	4	206	653	469.8	189.9
	8	Cadmium	15	17	0.342	4.52	1.8	1.3
		Copper	15	17	7.57	40.5	22.8	8.8
		Lead	15	17	7.54	130	47.2	26.3
		Zinc	15	17	88	840	459.5	234.4
	9	Cadmium	3	3	0.415	2	1.1	0.8
		Copper	3	3	8.35	34	21.8	12.9
		Lead	3	3	12.8	53	31.9	20.2
		Zinc	3	3	94.4	560	288.1	242.4
	10	Cadmium	1	1	2	2	2.0	
		Copper	1	1	31	31	31.0	
		Lead	1	1	37	37	37.0	
		Zinc	1	1	180	180	180.0	

Table 6-8

Summary Table of Groundwater Data (mg/L) in Reaches 5 through 10 for Periods 1, 2, and 3[1]

Deep Wells

Reach	Date	Cadmium[2]	Copper[3]	Lead[4]	Zinc[5]	Well-ID	Data Source
6	6/4/85			0.016		108800-001 @ Shangri La TC, Well #1	68
6	2/16/88	0.00004				108550-001 @ Mt Princeton MHP & RVP, Well #1	68
6	3/26/91	0.00005 <		0.001		108450-001 @ Collegiate Valley MV, Block Well	68
6	3/26/91			0.009		108550-001 @ Mt Princeton MHP & RVP, Well #1	68
6	12/17/92	0.0025 <	0.02	0.01 <		108100-001 @ Snowy Peaks RV & MHP, Well #1 - Irrigation only	68
6	5/10/93		0.006			108350-001 @ Buena Vista Correctional Fac., Cistern	68
6	5/10/94	0.0005 <	0.007	0.0005 <		108950-001 @ Valley MHP, Blend Tank #1	68
6	6/3/94	0.000125 <	0.08	0.0025 <		108050-001 @ Pinon Pines MHP, Well #1	68
6	6/8/94	0.0005 <	0.004	0.002		108800-001 @ Shangri La TC, Well #1	68
6	6/19/94		0.001			108100-002 @ Snowy Peaks RV & MHP, Well #2	68
6	6/29/94		0.008			108450-001 @ Collegiate Valley MV, Block Well	68
6	7/19/94		0.012	0.002		108550-001 @ Mt Princeton MHP & RVP, Well #1	68
6	7/27/94		0.02	0.005		108100-004 @ Snowy Peaks RV & MHP, Well #4 (aka NEW WELL)	68
6	9/9/96	0.000125 <	0.017	0.0005 <		108350-001 @ Buena Vista Correctional Fac., Cistern	68
6	5/12/97			0.004		108800-001 @ Shangri La TC, Well #1	68
6	5/20/97		0.02			108100-002 @ Snowy Peaks RV & MHP, Well #2	68
6	6/16/97	0.0005 <	0.0005 <	0.0005 <		108950-001 @ Valley MHP, Blend Tank #1	68
6	6/17/97		0.004	0.002		108550-001 @ Mt Princeton MHP & RVP, Well #1	68
6	6/23/97	0.000125 <	0.004	0.0005 <		108050-001 @ Pinon Pines MHP, Well #1	68
6	6/26/97		0.007			108450-001 @ Collegiate Valley MV, Block Well	68
6	6/7/99	0.00015 <	0.035	0.002		108350-001 @ Buena Vista Correctional Fac., Cistern	68
6	1/31/00	0.00015 <	0.16	0.0005 <		208200-001 @ Chateau Chaparrel CG, Well #1	68
6	1/31/00	0.00015 <	0.002 <	0.0005 <		208200-002 @ Chateau Chaparrel CG, Well #2	68
6	4/27/00	0.00005 <				108550-001 @ Mt Princeton MHP & RVP, Well #1	68
6	5/9/00	0.00005 <				108950-001 @ Valley MHP, Blend Tank #1	68
6	5/10/00	0.00015 <				108800-001 @ Shangri La TC, Well #1	68
6	5/18/00	0.00015 <				108050-001 @ Pinon Pines MHP, Well #1	68
6	5/31/00	0.00005 <				108450-001 @ Collegiate Valley MV, Block Well	68
6	6/21/00		0.0012			108100-005 @ Snowy Peaks RV & MHP, Pipeline for Wells #2 & #4	68
7	4/27/73		0.01 <	0.003	0.03	383254106010200 @ NA05000931BAB	31
7	5/12/92		0.14			108400-001 @ Fesslers MHP, Well #1 / West	68
7	5/2/94	0.000125 <	0.076	0.0025 <		108400-001 @ Fesslers MHP, Well #1 / West	68
7	6/18/97	0.000125 <	0.015	0.0005 <		108400-001 @ Fesslers MHP, Well #1 / West	68
7	4/24/00	0.00015 <				108400-003 @ Fesslers MHP, Wells #1 and #2	68
8	4/26/73			0.001 <	0.25	382912105225200 @ SC18-71-18BBB	31
8	4/27/73		0.01 <	0.003	0.12	382310105460800 @ NA04801129ACC	31
8	4/29/73			0.002	0.09	382215105412000 @ NA04801231BBD	31
8	5/4/94	0.000125 <	0.002 <	0.0025 <		108600-001 @ Mountain Vista Village, Pump House Tank	68
8	6/29/94	0.000125 <	0.2	0.0025 <		108200-001 @ Big Springs TP, Big Spring	68
8	4/7/97	0.000125 <	0.013	0.0005 <		108600-001 @ Mountain Vista Village, Pump House Tank	68
8	6/16/97		0.393			108200-001 @ Big Springs TP, Big Spring	68
8	6/19/00	0.0004				108200-001 @ Big Springs TP, Big Spring	68
8	6/26/00	0.00015 <				108600-001 @ Mountain Vista Village, Pump House Tank	68
9	4/15/72		0.01		0.03	382359105070900 @ SC01906916BAD3	31
9	4/26/73			0.002	0.03	382036104555600 @ SC02006706BAD	31
9	5/26/73		0.03		0.06	381846104514100 @ SC02006714BAC	31

Other (springs, etc)

Reach	Date	Cadmium	Copper	Lead	Zinc	Well-ID	Data Source
8	9/29/75		0.001 <	0.0045 <	0.02	382557105154600 @ CANON CITY HOT SPRING	31
8	10/10/75				0.01 <	382907105544100 @ WELLSVILLE WARM SPRINGS	31
8	6/2/1976	0.001 <			0.02	382849105532500 @ SWISSVALE WARM SPRING A	31

Well Depth Unknown

Reach	Date	Cadmium	Copper	Lead	Zinc	Well-ID	Data Source
8	4/27/73		0.01 <	0.007	0.02	382842105534100 @ NA49-10-20CDD	31
8	4/27/73			0.005	0.38	382843105534300 @ NA49-10-20CDC	31

[1] Data is from Consulting Team database.
[2] MCL = 0.005 mg/L.
[3] There is no MCL for copper, but it has a drinking water supply standard of 1.3 mg/L in Colorado.
[4] Ther is no MCL for lead, but it has an action level of 0.015 mg/L in Colorado.
[5] MCL = 5.0 mg/L.
< Indicates non-detect. For non-detects, one half of the detection limit is shown in this table as the data value.
For data set 68 CDPHE data, values are for total metals concentrations. For all other data sets, values are dissolved metals concentrations.

Table 6-9

Total Soil Concentrations for Lead and Zinc for Floodplain Soils in the Control Area (Reach 0) and for Reaches 6-9

Reach	**Lead**			**Zinc**		
	Mean	**Range**	**St. Dev.**	**Mean**	**Range**	**St. Dev**
0	238	97-464	136	428	184-857	224
6	376	20-1,603	457	868	40-4,393	1,213
7	86	32-180	44	328	105-1,232	332
8	40	20-126	28	281	42-813	160
9	20	20-29	1.3	71	40-150	29

Table 6-10

Average Metals Concentrations in Mixed Invertebrate Species by Reach and by Year from the Downstream Area (ppm, wet weight) [1]

Year (sample size)	Cadmium	Copper	Lead	Zinc
Reach 5				
1995 (n=1)	2.1	12.0	20.5	244.5
1996 (n=1)	3.2	7.9	25.3	338.0
1997 (n=1)	0.3	9.6	1.9	108.6
1998 (n=3)	0.8	7.4	12.8	198.0
Reach 6				
1995 (n=1)	3.8	13.1	88.2	671.8
1996 (n=4)	3.5	12.2	34.9	352.8
1997 (n=2)	0.8	7.7	8.7	143.6
1998 (n=4)	0.8	6.4	11.0	170.3
Reach 7				
1998 (n=3)	0.6	6.6	1.7	153.7
Reach 8				
1995 (n=3)	0.5	5.6	6.9	142.5
1996 (n=3)	1.5	7.6	6.2	184.3
1997 (n=7)	0.9	8.9	4.9	188.6
1998 (n=17)	0.3	6.7	1.3	109.3
Reach 9				
1998 (n=2)	0.1	4.9	1.5	41.4

[1] Data from Archuleta et al. (2000)

Table 6-11

Average Metal Concentrations in Mixed Invertebrate Species by Downstream Reach Compared to Reach 0 (ppm, wet weight) [1]

Reach (sample size)	Cadmium	Copper	Lead	Zinc
Reach 0 (n=12)	1.6	5.6	2.5	119.7
Reach 5 (n=6)	1.3	8.5	14.3	214.2
Reach 6 (n=11)	2.1	9.3	26.3	277.4
Reach 7 (n=3)	0.6	6.6	1.7	153.7
Reach 8 (n=30)	0.6	7.1	3.2	138.6
Reach 9 (n=2)	0.1	4.9	1.5	41.4
Benchmark	2.0	NR	2.0	50.0

[1] Data from Archuleta et al. (2000)

NR – Not Reported

Table 6-12

Average Metals Concentrations in American Dipper Blood and Liver Samples From Reaches 5-8 (ppm, wet weight)[1]

Blood	**n**	**Cadmium**	**Copper**	**Lead**	**Zinc**
Reach 5	5	0.04	0.29	0.22	6.29
Reach 6	10	0.01	0.16	0.13	3.77
Reach 7	4	0.01	0.07	0.04	2.88
Reach8	30	0.01	0.13	0.05	4.00
Reach 0	14	0.04	0.23	0.11	13.93
Study Reference	27	0.01	0.16	0.04	4.09
Benchmark	--	NR[3]	NR	0.20	60.00
Liver					
Reach 5	2	0.14	10.00	0.61	25.86
Reach 6	4	2.00	8.09	0.84	29.79
Reach 7	2	0.03	10.00	0.04	22.18
Reach8	13	0.17	5.86	0.09	25.57
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] Data from Archuleta et al. (2000)

[2] Study Reference Site: Poudre River, Colorado

[3] NR – Not Reported

Table 6-13

American Dipper ALAD for Reaches 5, 6, 7, 8, 0 and the Study Reference[1]

Location	N	ALAD Activity	% ALAD Reduction Compared to the Study Reference[2]	% ALAD Reduction Compared to Reach 0
Reach 5	4	612	49	17
Reach 6	9	530	56	28
Reach 7	4	629	48	14
Reach 8	24	903	25	0
Reach 0	10	735	39	
Study Reference	23	1203		

[1] From Archuleta et al. 2000

[2] Study Reference Site: Poudre River, Colorado

Table 6-14

Tree Swallow ALAD for Reaches 7, 8, 0 and the Study Reference[1]

Location	N	ALAD Activity	% ALAD Reduction Compared to the Study Reference	% ALAD Reduction Compared to Reach 0
Reach 7	62	65	12	0
Reach 8	6	48	40	13
Reach 0	21	55	31	--
Study Reference[2]	20	74	--	0

[1] From Custer et al 2003 In Press, and USFWS 2000

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

Table 6-15

Average Metals Concentrations in Tree Swallow Liver Samples from Reaches 6-8 (ppm, wet weight)[1]

Liver	n	Cadmium	Copper	Lead	Zinc
Reach 6	10	0.16	5.95	0.06	22.45
Reach 7	9	0.13	5.64	0.05	21.17
Reach8	3	0.12	9.04	0.21	20.77
Reach 0	10	0.05	5.16	0.06	21.09
Study Reference	30	<dl	17.71	<dl	70.8
Benchmark	--	40.00	NR	2.00	60.00

[1] Custer et al. 2003 In Press

NR – Not Reported

< - Less Than Detection Limit

Table 6-16

Average Metals Concentrations (μg/g) in Sediment Samples at Pueblo Reservoir from 1972 to 1988

	Cadmium	Copper	Lead	Zinc
Pre-impoundment (1972-1974) [1]	4.20	31.1	65.0	113
Post-impoundment (1974-1976) [1]	4.40	37.2	99.92	394
Mueller et al. (1991) [2]	2.0	40	61	360
Lewis and Edelmann (1994) [3]	---	35	52	278

[1] Data from Herrmann and Mahan (1977)

[2] One Sampling Site

[3] Mean From All Samples

FIGURES

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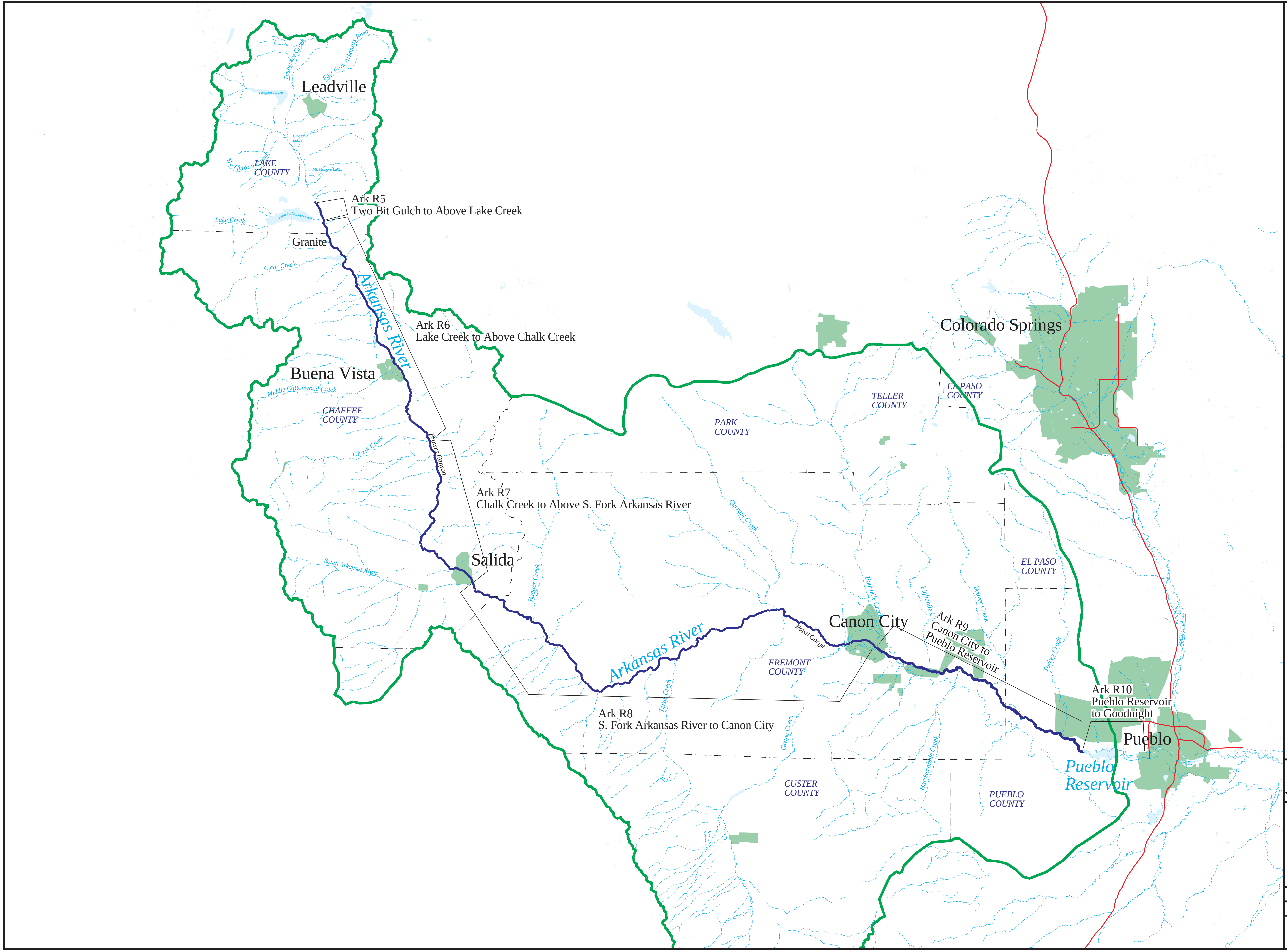

EXPLANATION

Hydrology

River or Stream

Watershed Boundary

Downstream Area of Arkansas River

Other Features

🟩 Town or Landmark

N

SCALE IN MILES

10 0 10

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 6 - 1

DOWNSTREAM AREA

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

MFG, Inc.

consulting scientists and engineers

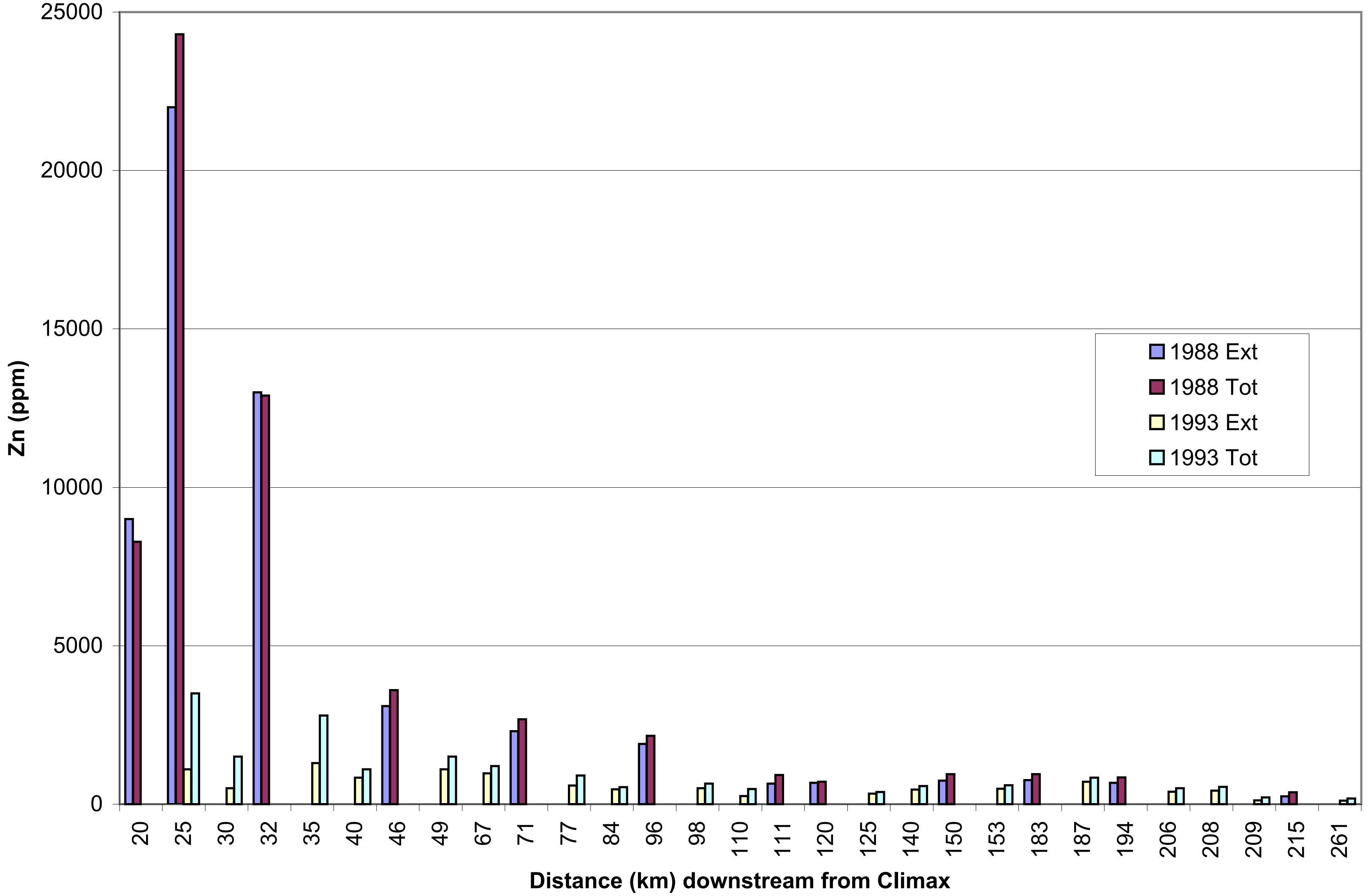

Figure 6-2

Comparison of Total (Tot) and Extractable (Ext) Zinc in Sediment Samples Collected during Kimball's 1988 and Church's 1993 Sediment Assessments

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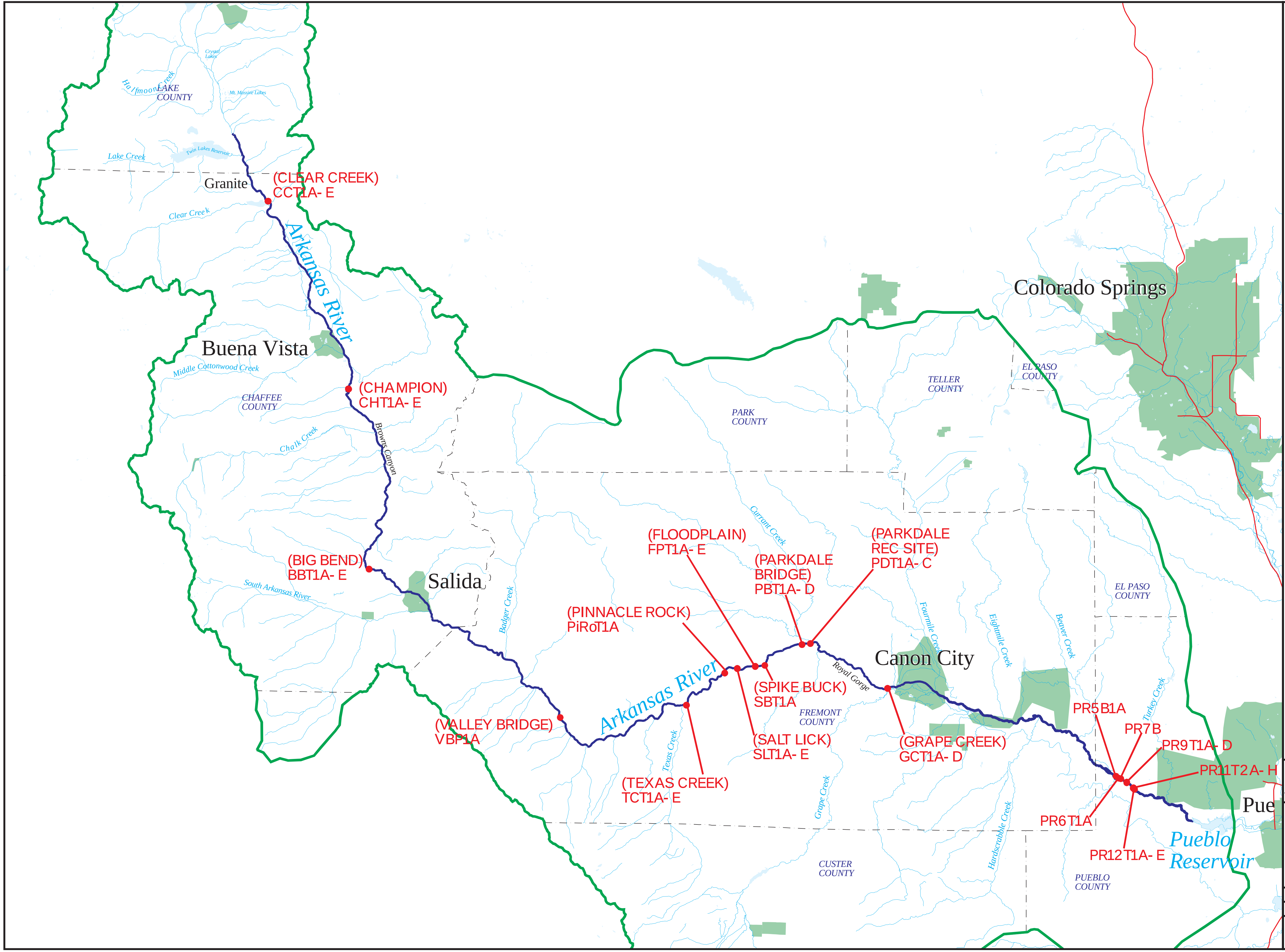


EXPLANATION

Hydrology

—	River or Stream
—	Watershed Boundary
—	Downstream Area of Arkansas River

Other Features

●	BLM 2000 Soil Sample Location
🟩	Town or Landmark

N

SCALE IN MILES

8 0 8

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 6- 3

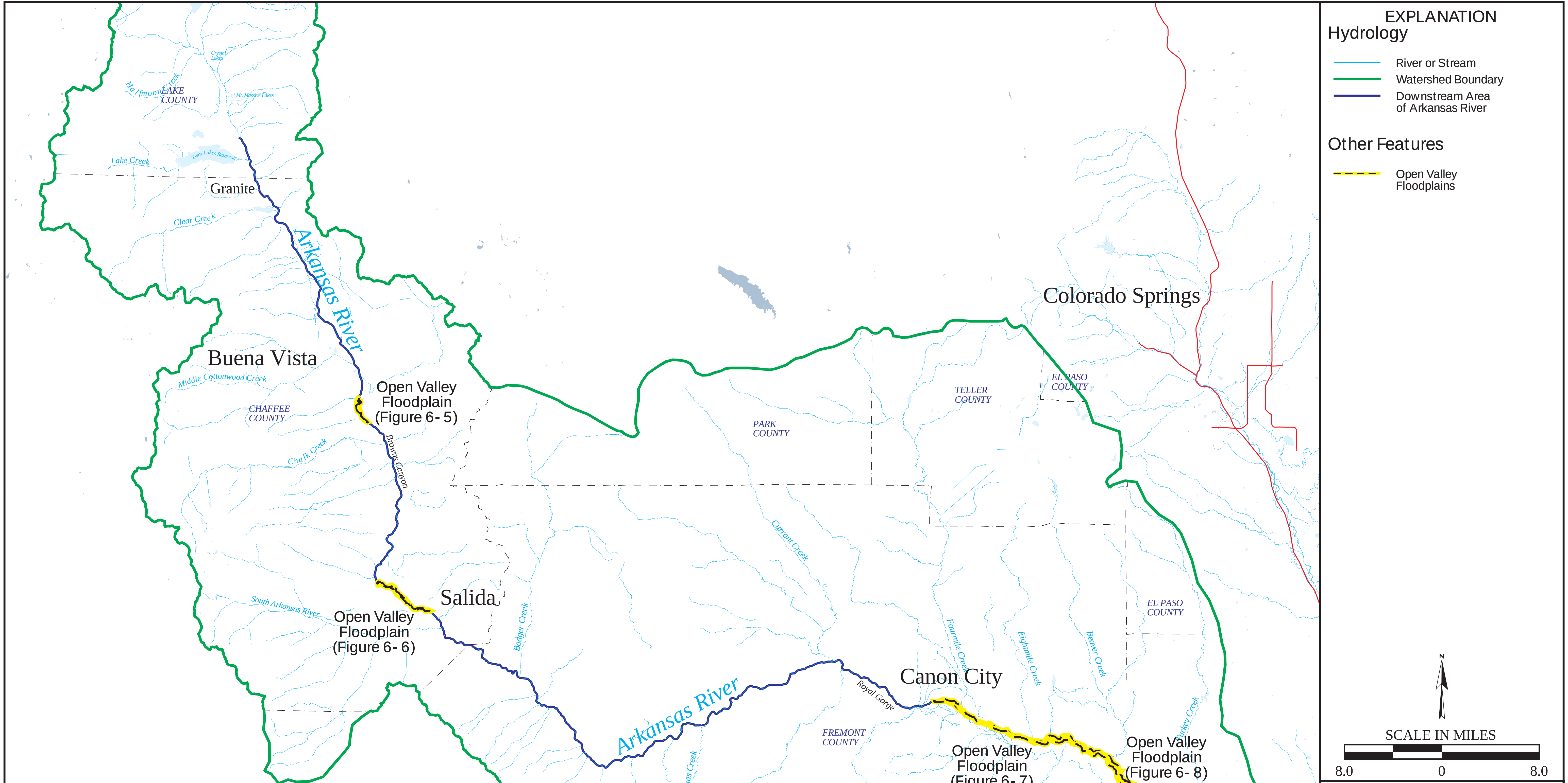
BLM 2000 SOIL SAMPLES
IN THE
DOWNSTREAM AREA

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

MFG, Inc.

consulting scientists and engineers

22-OCT-2002 GRA: N:\ARCPRJ2\010004\GRA\DS-RIPVEG0.GRA * AML: N:\ARCPRJ2\010004\AML\DS-RIPVEG.AML



UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 6- 4

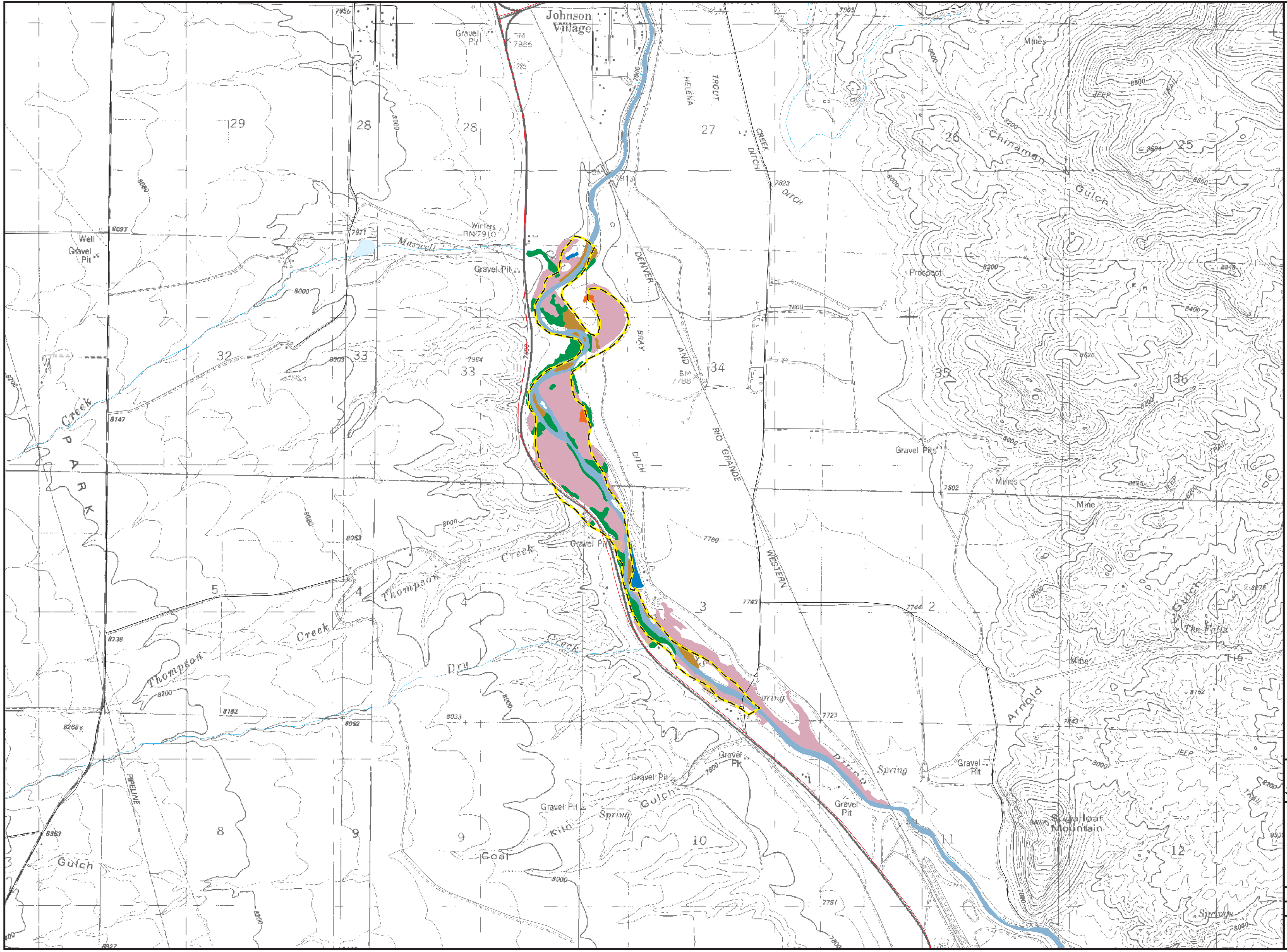
POTENTIAL SEDIMENT DEPOSITION AREAS IN THE DOWNSTREAM AREA

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

MFG, Inc.

consulting scientists and engineers

22-OCT-2002 GRA: N:\ARCPRJ2\010004\GRA\DS-RIPVEG1.GRA * AML: N:\ARCPRJ2\010004\AML\DS-RIPVEG.AML



EXPLANATION

Hydrology

— River or Stream

Other Features

- - - Open Valley Floodplains

Vegetation in the vicinity of open valley floodplains

🟫 Urban
🟦 Open Water - Lentic
🟦 Open Water - Riverine
🟩 Riparian Evergreen
🟧 Riparian Herbaceous (Standing Water)
🟪 Riparian Herbaceous (waterlogged Soils)
🟫 Willow
🟩 Cotton wood

N

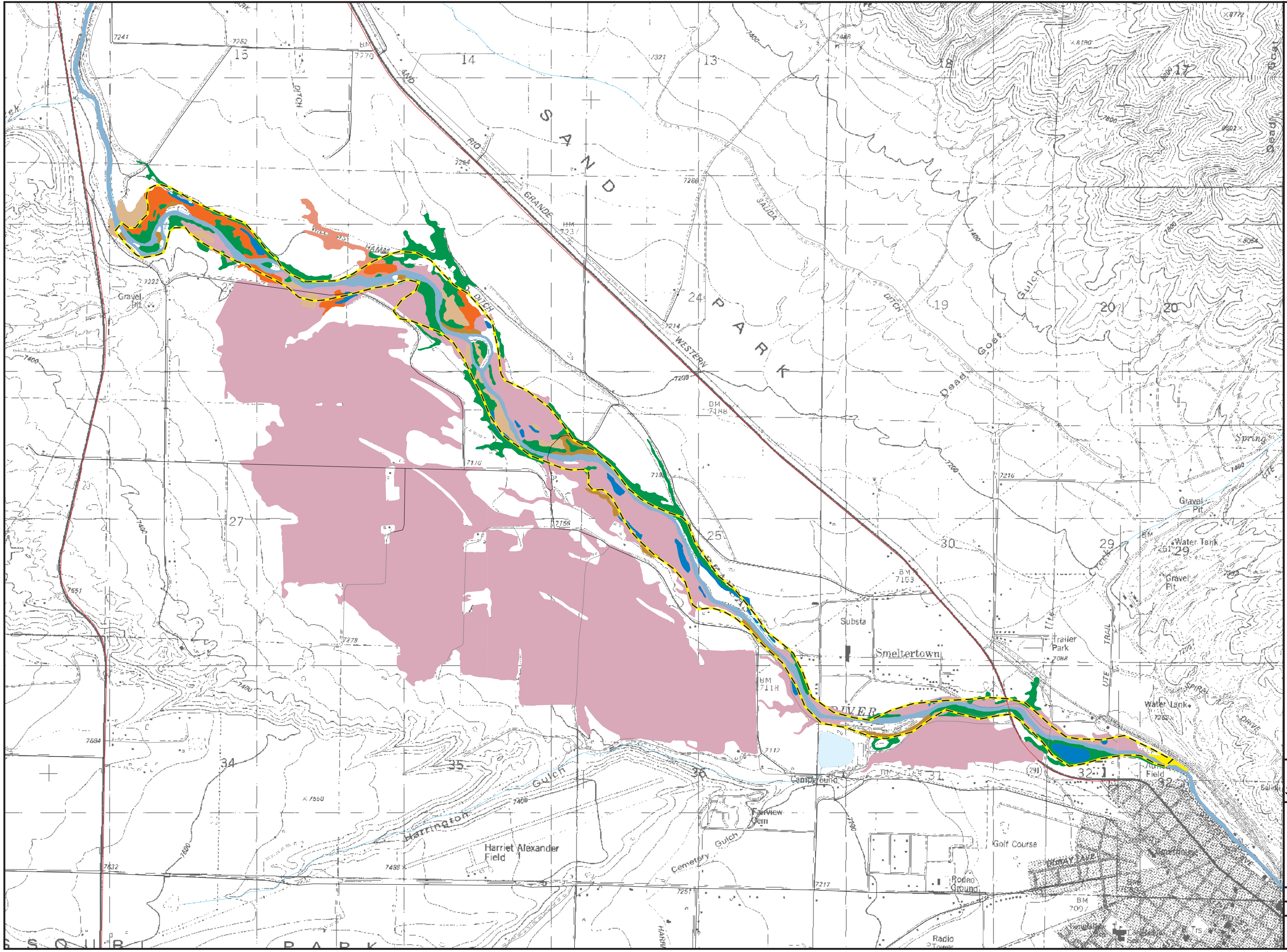
SCALE IN MILES
0.4 0 0.4

UPPER ARKANSAS RIVER BASIN
SITE CHARACTERIZATION SUMMARY

FIGURE 6- 5
RIPARIAN VEGETATION AND POTENTIAL SEDIMENT DEPOSITION AREAS IN THE BUENA VISTA AREA

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

MFG, Inc.
consulting scientists and engineers



EXPLANATION

Hydrology

— River or Stream

Other Features

- - - Open Valley Floodplains

Vegetation in the vicinity of open valley floodplains

🟫 Urban
🟦 Open Water - Lentic
🟦 Open Water - Riverine
🟩 Riparian Evergreen
🟧 Riparian Herbaceous (general)
🟧 Riparian Herbaceous (Standing Water)
🟪 Riparian Herbaceous (waterlogged Soils)
🟨 Riparian Shrub (general)
🟫 Willow
🟩 Cotton wood
🟥 Upland Shrub

N

SCALE IN MILES
0.4 0 0.4

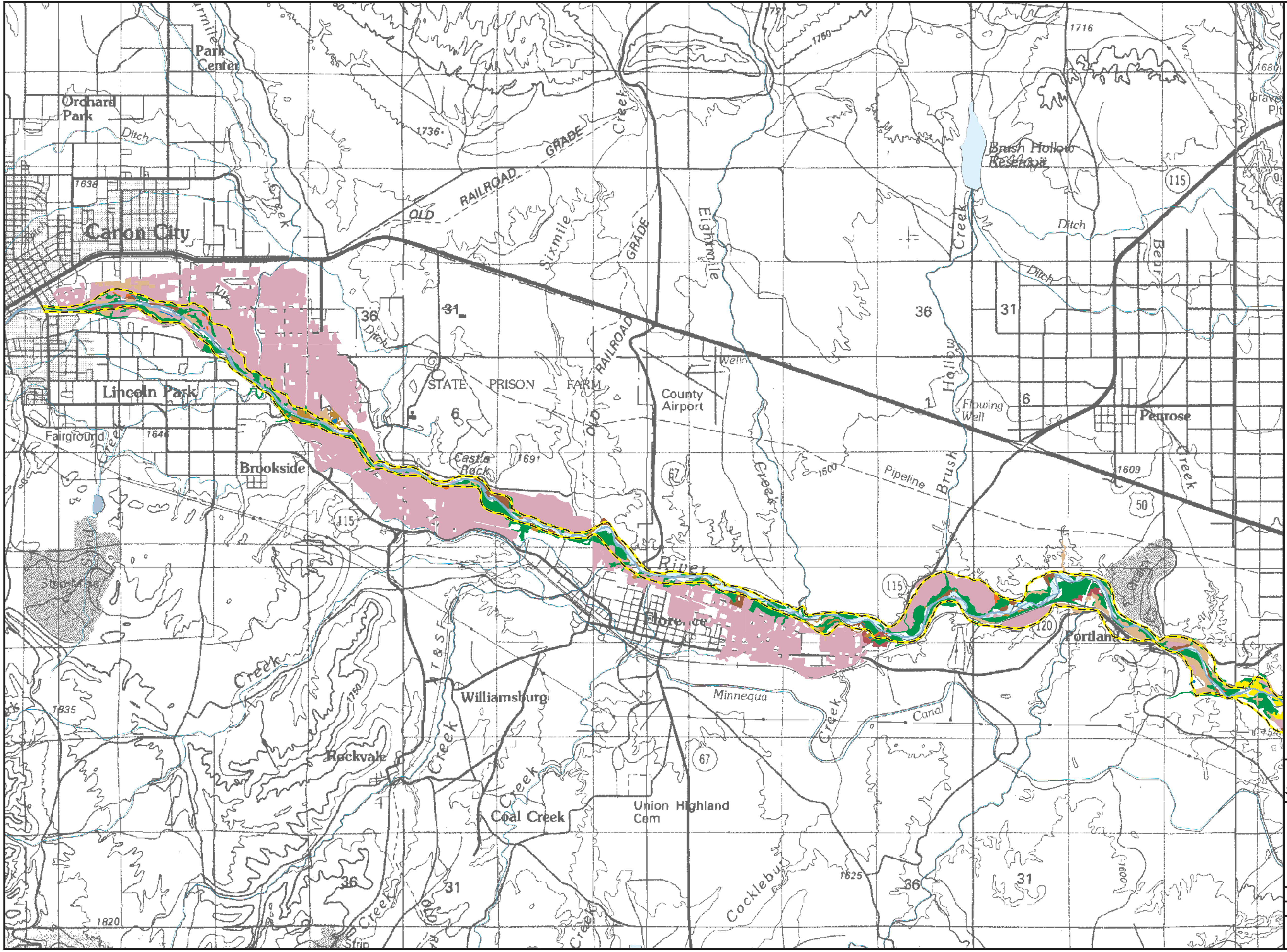
UPPER ARKANSAS RIVER BASIN
SITE CHARACTERIZATION SUMMARY

FIGURE 6- 6
RIPARIAN VEGETATION AND POTENTIAL SEDIMENT DEPOSITION AREAS IN THE SALIDA AREA

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

MFG, Inc.
consulting scientists and engineers

22-OCT-2002 GRA: N:\ARCPRJ2\010004\GRA\DS-RIPVEG3.GRA * AML: N:\ARCPRJ2\010004\AML\DS-RIPVEG.AML



EXPLANATION

Hydrology

River or Stream

Other Features

Open Valley Floodplains

Vegetation in the vicinity of open valley floodplains

- 🟩 Cotton wood
- 🟩 Riparian Evergreen
- 🟫 Upland Grass
- 🟨 Riparian Shrub (general)
- 🟦 Open Water - Lentic
- 🟦 Open Water - Riverine
- 🟧 Riparian Herbaceous (Standing Water)
- 🟪 Riparian Herbaceous (waterlogged Soils)
- 🟫 Willow
- 🟫 Tamarisk
- 🟥 Upland Shrub

SCALE IN MILES

1.0 0 1.0

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 6- 7

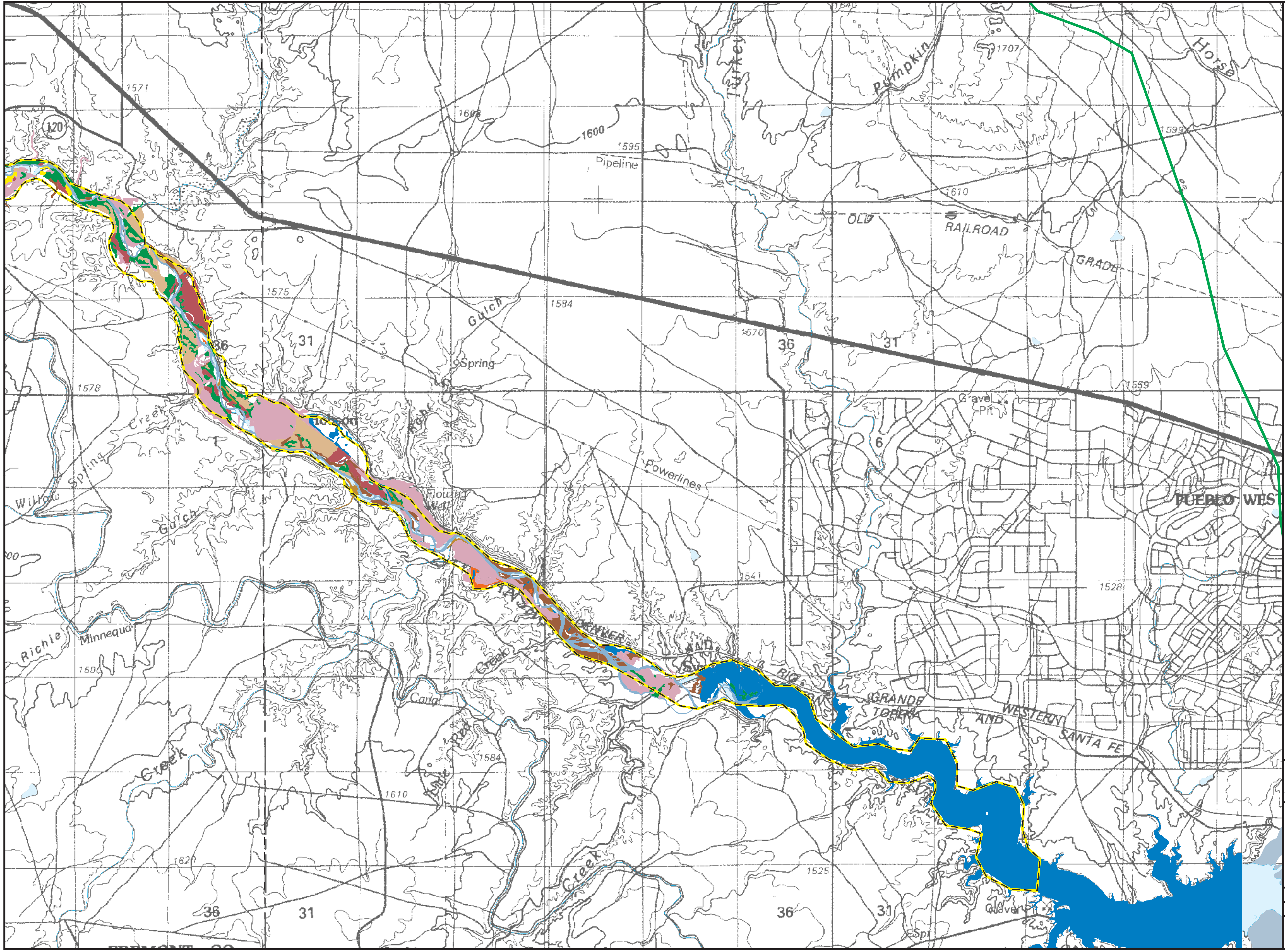
RIPARIAN VEGETATION AND POTENTIAL SEDIMENT DEPOSITION AREAS IN THE CANON CITY AREA

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

MFG, Inc.

consulting scientists and engineers

22-OCT-2002 GRA: N:\ARCPRJ2\010004\GRA\DS-RIPVEG4.GRA * AML: N:\ARCPRJ2\010004\AML\DS-RIPVEG.AML



EXPLANATION

Hydrology

—	River or Stream
—	Watershed Boundary

Other Features

- - -	Open Valley Floodplains

Vegetation in the vicinity of open valley floodplains

🟫	Urban
🟦	Open Water - Lentic
🟦	Open Water - Riverine
🟧	Riparian Herbaceous (Standing Water)
🟪	Riparian Herbaceous (waterlogged Soils)
🟨	Riparian Shrub (general)
🟫	Willow
🟫	Tamarisk
🟩	Cotton wood
⬜	Sandbar
🟥	Upland Shrub
🟩	Upland Tree

N

SCALE IN MILES

1.0 0 1.0

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 6- 8

RIPARIAN VEGETATION AND
POTENTIAL SEDIMENT DEPOSITION
AREAS IN THE
FLORENCE AREA

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

MFG, Inc.

consulting scientists and engineers

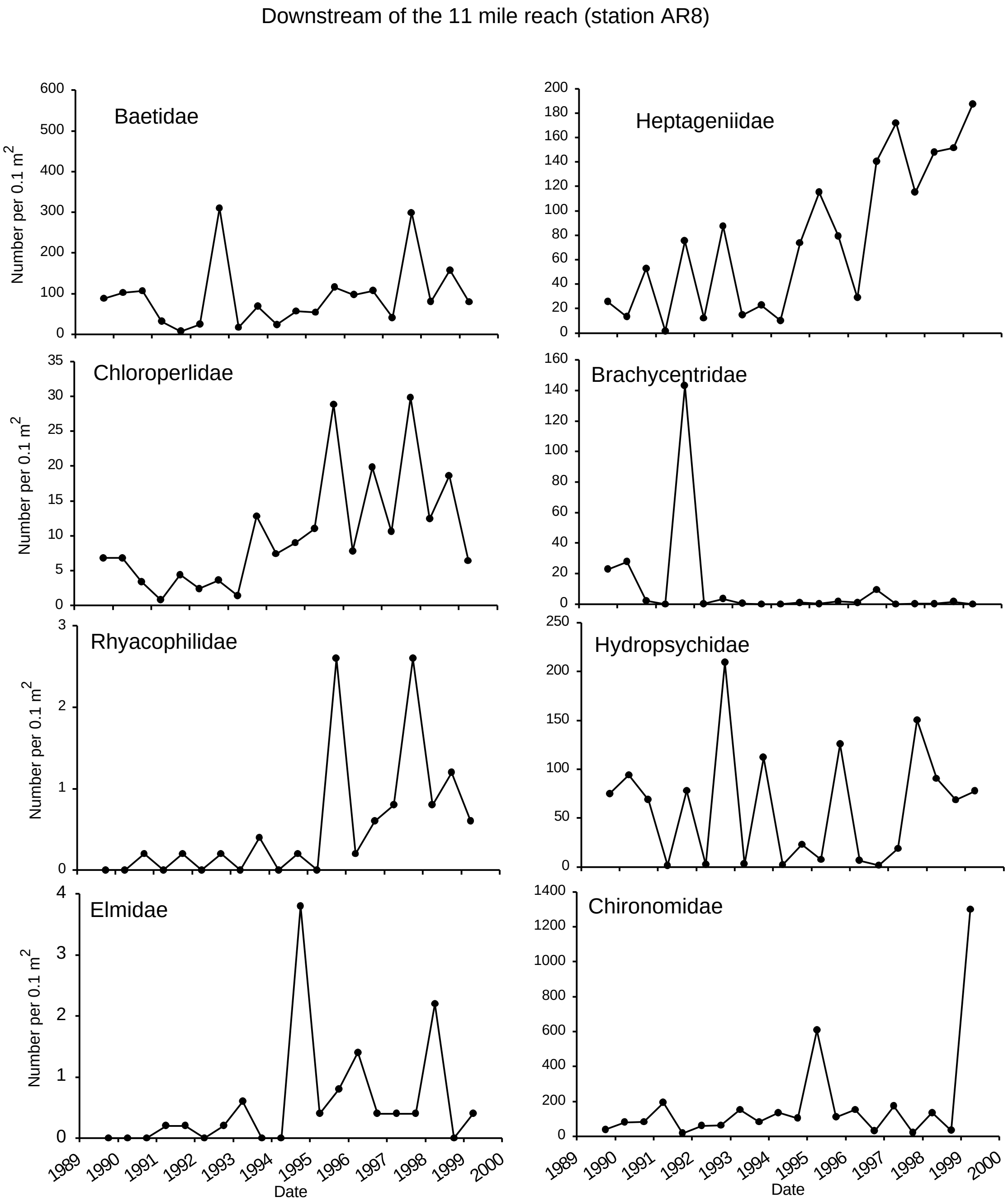


Figure 6-9

Abundance of Dominant Macroinvertebrate Taxa in the Arkansas River Downstream of the 11-Mile Reach (Station AR-8).

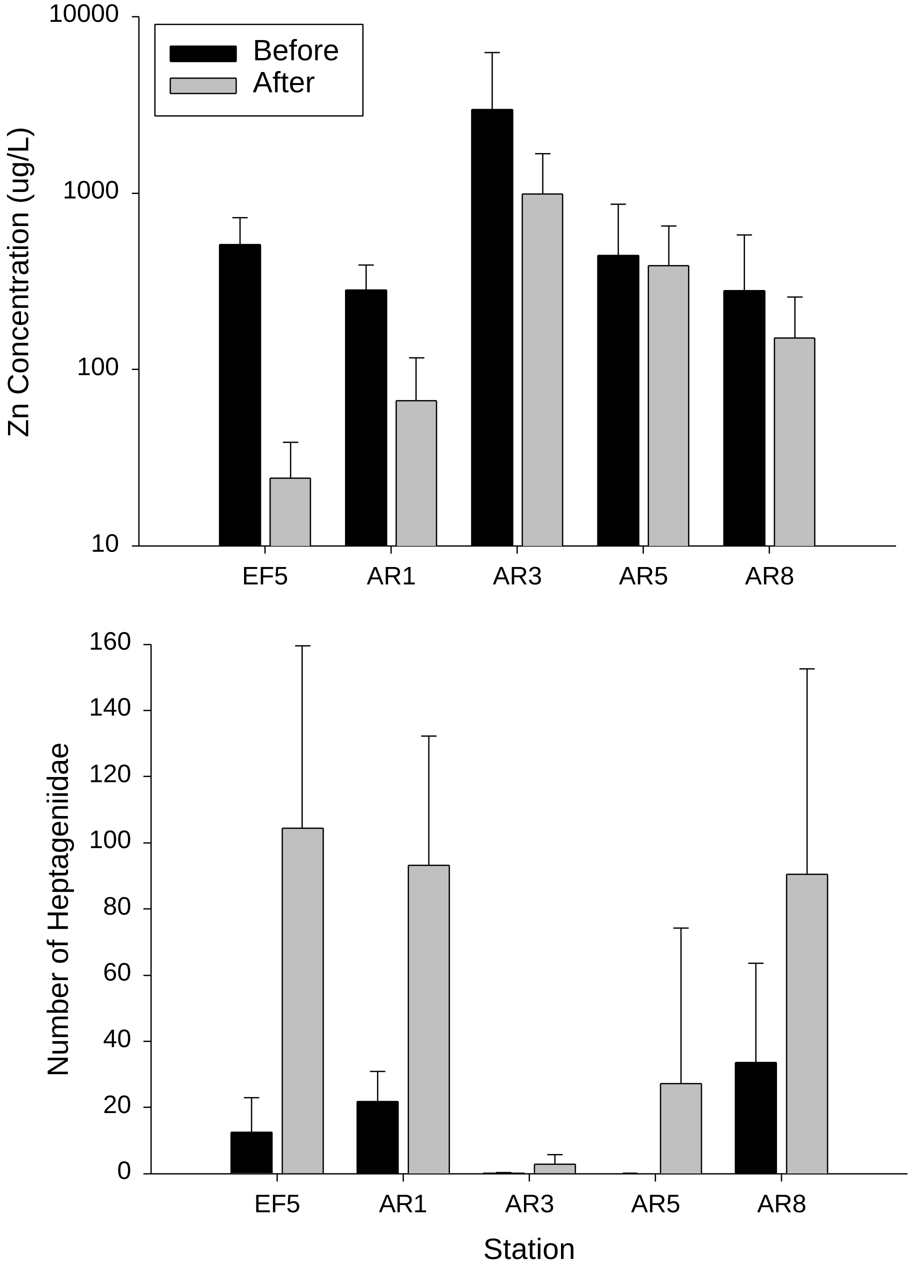


Figure 6-10

Changes in Total Zn Concentration and Number of Heptageniidae in Reach 0 (EF-5, AR-1), Reach 1 (AR-3), and Reach 3 (AR-5) before and after Remediation of LMDT and California Gulch. These Values are Compared to Data Collected below the 11-Mile Reach (AR-8).

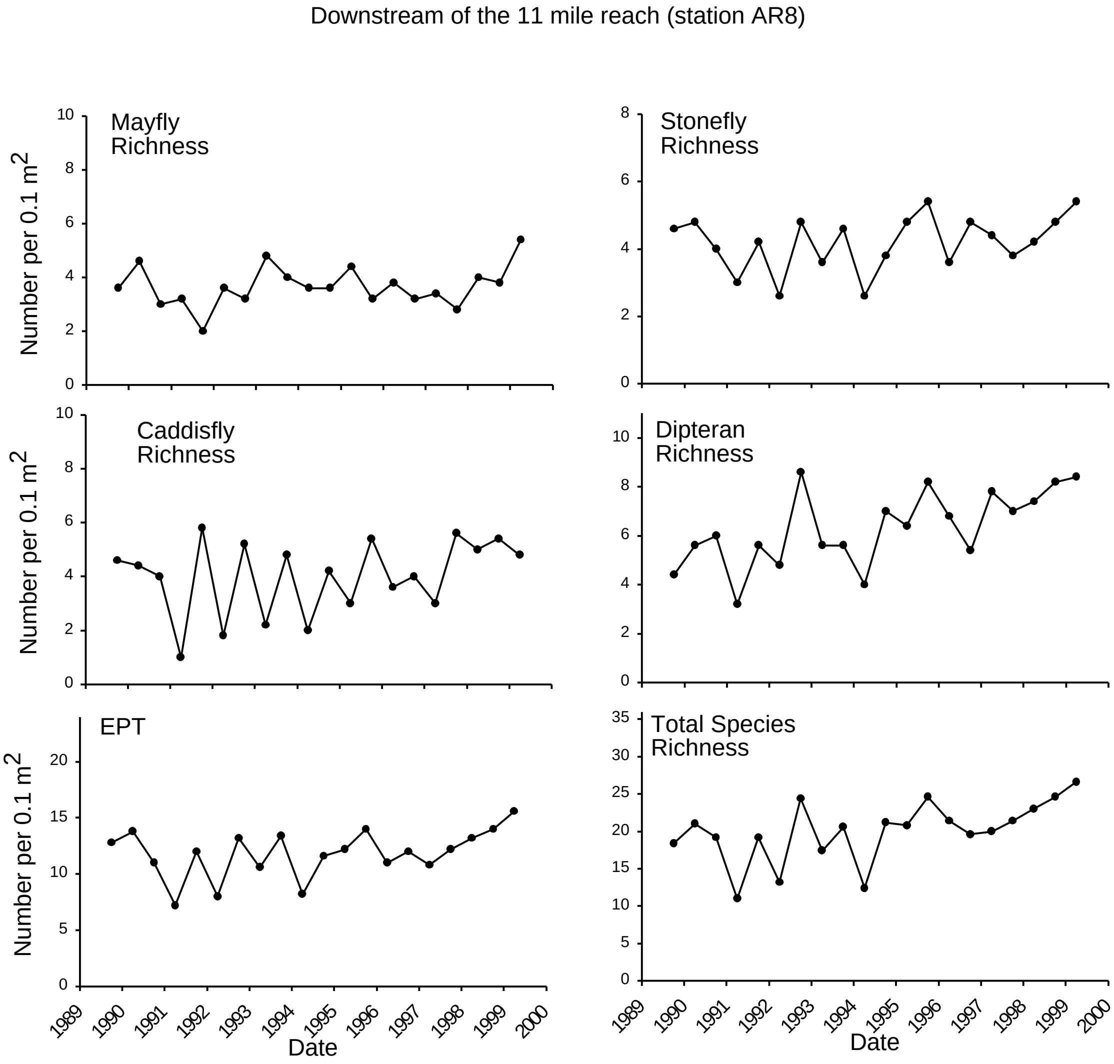


Figure 6-11

Species Richness of Major Macroinvertebrate Groups in the Arkansas River Downstream of the 11-Mile Reach (Station AR-8).

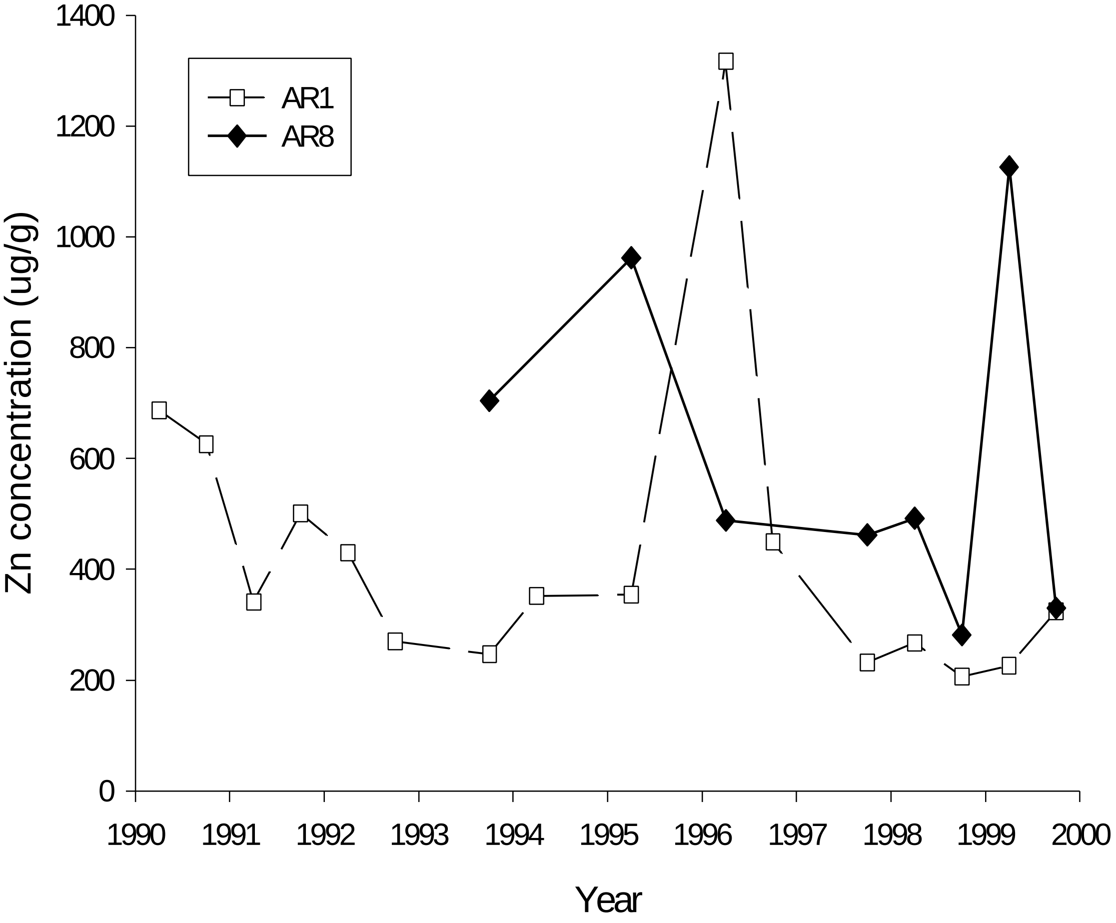


Figure 6-12

Metal Concentrations in the Caddisfly *Arctopsyche grandis* Collected from Stations AR-1 (Reach 0) and AR-8 (Downstream Area) of the Arkansas River.

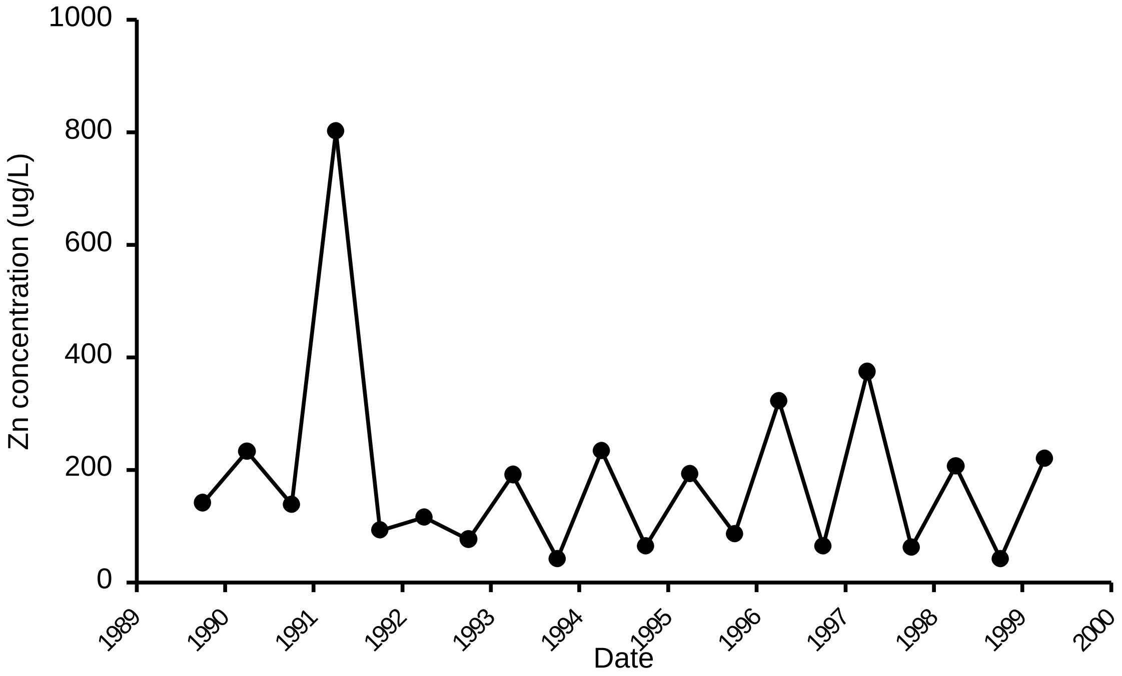


Figure 6-13

Total Zn Concentration (µg/L) Measured from 1989 to 1999 at Station AR-8 in the Downstream Reach.

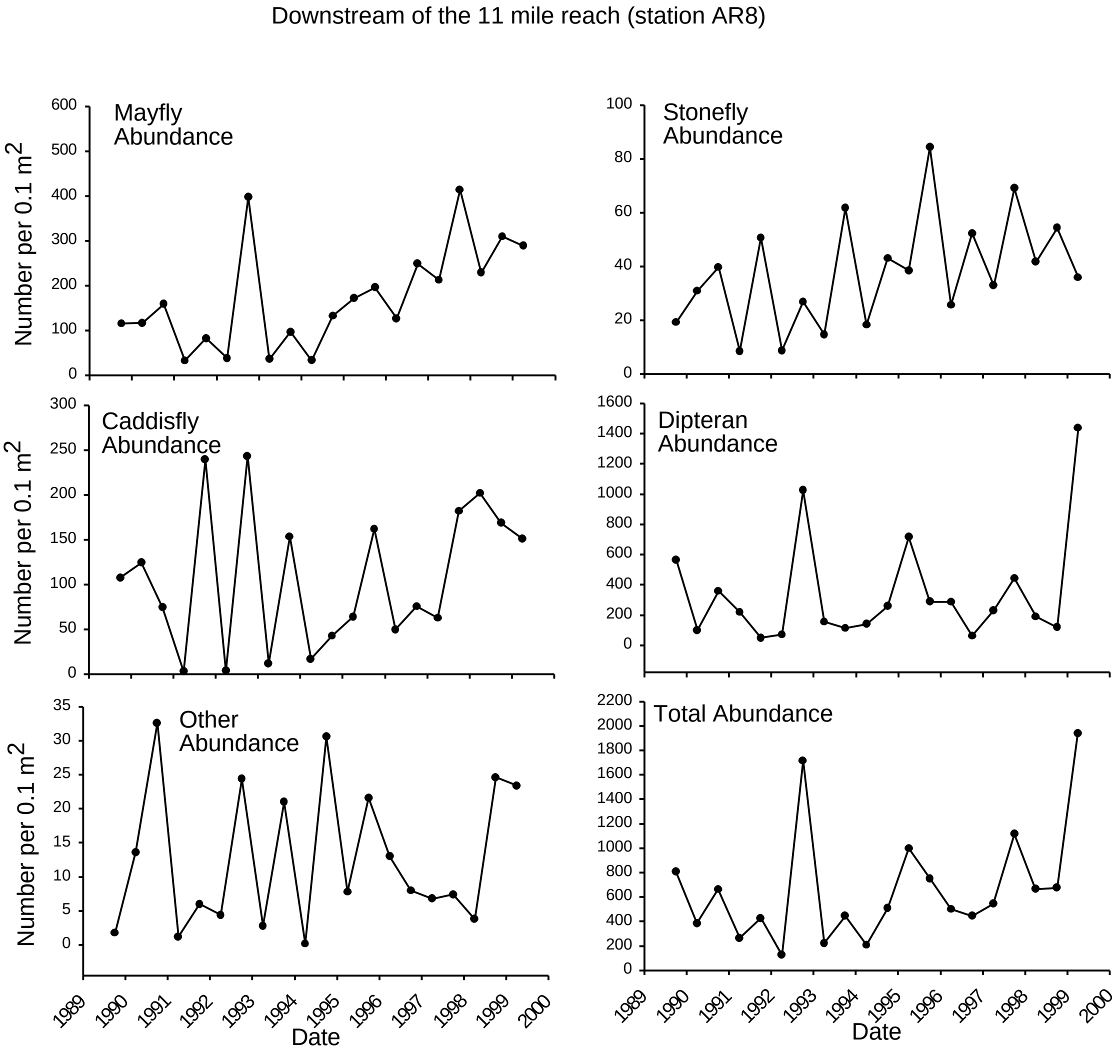


Figure 6-14

Abundance of Major Macroinvertebrate Groups in the Arkansas River Downstream of the 11-Mile Reach (Station AR-8).

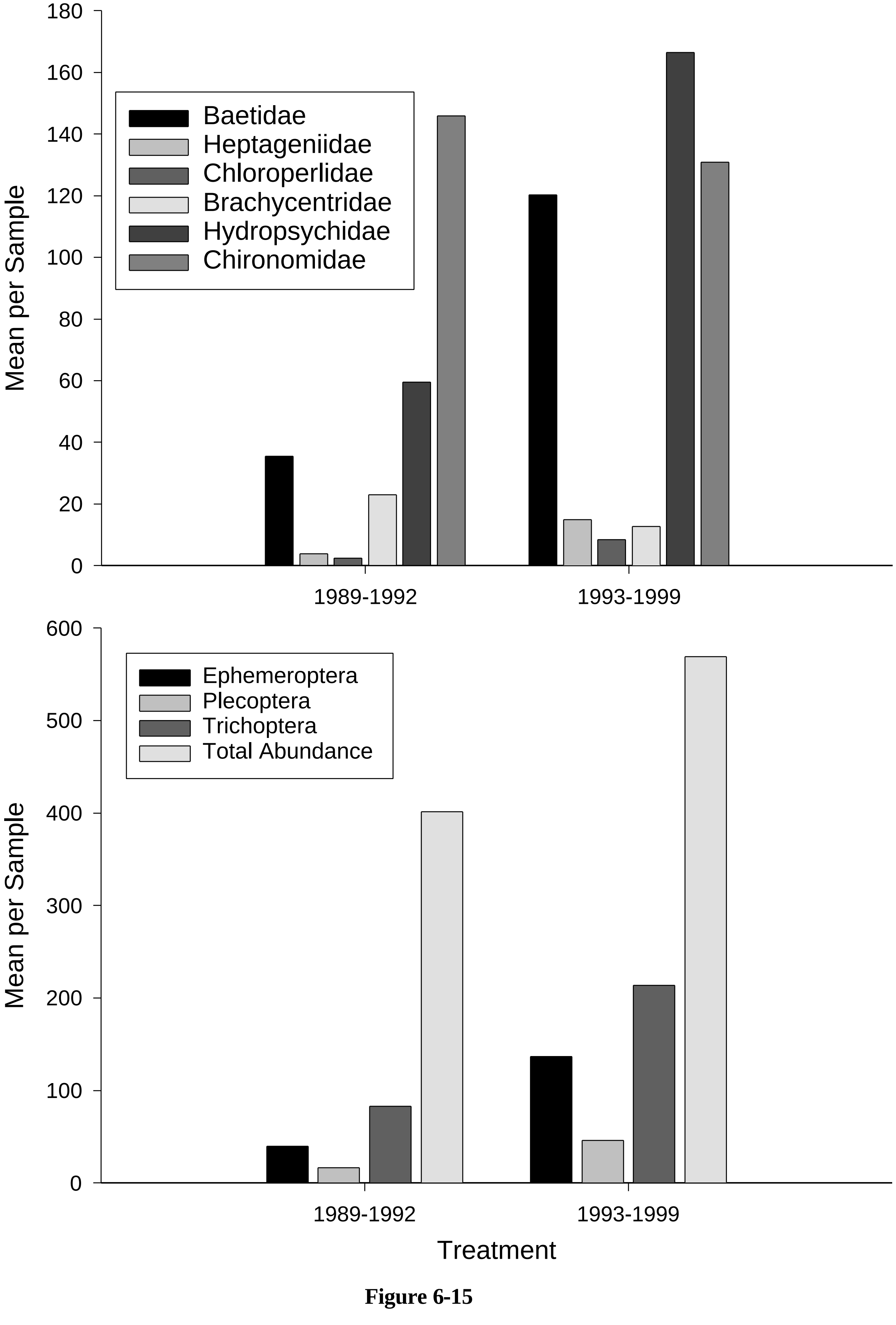


Figure 6-15

Changes in Abundance of Dominant Macroinvertebrate Groups in Reach 6 (station AR-7 near Granite) before (1989-1992) and after (1993-1999) Treatment of LMDT and California Gulch

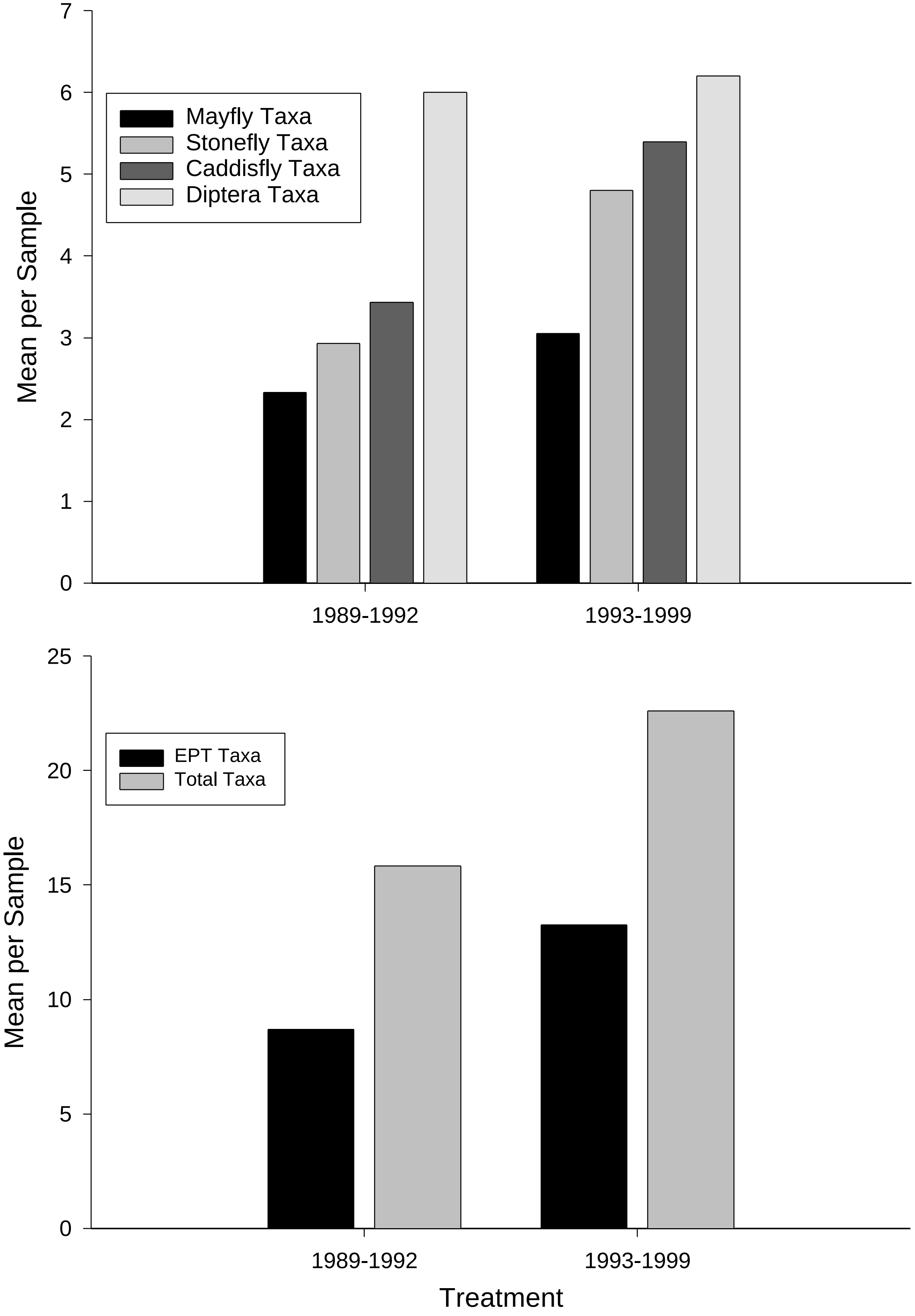


Figure 6-16

Changes in Species Richness of Dominant Macroinvertebrate Groups in Reach 6 (station AR-7 near Granite) before (1989-1992) and after (1993-1999) Treatment of LMDT and California Gulch

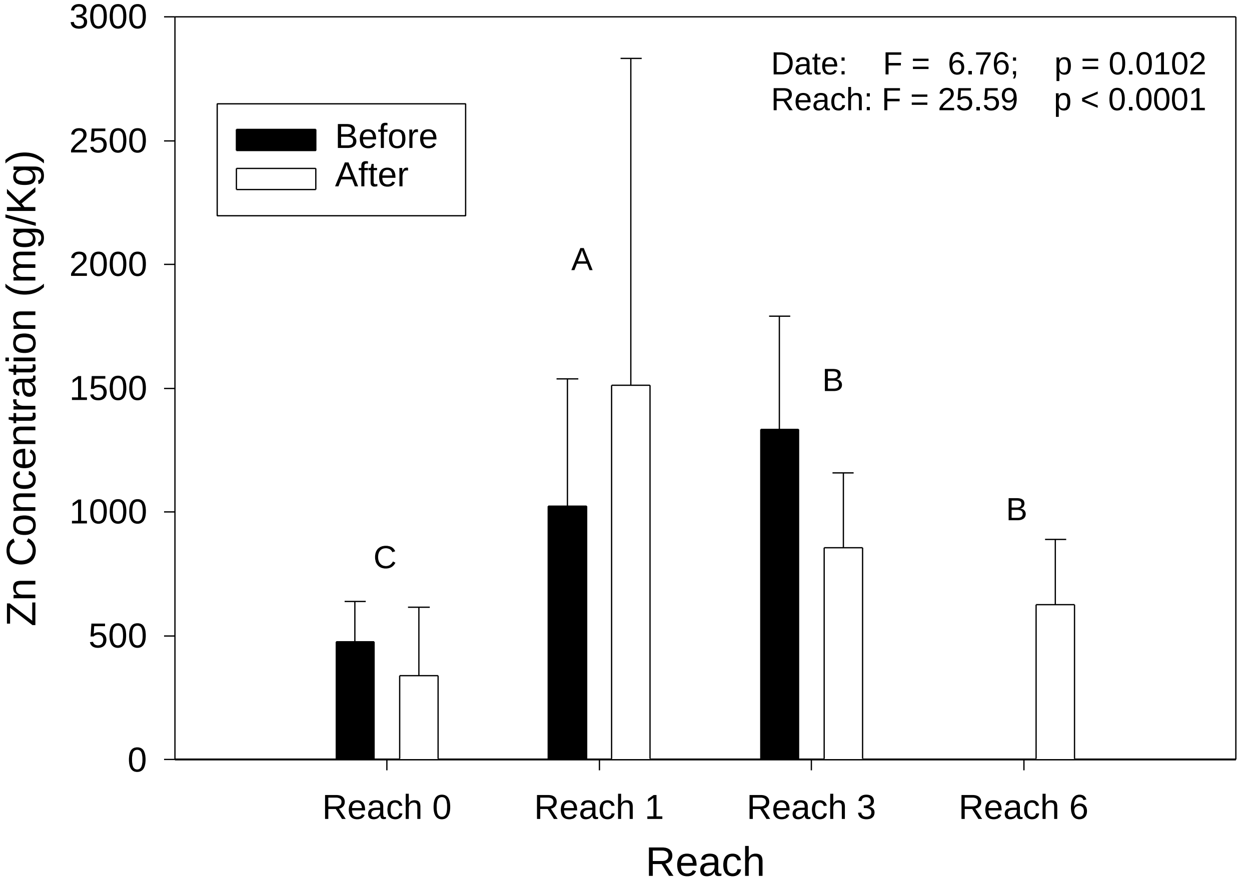


Figure 6-17

Mean (+SD) Zinc Concentrations (mg/kg) Measured in the Caddisfly *Arctopsyche grandis* before (1990-1992) and after (1993-1999) Remediation of LMDT and California Gulch [1]

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[1] Letters indicate results of multiple range tests. Across all dates, reaches with the same letter were not significantly different.

MATRIX SUMMARIZING INJURY CHARACTERIZATION
FOR THE DOWNSTREAM AREA OF THE
UPPER ARKANSAS RIVER BASIN

1. Surface Water Resources:

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

Surface Water 1992 to 2000 (Period 3)

Reach 5 – Two Bit Gulch to Lake Creek [2.2 river miles (RM)]

	High Flow	Low Flow
Regulatory Thresholds For Injury	Acute and chronic TVSs* based on mean hardness for each reach for cadmium, copper, lead, and zinc… [43 CFR 11.62(b)]	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 = 0.00078 (0.00015, 0.00254)
Diss Cu = 0.0042 (0.0021, 0.0073)
Diss Pb = 0.0017 (0.001, 0.0035)
Diss Zn = 0.222 (0.059, 0.568)

Regulatory Thresholds for Injury (mg/L)

Analyte	Acute	Chronic	Hardness
Cadmium	0.0029	0.0019	80.76
Copper	0.011	0.0075	80.76
Lead	0.0511	0.002	80.76
Zinc	0.0978	0.0983	80.76

Exceedence Data (# exceeding Regulatory Thresholds)

Analyte	Total n	Station	> Acute	> Chronic
Cadmium	10	1	0	1
Copper	10	1	0	0
Lead	9	1	0	4
Zinc	10	1	6	6

Low Flow

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

Diss Cd = 0.00061 (0.00035, 0.0011)
Diss Cu = 0.0038 (0.0012, 0.0127)
Diss Pb = 0.001 (0.001, 0.001)
Diss Zn = 0.149 (0.051, 0.347)

Regulatory Thresholds for Injury (mg/L)

Analyte	Acute	Chronic	Hardness
Cadmium	0.0041	0.0024	109.58
Copper	0.0146	0.0097	109.58
Lead	0.0713	0.0028	109.58
Zinc	0.127	0.1273	109.58

Exceedence Data (# exceeding Regulatory Thresholds)

Analyte	Total n	Station	> Acute	> Chronic
Cadmium	12	1	0	0
Copper	12	1	0	1
Lead	11	1	0	0
Zinc	12	1	5	5

Related Benchmark Comparisons

Summary metals statistics for Reach 5 show elevated concentrations when compared to Reach 0.

Statement of Injury: Surface waters in Reach 5 are injured during high flow due to concentrations of lead and zinc that exceed TVSs. Surface waters in Reach 5 are injured during low flow due to concentrations of zinc that exceed TVSs. A single exceedence for cadmium and copper was noted during both high and low flow, respectively.

Commentary: Exceedences for the four metals evaluated, except for zinc, are relatively infrequent. Based on mean concentrations, zinc exceeds TVSs during high flow and low flow. On average, zinc was roughly twice the chronic TVS. Exceedences can be linked to poor water quality upstream of Reach 5. The December 2000 CDPHE Status of Water Quality Report indicates that the Arkansas River from Lake Fork to Lake Creek is fully supporting its designated recreational and agricultural uses and partially supporting its aquatic life uses. The primary cause of non-support is zinc concentrations in surface waters.

Representativeness of Data: The amount of data available from this reach is limited; however, there are no substantial changes in flow or water quality in Reach 5 relative to Reaches 3 & 4 suggesting that collection of additional data would likely not provide any new insights about water quality in this reach. The spatial distribution of sample locations in Reach 5 shows that two points fall about one mile apart. One sampling point is located in the upper part of the reach just southwest of Holmes Gulch and the second point is located in the lower part of the reach just north of Lake Creek. The data, therefore, are considered to be representative.

Data Gaps: None.

Is current information sufficient for restoration planning? As with Reach 4 upstream, the data for Reach 5 provide an adequate assessment of the extent of water quality impacts from upstream sources. There are only a few small mine-waste deposits in the upper portion of Reach 5, and the length of Reach 5 is relatively short. Collection of new water quality data in Reach 5 would provide no additional information about restoration planning.

Related Text: Sections 6.4, 6.4.1 and 6.4.2

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* Both acute and chronic numbers adopted as stream standards are levels not to be exceeded more than once every three years on the average.

Surface Water 1992 to 2000 (Period 3)

Reach 6 – Lake Creek to Chalk Creek (29.5 RM)

	High Flow	**Low Flow**
Regulatory Thresholds For Injury	Acute and chronic TVSs* based on mean hardness for each reach for cadmium, copper, lead, and zinc… [43 CFR 11.62(b)]	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 = 0.00064 (0.00005, 0.029)
Diss Cu = 0.0027 (0.0001, 0.017)
Diss Pb = 0.0008 (0.0005, 0.031)
Diss Zn = 0.068 (0.005, 0.64)

Regulatory Thresholds for Injury (mg/L)

Analyte	Acute	Chronic	Hardness
Cadmium	0.0016	0.0013	47.05
Copper	0.0066	0.0047	47.05
Lead	0.0281	0.0011	47.05
Zinc	0.0618	0.0621	47.05

Exceedence Data (# exceeding Regulatory Thresholds)

Analyte	Total n	Stations	> Acute	> Chronic
Cadmium	212	9	9	10
Copper	210	9	2	17
Lead	199	9	1	13
Zinc	213	8	67	66

Low Flow

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

Diss Cd = 0.0003 (0.00005, 0.0025)
Diss Cu = 0.00176 (0.0001, 0.0079)
Diss Pb = 0.00062 (0.0005, 0.007)
Diss Zn = 0.0761 (0.004, 0.371)

Regulatory Thresholds for Injury (mg/L)

Analyte	Acute	Chronic	Hardness
Cadmium	0.0022	0.0016	62.79
Copper	0.0087	0.006	62.79
Lead	0.0388	0.0015	62.79
Zinc	0.079	0.0794	62.79

Exceedence Data (# exceeding Regulatory Thresholds)

Analyte	Total n	Stations	> Acute	> Chronic
Cadmium	187	9	9	9
Copper	184	9	0	2
Lead	182	10	0	2
Zinc	169	8	52	52

Related Benchmark Comparisons

Lake Creek discharges a substantial volume of water to the Arkansas River and alters the hydrology as well as the water chemistry. As a result, zinc concentrations in Reach 6 are one half of those in Reach 5 and are similar to Reach 0.

Statement of Injury: Surface waters in Reach 6 are injured during high and low flow due primarily to concentrations of zinc that exceed TVSs. Occasional exceedences were identified for surface waters in Reach 6 during high and low flow for cadmium, copper, lead, and zinc.

Commentary: Hardness values during both high and low flows are lower in this reach of the Arkansas River, resulting in lower TVSs. During both high and low flows, the frequency of exceedences for cadmium, copper, and lead is very low (8% or less), and high flow exceedences are more frequent than low flow exceedences. Zinc exceeds both the acute and chronic TVSs in about 30% of the samples during both high and low flows; however, on average, concentrations of zinc during high and low flow are very close to the TVSs. The December 2000 CDPHE Status of Water Quality Report indicates that the Arkansas River below Lake Creek is fully supporting its designated uses. The South Fork of Lake Creek is listed as partially supporting its aquatic life use due to metals. Discharge of this creek is through Twin Lake Reservoir, which is listed as fully supporting its designated uses. Additional metals may come from this drainage, although loading is expected to be small.

Representativeness of Data: The spatial and temporal distribution (1992-1999) of the sample data for this reach is the best of all of the downstream reaches with between 7 and 10 sample stations covering most of the reach. The spatial distribution of sample locations in Reach 6 shows there are multiple sample points that fall both in the upper and lower sections of the reach. Data are spatial and temporally representative for the reach.

Data Gaps: None.

Is current information sufficient for restoration planning? Yes.

Related Text: Sections 6.4, 6.4.1 and 6.4.2

* Both acute and chronic numbers adopted as stream standards are levels not to be exceeded more than once every three years on the average.

Surface Water 1992 to 2000 (Period 3)

Reach 7 – Chalk Creek to South Fork Arkansas River (21.2 RM)

Regulatory Thresholds For Injury

	High Flow	Low Flow
Regulatory Thresholds For Injury	Acute and chronic TVSs* based on mean hardness for each reach for cadmium, copper, lead, and zinc… [43 CFR 11.62(b)]	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 = 0.0002 (0.00005, 0.0012)
Diss Cu = 0.0024 (0.0001, 0.041)
Diss Pb = 0.00078 (0.0005, 0.005)
Diss Zn = 0.0398 (0.004, 0.137)

Regulatory Thresholds for Injury (mg/L)

Analyte	Acute	Chronic	Hardness
Cadmium	0.0019	0.0014	54.7
Copper	0.0076	0.0053	54.7
Lead	0.0333	0.0013	54.7
Zinc	0.0703	0.0706	54.7

Exceedence Data (# exceeding Regulatory Thresholds)

Analyte	Total n	Stations	> Acute	> Chronic
Cadmium	100	3	0	0
Copper	102	3	2	4
Lead	101	3	0	12
Zinc	103	3	12	12

Low Flow

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

Diss Cd = 0.000997 (0.00005, 0.066)
Diss Cu = 0.00182 (0.0001, 0.0124)
Diss Pb = 0.00151 (0.0005, 0.0253)
Diss Zn = 0.0396 (0.004, 0.14)

Regulatory Thresholds for Injury (mg/L)

Analyte	Acute	Chronic	Hardness
Cadmium	0.0028	0.0018	76.19
Copper	0.0104	0.0071	76.19
Lead	0.048	0.0019	76.19
Zinc	0.0931	0.0935	76.19

Exceedence Data (# exceeding Regulatory Thresholds)

Analyte	Total n	Stations	> Acute	> Chronic
Cadmium	89	3	1	1
Copper	85	3	1	2
Lead	86	3	0	19
Zinc	82	3	2	2

Related Benchmark Comparisons

Compared to Reach 6 upstream, average concentrations of zinc during high and low flow typically decrease in Reach 7. This is consistent with the trend observed from upstream reaches for zinc. Mean cadmium, copper, and lead in Reach 7 are similar to concentrations in Reach 6 during low flows and decrease during high flows. Mean concentrations are less than Reach 0.

Statement of Injury: Surface waters in Reach 7 are injured during high flow primarily due to concentrations of lead and zinc that exceed TVSs. Surface waters in Reach 7 are injured during low flow due primarily to concentrations of lead that exceed TVSs. Occasional exceedences of cadmium and copper were also identified during high flow, while occasional exceedences of cadmium, copper, and lead were observed during low flow.

Commentary: The number of high and low flow exceedences of acute TVSs in Reach 7 for cadmium, copper, and lead is smaller than that observed in Reach 6, indicating that the concentrations of these metals are decreasing. No acute or chronic exceedences of TVSs were observed for cadmium during high flow, and only one each was observed during low flow. Zinc exceedences during high flow were greater than during low flow. Exceedences of TVSs in Reach 7 are slightly lower for both flow conditions than those observed for Reach 6. Mean concentrations are below the TVSs for both high and low flows. The December 2000 CDPHE Status of Water Quality Report indicates that the Arkansas River below Lake Creek is fully supporting its designated uses. Chalk Creek may serve as an additional source of metals in this reach due to historical mining, and is listed as partially supporting its aquatic life use.

Representativeness of Data: Reach 7 data are considered to be representative both temporally and spatially for the reach. Data are temporally well distributed from 1992 to 1997. No post-1997 data were available. The spatial distribution of sample locations in Reach 7 shows that there are approximately nine points located throughout the middle and lower section of the reach, however, there are no sample points in the upper quarter of the reach, which covers approximately 6 miles.

Data Gaps: None.

Is current information sufficient for restoration planning? Yes.

Related Text: Sections 6.4, 6.4.1 and 6.4.2

---

* Both acute and chronic numbers adopted as stream standards are levels not to be exceeded more than once every three years on the average.

Surface Water 1992 to 2000 (Period 3)

Reach 8 – South Fork Arkansas River to Canon City (58.1 RM)

	High Flow	**Low Flow**
Regulatory Thresholds For Injury	Acute and chronic TVSs* based on mean hardness for each reach for cadmium, copper, lead, and zinc… [43 CFR 11.62(b)]	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 = 0.00011 (0.00005, 0.0009)
Diss Cu = 0.0019 (0.0001, 0.039)
Diss Pb = 0.0008 (0.0005, 0.0131)
Diss Zn = 0.041 (0.003, 0.226)

Regulatory Thresholds for Injury (mg/L)

Analyte	Acute	Chronic	Hardness
Cadmium	0.0027	0.0018	75.72
Copper	0.0103	0.0071	75.72
Lead	0.0476	0.0019	75.72
Zinc	0.0926	0.0931	75.72

Exceedence Data (# exceeding Regulatory Thresholds)

Analyte	Total n	Stations	> Acute	> Chronic
Cadmium	194	6	0	0
Copper	187	6	2	3
Lead	196	6	0	12
Zinc	191	6	16	15

Low Flow

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

Diss Cd = 0.00011 (0.00005, 0.0021)
Diss Cu = 0.00124 (0.0001, 0.0101)
Diss Pb = 0.0017 (0.0005, 0.1677)
Diss Zn = 0.036 (0.001, 0.175)

Regulatory Thresholds for Injury (mg/L)

Analyte	Acute	Chronic	Hardness
Cadmium	0.004	0.0024	107.48
Copper	0.0144	0.0095	107.48
Lead	0.0699	0.0027	107.48
Zinc	0.1246	0.1252	107.48

Exceedence Data (# exceeding Regulatory Thresholds)

Analyte	Total n	Stations	> Acute	> Chronic
Cadmium	199	8	0	0
Copper	197	7	0	1
Lead	204	7	1	5
Zinc	178	7	4	4

Related Benchmark Comparisons

Compared to Reach 7, mean concentrations of the metals evaluated in Reach 8 are typically similar to, or less than, those observed in Reach 7 during both high and low flows. Mean zinc concentrations between the two reaches are almost identical. Hardness increased in Reach 8 when compared to Reach 7, suggesting inputs from tributaries and effects of local land uses.

Statement of Injury: Surface waters in Reach 8 are injured during high flow due to concentrations of lead and zinc that exceed TVSs. Surface waters in Reach 8 are injured during low flow due to concentrations of lead, and zinc that exceed TVSs. Copper was also identified as occasionally exceeding the TVS.

Commentary: Cadmium does not exceed TVSs during either high or low flows. Copper exceedences are infrequent. Lead exceedences of the chronic TVSs were measured more frequently during high versus low flows. Occurrences of zinc exceedences are similar to Reach 7. Average values for cadmium, copper, lead, and zinc are well below the TVS. Based on mean concentrations, none of the evaluated metals exceed TVSs during either high or low flows. The December 2000 CDPHE Status of Water Quality Report indicates that the Arkansas River below Lake Creek is fully supporting its designated uses.

Representativeness of Data: Reach 8 data for Period 3 are temporally well distributed. Reach 8 is one of the longest of the downstream reaches evaluated. The spatial distribution of sample locations in Reach 8 shows there are multiple points that fall throughout the reach, however, there are two considerable gaps in between sample locations. One, located below Badger Creek, is 12 miles long and another, that is approximately 18 miles in length, is located between Texas Creek and Currant Creek. However, spatial distribution of the sample locations is adequate. Data are considered to be representative for the reach.

Data Gaps: None.

Is current information sufficient for restoration planning? Yes.

Related Text: Sections 6.4, 6.4.1 and 6.4.2

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* Both acute and chronic numbers adopted as stream standards are levels not to be exceeded more than once every three years on the average.

Surface Water 1992 to 2000 (Period 3)

Reach 9 – Canon City to Pueblo Reservoir (29 RM)

	High Flow	Low Flow
Regulatory Thresholds For Injury	Acute and chronic TVSs* based on mean hardness for each reach for cadmium, copper, lead, and zinc… [43 CFR 11.62(b)]	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 =	0.00007 (0.00005, 0.00025)
Diss Cu =	0.0012 (0.0003, 0.004)
Diss Pb =	0.00061 (0.00025, 0.002)
Diss Zn =	0.0241 (0.0015, 0.061)

Regulatory Thresholds for Injury (mg/L)

Analyte	Acute	Chronic	Hardness
Cadmium	0.0045	0.0025	118.61
Copper	0.0158	0.0104	118.61
Lead	0.0777	0.003	118.61
Zinc	0.1354	0.1361	118.61

Exceedence Data (# exceeding Regulatory Thresholds)

Analyte	Total n	Stations	> Acute	> Chronic
Cadmium	12	2	0	0
Copper	12	2	0	0
Lead	11	2	0	0
Zinc	12	2	0	0

Low Flow

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

Diss Cd =	0.00006 (0.00005, 0.0002)
Diss Cu =	0.00133 (0.0001, 0.0077)
Diss Pb =	0.00046 (0.00025, 0.001)
Diss Zn =	0.0148 (0.0015, 0.05)

Regulatory Thresholds for Injury (mg/L)

Analyte	Acute	Chronic	Hardness
Cadmium	0.0062	0.0032	159.76
Copper	0.0209	0.0134	159.76
Lead	0.1071	0.0042	159.76
Zinc	0.1743	0.1752	159.76

Exceedence Data (# exceeding Regulatory Thresholds)

Analyte	Total n	Stations	> Acute	> Chronic
Cadmium	23	3	0	0
Copper	25	3	0	0
Lead	28	3	0	0
Zinc	20	3	0	0

Related Benchmark Comparisons

Hardness and, correspondingly, the TVSs increase relative to Reach 8. At the same time, average and maximum concentrations decreased relative to upstream reaches.

Statement of Injury: Surface waters in Reach 9 are not injured during high or low flow.

Commentary: Within Reach 9 the Arkansas River changes from a high gradient, canyon stream to a wide floodplain stream. The December 2000 CDPHE Status of Water Quality Report indicates that the Arkansas River below Lake Creek is fully supporting its designated uses.

Representativeness of Data: The temporal distribution is limited (1992-1996) during the period, with most of the data collected closer to 1992. The spatial distribution of sample locations in Reach 9 shows there are multiple points that are located throughout the reach. There are three sample points in the upper section of the reach, two in the middle section and the remainder in the lower section. Available data are consistent with the downstream trend of improving water quality.

Data Gaps: None.

Is current information sufficient for restoration planning? Yes.

Related Text: Sections 6.4, 6.4.1 and 6.4.2

* Both acute and chronic numbers adopted as stream standards are levels not to be exceeded more than once every three years on the average.

Surface Water 1992 to 2000 (Period 3)

Reach 10 – Pueblo Reservoir (inlet to a point 1.5 miles below the outlet; 8.1 RM total)

	High Flow	Low Flow
Regulatory Thresholds For Injury	Acute and chronic TVSs* based on mean hardness for each reach for cadmium, copper, lead, and zinc… [43 CFR 11.62(b)]	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 =	0.00006 (0.00005, 0.0001)
Diss Cu =	0.00067 (0.0005, 0.003)
Diss Pb =	0.00061 (0.0005, 0.002)
Diss Zn =	0.02161 (0.003, 0.047)

Regulatory Thresholds for Injury (mg/L)

Analyte	Acute	Chronic	Hardness
Cadmium	0.0065	0.0033	167.57
Copper	0.0219	0.0139	167.59
Lead	0.1128	0.0044	167.59
Zinc	0.1815	0.1824	167.59

Exceedence Data (# exceeding Regulatory Thresholds)

Analyte	Total n	Stations	> Acute	> Chronic
Cadmium	21	2	0	0
Copper	21	2	0	0
Lead	22	2	0	0
Zinc	18	2	0	0

Low Flow

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

Diss Cd =	0.00008 (0.00005, 0.0003)
Diss Cu =	0.00069 (0.0002, 0.002)
Diss Pb =	0.0005 (0.0005, 0.0005)
Diss Zn =	0.01429 (0.003, 0.048)

Regulatory Thresholds for Injury (mg/L)

Analyte	Acute	Chronic	Hardness
Cadmium	0.0079	0.0037	200.38
Copper	0.0259	0.0162	200.38
Lead	0.1364	0.0053	200.38
Zinc	0.2112	0.2123	200.38

Exceedence Data (# exceeding Regulatory Thresholds)

Analyte	Total n	Stations	> Acute	> Chronic
Cadmium	20	2	0	0
Copper	20	2	0	0
Lead	20	2	0	0
Zinc	17	2	0	0

Related Benchmark Comparisons

Similar to Reach 9, none of the metals evaluated exceed the TVSs.

Statement of Injury: Surface waters in Reach 10 are not injured during high or low flow.

Commentary: Period 3 data used for Reach 10 analyses reflect reservoir tailwaters to approximately 1.5 miles downstream. No surface water quality data for metals were available during Period 3 in the reservoir. Data collected at the tailwaters of the reservoir indicate that none of the evaluated metals exceed TVSs during either high or low flows. When considered with that from Reach 9, which showed a similar trend, the data suggests that metals concentrations in the reservoir do not likely exceed TVSs. The December 2000 CDPHE Status of Water Quality Report indicates that the Pueblo Reservoir and the Arkansas River downstream of the reservoir is fully supporting its designated uses.

Representativeness of Data: Sample locations for Period 3 data are located immediately downstream of the reservoir as well as about 1.5 miles downstream and provide adequate spatial coverage. The temporal distribution of the data extends from 1992 to about 1998. Although no surface water quality data for metals are available for the reservoir during the evaluation period, tail water quality is directly influenced by discharge from the reservoir; therefore, these data are considered to provide a representative picture of the metals concentrations for this reach. This evaluation is augmented by reservoir data from prior to 1991 that shows relatively good water quality during the pre-LMDT and Yak Tunnel treatment era.

Data Gaps: None.

Is current information sufficient for restoration planning? Yes.

Related Text: Sections 6.9, 6.9.1 and 6.9.2

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* Both acute and chronic numbers adopted as stream standards are levels not to be exceeded more than once every three years on the average.

Instream Sediment 1992 to 2000 (Period 3)

Reach 5 – Two Bit Gulch to Lake Creek (2.2 RM)

Regulatory Thresholds For Injury

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)(1)(v)].

Summary Data (mg/kg)

Analyte (dry weight)	River Reach	Period	Avg	Min	Max	Station Count	n
Cadmium	Ark R5	Period 3	10.4	5.48	16	3	5
Copper	Ark R5	Period 3	40.5	23.6	63	3	5
Lead	Ark R5	Period 3	686	602	770	2	2
Zinc	Ark R5	Period 3	1,543.7	310.85	2,800	3	5

Related Benchmark Comparisons

Sediment metals concentrations are elevated in Reach 5 over those found in Reach 0. Mean concentrations of cadmium, copper, lead, and zinc are about 1.7, 1.6, 7.7, and 4.5 times greater, respectively, in Reach 5 sediments when compared to Reach 0 sediments.

Statement of Injury: No definitive criteria are available for sediments in the regulations. Given the small sediment load, it is not expected that metals in sediment are causing injury to groundwater or surface water resources. 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 other tributary streams where historical mining has occurred. There is a limited amount of recent data available for this reach and concentrations for each metal are similar to those observed in Reach 4, which also had little data available for sediments. Due to the fluvial dynamics of this system, retention of fine sediments is low. Additionally, the quantity of fine-grained sediments in this reach was observed to be small. Collecting additional sediment quality data in a system that is routinely flushed would not provide any additional insights on overall sediment quality.

Representativeness of Data: The spatial distribution of sample locations in Reach 5 shows there are only three sample points, which are in close proximity to one another at the extreme south end of the reach. Further sampling is not anticipated to provide significant additional information for metals in sediments. Available data are not spatially or temporally diverse; however, these data are considered to be adequate for injury characterization.

Data Gaps: None.

Is current information sufficient for restoration planning? Yes.

Related Text: Sections 6.5, 6.5.1 and 6.5.2

Instream Sediment 1992 to 2000 (Period 3)

Reach 6 – Lake Creek to Chalk Creek (29.5 RM)

Regulatory Thresholds For Injury

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)(1)(v)]

Summary Data (mg/kg)

Analyte (dry weight)	River Reach	Period	Avg	Min	Max	Station Count	n
Cadmium	Ark R6	Period 3	4.80	1.35	15.4	11	17
Copper	Ark R6	Period 3	29.10	7.04	79.78	11	17
Lead	Ark R6	Period 3	296.94	67.6	550	8	8
Zinc	Ark R6	Period 3	1,046.63	238.39	2,559	11	17

Related Benchmark Comparisons

Sediment metals concentrations for copper are slightly elevated in Reach 6 over those found in Reach 0 (e.g., 1.1 times greater). Mean concentrations of lead and zinc are 3.2, and 2.8 times greater, respectively, in Reach 6 sediments when compared to Reach 0 sediments. Cadmium in sediments was not elevated in Reach 6 compared to Reach 0. On average, concentrations are lower than in Reach 5.

Statement of Injury: No definitive criteria are available for sediments in the regulations. Given the small sediment load and large dilution flows of Lake Creek, it is not expected that metals in sediment are causing injury to groundwater or surface water resources. 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 other tributary streams where historical mining has occurred. There is a limited amount of temporal data available for this reach; however, the sediment data appear to be spatially well distributed. Due to the fluvial dynamics of this system as well as the increased flows discharged by Lake Creek, retention of fine sediments is expected to be low. The quantity of fine-grained sediments in this reach was observed to be small. Collecting additional sediment quality data in a system that is routinely flushed would not provide any further insights on overall sediment quality.

Representativeness of Data: The spatial distribution of sample locations in Reach 6 shows that there are multiple points that fall throughout the reach.

Data Gaps: None.

Is current information sufficient for restoration planning? Yes.

Related Text: Sections 6.5, 6.5.1 and 6.5.2

Instream Sediment 1992 to 2000 (Period 3)

Reach 7 – Chalk Creek to South Fork Arkansas River (21.2 RM)

Regulatory Thresholds For Injury	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)(1)(v)]

Summary Data (mg/kg)

Analyte (dry weight)	River Reach	Period	Avg	Min	Max	Station Count	n
Cadmium	Ark R7	Period 3	1.43	0.69	3.04	4	4
Copper	Ark R7	Period 3	20.29	8.74	32	4	4
Lead	Ark R7	Period 3	89.38	38.5	127	4	4
Zinc	Ark R7	Period 3	469.75	206	653	4	4

Related Benchmark Comparisons	Sediment concentrations of cadmium and copper in Reach 7 are not elevated over those found in Reach 0. Sediment concentrations of lead are less than 1 mg/kg higher in Reach 7 sediments compared to Reach 0 sediments whereas zinc concentrations are 1.4 times higher in Reach 7 sediments compared to Reach 0.

Statement of Injury: No definitive criteria are available for sediments in the regulations. Given the small sediment load and the large dilution flows of Lake Creek and other tributaries it is not expected that metals in sediment are causing injury to groundwater or surface water resources. For additional information about the potential for injury, see the surface water and/or biological sections of the matrix.

Commentary: Concentrations of cadmium and copper in sediments from Reach 7 are not elevated over those observed in Reach 0 while concentrations of lead show a negligible increase. Zinc in sediments of Reach 7 is elevated, but not substantially. Overall, Reach 7 sediment metals concentrations are considerably lower than those observed upstream in Reach 6.

Representativeness of Data: Only a small amount of sediment data is available for this reach both temporally and spatially. However, the spatial distribution of sample locations in Reach 7 shows multiple points that fall throughout the reach. There are a couple of large breaks (approximately 5 miles in length) between data points in the middle to lower middle sections of the reach. As with upstream reaches, sediment data availability is low, but the initial data are viewed to be representative.

Data Gaps: None.

Is current information sufficient for restoration planning? Yes.

Related Text: Sections 6.5, 6.5.1 and 6.5.2

Instream Sediment 1992 to 2000 (Period 3)

Reach 8 – South Fork Arkansas River to Canon City (58.1 RM)

Regulatory Thresholds For Injury

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)(1)(v)]

Summary Data (mg/kg)

Analyte (dry weight)	River Reach	Period	Avg	Min	Max	Station Count	n
Cadmium	Ark R8	Period 3	1.76	0.342	4.52	15	17
Copper	Ark R8	Period 3	22.78	7.57	40.5	15	17
Lead	Ark R8	Period 3	47.22	7.54	130	15	17
Zinc	Ark R8	Period 3	459.53	88	840	15	17

Related Benchmark Comparisons

Mean sediment concentrations of cadmium, copper, and lead in Reach 8 are not elevated over those found in Reach 0. The mean zinc concentration in sediments in Reach 8 is 1.3 times greater than the mean value for zinc observed in Reach 0.

Statement of Injury: No definitive criteria are available for sediments in the regulations. For additional information about the potential for injury, see the surface water and/or biological sections of the matrix.

Commentary: Concentrations of cadmium, copper, and lead in sediments from Reach 8 are lower than concentrations of metals in sediments from Reach 0 while zinc is only slightly elevated. Compared to Reach 7, there are substantially more sediment quality data in Reach 8 than in Reach 7, yet on average sediment metals concentrations in Reach 8 are lower than those observed in Reach 7. The geomorphological assessment suggests that a 5-mile stretch of river upstream of Salida in Reach 8 has morphological characteristics for sediment retention.

Representativeness of Data: The spatial distribution of sample locations in Reach 8 shows there are many sample points in the upper section of the reach, but there is a large break between sample points starting above Texas Creek and ending around Currant Creek. Other than this break the points are well distributed. As with upstream reaches, sediment data availability is low, but it is assumed that these data are representative.

Data Gaps: None.

Is current information sufficient for restoration planning? Yes.

Related Text: Sections 6.5, 6.5.1 and 6.5.2

Instream Sediment 1992 to 2000 (Period 3)

Reach 9 – Canon City to Pueblo Reservoir (29 RM)

Regulatory Thresholds For Injury

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)(1)(v)]

Summary Data (mg/kg)

Analyte (dry weight)	River Reach	Period	Avg	Min	Max	Station Count	n
Cadmium	Ark R9	Period 3	1.14	0.415	2	3	3
Copper	Ark R9	Period 3	21.78	8.35	34	3	3
Lead	Ark R9	Period 3	31.93	12.8	53	3	3
Zinc	Ark R9	Period 3	288.13	94.4	560	3	3

Related Benchmark Comparisons

Sediment metals concentrations in Reach 9 are not elevated over those found in Reach 0. Moreover, concentrations of metals in Reach 9, except for copper, are considerably lower than mean metal concentrations in Reach 0.

Statement of Injury: No definitive criteria are available for sediments in the regulations; however, concentrations are lower than those found in Reach 0.

Commentary: Concentrations of metals in sediments from Reach 9 are considerably lower than concentrations of metals in sediments from Reach 0; however, only a small amount of sediment data are available for this reach both temporally and spatially. Below Canon City, the canyons and high gradient stream system gives way to a broader floodplain that extends to Pueblo Reservoir. Despite this lower gradient and higher potential for sediment deposition downstream of Canon City, all sediment metals concentrations evaluated are less than Reach 0 as well as the immediately upgradient reaches.

Representativeness of Data: The three sample locations in Reach 9 are distributed throughout the reach. There is an approximate 10-mile stretch from above Beaver Creek to just above Turkey Creek where data are not available. As with upstream reaches, sediment data availability is low, but it is assumed that these data are representative.

Data Gaps: None.

Is current information sufficient for restoration planning? Yes.

Related Text: Sections 6.5, 6.5.1 and 6.5.2

Instream Sediment 1992 to 2000 (Period 3)

Reach 10 – Pueblo Reservoir (inlet to a point 1.5 miles below the outlet; 8.1 RM total)

Regulatory Thresholds For Injury

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)(1)(v)]

Summary Data (mg/kg)

Analyte (dry weight)	River Reach	Period	Avg	Min	Max	Station Count	n
Cadmium	Ark R10	Period 3	2.00	2	2	1	1
Copper	Ark R10	Period 3	31.00	31	31	1	1
Lead	Ark R10	Period 3	37.00	37	37	1	1
Zinc	Ark R10	Period 3	180.00	180	180	1	1

Related Benchmark Comparisons

Sediment metals concentrations in Reach 10, except for copper, are not elevated over those found in Reach 0. Moreover, concentrations of cadmium, lead, and zinc in Reach 10 are considerably lower than mean metal concentrations in Reach 0. Copper is 1.3 times higher in Reach 10 sediments compared to Reach 0 sediments.

Statement of Injury: No definitive criteria are available for sediments in the regulations. However, sediment metal concentrations are not 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: Pueblo Reservoir is a sediment sink. Studies conducted prior to 1992 indicate somewhat elevated concentrations of metals in the delta of the reservoir relative to pre-reservoir sediments. However, continued sediment delivery to the reservoir reflects improvements in water quality.

Representativeness of Data: This reach includes the reservoir and its tailwaters to about 1.5 miles downstream. Sediment data were only found for the reservoir during Period 3. One sample point is not representative. Upstream sediment data suggest that Pueblo Reservoir sediments are continually being covered by new, cleaner sediments.

Data Gaps: Although current sediment data are limited, given the relatively low concentrations in the reservoir and in Reaches 7-9 sediment quality is not a focus. Therefore lack of sediment sample results is not identified as a data gap.

Is current information sufficient for restoration planning? Yes.

Related Text: Sections 6.9, 6.9.1 and 6.9.2

2. Groundwater Resources:

A. Groundwater

<table>
<tr><th colspan="3">Groundwater 1992 to 2000</th></tr>
<tr><td colspan="3">Reaches 5-10 – Two-Bit Gulch to a Point 1.5 Miles below the Outlet of Pueblo Reservoir (148.1 RM)</td></tr>
<tr><td></td><td>High Flow</td><td>Low Flow</td></tr>
<tr><td><i>Regulatory Thresholds For Injury</i></td><td>Exceedence of the maximum contaminant levels…
[43 CFR 11.62(c)]</td><td>Exceedence of the maximum contaminant levels…
[43 CFR 11.62(c)]</td></tr>
<tr><td></td><td><u>Summary Data - Mean (min, max) mg/L</u>

No groundwater data available during Period 2 or 3.

Regulatory Thresholds for Injury (mg/L)
<table>
<tr><th>Analyte</th><th>MCL</th></tr>
<tr><td>Cadmium</td><td>0.005</td></tr>
<tr><td>Copper</td><td>1.0*</td></tr>
<tr><td>Lead</td><td>0.05</td></tr>
<tr><td>Zinc</td><td>5.0</td></tr>
</table>
<u>Exceedence Data (# exceeding Regulatory Thresholds)</u>

No groundwater data available for Periods 2 or 3 to compare to Regulatory thresholds</td><td><u>Summary Data - Mean (min, max) mg/L</u>

No groundwater data available during Period 2 or 3

Regulatory Thresholds for Injury (mg/L)
<table>
<tr><th>Analyte</th><th>MCL</th></tr>
<tr><td>Cadmium</td><td>0.005</td></tr>
<tr><td>Copper</td><td>1.0*</td></tr>
<tr><td>Lead</td><td>0.05</td></tr>
<tr><td>Zinc</td><td>5.0</td></tr>
</table>
<u>Exceedence Data (# exceeding Regulatory Thresholds)</u>

No groundwater data available for Periods 2 or 3 to compare to Regulatory thresholds</td></tr>
<tr><td><i>Related Benchmark Comparisons</i></td><td colspan="2"></td></tr>
<tr><td></td><td colspan="2"><u>Statement of Injury</u>: No injury.

<u>Commentary</u>: The finding of no injury is in large part based upon a review of data for the 11-mile reach. Data for the 11-mile reach indicate that water quality in the valley fill system is not measurably influenced by sources within the 11-mile reach or upstream (e.g., California Gulch). Although metals are contributed to the groundwater system from those sources, a combination of attenuation and dilution result in a rapid reduction in metals concentration. Domestic wells within the 11-mile reach are not in exceedence of the relevant criteria. Given the increasing downstream dilution, no injury is expected below the 11-mile reach. There are several public and municipal wells located in the basin in the downstream area. Information reported from EPA’s Safe Drinking Water Information System (SDWIS) indicates that of the wells monitored by the State in Chaffe and Fremont county, none were found to exceed MCLs during Period 3.

<u>Representativeness of Data</u>: Data provide adequate spatial coverage to confirm water quality is meeting the relevant criteria.

<u>Data Gaps</u>: None

<u>Is current information sufficient for restoration planning</u>?

<u>Related Text</u>: Sections 6.6, 6.6.1, 6.6.2 6.9, 6.9.1 and 6.9.2</td></tr>
</table>

* There is no MCL for copper, but copper has a drinking water supply standard of 1.0 mg/L in Colorado. Zinc value is a secondary standard to address staining.

3. Geologic Resources:

A. Floodplain Soils (including floodplain mine-waste deposits)

Floodplain Soils	
Reach 5 – Two Bit Gulch to Lake Creek (2.2 RM)	
Regulatory Thresholds For Injury	1. Concentrations of metals in soils sufficient to cause a phytotoxic response… [43 CFR 11.62(e)(10)] 2. Soil pH… [43 CFR 11.62(e)(2)]
	Summary Data: No data are available for floodplain soils in Reach 5. Some small mine-waste deposits exist in Reach 5; however, they have not been quantified with respect to surface area, volume, and chemical properties.
Related Benchmark Comparisons	There are no data for plant-available metal concentrations for comparative purposes.
	Statement of Injury: Field observations indicate low vegetation cover on several small mine-waste deposits in the upper portion of Reach 5. Soil pH and/or metal concentrations may be influencing plant growth on these deposits, reflecting injury to soils at those locations. No other injury has been observed from field reconnaissance conducted in 2001. Commentary: Vegetation growing in floodplain soils along this reach is productive, but plant growth on mine-waste deposits is poor. The potential for mine-waste deposits to influence metals concentrations in both surface 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 are available. Data Gaps: The primary data gap is a lack of mapping of floodplain mine-waste deposits. Correspondingly, there are no data regarding the physical and chemical properties of soils and mine-waste deposits. Is current information sufficient for restoration planning? No. Mapping of the deposits is necessary and physical and chemical data on mine-waste deposits would also be helpful for restoration planning. Related Text: Sections 6.7, 6.7.1 and 6.7.2

Floodplain Soils	
Reach 6 – Lake Creek to Chalk Creek (29.5 RM)	
Regulatory Thresholds For Injury	1. Concentrations of metals in soils sufficient to cause a phytotoxic response… [43 CFR 11.62(e)(10)] 2. Soil pH… [43 CFR 11.62(e)(2)]
	Summary Data: Floodplain soils data exist for Reach 6. This includes total metal concentrations for lead and zinc for all sites sampled and cadmium and copper for a subset of these sites. There is some evidence of anthropogenic influence in Reach 6.
Related Benchmark Comparisons	There are no data for plant-available metal concentrations for comparative purposes.
	Statement of Injury: The elevated concentrations of zinc in floodplain soils at the confluence of Clear Creek (Reach 6) indicated the potential for injury in this location. The source of these metals is unknown because this is not an area where mine-waste deposits were predicted to occur, based on stream morphology. Regardless of the source, total metal concentrations are potentially high enough to cause injury to soils at this location. However, this cannot be confirmed without further soil sampling and analysis. Commentary: Other than the sample sites along Reach 6, there is no other evidence to indicate injury to floodplain soils in the remaining portions of Reach 6. Floodplain soils are not considered injured in most of Reach 6 because total metal concentrations along these reaches are similar to Reach 0 and riparian vegetation does not show signs of metal toxicity. Representativeness of Data: BLM data from 2000 includes samples from floodplain soils in Reach 6. However, data are for total metals and no data exists for plant-available concentrations. Data Gaps: None. Is current information sufficient for restoration planning? Yes. Related Text: Sections 6.7, 6.7.1 and 6.7.2

Floodplain Soils	
Reaches 7-10 – Chalk Creek to Pueblo Reservoir (108.3 RM)	
Regulatory Thresholds For Injury	3. Concentrations of metals in soils sufficient to cause a phytotoxic response… [43 CFR 11.62(e)(10)] 4. Soil pH… [43 CFR 11.62(e)(2)]
	Summary Data: Floodplain soils data exist for Reaches 7-9. This includes total metal concentrations for lead and zinc for all sites sampled and cadmium and copper for a subset of these sites.
Related Benchmark Comparisons	There are no data for plant-available metal concentrations for comparative purposes.
	Statement of Injury: There is no other evidence to indicate injury to floodplain soils in Reaches 7-9. Floodplain soils are not considered injured in these reaches because total metal concentrations along these reaches are similar to Reach 0 and riparian vegetation does not show signs of metal toxicity. Commentary: Vegetation growing in floodplain soils along Reaches 7-9 is productive, based on field observations. Representativeness of Data: BLM data from 2000 includes samples from floodplain soils in Reaches 7-9. However, data are for total metals and no data exists for plant-available concentrations. Data Gaps: None. Is current information sufficient for restoration planning? Yes. Related Text: Sections 6.7, 6.7.1, 6.7.2, 6.9, 6.9.1 and 6.9.2

4. Biological Resources:

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

Vegetation	
Reach 5 – Two Bit Gulch to Lake Creek (2.2 RM)	
Regulatory Thresholds For Injury	Tissue metal concentrations considered to be toxic to vegetation… [43 CFR 11.62(f)(1)(i)]
	Summary Data: No data are available regarding plant tissue concentrations or physiological/morphological effects in Reach 5.
Related Benchmark Comparisons	No data are available for vegetation cover, production, or tissue metal concentrations.
	Statement of Injury: Field observations confirm that vegetation is productive and shows no signs of injury associated with elevated metal concentrations in floodplain soils. However, plant growth is limited on several small mine-waste deposits along Reach 5, based on field observations. This indicates injury to vegetation where mine-waste deposits occur in Reach 5. Commentary: Field observations along Reach 5 confirm that vegetation is productive in floodplain soils but not on mine-waste deposits. Representativeness of Data: No quantitative data are available. Data Gaps: There is no data on vegetation cover, production, or tissue metal concentrations on mine-waste deposits. Although these data would be informative, they are not essential for defining injury or for restoration planning if mapping of mine-waste deposits is available. Is current information sufficient for restoration planning? Yes. Related Text: Sections 6.8, 6.8.1, 6.8.1.1 and 6.8.1.2

Vegetation	
Reaches 6-9 – Lake Creek to Pueblo Reservoir (137.8 RM)	
Regulatory Thresholds For Injury	Tissue metal concentrations considered to be toxic to vegetation… [43 CFR 11.62(f)(1)(i)]
	Summary Data: No data are available regarding plant tissue concentrations or physiological/morphological effects in Reaches 6-9.
Related Benchmark Comparisons	No data are available for vegetation cover, production, or tissue metal concentrations.
	Statement of Injury: Field observations confirm that vegetation is productive and shows no signs of injury associated with elevated metal concentrations in floodplain soils. Vegetation type mapping conducted by Colorado Division of Wildlife also indicates vegetation cover types are consistent with floodplain setting for non-injured areas. Commentary: Field observations along Reaches 6-9 confirm that vegetation is productive in floodplain soils. There are no identifiable deposits of flood plain mine-waste. Representativeness of Data: Information is limited to field observations and vegetation type mapping. Data Gaps: None. Is current information sufficient for restoration planning? Yes. Related Text: Sections 6.8, 6.8.1, 6.8.1.1 and 6.8.1.2

Benthic Macroinvertebrates (1989-2000)	
Reach 5 – Two Bit Gulch to Lake Creek (2.2 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. Microcosm experiments… [43 CFR 11.62(f)(2)(iii)]
	Summary Data: Based on results of microcosm experiments, metal concentrations in Reach 5 are sufficient to cause injury to benthic macroinvertebrates.
Related Benchmark Comparisons	1. Comparisons to benchmark: Reach 0. a. Community structure. 2. Results of microcosm experiments showing direct effects of metals.
	Statement of Injury: There are no benthic data from Reach 5. Results of microcosm experiments conducted in 1998 showed that exposure of benthic communities to a mixture of cadmium, copper, and zinc at a concentration similar to that measured in Reach 5 had a significant effect on community composition, species richness of mayflies, and abundance of metal-sensitive species. Commentary: Because water quality in Reach 5 is similar to that observed in Reach 3 (where injury was observed) and because metal levels in Reach 5 exceed those known to be toxic to metal-sensitive species, it is likely that benthic macroinvertebrates are injured in Reach 5. Representativeness of Data: There are no benthic data from Reach 5. Data Gaps: The most significant data gap for benthic macroinvertebtrates in these reaches is the lack of information from Reach 5 and the upper section of Reach 6 near the confluence of Lake Creek. Analysis of benthic data from these reaches would allow for a more precise definition of injury. Is current information sufficient for restoration planning? Yes. Related Text: Sections 6.8.2, 6.8.2.1 and 6.8.2.2

Benthic Macroinvertebrates (1989-2000)	
Reach 6 – Lake Creek to Chalk Creek (29.5 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. Microcosm experiments… [43 CFR 11.62(f)(2)(iii)]
	Summary Data: Metal concentrations in Reach 6 are unlikely to cause injury to benthic macroinvertebrates. Results of microcosm experiments show that current metal concentrations in the lower section of Reach 6 (Buena Vista) are generally below levels known to be toxic to benthic macroinvertebrates.
Related Benchmark Comparisons	1. Comparisons to benchmark: Reach 0. b. Community structure. c. Metal levels in the caddisfly *Arctopsyche grandis*. d. Metal levels in periphyton. 2. Results of microcosm experiments showing direct effects of metals.
	Statement of Injury: Analysis of community structure for benthic macroinvertebrates collected from the lower portion of reach 6 (Buena Vista) shows significant improvement in species richness, diversity and abundance of metal-sensitive species. In particular, abundance of Heptageniidae, a highly metal-sensitive group, has increased 2-3 times since remediation of Leadville Mine Drainage Tunnel and California Gulch was initiated in 1992. Abundance of these organisms after 1996 was similar to that observed in Reach 0. Metal concentrations in the caddisfly *Arctopsyche grandis* collected from Reach 6 have significantly decreased since 1994 and are similar to those values measured in Reach 0. The only exception to this pattern is an unexplained spike in zinc concentration in caddisflies in 1999. Zinc levels in periphyton measured at Reach 6 (1,031-1,273 µg/g) in 1995 and 1996 were also within the range of values observed in Reach 0 (409-4,200 µg/g). Results of microcosm experiments conducted in 1998 showed that exposure of benthic communities to a mixture of cadmium, copper, and zinc at concentrations similar to those in Reach 6 had no effect on community composition, species richness of mayflies, or abundance of metal-sensitive species. Commentary: Water quality in Reach 6 is greatly improved by the dilution from lake Creek. Recent survey data indicate that there is no injury to benthic macroinvertebrates in the lower portion of Reach 6 near Buena Vista. Representativeness of Data: The most extensive data are from a long-term analysis of water quality and benthic macroinvertebrates from a single station in Reach 6 (station AR8 in Buena Vista) (Clements, unpublished data). Metal levels in the caddisfly *Arctopsyche grandis* were based on data collected between 1993 and 1999. Metal concentrations in periphyton were determined in 1990 (Kiffney and Clements 1993) and between 1995-1996 (Harrrahy 2000). Data Gaps: None Is current information sufficient for restoration planning? Yes. Related Text: Sections 6.8.2, 6.8.2.1 and 6.8.2.2

Benthic Macroinvertebrates (1989-2000)	
Reaches 7-8 – Chalk Creek to Canon City (79.3 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. 3. Microcosm experiments… [43 CFR 11.62(f)(2)(iii)]
	Summary Data: Metal concentrations in Reaches 7 and 8 are generally below levels known to cause injury to benthic macroinvertebrates.
Related Benchmark Comparisons	1. Comparisons to benchmark: Reach 0. a. Community structure. 2. Results of microcosm experiments showing direct effects of metals.
	Statement of Injury: Few data are available from Reaches 7 and 8 of the Arkansas River. Results of microcosm experiments conducted in 1998 showed that exposure of benthic communities to a mixture of cadmium, copper, and zinc at concentrations similar to those measured at Reaches 7 and 8 had no effect on community composition, species richness of mayflies, or abundance of metal-sensitive species. Quantitative collections of benthic macroinvertebrates by the United States Fish and Wildlife Service (USFWS) showed no spatial trends that could be related to heavy metals in Reaches 7 and 8. Based on these results, there is no injury to benthic macroinvertebrates in Reaches 7 and 8. Commentary: The dramatic recovery of benthic macroinvertebrates observed in Reach 6 (Buena Vista) following remediation of upstream metal sources suggests that there is no injury to benthic macroinvertebrates in Reaches 7 and 8. Representativeness of Data: There are no macroinvertebrate surveys for Reaches 7 and 8 that are both spatially and temporally comprehensive. The USFWS collected the only spatially extensive data available from these reaches in 1995. Data Gaps: None. Is current information sufficient for restoration planning? Yes. Related Text: Sections 6.8.2, 6.8.2.1 and 6.8.2.2

<table>
<tr><th colspan="2">Benthic Macroinvertebrates (1989-2000)</th></tr>
<tr><td colspan="2">Reaches 9-10 – Canon City to a Point 1.5 Miles below the Outlet of Pueblo Reservoir (37.1 RM)</td></tr>
<tr><td><i>Regulatory Thresholds For Injury</i></td><td>1. Metal concentrations considered to be toxic to macroinvertebrates… [43 CFR 11.62(f)(1)(i)]
2. See surface water.
3. Microcosm experiments… [43 CFR 11.62(f)(2)(iii)]</td></tr>
<tr><td></td><td><u>Summary Data</u>: Metal concentrations in Reaches 9 and 10 are generally below levels known to cause injury to benthic macroinvertebrates.</td></tr>
<tr><td><i>Related Benchmark Comparisons</i></td><td>1. Comparisons to benchmark: Reach 0.
a. Community structure.
2. Results of microcosm experiments showing direct effects of metals.</td></tr>
<tr><td></td><td><u>Statement of Injury</u>: Very few data are available from Reaches 9 and 10 of the Arkansas River. Results of microcosm experiments conducted in 1998 showed that exposure of benthic communities to a mixture of cadmium, copper, and zinc at target concentrations greater than those generally observed at Reaches 9 and 10 had no effect on community composition, species richness of mayflies, or abundance of metal-sensitive species. Quantitative collections of benthic macroinvertebrates by the USFWS showed no spatial trends that could be related to heavy metals. Based on these results, there is no current injury to benthic macroinvertebrates in Reaches 9 and 10.
<u>Commentary</u>: The dramatic recovery of benthic macroinvertebrates observed in Reach 6 (Buena Vista) following remediation of upstream metal sources suggests that injury to benthic macroinvertebrates in Reaches 9 and 10 is not occurring.
<u>Representativeness of Data</u>: There are no macroinvertebrate surveys for Reaches 9 and 10 that are both spatially and temporally comprehensive. The USFWS collected the only spatially extensive data available from these reaches in 1995.
<u>Data Gaps</u>: None.
<u>Is current information sufficient for restoration planning</u>? Yes.
<u>Related Text</u>: Sections 6.8.2, 6.8.2.1, 6.8.2.2, 6.9, 6.9.1 and 6.9.2</td></tr>
</table>

Brown Trout	
Reach 5 – Two Bit Gulch to Lake Creek (2.2 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.
	Summary Data: Aqueous metal concentrations in Reach 5 are sufficient to cause injury to brown trout. Maximum metal concentrations, especially during high flow conditions, exceed levels known to be toxic to brown trout based on results of laboratory toxicity tests. Surveys of brown trout show reduced abundance and biomass in Reach 5 compared to Reach 0.
Related Benchmark Comparisons	1. Comparisons to benchmark: Reach 0 a. Abundance (number per acre) and biomass (pounds per acre); and b. Length-frequency distributions. 2. Results of acute and chronic toxicity tests.
	Statement of Injury: Metal concentrations in Reach 5 exceed levels known to be toxic to brown trout. The brown trout population in Reach 5 was characterized by reduced overall abundance but somewhat larger individuals compared to the reference reach. Commentary: Brown trout data from Reach 5 relatively sparse; however, because water quality in Reach 5 was similar to that measured in Reach 3 (where injury was observed), we conclude that there is also injury to brown trout in this reach. Metal concentrations in Reach 5 exceed levels known to be toxic to brown trout. Abundance, biomass, and length frequency distributions of brown trout from Reach 3 and Reach 5 were generally similar. The lower abundance and biomass of brown trout in Reach 5 compared to Reach 0 is consistent with metal impacts. Representativeness of Data: All brown trout data were obtained from the Colorado Division of Wildlife. Relatively few data are available in Reach 5 prior to remediation of the Leadville Mine Drainage Tunnel and California Gulch, and therefore it is difficult to assess temporal variation in brown trout biomass and abundance. Data Gaps: Few data are available on brown trout populations in Reach 5. Is current information sufficient for restoration planning? Yes. Related Text: Sections 6.8.3, 6.8.3.1 and 6.8.3.2

Brown Trout	
Reach 6 – Lake Creek to Chalk Creek (29.5 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.
	Summary Data: Aqueous metal concentrations in Reach 6 are unlikely to cause injury to brown trout. Metal concentrations decrease significantly downstream from Lake Creek, and mean values approach the regulatory threshold levels in Reach 6. However, maximum metal concentrations, especially during high flow conditions, may exceed levels known to be toxic to brown trout.
Related Benchmark Comparisons	1. Comparisons to benchmark: Reach 0 a. Abundance (number per acre) and biomass (pounds per acre); and b. Length-frequency distributions. 2. Results of acute and chronic toxicity tests.
	Statement of Injury: The brown trout population in Reach 6 was characterized by reduced overall abundance but somewhat larger individuals compared to the reference reach. Commentary: Because of natural and anthropogenic changes in physical characteristics of the Arkansas River, particularly flow alterations associated with discharge from Lake Creek and poor instream habitat, quantifying the importance of metals relative to other habitat features is difficult in this reach. Representativeness of Data: All brown trout data were obtained from the Colorado Division of Wildlife. Relatively few data are available in Reach 6 prior to remediation of the Leadville Mine Drainage Tunnel and California Gulch, and therefore it is difficult to assess temporal variation in brown trout biomass and abundance. Data Gaps: Uncertainty associated with the relative influence of heavy metals and flow alterations in Reach 6 immediately downstream from Lake Creek results in a data gap. Discharge from Lake Creek significantly dilutes heavy metals (a positive effect), but may also influence brown trout recruitment and growth. It is possible that flow alterations immediately downstream from Lake Creek impact fish populations; however there are no quantitative data showing direct effects of these flow modifications on brown trout. A quantitative sampling effort of brown trout upstream and downstream from Lake Creek that examines seasonal and annual variation in both flow and water quality may reduce uncertainty regarding the relative importance of these two stressors. Is current information sufficient for restoration planning? Yes. Related Text: Sections 6.8.3, 6.8.3.1 and 6.8.3.2

<table>
<tr><th colspan="2">Brown Trout</th></tr>
<tr><td colspan="2">Reaches 7-8 – Chalk Creek to Canon City (79.3 RM)</td></tr>
<tr><td><i>Regulatory Thresholds For Injury</i></td><td>1. Metal concentrations considered to be toxic to fish… [43 CFR 11.62(f)(1)(i)]
2. See surface water.</td></tr>
<tr><td></td><td><u>Summary Data</u>: Aqueous metal concentrations in Reach 7 and 8 occasionally exceed levels sufficient to cause injury to brown trout.</td></tr>
<tr><td><i>Related Benchmark Comparisons</i></td><td>1. Comparisons to benchmark: Reach 0
a. Abundance (number per acre) and biomass (pounds per acre); and
b. Length-frequency distributions.
2. Results of acute and chronic toxicity tests.</td></tr>
<tr><td></td><td><u>Statement of Injury</u>: Brown trout biomass and abundance improved significantly in Reach 8 (Wellsville) compared to Reaches 3 and 6. Although overall abundance is lower compared to Reach 0, total biomass is generally similar to or greater than at the reference reach. The significant improvement in biomass and abundance of brown trout in Reach 8 and the similarity to the reference reach suggests there is no injury to brown trout in Reach 8.

<u>Commentary</u>: Conditions within Reach 7 (e.g., water quality) are essentially the same as Reach 8, therefore, no injury is expected within Reach 7.

<u>Representativeness of Data</u>: All data were obtained from the Colorado Division of Wildlife. Relatively few data are available from Reaches 7 and 8 prior to remediation of the Leadville Mine Drainage Tunnel and California Gulch, and therefore it is difficult to assess temporal variation in brown trout biomass and abundance.

<u>Data Gaps</u>: None.

<u>Is current information sufficient for restoration planning</u>? Yes.

<u>Related Text</u>: Sections 6.8.3, 6.8.3.1 and 6.8.3.2</td></tr>
</table>

<table>
<tr><th colspan="2">Brown Trout</th></tr>
<tr><td colspan="2">Reaches 9-10 – Canon City to a Point 1.5 Miles below the Outlet of Pueblo Reservoir (37.1 RM)</td></tr>
<tr><td><i>Regulatory Thresholds For Injury</i></td><td>1. Metal concentrations considered to be toxic to fish… [43 CFR 11.62(f)(1)(i)]
2. See surface water.</td></tr>
<tr><td></td><td><u>Summary Data</u>: Aqueous metal concentrations in Reach 9 and 10 do not exceed levels sufficient to cause injury to brown trout.</td></tr>
<tr><td><i>Related Benchmark Comparisons</i></td><td>1. Comparisons to benchmark: Reach 0
a. Abundance (number per acre) and biomass (pounds per acre); and
b. Length-frequency distributions.
2. Results of acute and chronic toxicity tests.</td></tr>
<tr><td></td><td><u>Statement of Injury</u>: Brown trout biomass and abundance improved significantly in Reach 8 at the Wellsville station. Although overall abundance is lower compared to Reach 0, total biomass is generally similar to or greater than at the reference reach. The significant improvement in biomass and abundance of brown trout in Reach 8 and the similarity to the reference reach suggests there is no injury further downstream in Reaches 9 and 10.
<u>Commentary</u>: Natural longitudinal changes in the physicochemical and habitat characteristics of the Arkansas River complicate comparisons with upstream reaches. Correspondingly, it should be noted that within Reach 9 the Arkansas River transitions from a brown trout fishery.
<u>Representativeness of Data</u>: All data were obtained from the Colorado Division of Wildlife. Relatively few data are available from Reaches 9 and 10 prior to remediation of the Leadville Mine Drainage Tunnel and California Gulch, and therefore it is difficult to assess temporal variation in brown trout biomass and abundance.
<u>Data Gaps</u>: None.
<u>Is current information sufficient for restoration planning</u>? Yes.
<u>Related Text</u>: Sections 6.8.3, 6.8.3.1,6.8.3.2, 6.9, 6.9.1 and 6.9.2</td></tr>
</table>

Terrestrial Wildlife – Small Mammals	
Reach 5 – Two Bit Gulch to Lake Creek (2.2 RM)	
Regulatory Thresholds For Injury	1. Histopathological lesions… [43 CFR 11.62(f)(4)(vi)(D)]
	Summary Data: There are no small mammal data for Reach 5.
Related Benchmark Comparisons	1. Metal concentrations in organs.
	Statement of Injury: Based on declining metals concentrations in soils and vegetation from Reach 1 to 5 and because injury was not documented in areas of high exposure, small mammals are not expected to be injured in Reach 5. Commentary: There are areas of mine-waste deposits in Reach 5, but there are fewer areas compared to other reaches and they are all small deposits. Riparian vegetation is relatively dense in Reach 5 and based on declining metals concentrations in soils and vegetation, metals exposure for small mammals is expected to be minimal. Representativeness of Data: There are no small mammal data for Reach 5 nor are there soils or vegetation data. Data Gaps: None. Is current information sufficient for restoration planning? Yes. Related Text: Sections 6.8.4, 6.8.4.1 and 6.8.4.2

Terrestrial Wildlife – Small Mammals	
Reaches 6-10 – Lake Creek to a Point 1.5 Miles below the Outlet of Pueblo Reservoir (145.9 RM)	
Regulatory Thresholds For Injury	1. Histopathological lesions… [43 CFR 11.62(f)(4)(vi)(D)]
	Summary Data: There are no small mammal data for Reaches 6-10.
Related Benchmark Comparisons	1. Metal concentrations in organs.
	Statement of Injury: Injury to small mammals is not expected to occur in Reaches 6-10. Commentary: Within the 11-mile reach, tissue concentrations and histopathology indicate that there is no injury to small mammals. Because there are no known fluvial mine-waste deposits in Reaches 6-10 and because floodplain soils concentrations are relatively low, the potential for injury to small mammals is very low. Representativeness of Data: Floodplain soils data indicate that metals concentrations are well below benchmark values. Data Gaps: None. Is current information sufficient for restoration planning? No known injury requiring restoration. Related Text: Sections 6.8.4, 6.8.4.1, 6.8.4.2, 6.9, 6.9.1 and 6.9.2

Terrestrial Wildlife – Migratory Birds

Reach 5 – Two-Bit Gulch to Lake Creek (31.7 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 percent was measured… [43 CFR 11.62(f)(4)(v)(D)]
2. Reduced reproduction… [43 CFR 11.62(f)(4)(v)(B)]

Summary Data

Average Blood Metal Concentrations
in American Dippers (mg/kg wet weight)

Blood	n	Cadmium	Copper	Lead	Zinc
Reach 5	5	0.04	0.29	0.22	6.29
Reach 0	14	0.04	0.23	0.11	13.93
Study Reference	27	0.01	0.16	0.04	4.09
Benchmark	--	NR	NR	0.20	60.00

NR – Not Reported

Average Liver Metal Concentrations
in American Dippers (mg/kg wet weight)

Liver	n	Cadmium	Copper	Lead	Zinc
Reach 5	2	0.14	10.00	0.61	25.86
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

NR – Not Reported

% ALAD Reduction Compared to the Study Reference

Reach	n	% ALAD Reduction Compared to Study Reference	% ALAD Reduction Compared to Reach 0
Reach 5	4	49	17
Reach 0	10	39	0

Average Metal Concentrations In mixed Invertebrate Species (ppm, wet weight)

Reach (sample size)	Cadmium	Copper	Lead	Zinc
Reach 0 (n=12)	1.6	5.6	2.5	119.7
Reach 5 (n=6)	1.3	8.5	14.3	214.2
Benchmark	2.0	NR	2.0	50.0

NR – Not Reported

Related Benchmark Comparisons

1. Metal concentrations in organs.
2. Metal concentrations in blood.

Statement of Injury: ALAD suppression in American dippers was 49 percent compared to the Study Reference. This is representative of a significant exposure to lead. Blood lead exceeds the literature-based benchmark and liver lead is elevated compared to Reach 0. Invertebrates exceed the dietary benchmark for migratory birds. There is injury to migratory birds in Reach 5.

Commentary: Aquatic invertebrates continue to accumulate lead which results in significant environmental exposure for dippers.

Representativeness of Data: The American dipper studies were conducted to evaluate metals exposure and ALAD suppression. Depressed ALAD is consistent with the elevated lead in blood and liver.

Data Gaps: These data represent potential metals exposure to migratory birds via the aquatic food chain; however, they do not represent exposure via terrestrial food chains that could result from fluvial deposits present in Reach 5. There are no data available that represent migratory birds with a terrestrial food base.

Is current information sufficient for restoration planning? Yes, the current information is sufficient for restoration planning. The current information indicates that the fluvial deposits are a source of metals and represent potential exposure pathway for terrestrial feeding migratory birds. Injury specific data for terrestrial feeding migratory birds would not influence restoration planning.

Related Text: Sections 6.8.5, 6.8.5.1 and 6.8.5.2

Terrestrial Wildlife – Migratory Birds

Reach 6 – Lake Creek to Chalk Creek (31.7 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 percent was measured… [43 CFR 11.62(f)(4)(v)(D)]
2. Reduced reproduction… [43 CFR 11.62(f)(4)(v)(B)]

<u>Summary Data</u>

Average Blood Metal Concentrations in American Dippers (mg/kg wet weight)

Blood	n	Cadmium	Copper	Lead	Zinc
Reach 6	10	0.01	0.16	0.13	3.77
Reach 0	14	0.04	0.23	0.11	13.93
Study Reference	27	0.01	0.16	0.04	4.09
Benchmark	--	NR	NR	0.20	60.00

NR - Not Reported

Average Liver Metal Concentrations in American Dippers (mg/kg wet weight)

Liver	n	Cadmium	Copper	Lead	Zinc
Reach 6	4	2.00	8.09	0.84	29.79
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

NR – Not Reported

% ALAD Reduction Compared to the Study Reference

Reach	n	% ALAD Reduction Compared to Study Reference	% ALAD Reduction Compared to Reach 0
Reach 6	9	56	28
Reach 0	10	39	0

Average Metal Concentrations In mixed Invertebrate Species (ppm, wet weight)

Reach (sample size)	Cadmium	Copper	Lead	Zinc
Reach 0 (n=12)	1.6	5.6	2.5	119.7
Reach 6 (n=11)	2.1	9.3	26.3	277.4
Benchmark	2.0	NR	2.0	50.0

NR- Not Reported

Related Benchmark Comparisons

1. Metal concentrations in organs.
2. Metal concentrations in blood.

<u>Statement of Injury</u>: ALAD in American dippers is suppressed by 56 percent compared to the Study Reference. Blood and liver lead are elevated, but do not exceed the benchmark. Lead concentrations in invertebrates exceed the dietary benchmark for migratory birds. There is injury to migratory birds in Reach 6.

<u>Commentary</u>: American dipper data are from the Granite area and the tree swallow data are from near Buena Vista. Blood and liver lead concentrations decrease compared to Reach 5, but continue to be elevated compared to Reach 0. The tree swallow colony sampled in Reach 6 is located in the open valley floodplain-a potential sediment deposition area. However, none of the swallow data exceeded benchmark values.

<u>Representativeness of Data</u>: Both the tree swallow data and the American dipper studies were conducted to evaluate metals exposure and ALAD suppression. The swallow and dipper data provide a good representation of metals exposure from aquatic invertebrates.

<u>Data Gaps</u>: None.

<u>Is current information sufficient for restoration planning</u>? Yes, the current information is sufficient for restoration planning.

<u>Related Text</u>: Sections 6.8.5, 6.8.5.1 and 6.8.5.2

Terrestrial Wildlife – Migratory Birds

Reaches 7-8 – Chalk Creek to Canon City (79.3 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 percent was measured… [43 CFR 11.62(f)(4)(v)(D)]
2. Reduced reproduction… [43 CFR 11.62(f)(4)(v)(B)]

<u>Summary Data</u>

Average Blood Metal Concentrations
in American Dippers (mg/kg wet weight)

Blood	n	Cadmium	Copper	Lead	Zinc
Reach 7	4	0.01	0.07	0.04	2.88
Reach 8	30	0.01	0.13	0.05	4.00
Reach 0	14	0.04	0.23	0.11	13.93
Study Reference	27	0.01	0.16	0.04	4.09
Benchmark	--	NR	NR	0.20	60.00

NR – Not Reported

Average Liver Metal Concentrations
in American Dippers (mg/kg wet weight)

Liver	n	Cadmium	Copper	Lead	Zinc
Reach 7	2	0.03	10.00	0.04	22.18
Reach8	13	0.17	5.86	0.09	25.57
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

NR – Not Reported

% ALAD Reduction Compared to the
Study Reference

Reach	n	% ALAD reduction compared to Study Reference	% ALAD reduction compared to Reach 0
Reach 7	4	48	14
Reach 8	24	25	0
Reach 0	10	39	0

Average Metal Concentrations In mixed Invertebrate
Species (ppm, wet weight)

Reach (sample size)	Cadmium	Copper	Lead	Zinc
Reach 0 (n=12)	1.6	5.6	2.5	119.7
Reach 7 (n=3)	0.6	6.6	1.7	153.7
Reach 8 (n=30)	0.6	7.1	3.2	138.6
Reach 9 (n=2)	0.1	4.9	1.5	41.4

Related Benchmark Comparisons

1. Metal concentrations in organs.
2. Metal concentrations in blood.

<u>Statement of Injury</u>: ALAD in American dippers was suppressed by 48 percent in Reach 7 and 25 percent in Reach 8 compared to the Study Reference. Blood lead concentrations in Reaches 7 & 8 were similar to Reach 0. All tissue metal concentrations were below benchmark values. All tissue metal concentrations were below benchmark values. ALAD suppression in tree swallows was 1-35 percent compared to Reach 0 and nest data from tree swallow colonies showed no reproductive impairment. There is no injury to migratory birds in Reaches 7 and 8.

<u>Commentary</u>: Even though ALAD suppression was 48 percent in Reach 7, environmental exposure is near Reach 0 levels for lead and other metals. Tissue metal concentrations for Reaches 7 and 8 are near Reach 0 levels and do not exceed benchmarks.

<u>Representativeness of Data</u>: Both the tree swallow and American dipper studies were conducted to evaluate metals exposure and ALAD suppression. While not all reaches had the same number of samples, there was a sufficient number of samples to evaluate injury. Along with aquatic invertebrate samples, these data are representative of exposure and injury to migratory birds dependant upon the aquatic food chain.

<u>Data Gaps</u>: None.

<u>Is current information sufficient for restoration planning</u>? Yes, the current information is sufficient for restoration planning.

<u>Related Text</u>: Sections 6.8.5, 6.8.5.1 and 6.8.5.2

Terrestrial Wildlife – Migratory Birds

Reaches 9 – Canyon City to Pueblo Reservoir (29 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 percent was measured… [43 CFR 11.62(f)(4)(v)(D)]
2. Reduced reproduction… [43 CFR 11.62(f)(4)(v)(B)]

Summary Data

Average Metal Concentrations In mixed Invertebrate Species (ppm, wet weight)

Reach (sample size)	Cadmium	Copper	Lead	Zinc
Reach 0 (n=12)	1.6	5.6	2.5	119.7
Reach 9 (n=2)	0.1	4.9	1.5	41.4

Related Benchmark Comparisons

1. Metal concentrations in organs.
2. Metal concentrations in blood.

Statement of Injury: Based on decreasing environmental exposure, injury to migratory birds is not expected in this reach.

Commentary: Concentrations in aquatic invertebrates are lower than Reach 0 levels for all metals and concentrations in other media have generally decreased.

Representativeness of Data: There are no migratory bird data for Reach 9, but there are data for aquatic invertebrates. These data indicate decreasing food chain exposure, which is consistent with water chemistry data.

Data Gaps: None.

Is current information sufficient for restoration planning? Yes, the current information is sufficient for restoration planning.

Related Text: Sections 6.8.5, 6.8.5.1 and 6.8.5.2

Terrestrial Wildlife – Migratory Birds	
Reach 10 – Pueblo Reservoir (inlet to a point 1.5 miles below the outlet; 8.1 RM total)	
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 percent was measured… [43 CFR 11.62(f)(4)(v)(D)] 2. Reduced reproduction… [43 CFR 11.62(f)(4)(v)(B)]
	Summary Data: Custer et al. (2003 In Press) collected 3 swallow samples in 1997 and 3 samples in 1998. Mueller et al. (1991) sampled adult and nestling waterfowl and shorebirds in 1991.
Related Benchmark Comparisons	1. Metal concentrations in organs. 2. Metal concentrations in blood.
	Statement of Injury: All bird tissues sampled were below benchmark values. There does not appear to be a significant route of exposure that would result in injury to migratory birds. Commentary: Metal concentrations in all environmental media are at or lower than Reach 0. The existing data indicate that there is little chance of food-chain exposure. Representativeness of Data: There are few bird samples, but the existing data are collected in different years and represent a variety of species. Data Gaps: None. Is current information sufficient for restoration planning? Yes. Related Text: Sections 6.9, 6.9.1 and 6.9.2