UPPER ARKANSAS RIVER BASIN
NATURAL RESOURCE DAMAGE ASSESSMENT

PRELIMINARY ESTIMATE OF DAMAGES

Prepared For:

US Fish and Wildlife Service, US Department of Interior
Bureau of Land Management, US Department of Interior
Bureau of Reclamation, US Department of Interior
Colorado Attorney General's Office
Colorado Department of Natural Resources
Colorado Department of Public Health and Environment

December 2006

ACKNOWLEDGEMENTS

This preliminary estimate of damages was prepared by Industrial Economics, Incorporated (IEc) under contract GS-10F-0224J with the U.S. Fish and Wildlife Service. IEc would also like to acknowledge the significant contributions of Stratus Consulting, Inc. to this document.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION AND EXECUTIVE SUMMARY CHAPTER 1

1.0 INTRODUCTION

Under Federal law, designated Federal and state agencies are authorized to act as Trustees of natural resources on behalf of the public. In this role, Trustees assess and recover damages resulting from injuries to natural resources due to hazardous substance releases, and use these recovered damages to plan and implement actions to restore, replace, rehabilitate, or acquire the equivalent of injured natural resources (hereafter referred to as restoration).

A Trustee Council has been formed to assess natural resource injuries resulting from releases of hazardous substances at and from California Gulch and its tributaries. This Council consists of the U.S. Fish and Wildlife Service, the Bureau of Land Management, and the Bureau of Reclamation on behalf of the U.S. Department of the Interior (DOI) and the Colorado Attorney General's Office, Colorado Department of Public Health and Environment, and Department of Natural Resources on behalf of the State of Colorado. The U.S. Environmental Protection Agency (EPA) has been investigating the sources, nature, and magnitude of metals pollution within and emanating from the National Priorities List (NPL) Site and has been working with potentially responsible parties (PRPs) to develop and implement response actions on the NPL site. Pursuant to relevant regulations, any restoration plan selected by the Trustees will consider the results of any actual or planned response actions.[1]

This Preliminary Estimate of Damages (PED) was developed to assist the Trustees in their natural resource damage assessment efforts. PEDs provide a rapid review of readily available information focused on resources for which Federal or State agencies and/or Indian tribes may assert trusteeship. The primary purpose of a PED is to ensure that the scientific investigations and valuation methodologies to be used in the Natural Resource Damage Assessment (NRDA) are reasonable as required by relevant regulations. PEDs inform Trustee efforts (and potential settlement discussions with Responsible Parties) by providing preliminary estimates, as readily available information allows, of the magnitude of natural resource injuries and the associated cost of actions needed to restore, replace, rehabilitate, or acquire the equivalent of injured natural resources.[2] In addition, PEDs can help identify key data gaps that may need to be filled as part of future assessment activities.

---

[1] See 43 CFR 11.82(d)(4).

[2] See 43 CFR 11.25(e).

1.1 LOCATION AND DESCRIPTION OF THE UPPER ARKANSAS RIVER BASIN

The Arkansas River (River) originates in the alpine and sub-alpine basins of the Mosquito and Sawatch Ranges above Leadville in Central Colorado. Its headwaters emanate largely from winter snowpack and become confluent just outside of Leadville at 10,100 feet (3,100 m) elevation to form the River mainstem. From there, the River flows through a valley flanked by the Mosquito and Sawatch Ranges from which it receives tributary flow from numerous low-order perennial and intermittent drainages (Figure 1-1).

Near Leadville, the River meanders through a broad mountain valley, creating significant wetland and floodplain meadow acreage. Predominant land uses include irrigated pasture and haying operations, livestock production, recreation, and residential development. Approximately 12 miles (19 km) downstream from Leadville, the River becomes entrenched in a canyon setting formed by the convergence of the Mosquito and Sawatch ranges, resulting in a narrow floodplain. The River descends through montane and transition life zones, flowing through deep canyons between Buena Vista and Cañon City. Ultimately, the River drains some 28,000 square miles (75,600 km^2) and empties into Pueblo Reservoir more than 160 miles (267 km) distant from and 7,000 feet (2,100 m) below its alpine origins before continuing to eastern Colorado and Nebraska.

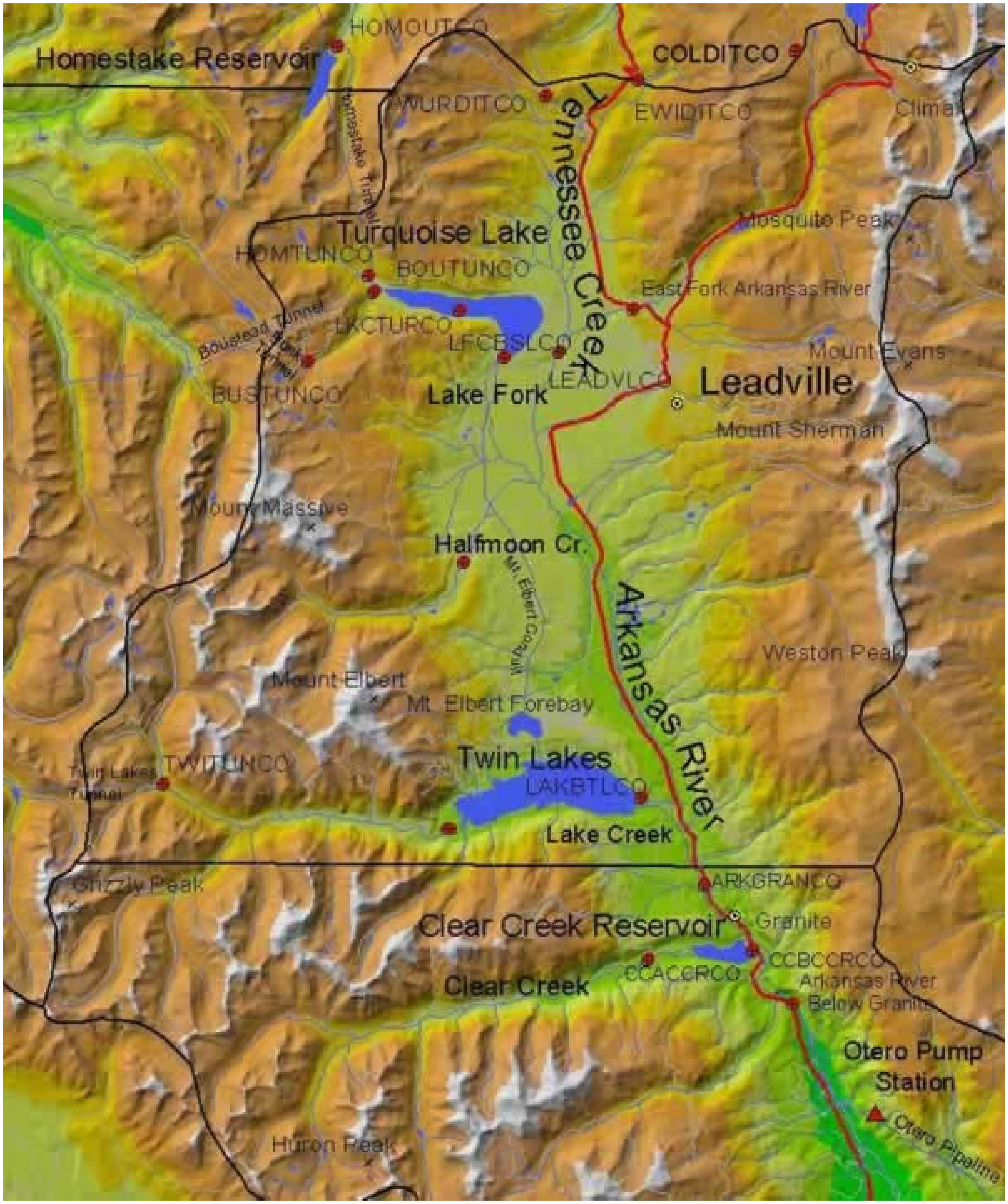
Several perennial and ephemeral drainages including Stray Horse, Oregon, Georgia, California and Evans Gulches drain an 18 1/2 square mile (48 km^2) watershed into the Arkansas River southwest of Leadville. Most of these drainages are included in the NPL Study Area identified in a 1994 Consent Decree entered into by the EPA, State of Colorado and certain mining companies.

1.2 OVERVIEW OF MINING ACTIVITY

Multiple mining methods were used in the Leadville mining district, as targeted ores changed. Mining activity also took place in many different locations throughout the district (Figure 1-2). As mining progressed from oxide down into sulfide ores, changes in the style of mining and mineral processing means occurred. Each style and ore has characteristic waste material and resulting pollution effects.

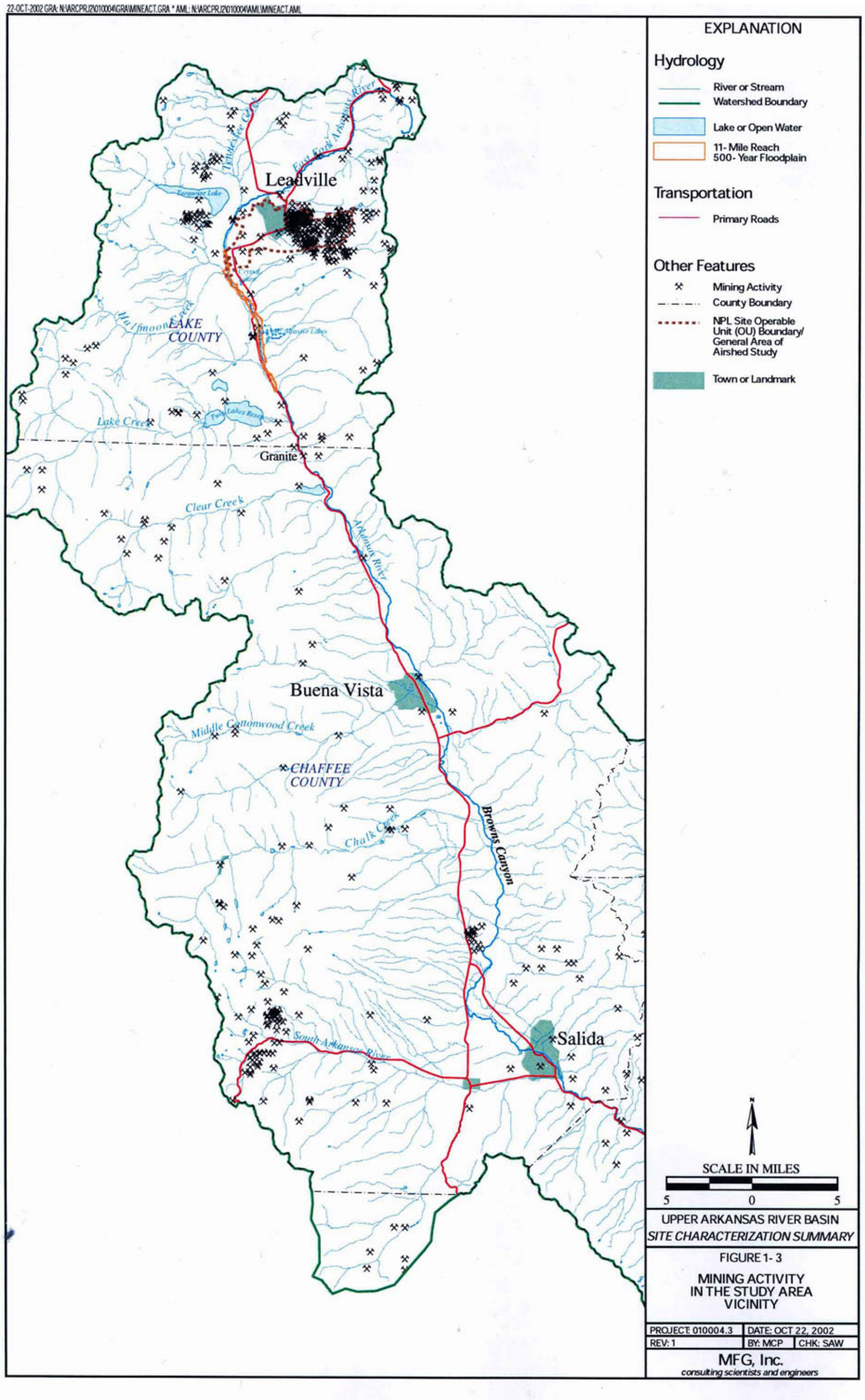
The first mining in the district, in oxide ores, was conducted by placer methods. Gold was recovered from stream placers while other material was removed from colluvium that lay down slope from exposed mineralization. Hydraulic mining was used to dislodge at least some material from the placer deposits. Hydraulic mining of oxide ores disturbed and/or removed significant amounts of surficial sediments. Heavy minerals, including gold, were segregated from the sediments using gravity methods to recover visible gold, and the waste sediment was sluiced aside. Waste sediment from these ores consisted of quartz and minor amounts of other refractory silicate minerals, stable (inert) iron hydroxides, and clay. These wastes may have presented problems for aquatic habitat and biota due, for example, to smothering of eggs or loss of substrate habitat due to sediment cover. However, these wastes, by and large, would neither leach metals nor produce acid drainage.

Figure 1-1
Upper Arkansas River Basin



Source: USGS 2005.

Figure 1-2



Source: SCR 2002.

The nature of sediment injury during this period is not well quantified. If the current conditions are any indication, the Arkansas River, which is a high gradient stream with significant sediment-carrying capacity, may not have had significant sediment problems in the early days of mining, as the stream is sediment-poor. Increased sediment might have improved aquatic habitat, especially for species that require fine sediment.

With the advent of sulfide mining, hard rock ores initially were crushed using stamp mills then placed in jigs to produce mineral concentrates. Such concentrates could have included sphalerite (zinc concentrate), galena (lead concentrate) or any of several copper mineral concentrates. Waste tails from these jigged ores would have included all of the above metals plus iron sulfides. Surface waters would have become contaminated by acid drainage that would have included dissolved toxic metals that are the subject of the CERCLA cleanup today.

During the later stages of sulfide mining, mineral concentrates were produced by flotation. Flotation tails would have been finer grained than jig tails, but the metal content and the tendency to form acid drainage would have been similar. Overall, tailings that were released from oxide ore processes, which were mined by placer methods, would have produced problems from sediment deposition, but not from dissolved metals or acid drainage. Tailings that were released from sulfide ore processing, whether produced by jigging or flotation, could have produced sediment problems, along with problems with dissolved metals and acid drainage.

The Yak tunnel has been a significant channel for contamination to California Gulch. Construction of the initial portion of the Yak tunnel began in 1895 to dewater mines by drainage to the California Gulch. Several expansions to the tunnel increased its length, with a final length by 1923 of over four miles and an estimated void space of 55 to 74 million cubic feet. The Yak tunnel was a primary focus of studies and cleanup activities between 1989 and 1994. Prior to construction of the Yak Water Treatment Plant, the tunnel discharged about 210 tons of metals each year into California Gulch, which drains into the Arkansas River.

1.3 INTEGRATION OF NRDAR PROCESS WITH USEPA SUPERFUND EFFORTS

Under natural resource damage regulations, damages recoverable by the Trustees include the cost of restoration. Damages also may include, at the discretion of the Trustees, the compensable value of all or a portion of the value of the services lost to the public for the time period from the release of hazardous substances until the attainment of such restoration to baseline conditions (often referred to as "interim loss").[3] This focus is related to, but different from EPA’s and States’ response programs which focuses instead on reduction of risks posed by releases and threatened releases of hazardous substances. Analyses undertaken by Trustees as part of the natural resource damage assessment process mandated in the CERCLA statute take into account the improvements to natural resources and affected services back toward baseline by remedial response actions, and therefore are complementary rather than duplicative.

---

[3] As specified in the DOI natural resource damage regulations, Trustees’ claims for natural resource damages may include additional components not identified in this discussion (e.g., the costs of emergency restoration efforts, the reasonable and necessary costs of the assessment, and interest on the amounts recoverable).

The California Gulch Superfund Site is located within the Upper Arkansas River Basin 100 miles southwest of Denver, Colorado. It was placed on the NPL in 1983, and covers 16.5 square miles affected by mining in the California Gulch watershed that drains to the Arkansas River.[4] The Site is divided into 12 Operable Units (OUs). Operable Units 1 through 11 are distinctly bounded geographic areas. Operable Unit 12 was added to address site-wide surface and groundwater quality issues remaining after source controls are addressed at the other 11 Operable Units (USEPA 2005). Figure 1-3 shows the Study Area as defined in the Parties' 1994 Consent Decree and the locations of the 11 geographically-based OUs. Table 1-1 provides a summary of the OUs and the designated remediation leads for each OU.

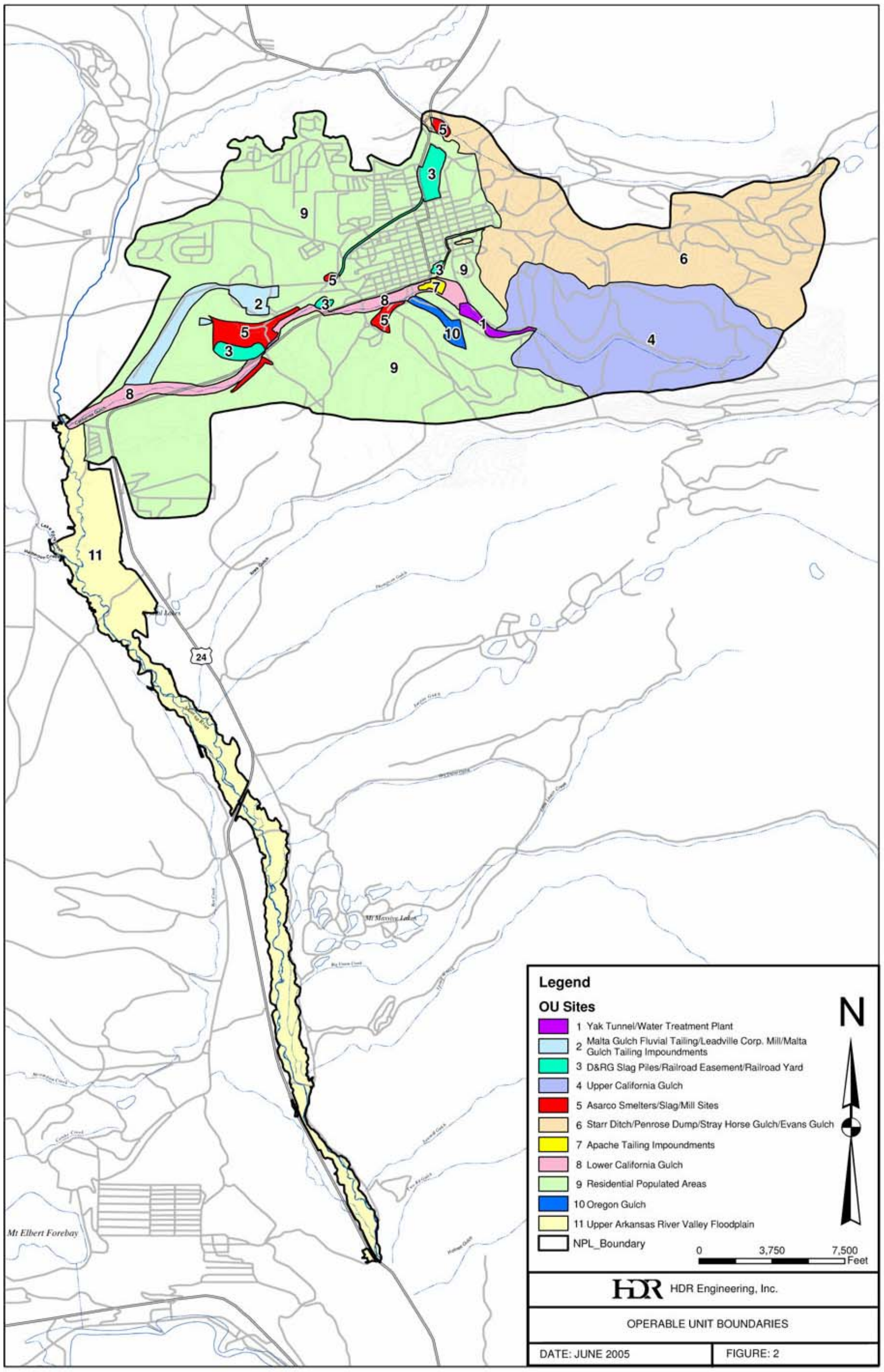
Table 1-1
Operable Units at California Gulch Superfund Site

OU	Operable Unit Name	Remediation Lead
1	Yak Tunnel/ Water Treatment Plant	Res-ASARCO joint venture
2	Malta Gulch Fluvial Tailing/Leadville Corp. Mill/Malta Gulch tailing impoundments	EPA
3	D&RGW Slag Piles/Railroad easement/Railyard	Union Pacific
4	Upper California Gulch	Resurrection
5	ASARCO smelters/Slag/Mill sites	ASARCO
6	Starr Ditch/Penrose Dump/Stray Horse Gulch/Evans Gulch	EPA
7	Apache Tailing Impoundments	ASARCO
8	Lower California Gulch	Resurrection
9	Residential Populated Areas	ASARCO
10	Oregon Gulch	Resurrection
11	Upper Arkansas River Floodplain	EPA, State of Colorado, and mining companies
12	Site-wide Surface and Groundwater Quality	EPA, State of Colorado, and mining companies

---

[4] EPA FY 2004 New Construction Fact Sheets: California Gulch http://www.epa.gov/superfund/accomp/not_funded/calgul.htm. Accessed 10/14/05.

Figure 1-3



Source: ROD OU11 2005

1.4 PED STUDY AREA

The geographic/resource focus of this PED is on potential injuries to services provided by the following resources:

a) Surface water and groundwater associated with California Gulch and its tributaries[5];

b) The Arkansas River (from its confluence with California Gulch to Pueblo Reservoir);

c) The 500 year floodplain of the Arkansas River within the 11 mile reach, including riparian areas, irrigated meadows and fluvial deposits, as well as areas outside the floodplain that are known to have been irrigated with contaminated water;

d) Superfund Operable Units 4 and 8 fluvial deposits; and

e) Operable Units 5, 7, 8 and 10 mine waste deposits.

The PED focuses on injuries to the above-listed resources for two reasons: first, sufficient information regarding these injuries is available to perform a preliminary estimation, and second, this information indicates that these trust natural resources have been injured as a result of hazardous substances released due to the mining activities that are the subject of the Trustees' assessment. It is important to recognize, however, that other trust natural resources within the Arkansas River Basin may have been affected by such releases. While readily available information does not provide a sufficient basis for their evaluation at the current time, injuries could be substantial. For example, this PED does not evaluate the potential for recreational injuries, smelter-related terrestrial injuries (e.g., contamination from slag piles or soils contaminated by smelter emissions) or injuries related to OU 6 mine waste piles. Studies on additional species (e.g., reptiles, amphibians) may indicate further injury. As a result, damage estimates presented in this document do not fully capture potential natural resource damages within the Upper Arkansas River Basin attributable to the subject releases.

1.5 CONTAMINANTS OF POTENTIAL CONCERN

Numerous studies document the widespread presence of many contaminants of potential concern (COPCs) in the study area. The Site Characterization Report for the Upper Arkansas River Basin (SCR), a key summary source of information on contamination and natural resource injuries in the study area, focuses its evaluation on four primary metals: cadmium, copper, lead and zinc. As noted in the SCR, this contaminant focus is based on a review of existing studies and data, a basic understanding of the mining history and ore bodies, toxicity considerations and the predominance of these metals in the fluvial systems of the UARB (SCR 2002, pp. 2-1, 2-2). Further, as indicated in the SCR:

---

[5] Several California Gulch tributaries currently have EPA assigned as remediation lead. Potential injuries at these locations (e.g., Malta Gulch, Stray Horse Gulch, Evans Gulch, Oregon Gulch) are not included in the current draft of the PED but may be considered at a future time.

> "The presence and consistent occurrence of these metals is representative of the nature and extent of all metals that have increased presence due to mining. Existing data, along with an understanding of both mining and milling processes and fate and transport processes, indicate that these metals define the nature and extent of contamination. As such, mining impacts will be accurately defined by these constituents. A focused approach, using a smaller group of signature metals, is consistent with CERCLA investigations conducted for other large mining sites" (SCR 2002, p. 2-2).

Additional metals and metalloids have been and continue to be released from the Site, including (but not limited to) arsenic, manganese, aluminum, and iron. Low pH of ground water and surface water affected by acid mine drainage is also a concern. While the information presented in this PED generally focuses on cadmium, copper, lead and zinc, injuries associated with other hazardous substance releases are identified as relevant.

1.6 BASELINE CONDITIONS

For natural resource damage assessment purposes, baseline conditions are defined as the conditions that would have existed in the assessment area had the release of hazardous substances under investigation not occurred.[6] Geological information indicates that, except in the glaciated valleys, sulfides below the oxidized zone were below the water table that would have existed just prior to mining, and that, therefore, acid mine drainage would have been minimal (Tweto 1968). Baseline conditions, consequently, are assumed to include some physical disturbances but not significant chemical contamination.

1.7 TEMPORAL SCOPE OF NRD INJURY EVALUATION

While contamination-related resource injuries have been observed in the study area for many decades, consistent with relevant regulations the PED calculates interim service losses beginning in 1981 (the first full year after CERCLA promulgation).[7] Loss calculations continue until services are expected to return to baseline condition, taking benefits from remediation activities and natural attenuation processes into account.

1.8 SUMMARY OF PRELIMINARY FINDINGS

Significant injuries to both aquatic and terrestrial resources as a result of mining activities are identified. Past injuries (i.e. 1981 to present) are the largest portion of the loss. Quantification of damages from aquatic injuries in the 11-mile reach indicates potential costs of \$9.3 to \$12.1 million for compensatory restoration. In California Gulch, preliminary damage estimates for groundwater and surface water are \$18.7 to \$21.8 million. In the Arkansas River downstream of the 11-mile reach, service losses are lower per acre, but cover a much larger area,

---

[6] See 43 CFR 11.14(e).

[7] See 43 CFR 11.24(b)(1)(ii).

leading to a preliminary damage estimate of between $9.5 and $17.8 million. The preliminary damage estimate for terrestrial resources is $16.3 million. In total, these preliminary damage estimates range between approximately $53.8 and $68.0 million. As noted previously, these preliminary damage estimates do not fully capture potential natural resource damages within the Upper Arkansas River Basin attributable to the subject releases (e.g., potential injuries to California Gulch tributaries, recreational use, smelter-affected terrestrial resources, OU 6 mine waste piles, and wildlife and birds). These and other potential injuries may be evaluated as part of future assessment activities; associated damage estimates would be in addition to those presented in this document.

1.9 OUTLINE OF THE PED

The remainder of the PED is organized as follows:

- Chapter 2 provides a preliminary evaluation of California Gulch surface water and groundwater degradation, as well as surface water service degradation in the 11-mile reach of the Arkansas River and downstream areas;

- Chapter 3 provides a preliminary evaluation of terrestrial service loss in the 500 year floodplain of the Arkansas River, Superfund OU 4 and 8 fluvial deposits, and Superfund OU 5, 7, 8 and 10 mine waste deposits.

CALIFORNIA GULCH AND UPPER ARKANSAS RIVER CHAPTER 2

2.1 INTRODUCTION

This chapter summarizes readily available information concerning injuries to California Gulch surface water and groundwater, Upper Arkansas River surface waters, and associated biota.[1] It also provides a preliminary estimate of restoration costs needed to offset these injuries. For California Gulch groundwater, a market value approach also is applied to provide an estimate of potential replacement costs needed to offset reduced water availability due to contamination. Consistent with existing analyses of these resources, this chapter presents information by the following three geographic sub-segments:

a) California Gulch;

b) The "11-mile reach" of the Upper Arkansas River, extending between its confluences with California Gulch and Two Bit Gulch (reaches 1-4); and

c) The "downstream" section of the Upper Arkansas River extending from its confluence with Two Bit Gulch to Pueblo Reservoir (reaches 5-10).

Surface water resources provide a variety of important ecological services (e.g., habitat for benthic biota, fish and birds) and human use services (e.g., for recreation, agriculture and drinking water supply). Table 2-1 summarizes designated uses established by the Colorado Water Quality Control Commission for relevant portions of the mainstem of the Arkansas River and shows where the above-defined reaches fall in relationship to these stream segments. Groundwater supports a variety of human uses (e.g., agricultural, drinking water and industrial water supply), and also is a critical pathway resource integrally connected with surface water.

Based on the preliminary analyses presented in this chapter, the cost of restoration projects needed to offset post-1981 natural resource service impairment in the 11-mile reach is expected to be on the order of approximately $9.3 to $12.0 million. Similar calculations suggest that the total magnitude of injuries to downstream areas is approximately $9.5 to $17.9 million, for a total of $18.8 to $29.9 million dollars as a restoration cost-based preliminary damage

---

[1] Consistent with DOI natural resource damage regulations, Arkansas River and California Gulch "surface water" is defined to include the waters themselves as well as sediments suspended in the water or lying on the bank, bed, or shoreline. "Groundwater" includes water in a saturated zone or stratum beneath the surface of land or water and the rocks or sediments through which groundwater moves.

estimate. Injuries to California Gulch surface water and ground water add an additional $18.9 to $21.6 million to estimated water-related damages.

Table 2-1

Stream Classifications for the Arkansas River

Stream Segment	Segment Description	Designated Uses	Corresponding Reach
2a	Mainstem of the East Fork of the Arkansas River and the Arkansas River from a point immediately above the confluence with Birdseye Gulch to a point immediately above the confluence with California Gulch	Aq Life Cold 1	Reach 0
		Recreation 2	
		Water Supply	
		Agriculture	
2b	Mainstem of the Arkansas River from a point immediately above California Gulch to a point immediately above the confluence with Lake Fork	Aq Life Cold 1	Reach 1
		Recreation 2	
		Agriculture	
2c	Mainstem of the Arkansas River from a point immediately above the confluence with Lake Fork to a point immediately above the confluence with Lake Creek.	Aq Life Cold 1	Reaches 2-4
		Recreation 2 Agriculture	Reach 5
		Aq Life Cold 1	
3	Mainstem of the Arkansas River from a point immediately above the confluence with Lake Creek to the inlet to Pueblo Reservoir	Recreation 2	Reaches 6-10
		Water Supply	
		Agriculture	
		Agriculture	

2.2 CALIFORNIA GULCH

California Gulch encompasses OU4 (Upper California Gulch) and OU8 (Lower California Gulch), and receives water from throughout the District, including Oregon Gulch, Stray Horse Gulch, the Yak Tunnel Water Treatment Plant and Starr Ditch. The California Gulch area, for the purposes of this PED, is 3.4 acres.[2] Surface water flow in upper California Gulch and its tributaries is generally intermittent, typically occurring only as the result of snow-melt runoff and high intensity summer precipitation events which may mobilize contaminants from the mine waste piles throughout the area (ROD OU4 1998, Section 5.1).

2.2.1 Evidence of Injury

Water samples from the mouth of California Gulch (spring runoff, 1994 to 2005) exceed chronic thresholds for zinc and cadmium (CDOW, 2006, Table 21). Monthly average zinc and cadmium values are roughly ten times those measured downstream in Reach 1 of the Upper Arkansas (CDOW, 2006, Tables 8 and 9). Current surface and shallow groundwater flows from California Gulch greatly exceed the Colorado Table Value Standards (TVSs) and are the primary pathway for elevated metals concentrations in the surface water of the 11-mile reach of the Arkansas River (SCR, 2002, p. 3-5). The contamination has resulted in the loss of a benthic invertebrate community in California Gulch. Sampling in the fall of 1989 indicated the absence

---

[2] Potential injuries at Malta Gulch, Stray Horse Gulch, Evans Gulch and Oregon Gulch are not included in the current draft of the PED but may be considered at a future time.

of macroinvertebrates in California Gulch (CDOW, 1990, p.4).[3] Sampling the following spring found a few larvae (*Limnophora* and *Diplocladius cultriger*) downstream of the Leadville wastewater treatment plant (WTP) discharge. No macroinvertebrates were found upstream of the plant (CDOW, 1990, p. 4). From 1995 to 1997, mayfly densities were below one percent of values at reference locations in the Arkansas River and East Fork. California Gulch sites also included a significantly reduced number of taxa relative to reference locations (Chadwick 1998). No fish were observed in California Gulch during fall sampling in 1989 (CDOW, 1990, p. 4).

The majority of wells in Stray Horse Gulch, Evans Gulch, Oregon Gulch, and along the entire length of California Gulch still have metals contamination exceeding groundwater criteria (Tetra Tech, 2004). Exceedences have been consistent for at least 20 years. In 1985, most of the 33 permitted domestic use wells in the California Gulch alluvium were abandoned due to color, taste, odor, and high cadmium levels (Engineering Sciences, 1986). Several residents, particularly near Stringtown, were placed on the Parkville Water District public water supply after their wells were retired from service due to contamination.

The dynamics between surface water and groundwater complicate the analysis of groundwater contamination independent of surface water. Figure 3.2-2 from the Golder Associates (1996) report shows that the majority of the reaches in California Gulch are losing reaches, meaning that surface water is migrating into groundwater. Approximately 3,500-4,000 linear feet of the channel are gaining reaches, where groundwater is driven into the surface water. Given this complex system, it is likely that contaminated water may journey from groundwater to surface water and back to groundwater several times en route from upper California Gulch to the Arkansas River.

For purposes of this PED, the Trustees have evaluated California Gulch surface water and groundwater as a single interconnected system to account for potential injuries to water at the various gaining and losing reaches.

2.2.2 Injury Quantification

Injury quantification is based on flux calculations of both surface water and groundwater. Flux is calculated concurrently for surface water and groundwater at temporally and geographically paired locations. The flux calculations were performed for a location slightly upstream of the California Gulch-Malta Gulch confluence.

Surface water flux is equivalent to stream flow. The quantity of surface water flow is based on average flow data from 1989 through 2005. The 1989-2005 period includes both higher flow periods in the 1990s and lower flow periods after 2000. The OU12 Remedial Investigation (Draft RI; HDR, 2006) shows the calculated average daily flow at CG-5 (just downstream of the airport) between 1989 and 2006 to be 2.24 cfs (n = 92), and the average daily flow at CG-6 (mouth of California Gulch, downstream of Malta) between 1994 and 2006 to be 2.71 cfs (n = 380). The site selected for estimating flux is approximately midway between these two sampling

---

[3] A small number of specimens (one Hemipteran, one Coleoptera, and 91 *Daphnia*) were found in a station near the Leadville municipal wastewater treatment Plant, and were thought to have originated in the discharge (CDOW, 1990, p. 4).

stations, but is upstream of Malta Gulch. The annual average surface water flow therefore was estimated to be 2.48 cfs or 1,795 acre-feet/year (AF/yr).

Groundwater flux estimates were developed using the following equation: Q = KiA, where Q is groundwater flux (ft^3/d), K is hydraulic conductivity (ft/d), i is gradient (ft/ft), and A is the cross-sectional area of the plume equal to Depth x Width (ft^2).

2.2.2.1 Hydraulic Conductivity (K)

Few studies have analyzed the characteristics of the California Gulch alluvial aquifer. One of the early studies of the California Gulch groundwater was from Turk & Taylor (1979) whose data were cited by others. They included an estimate of average hydraulic conductivity (K) of 1.5 ft/d, and an estimated flux of 1.3 ft^3/s across an area one mile wide and 1,000 ft thick at an unspecified location. Back-calculating from those data, they assumed a gradient of 0.014 ft/ft. Their estimate of K is reasonable for the alluvial aquifer.

Golder Associates (1996) calculated hydraulic conductivities at several locations throughout California Gulch. Hydraulic conductivities ranged by several orders of magnitude, even in wells that were close to each other. In the shallower portions of California Gulch (upper 4 – 5 ft), the K for the alluvium was higher, but varied by three orders of magnitude (6.6×10^0 to $1.1 \times 10^{+3}$(ft/d)). In the deeper portions of California Gulch alluvium (20 – 140 ft deep) near the tailings and mine waste areas, K values ranged from 4.91×10^{-3} to $4.12 \times 10^{+2}$ ft/d. The dynamics between surface water and groundwater complicate the analysis of groundwater contamination. In the losing reaches, some piezometers showed an unsaturated zone below the riverbed, indicating areas where there is no direct hydraulic connection between surface water and groundwater. Given this complex system, it is possible that a molecule of contaminated water may journey from groundwater to surface water and back to groundwater several times en route from upper California Gulch to the Arkansas River.

2.2.2.2 Hydraulic Gradient (i)

Golder (1996, Table 3.1-1) also presents a range of hydraulic gradients in the alluvial aquifer under California Gulch. Using piezometers in California Gulch itself, the gradient ranged from 0.019 ft/ft to 0.05 ft/ft. The estimate of average gradient through California Gulch alluvium was 0.03 ft/ft (Golder, 1996). The hydraulic gradients for the California Gulch tributaries and areas near Leadville generally fall within that range as well.

2.2.2.3 Alluvium Thickness (D)

The Pendery fault runs approximately north-south along the eastern end of Leadville, downstream of the tunnel portals. This fault has a displacement of at least 200 ft, with the entire displaced area backfilled with alluvium (Engineering Sciences, 1986). Downstream of this fault, the alluvium is very thick, heterogeneous and anisotropic. Golder Associates (1996) estimates the saturated thickness of alluvium exceeds 1,000 ft in many places; the three downstream wells that Golder sunk into bedrock ranged from 420 to 1,265 ft deep.

Those three bedrock wells are nested with piezometers in the alluvium. Two of the three had an upward gradient, meaning groundwater was moving from deep into shallow (and therefore contamination in the shallow aquifer would not be expected to reach the deep aquifer), and one nested site had a downward gradient. The site with the downward gradient was near the Leadville Mine Drainage Tunnel, so it is possible (or likely) that the sump effect of the tunnel reduced the head of the bedrock well enough to induce the downward gradient (Golder, 1996).

The available studies do not contain any data with multi-level wells, where one could definitively ascertain the depth of contaminated groundwater in the California Gulch alluvium. The alluvium itself is saturated for up to 1,000 ft (Golder Associates, 1996), but the contamination most likely stays near the surface. Estimates of the depth of contamination include 25 ft (RMC, 2001), 25 to 50 ft (1987 RI report in HDR, 2003), 50 ft (Engineering Sciences, 1986), and 100 to 200 ft (Lee Pivonka & Mike Wireman, 2003). TetraTech (2004) also provides information for calculating contaminated saturated thickness (screened intervals and concentrations). Using this information, the contaminated saturated thickness in the upper California Gulch area (near Penrose Tailings) is 140.7 ft, and the saturated thickness in the lower California Gulch area (near the confluence with the Arkansas River) is 50 ft.

2.2.2.4 Plume Width (W)

Width of the plume is developed from HDR, 2006 (Figures 4-63 and 4-64) that show plan views of inferred alluvial groundwater contamination in California Gulch. Based on the plume depicted in HDR, 2006 (Figures 4-63 and 4-64), contaminated plume widths range from 300 to 500 ft.

2.2.2.5 Groundwater Flux Summary

To account for variability in the available information, we provide three alternative estimates of groundwater flux based on a range of conductivity (K) and plume areas. Table 2-2 shows a range of flux calculations based on the aforementioned ranges in input data. The calculated flux ranges widely, governed mainly by the multiple orders of magnitude range in K values for the upper alluvium. The flux value presented as the medium range in Table 2-2 (185,400 ft^3/d) uses the high end of the K values for the deeper (20-140 ft) piezometers in the aquifer, and the low end of contaminated saturated thickness from TetraTech (2004). We believe this provides a reasonable flux value for the aquifer as a whole, given the available data.

Combining the surface water and groundwater flux estimates provides the total injury quantification for California Gulch. These estimates are:

1,795 AF/yr (surface) + 1,554 AF/yr (ground) = 3,349 AF/yr.

2.2.3 California Gulch Preliminary Estimate of Damages

Damages for injury to California Gulch water resources were calculated using two alternative approaches. First, a restoration-based approach using a Resource Equivalency Analysis (REA) framework is developed. Then, because surface water and groundwater in this area are integrally related and regional water markets exist, the Trustees have utilized a market valuation approach, using the cost of acquiring water rights in the area, as an alternative measure of damages.

Using the above estimate of contaminated water resource, a 3% discount rate and the assumption that water resources in this area have been injured since 1981 and will continue to be injured into the relevant planning future, we can calculate the net present discounted quantity of groundwater resources injured. This quantity is often referred to as the REA Debit. For the annual injury presented at the end of Section 2.2.2, the debit estimate is 234,939 acre-foot years (AFY).

2.2.3.1 Restoration Cost Approach

The restoration cost approach identifies representative restoration projects that could be undertaken to restore natural resources similar to those injured from the release. The cost to undertake a sufficient scale of projects to offset the debit is the basis of the restoration cost damage claim.

One set of restoration projects evaluated is the reduction or removal of sources of surface/groundwater contamination in nearby aquifers. These projects include activities such as isolation of upslope tailing piles to reduce acid mine drainage (AMD) loadings, creation of treatment wetlands to eliminate AMD, and/or sealing of leaking tunnels and diversion of flow for treatment. A brief description of the representative projects is provided in Table 2-3. We assume that each of the projects would improve water quality such that water quality standards are no longer exceeded. This is assumed to be equivalent to a 100% improvement in water resource services.

The benefits to natural resources from implementation of representative restoration projects are referred to as REA credits. Restoration credits can be calculated based on when projects begin to provide benefits and the degree of benefits provided by each project. For purposes of this PED we assume that the restoration projects are initiated in 2008, become fully effective in 2010, and provide benefits into the foreseeable planning future. Based on these assumptions, improving water quality to one acre-foot of water annually is equivalent to providing 30 present value AFY over the lifetime of the restoration project. For each of the representative restoration projects, Table 2-4 shows the estimated restoration credit generated.

Project costs are based on estimates of engineering costs from similar local projects including a standard contingency of 25% of the initial engineering cost. In addition to the project engineering cost, the Trustees have included oversight and administration costs, calculated as 40% of initial engineering cost. For each of the representative restoration projects, Table 2-4 shows the estimated project costs per AF of credit generated. The average cost per AF of credit is calculated to be $2,755.

Using the best estimate of injury debits, restoration credits, and average project costs, the estimated restoration-based measure of damages to California Gulch water resources is $21.8 million. Table 2-4 presents a summary of the restoration cost damage calculations.

Table 2-2

Range of groundwater flux calculations for California Gulch near Malta. Flux (Q) is based on the following equation:
Q = KiA, where K = hydraulic conductivity, i = hydraulic gradient, and A = cross-sectional area = width (W) x depth (D)

Estimate	K (ft/d)	i (ft/ft)	W (ft)	D (ft)	Q
Low	6.57	0.019	150	25	470 ft^3/d
	(Golder, p.3-15)	*(Golder, Table 3.1-1)*	*(USGS aerial photo)*	*(RMC, 2001)*	3.94 ac-ft/yr
Medium	412	0.03	300	50	185,400 ft^3/d
	(Golder, Table 3.1-1)	*(Golder, Table 3.1-1)*	*(USGS aerial photo)*	*(Eng.-Sciences., 1986; TetraTech, 2004)*	1,554 ac-ft/yr
High	1,100	0.05	600	150	4,950,000 ft^3/d
	(Golder, Table 3.1-1)	*(Golder, Table 3.1-1)*	*(USGS aerial photo)*	*(Pivonka & Wireman 2004; TetraTech, 2004)*	41,479 ac-ft/yr

Table 2-3

Representative Restoration Projects, Estimated Benefits (AF/yr), and Cost ($/AF)

Project	Project Costs	Benefit (cfs)	Benefit (AF/yr)	Cost/AF
L. Griffith waste rock isolation: Low cost and lower estimate for flow(1)	$330,000	0.3	217	$1,520
L. Griffith waste rock isolation: Low cost and higher estimate for flow(1)	$330,000	0.5	362	$912
L. Griffith waste rock isolation: High cost and lower estimate for flow(1)	$660,000	0.3	217	$3,039
L. Griffith waste rock isolation: High cost and higher estimate for flow(1)	$660,000	0.5	362	$1,824
Tiger Shaft waste rock isolation: Low cost(2)	$330,000	0.4	290	$1,140
Tiger Shaft waste rock isolation: High cost(2)	$660,000	0.4	290	$2,279
Dinero tunnel investigation and sealing: Low cost (3)	$495,000	0.1	72	$6,838
Dinero tunnel investigation and sealing: High cost(3)	$660,000	0.1	72	$9,118
Lower Colorado Gulch treatment wetlands – Low cost(4)	$330,000	1.3	941	$351
Lower Colorado Gulch treatment wetlands – High cost(4)	$495,000	1.3	941	$526
Average				**$2,755**

Project Information Sources:
(1) Cost: Jim Herron, Colorado Division of Minerals and Geology. Flux of 0.3 – 0.5 cfs represents a range of average low-flow conditions from USGS surface water data for St. Kevins Gulch for 1993 – 1996
(2) Cost: Jim Herron, Colorado Division of Minerals and Geology. Flux of 0.4 cfs represents high-flow conditions for the East Fork of the Little Frying Pan; no flow occurs under low-flow conditions (Thompson, 2005)
(3) Cost and Flux: Jim Herron, Colorado Division of Minerals and Geology and Dan Grenard, Bureau of Land Management
(4) Cost and Flux: Karmen King, Aquatox, Inc.

Table 2-4

Summary of Restoration Based Damages: California Gulch

Debit	Credit/AF of Restoration	AFY Necessary for Full Compensation	Cost/AF	Damage Estimate ($million)
234,939 AFY	29.7	7,912	$2,755	$21.8

2.2.3.2 Market Value Approach

An alternative approach to estimate damages for water resource injuries in California Gulch is to use the market value approach. The market value approach relies on the fact that for some natural resources, such as water in the western United States, there are reasonably competitive markets from which market prices can be developed. The DOI NRDA regulations support the use of market value approaches to estimating damages when there is a reasonable competitive market for the natural resource in question.[4] Given the high connectivity between groundwater and surface water in this area and a demonstrated market for water, this is a reasonable alternative approach to estimating natural resource damages.

For the purposes of this PED, we estimate the market price measure of damages as the price of a quantity of water rights equal to the amount of injured water. For each AF of water right hypothetically purchased in 2006, that right would produce a net present discounted quantity of 32.3 AFY (credit). The market price of water in the region of the California Gulch is based on appraisal of surface water rights associated with the Moyer Easement (Sartucci, 2006, pg. 39). Table 2-5 reproduces Sartucci's (2006) table on comparable water right sales in the region of California Gulch.

Table 2-5

Summary of Comparable Water Right Sales in the Region

Name (Water Source)	Appropriation Dates	Annual Avg. Yield	Seller/Buyer	Sale Date	Sale Price
¼ Cameron Ditch (N. Fork. Arkansas)	1/10/1868 6/20/1890	300 AF	William and June Lake/ Upper Arkansas Water Conservation District	10/6/04	$600,000 ($2,000/AF)
85.7% of Tennessee Ditch (S. Fk. Arkansas)	4/30/1866 12/31/1878	1,749 AF	Glen and Julia Vandaveer/City of Salida	6/30/04	$1,200,000 ($686/AF)
Pioneer Ditch, Gas Creek Ditch, Willowdale Ditch, Pike Ditch, Princeton Ditch, Pioneer Ditch 2nd, and Bowen Ditch (Browns Cr.)	5/17/1866 4/1/1872 7/29/1911 6/9/1890 3/30/1881 7/15/1887 7/15/1907 3/1/1889 5/31/1867 9/24/1888 12/31/1866	2,010 AF total	Western Water Rights LP (Gary Hill)/ Pueblo West Metro Dist.	6/4/01	$2,600,000 ($1,294/AF)
Crystal Lake Ditch Empire Cr. Ditch	12/31/1871 12/31/1876 12/31/1883 12/31/1881	2,056 AF total	Moyer Family	9/21/06	-----

The actual value of water rights depends on the seniority of the right, location of the right, and estimated quantity of consumptive use available in the right. Based on the appraisal of the Moyer property and taking into account location and seniority, Sartucci estimates that the value of secure consumptive irrigation water rights is best set at approximately $2,600/AF of average annual yield. For purposes of this PED, we use an estimated value of $2,600/AF of permanent senior water right. Table 2-6 summarizes calculated damages for California Gulch water. Based on the cost of comparable water rights, damages are $18.7 million.

---

[4] Under the DOI regulations, valuation methodologies can be used to calculate "compensable values" for interim lost public uses. Valuation methodologies include several economic methods such as marketed methodologies (e.g., market price and/or appraisal) [43 CFR §11.83].

Table 2-6 Summary of Market Price Damages				
Debit	**Credit/AF of Water Right Purchased**	**AFY Necessary for Full Compensation**	**Cost/AF**	**Damage Estimate ($million)**
234,939 AFY	32.6	7,207	$2,600	$18.7

2.2.4 Summary of California Gulch Damage Calculations

Table 2-7 presents a summary the California Gulch damage calculations.

Table 2-7 Summary of Natural Resource Damages: California Gulch	
Resource Category	**Damage Estimates ($million)**
Restoration Cost Method	$21.8
Market Price Method	$18.7

2.3 ARKANSAS RIVER: 11-MILE REACH

The SCR separates the 11-mile reach into multiple sub-reaches, based on river geomorphology and hydrology. This convention is maintained in the PED. As shown in Figure 2-1, sub-reaches associated with the 11-mile reach include:

a) Reach 0 (reference area used for comparison to Reaches 1-4)[5] - confluence of Tennessee Creek and East Fork Arkansas River to County Road 300 upstream of California Gulch confluence [2.8 river miles (RM)];

b) Reach 1 - California Gulch confluence downstream to Lake Fork confluence (1.6 RM);

c) Reach 2 - Lake Fork confluence to Highway 24 Bridge (3.3 RM);

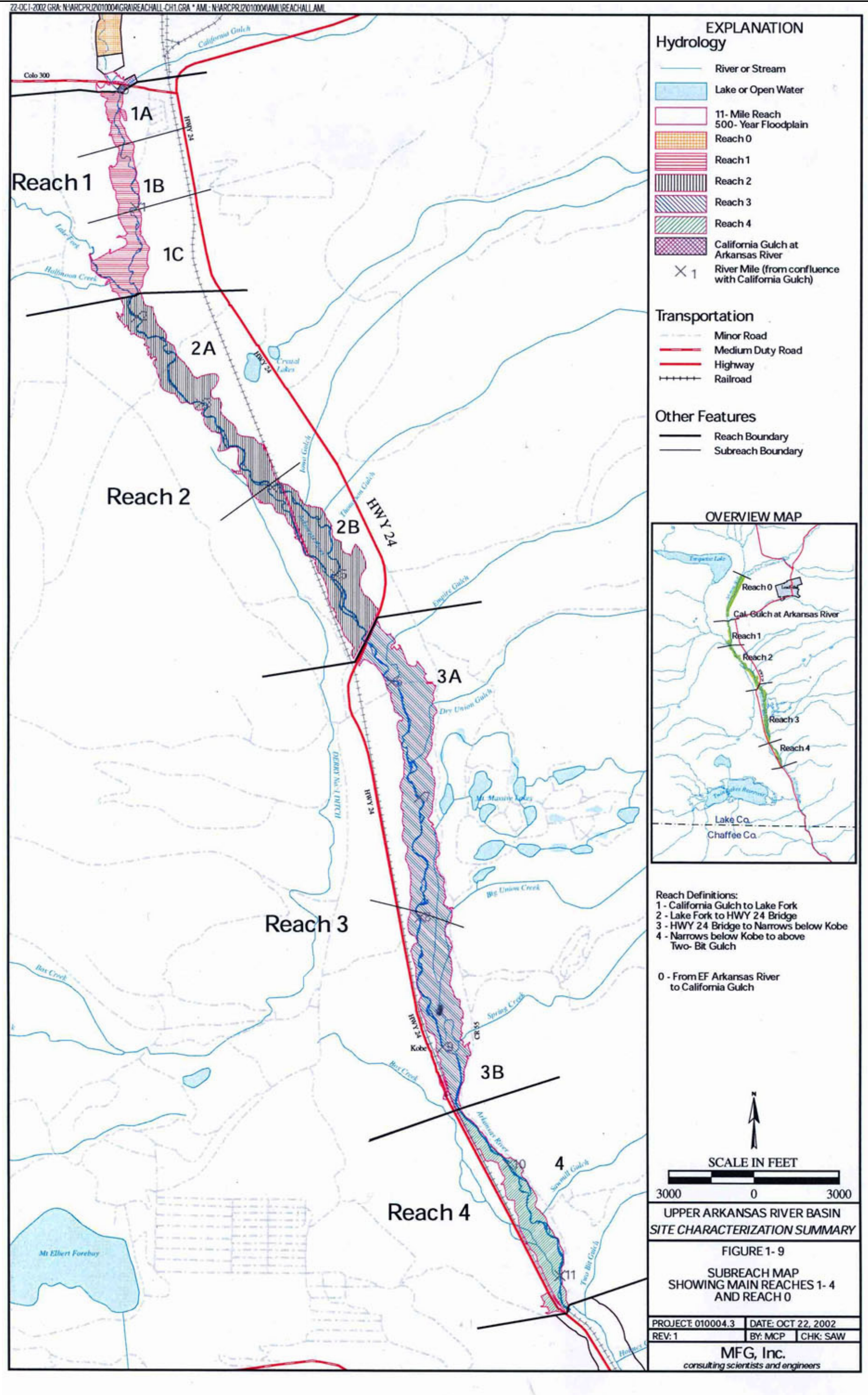
d) Reach 3 - Downstream of Highway 24 Bridge to narrows near Kobe (3.5 RM); and

---

[5] In the SCR, a portion of the UARB drainage upstream of the 11-mile reach (Reach 0) is used as a "control" area for establishing baseline conditions within the 11-mile reach, although metals levels in the reach have been affected by mining-related contamination and historically have exceeded chronic toxicity levels. Reach 0 metals levels have declined significantly since remediation of the Leadville Mine Drainage Tunnel began in 1992, and biological conditions have shown dramatic improvement. The results of a large-scale monitoring program conducted by USEPA (Clements et al. 1999) indicate that benthic communities and overall water quality within Reach 0 are similar to other Colorado streams (SCR 2002, p. 1-5).

e) Reach 4 - Downstream of narrows near Kobe to Two Bit Gulch (1.6 RM) (SCR, 1-24).

Figure 2-1



Source: SCR 2002.

2.3.1 Evidence of Injury

Multiple lines of evidence indicate injuries related to releases of hazardous substances due to mining activities, including impairment of habitat, forage and other ecological services provided by surface waters (and associated bed, bank and shoreline sediments) in the 11-mile reach of the Upper Arkansas River. These potential injuries arise from discharges of mine-waste and waters with elevated metals concentrations from California Gulch and other tributary drainages (see, for example SCR 2002, p. 3-1). The primary source of metals contamination in the 11-mile reach continues to be the inflow of surface water from California Gulch (SCR 2002, p. 3-1; CDOW 2006, p. 5).

The Site Characterization Report (SCR 2002) compiles and evaluates data available through 2001, and is the primary source of information cited in this subsection. Key findings are summarized below. More detailed information can be found in the SCR.

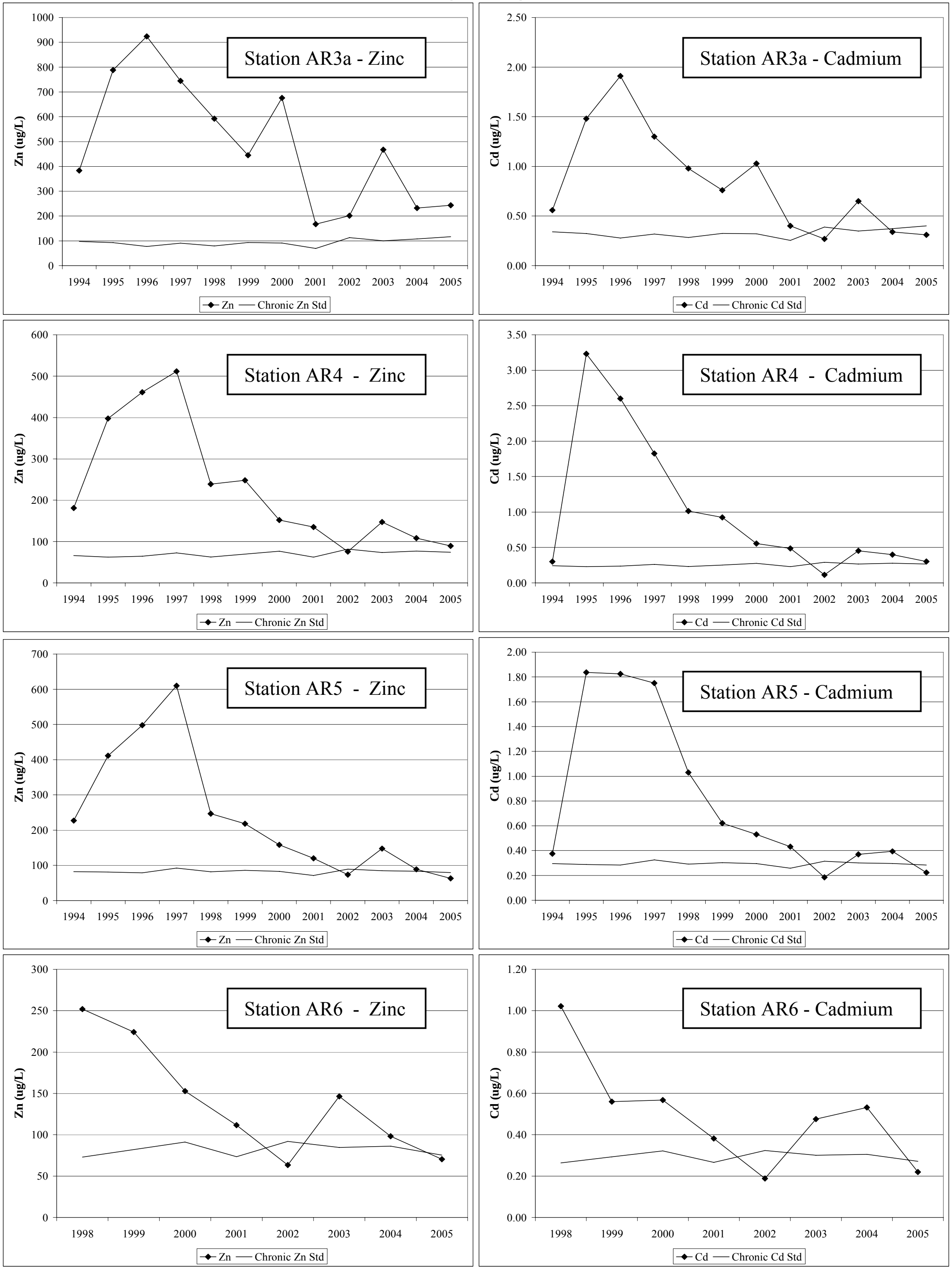
2.3.1.1 Water Quality (Ecological Use)

Tables 2-8 and 2-9 summarize documented exceedances in the 11-mile reach of water quality criteria established by the State of Colorado for the protection of aquatic life.[6] Table 2-8 presents data from June 1981 through February 1992 (referred to as "Period 2"); Table 2-9 presents data from February 1992 through September 2001 (referred to as "Period 3"). As shown in these tables, numerous exceedances of acute and chronic water quality criteria have been documented in Reaches 1, 2, and 3 throughout the 1981-2001 period, during high and low flow conditions, for several metals (cadmium, copper, lead and zinc). Metals contamination data are not available for Reach 4. More recent data through 2005 indicate continued exceedances of chronic thresholds for both zinc and cadmium in Reaches 1 to 3 (Figure 2-2, from CDOW 2006). Reach 4 is expected to have similar water quality to Reach 3. Although there are two tributaries to Reach 4, neither is expected to dramatically influence water quality (SCR 2002, Chapter 3 Matrix Summary p. 6). The water quality data indicate that the Upper Arkansas River in Reaches 1 through 4 exceeds applicable standards for the protection of aquatic life (as determined through Colorado's basic standards for surface waters), and thus represents an injury to aquatic resources.

---

[6] For more information see the Colorado Table Value Standards (TVSs) from Colorado's Regulation No. 31, Basic Standards and Methodologies for Surface Waters (5 CCR 1002-31). TVS levels are not to be exceeded more than once every three years on the average for both acute and chronic concentration thresholds.

Figure 2-2
Mean Measured Dissolved Zinc and Cadmium Concentrations and Hardness-based Chronic Standards in the Arkansas River during Spring Run-off 1994-2005.



Source: CDOW 2006, Tables 22-25.

Table 2-8

Summary Statistics for Dissolved Metals Concentrations(mg/L) in Surface Waters of the 11-mile Reach during Period 2, Table Value Standards (TVS), and Exceedances of TVSs for each Metal during High and Low Flows

Reach	Analyte	Flow	StaCnt	n	Min	Max	Avg	Stdev	Avg Hard	Acute TVS[1]	Chronic TVS[2]	No. > Acute TVS	No. > Chronic TVS	% Exceedence By Flow Period		% Exceedence Across All Flows	
														%>Acute	%>Chronic	%>Acute	%>Chronic
0	Cd	H	3	20	0.00008	0.0032	0.0011	0.001	52.13	NA	NA	NA	NA	NA	NA	NA	NA
		L	4	25	0.00016	0.0025	0.001	0.0006	115.42	NA	NA	NA	NA	NA	NA	NA	NA
	Cu	H	3	16	0.0005	0.008	0.0033	0.0022	52.13	NA	NA	NA	NA	NA	NA	NA	NA
		L	4	19	0.0005	0.007	0.0027	0.002	115.42	NA	NA	NA	NA	NA	NA	NA	NA
	Pb	H	3	16	0.00025	0.0067	0.0025	0.0025	52.13	NA	NA	NA	NA	NA	NA	NA	NA
		L	4	19	0.00025	0.015	0.0031	0.0037	115.42	NA	NA	NA	NA	NA	NA	NA	NA
	Zn	H	3	18	0.005	0.53	0.1473	0.1252	52.13	NA	NA	NA	NA	NA	NA	NA	NA
		L	4	19	0.0087	0.434	0.2217	0.1159	115.42	NA	NA	NA	NA	NA	NA	NA	NA
1	Cd	H	6	35	0.00016	0.0085	0.0027	0.002	72.85	0.0026	0.0018	13	20	37.14	57.14	37.25	60.78
		L	6	16	0.00007	0.011	0.0041	0.003	117.15	0.0044	0.0025	6	11	37.50	68.75		
	Cu	H	6	22	0.0012	0.0289	0.0073	0.0083	72.85	0.01	0.0068	4	7	18.18	31.82	10.53	21.05
		L	7	16	0.0005	0.0125	0.0048	0.0034	117.15	0.0156	0.0103	0	1	0.00	6.25		
	Pb	H	5	20	0.0005	0.0055	0.0013	0.0013	72.85	0.0457	0.0018	0	6	0.00	31.58	0.00	31.25
		L	6	13	0.0005	0.015	0.0031	0.004	117.15	0.0767	0.003	0	4	0.00	30.77		
	Zn	H	6	21	0.005	1.66	0.5841	0.468	72.85	0.0896	0.0901	17	17	80.95	80.95	77.14	77.14
		L	6	14	0.0056	1.7	0.8896	0.6771	117.15	0.134	0.1347	10	10	71.43	71.43		
2	Cd	H	2	8	0.0005	0.003	0.0014	0.0008	62.17	0.0022	0.0016	1	3	12.50	37.50	16.67	33.33
		L	5	10	0.001	0.011	0.003	0.0031	90.69	0.0033	0.0021	2	3	20.00	30.00		
	Cu	H	2	7	0.0019	0.01	0.008	0.0034	62.17	0.0086	0.006	5	5	71.43	71.43	41.18	58.82
		L	5	10	0.0011	0.021	0.0076	0.0064	90.69	0.0123	0.0082	2	5	20.00	50.00		
	Pb	H	2	7	0.0005	0.04	0.0116	0.0133	62.17	0.0384	0.0015	1	5	14.29	71.43	5.88	70.59
		L	5	10	0.0005	0.015	0.0075	0.0055	90.69	0.0581	0.0023	0	7	0.00	70.00		
	Zn	H	3	9	0.016	0.52	0.2468	0.1645	62.17	0.0783	0.0787	7	7	77.78	77.78	78.95	78.95
		L	5	10	0.0045	0.875	0.4817	0.3222	90.69	0.1079	0.1084	8	8	80.00	80.00		

Source: SCR 2002.

Table 2-8 Continued

Reach	Analyte	Flow	StaCnt	n	Min	Max	Avg	Stdev	Avg Hard	Acute TVS[1]	Chronic TVS[2]	No. > Acute TVS	No. > Chronic TVS	% Exceedence By Flow Period		% Exceedence Across All Flows	
3	Cd	H	2	9	0.0009	0.0018	0.0013	0.0003	68.44	0.0025	0.0017	0	1	0.00	11.11	0.00	11.11
		L	2	9	0.0004	0.0027	0.0012	0.0008	95.12	0.0035	0.0022	0	1	0.00	11.11		
	Cu	H	2	9	0.002	0.014	0.0056	0.0038	68.44	0.0094	0.0065	1	2	11.11	22.22	10.53	15.79
		L	2	10	0.0005	0.0334	0.0052	0.01	95.12	0.0128	0.0086	1	1	10.00	10.00		
	Pb	H	2	9	0.00025	0.0017	0.0008	0.0006	68.44	0.0426	0.0017	0	0	0.00	0.00	0.00	10.53
		L	2	10	0.00025	0.01	0.0025	0.0038	95.12	0.0612	0.0024	0	2	0.00	20.00		
	Zn	H	2	12	0.11	0.33	0.2299	0.0649	68.44	0.085	0.0854	12	12	100.00	100.00	85.71	85.71
		L	2	9	0.005	0.53	0.235	0.1739	95.12	0.1123	0.1129	6	6	66.67	66.67		

Note: Only reaches where data are available are shown.

[1] Acute TVSs for a reach and/or period were derived using the State of Colorado's hardness based standards for cadmium, copper, lead and zinc using the mean hardness for the reach and time period that the TVS represents.

[2] Chronic TVSs for a reach and/or period were derived using the State of Colorado's hardness based standards for cadmium, copper, lead and zinc using the mean hardness for the reach and time period that the TVS represents.

NA = Not applicable, Reach 0 is the baseline comparison site and is not being evaluated for injury.

Source: SCR 2002.

Table 2-9
Summary Statistics for Dissolved Metals Concentrations(mg/L) in Surface Waters of the 11-mile Reach during Period 3, Table Value Standards (TVS), and Exceedances of TVSs for each Metal during High and Low Flows

Reach	Analyte	Flow	StaCnt	n	Min	Max	Avg	Stdev	Avg Hard	Acute TVS[1]	Chronic TVS[2]	No. > Acute TVS	No. > Chronic TVS	% Exceedence By Flow Period		% Exceedence Across All Flows	
														%>Acute	%>Chronic	%>Acute	%>Chronic
0	Cd	H	5	49	7.5E-05	0.009	0.0011	0.0017	57.57	NA	NA	NA	NA	NA	NA	NA	NA
		L	6	90	0.00005	0.0027	0.0007	0.0008	100.12	NA	NA	NA	NA	NA	NA	NA	NA
	Cu	H	5	48	0.0005	0.015	0.0033	0.0033	57.57	NA	NA	NA	NA	NA	NA	NA	NA
		L	6	88	0.0005	0.008	0.0021	0.0015	100.12	NA	NA	NA	NA	NA	NA	NA	NA
	Pb	H	5	42	0.0001	0.01	0.0014	0.002	57.57	NA	NA	NA	NA	NA	NA	NA	NA
		L	6	79	0.0001	0.005	0.0011	0.0012	100.12	NA	NA	NA	NA	NA	NA	NA	NA
	Zn	H	5	50	0.01	0.87	0.1089	0.1562	57.57	NA	NA	NA	NA	NA	NA	NA	NA
		L	6	89	0.0035	0.47	0.0974	0.1119	100.12	NA	NA	NA	NA	NA	NA	NA	NA
1	Cd	H	7	125	5.5E-05	0.014	0.0017	0.0025	83.54	0.003	0.002	17	23	13.60	18.40	9.87	16.59
		L	7	98	0.00005	0.012	0.0018	0.002	150.3	0.0058	0.003	5	14	5.10	14.29		
	Cu	H	8	130	0.0005	0.036	0.0052	0.0068	83.54	0.0113	0.0077	20	21	15.38	16.15	8.70	9.13
		L	7	100	0.0005	0.012	0.0029	0.0025	150.3	0.0197	0.0127	0	0	0.00	0.00		
	Pb	H	7	121	0.0001	0.14	0.0037	0.0143	83.54	0.0531	0.0021	1	16	0.83	13.22	0.48	12.92
		L	7	88	0.0001	0.05	0.0031	0.0083	150.3	0.1003	0.0039	0	11	0.00	12.50		
	Zn	H	7	126	0.005	2.15	0.4033	0.4326	83.54	0.1006	0.1011	112	112	88.89	88.89	86.94	86.94
		L	7	96	0.005	2.23	0.559	0.459	150.3	0.1655	0.1664	81	81	84.38	84.38		
2	Cd	H	3	28	0.00015	0.0068	0.0016	0.0017	63.26	0.0023	0.0016	8	8	28.57	28.57	14.55	16.36
		L	3	27	9.5E-05	0.0025	0.0006	0.0006	86.62	0.0032	0.002	0	1	0.00	3.70		
	Cu	H	3	28	0.0005	0.025	0.0068	0.0072	63.26	0.0087	0.0061	7	9	25.00	32.14	14.29	17.86
		L	3	28	0.0005	0.025	0.0035	0.0046	86.62	0.0117	0.0079	1	1	3.57	3.57		
	Pb	H	3	28	0.0001	0.0171	0.0028	0.0042	63.26	0.0391	0.0015	0	11	0.00	39.29	0.00	21.82
		L	3	27	0.0001	0.0025	0.0006	0.0005	86.62	0.0552	0.0022	0	1	0.00	3.70		
	Zn	H	3	29	0.05	1.15	0.3127	0.3146	63.26	0.0795	0.0799	25	25	86.21	86.21	80.70	80.70
		L	3	28	0.005	0.63	0.1874	0.1448	86.62	0.1038	0.1043	21	21	75.00	75.00		

Source: SCR 2002.

Table 2-9 continued.

Reach	Analyte	Flow	StaCnt	n	Min	Max	Avg	Stdev	Avg Hard	Acute TVS[1]	Chronic TVS[2]	No. > Acute TVS	No. > Chronic TVS	% Exceedence By Flow Period		% Exceedence Across All Flows	
3	Cd	H	7	76	0.0002	0.006	0.0018	0.0012	69.5	0.0025	0.0017	4	42	5.26	55.26	2.72	44.22
		L	7	71	0.0001	0.0025	0.0011	0.001	100.79	0.0037	0.0023	0	23	0.00	32.39		
	Cu	H	7	77	0.0005	0.025	0.0131	0.0107	69.5	0.0095	0.0066	39	41	50.65	53.25	37.58	38.93
		L	7	72	0.0005	0.025	0.0077	0.0098	100.79	0.0135	0.009	17	17	23.61	23.61		
	Pb	H	7	72	0.00015	0.027	0.0031	0.0042	69.5	0.0434	0.0017	0	44	0.00	61.11	0.00	34.07
		L	7	63	0.00015	0.045	0.0019	0.0057	100.79	0.0651	0.0025	0	2	0.00	3.17		
	Zn	H	7	84	0.026	1.04	0.2404	0.2475	69.5	0.0861	0.0865	56	56	66.67	66.67	63.35	63.35
		L	7	77	0.005	0.64	0.1719	0.125	100.79	0.118	0.1186	46	46	59.74	59.74		

Note: Only Reaches where data are available are shown.

[1] Acute TVSs for a reach and/or period were derived using the State of Colorado's hardness based standards for cadmium, copper, lead and zinc using the mean hardness for the reach and time period that the TVS represents.

[2] Chronic TVSs for a reach and/or period were derived using the State of Colorado's hardness based standards for cadmium, copper, lead and zinc using the mean hardness for the reach and time period that the TVS represents.

NA = Not applicable, Reach 0 is the baseline comparison site and is not being evaluated for injury.

Source: SCR 2002.

2.3.1.2 Benthic Communities

Benthic community species richness, abundance, and function, as they support Upper Arkansas River Basin ecology, have been injured throughout the 11-mile reach. Results of microcosm experiments show that, as of 2001, aqueous metal levels were sufficient to cause significant mortality to most macroinvertebrate taxa in Reaches 1, 2 and 3 (SCR 2002, Chapter 3 Matrix Summary pp. 31-34). Metal-sensitive taxa present in Reach 0 (reference area) populations are absent in the benthic communities below California Gulch, replaced by more metal tolerant types such as chironomids (midges), and caddisflies (SCR 2002, p. 3-45). For example, large reductions in the abundance of mayflies (particularly the metal-sensitive Heptageniid family) were observed in all three reaches. Sediments collected from Reaches 1 and 3 were found to have a significant, adverse effect on the growth and survivorship of chironomids. In addition, metal levels were greatly elevated in periphyton collected from these reaches (SCR 2002, Chapter 3 Matrix Summary pp. 31-34). Although exposure to metals in water is important for some groups, metals in periphyton, a food source for benthic macroinvertebrates, have been and may continue to be a major route of exposure for many taxa (SCR 2002, p. 3-22).

The data underlying these findings generally were collected between the late 1980s and the late 1990s. Data availability is greatest for Reaches 1 and 3. More limited data are available for Reach 2; benthic macroinvertebrate data are unavailable for Reach 4. However, based on metals levels measured in Reach 4 and results of microcosm experiments, it is likely that benthic communities in that reach are injured (SCR 2002, Chapter 3 Matrix Summary p. 34). Invertebrate studies from 2000-2004 (at least one site each from Reaches 0-3) indicate that sensitive subpopulations (i.e. Heptageniidae) remain depressed in Reaches 1-3, relative to sites above California Gulch. However, the overall number of Ephemeroptera taxa in Reach 1 has increased since 2000 for spring sampling events, and numbers of EPT taxa are similar at all Arkansas River sites.[7] Macroinvertebrate density is more variable from year to year, particularly for spring sampling, at Reaches 1-3 versus sites above California Gulch (Chadwick 2005).

The benthic invertebrate community in the Upper Arkansas River is potentially injured, as indicated by historical and current reductions in abundance and biomass. These potential injuries to the benthic invertebrate community, as shown by decreased populations, also indicate decreased food availability, and therefore reduced population health, for brown trout.

2.3.1.3 Fish

Several lines of evidence confirm that fish have been injured as a result of releases of hazardous substances. According to toxicity studies performed by the Colorado Division of Wildlife, and confirmed by EPA scientists, aqueous metal concentrations have historically been sufficient to cause acute toxic effects to brown trout in Reaches 1-4. Through the 1990s, large reductions in mean abundance (40 to 80 percent reduction, 70 percent average) and biomass (20

---

[7] EPT refers to Ephemeroptera, Plecoptera, and Trichoptera, a taxa richness metric used to measure stream water quality that is included in EPA's rapid bioassessment protocols.

to 80 percent reduction, 50 percent average) were observed in all four Reaches (compared to Reach 0) across all sampling events (SCR 2002, Chapter 3 Summary Matrix). Improvements in brown trout have been noted since 2002 (Chadwick 2005). Data collected during fall sampling events from 2001 to 2004 indicate that abundance and density of brown trout are similar above and below California Gulch. However, length-frequency relationships continue to differ at stations above and below California Gulch. Since the 1990s, the percentage of smaller fish at stations below California Gulch has increased significantly, while the overall total number of fish has also increased.

2.3.1.4 Aquatic-dependent Birds

Aquatic-dependent birds in the Upper Arkansas River feed on macroinvertebrates in their larval or emergent stages, and are therefore exposed to dietary metals concentrations similar to those to which fish are exposed. American dippers (*Cinclus mexicanus*) and tree swallows (*Tachycineta bicolor*) in the 11-mile reach were studied as suitable indicator avian species to evaluate potential injuries associated with metals exposure. American dippers feed primarily on insects by diving into a stream, walking along the bottom and scavenging invertebrates from rocks and other substrate. Tree swallows forage on emerging aquatic insects, and nest in cavities along the Arkansas River (SCR 2002, pp. 2-15, 2-16 and 2-25). Sampling for the bird studies was conducted in Reaches 2 and 3.

Tree swallow nest success in Reach 2 was lower than nationwide averages, significantly less than nest success in Reach 0, and the lowest of any colony sampled on the Arkansas River. Average blood lead in American dippers from Reach 3 exceeded literature-based benchmarks and was significantly higher than in Reach 0. ALAD in American dippers and tree swallows was significantly reduced (by 67% for American dippers and 39% for tree swallows in Reach 3, and by less than 50% for both species in Reach 2) compared to study references (from the Poudre River) (SCR 2002, pp. 3-36, 3-37, 3-47 and 3-48).[8]

The data underlying these findings generally were collected during the late 1990s and into early 2000. Although dipper and swallow data were not collected from Reaches 1 and 4, injuries likely are present. Exposure in Reach 4 is expected to be similar to Reaches 3 and 5. Invertebrate and dipper blood samples from Reach 5 have similar metal concentrations as Reach 3 and cadmium, copper, lead and zinc in dipper blood from Reach 5 are in the same range as Reach 3. Liver cadmium and lead increase slightly from Reach 3 to Reach 5. With respect to Reach 1, metals concentrations are elevated in water, invertebrates, and sediments compared to Reach 0 and most downstream reaches. Because dipper and swallow injuries were documented in downstream reaches where exposure concentrations were lower, and because birds move between reaches, injuries are expected in Reach 1 (SCR 2002, pp. 3-25 and 3-52).

---

[8] Aminolevulinic acid dehytratase (ALAD) is an enzyme involved in formation of hemoglobin; ALAD suppression (by more than 50%) is defined by DOI natural resource damage regulations to be an injury. 11-mile reach tree swallow and American Dipper ALAD data were compared to Reach 0, but were not found to be significantly different. This may be due to low-level lead exposure in Reach 0 (SCR 2002, p. 3-48).

2.3.1.5 Human Use

Surface water from the 11-mile reach has been used in the post-1980 period for irrigation purposes; potential injuries associated with the use of metals-contaminated irrigation water are addressed in Chapter 3. Some water right holders abandoned diversion points along California Gulch and downstream of its confluence with the Arkansas River due to releases of hazardous substances from the NPL site. Access limitations have historically limited recreational opportunities (e.g., fishing, boating) in the 11-mile reach, although increased accessibility in recent years may increase the potential for such uses. The preliminary estimate of surface water damages is based on costs of restoration projects rather than value of lost agricultural, recreational and other human use services. The Trustees may undertake additional analysis of such lost services in the future.

2.3.2 Eleven Mile Reach Preliminary Estimate of Damages

For PED purposes, the potential magnitude of damages is assessed through development of preliminary estimates of the cost of restoration projects potentially appropriate to offset the resource service injuries observed in the 11-mile reach. Restoration project costs are a measure of natural resource damages required by relevant regulations.[9] In this case, as noted above, readily available information indicates that contamination in the 11-mile reach has resulted in exceedances of table value standards, reduced density and biomass of fish, and injuries to macroinvertebrates and migratory birds. Instream habitat enhancement and bank stabilization projects, within the Arkansas River and other streams, can increase the river's capacity to support such communities by reducing river bank erosion, improving channel configuration and increasing the amount, diversity, and quality of aquatic and riparian habitat, thereby providing benefits similar in type to services lost. Benefits include increased populations of uncontaminated benthic invertebrates and healthy populations of fish and migratory birds that feed on them.[10] Such projects have been undertaken in many Colorado streams, are compatible with natural river processes, have a high likelihood of success, and are reasonable in cost.

Several pieces of information are needed to develop a preliminary estimate of the magnitude of restoration costs required to offset documented injuries. Specifically, judgments must be made about the severity and duration of injury, the timing, degree and duration of ecological service enhancement expected from restoration, and the unit costs of restoration. With such inputs, habitat equivalency analysis (HEA) can be applied to estimate project scale, which in turn can be used to estimate total project costs.[11]

---

[9] See 43 CFR 11.81 – 82.

[10] Project size, location, duration and/or other parameters can be adjusted as needed to reasonably match the value of restored and injured services.

[11] Habitat equivalency analysis, first introduced by Unsworth and Bishop ("Assessing Natural Resource Damages using Environmental Annuities" *Ecological Economics*, 11: 35-41, 1994), provides a quantitative approach for determining the scale of appropriate compensatory actions that relies on discounting to balance past and future service losses and gains. The HEA methodology is widely used in natural resource damage assessment.

Consistent with the objectives of this PED, the Trustees have implemented two HEA approaches to provide a robust assessment of the approximate magnitude of potential restoration scale (and cost). The first (HEA Injury Approach 1) derives quantitative loss estimates through evaluation of direct injury to brown trout as well as behavioral avoidance of otherwise suitable habitat. The second (HEA Injury Approach 2) is derived from the frequency and magnitude of exceedences of TVSs, using data provided in the SCR. More detailed analysis and/or alternative approaches may be undertaken as part of future assessment activities.

2.3.2.1 HEA Injury Approach 1 - Direct Injury to Brown Trout and Behavioral Avoidance

The aquatic HEA for the first injury approach included two components: direct injury to brown trout (based on brown trout fry mortality, brown trout population reduction, and mayfly reduction), and injury to brown trout through behavioral avoidance of otherwise suitable habitat. Review of readily available water quality data provided evidence of aquatic injury throughout the 11-mile reach.

2.3.2.2 Service Loss Based on Direct Injuries to Brown Trout

For this component of the HEA the 11-mile reach ecological service levels were based on a combined metric of predicted brown trout fry mortality, reductions in brown trout density compared to reference (baseline) locations, and reductions in mayfly abundance compared to reference (baseline) locations. These metrics were combined as follows: Aquatic trout fry mortality was assigned 50% of total aquatic services. The remaining 50% of aquatic services were comprised of mayfly abundance, which was given a 33% weighting factor, and brown trout density, which was given a 67% weighting factor.[12]

Trout fry mortality is dependent on water quality, particularly during spring/early summer high-flow conditions (May-July) when metals concentrations in the Arkansas tend to be highest. Available water quality data for the Arkansas River for May-July from 1981 to 2005 were used to estimate annual trout fry mortality based on acute toxicity tests for brown trout fry exposed to zinc or cadmium (CDOW, 2006). The maximum predicted mortality for zinc or cadmium was used as the estimate of trout fry mortality for a particular year because the maximum mortality for the year is what determines the proportion of the trout fry population able to survive and potentially develop into adult brown trout. For example, in a year where the concentration of zinc or cadmium is high enough at some point during the spring to kill all of the trout fry (100% predicted mortality), there would be no recruitment of trout into the adult population at that location. Calculations of predicted trout fry mortality were based on equations developed by Steve Brinkman (CDOW, 2006). Figure 2-3 shows predicted trout fry mortality as a function of the zinc hazard quotient, based on the equation:

$$\text{Mortality fraction} = 0.022 + (0.978 \times \text{NORMSDIST}(-1.567 + 1.462 \times (\text{LN}(\text{HQ})))) \qquad (1)$$

---

[12] Total aquatic services therefore were calculated as follows: 0.5 (trout fry mortality) + 0.5 [0.33 (mayfly abundance) + 0.67 (brown trout density)].

The mortality fraction is the proportion of the trout fry population predicted to be killed at a given concentration of zinc and hardness. This is the value used as an input to the service loss equations.

The hazard quotient (HQ) is defined using the equation:

$$\text{Zn HQ} = C(h)/LC_{50}(h) \qquad (2)$$

where C(h) is measured Zn concentration at hardness h, and $LC_{50}(h)$ is the estimated LC_{50} at hardness h. In general, a hazard quotient is defined as the concentration of a substance, divided by a toxicity threshold for that substance.

The estimated LC_{50} is defined using the equation for the 96 hr Zn:

$$LC_{50} = e^{(0.9634 \times (\ln(\text{hardness})) + 2.679)} \qquad (3)$$

For cadmium, predicted trout fry mortality is defined using the equation:

$$\text{Mortality fraction} = 1 + e^{(-2.4011 \times \text{HQ} - 5.067)} \qquad (4)$$

where the HQ is defined using the equation:

$$\text{Cd HQ} = C(h)/\text{Acute Cd threshold } (h) \qquad (5)$$

where C(h) is measured Cd concentration at hardness h, and the acute Cd threshold is defined using the equation:

$$\text{Acute Cd threshold} = e^{(1.258 \times (\ln(\text{hardness})) - 4.692)} \qquad (6)$$

Trout fry mortality levels were averaged for the periods 1993-1999 and 2000-2005 to reduce interannual variability and create an averaged or “smoothed” input to the service loss equations. Separate averages were calculated for 1993 – 1999 and 2000 – 2005 so that the service loss calculations would reflect potential changes in brown trout service loss resulting from the ongoing remedial work. For the period 1981-1992 (which corresponds to the time before extensive remediation efforts began), water quality data were more limited. An examination of the available data revealed that concentrations of zinc and cadmium during pre-remediation years from 1981-1992 appeared to be approximately 50% higher than concentrations after 1993. Therefore, concentrations of zinc and cadmium from available water quality data from 1994-1998 were increased by 50% to estimate trout fry mortality for the period from 1981-1992. For future service loss, ongoing remedial work was assumed to result in a 20% improvement in water quality for the period from 2006-2011 and an additional 10% improvement in water quality for the period from 2012-2107.

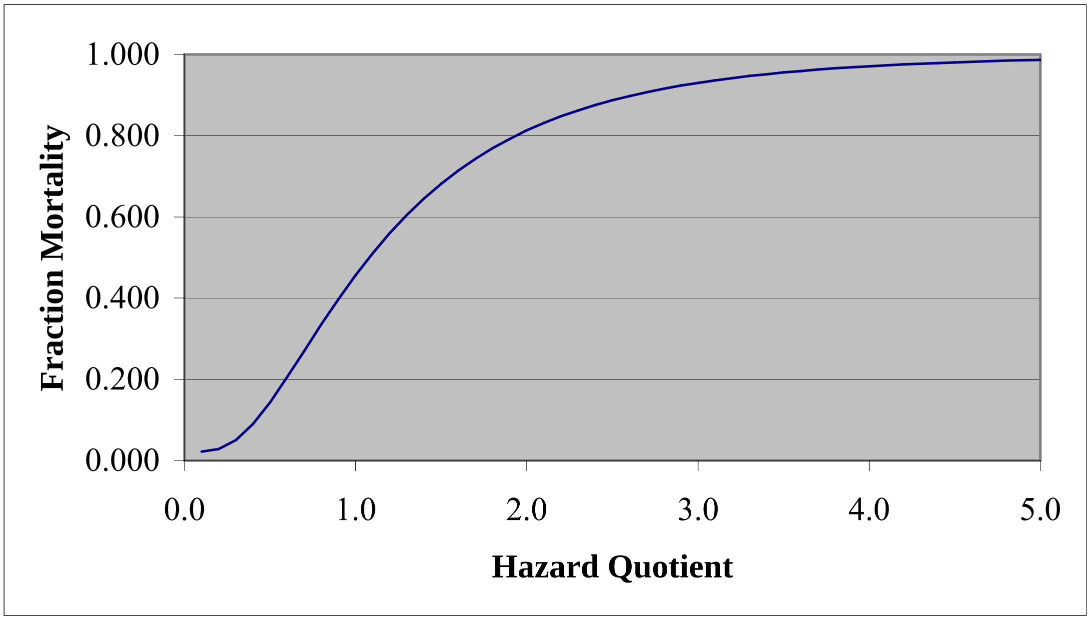


Figure 2-3. Relationship between brown trout fry mortality and hazard quotient for zinc.

Source: Steve Brinkman, Colorado DOW, personal communication

For the biological metrics, service loss was estimated based on reductions in mayfly abundance and adult brown trout density compared to reference conditions just upstream of the confluence with California Gulch. Data for mayfly abundance are from Chadwick Ecological Consultants (2003, 2004). Data for adult brown trout density are from Chadwick Ecological Consultants (2003, 2004) and additional unpublished data from the CDOW. Again because of interannual variability, rounded averages were used for the periods 1993-1999 and 2000-2005 as inputs into the service loss equations. A similar 50% increase in the biology service loss function for the period 1981-1992 was applied to match the higher concentrations of zinc and cadmium during that period. For the period from 2006-2011 and for the period 2012-2107, biological recovery was assumed to improve at the same rate as the estimated water quality improvements.

The maximum calculated service loss for the 11-mile reach was 90% for the section closest to California Gulch (Reach 2 as defined in the SCR), during the period from 1981-1992. Service loss declined over time and with distance downstream. The lowest service loss for the downstream portion of the 11-mile reach (Reach 4) in 2107 was 22%.

2.3.2.3 Service Loss Based on Brown Trout Behavioral Avoidance

Brown trout behavioral avoidance injury was based on studies demonstrating that brown trout will avoid Zn when concentrations exceed certain threshold levels. Because behavioral avoidance may reduce the numbers of trout that occupy otherwise viable habitat in the Arkansas River, we assumed that the ecological consequence of avoidance responses is to reduce the carrying capacity of the available habitat for trout. An avoidance threshold of 50 µg Zn/L was used based on Woodward et al. (1997) with the assumption of a constant level of 50% avoidance when concentrations exceed the threshold. The degree of ecological impact was estimated to be between 1% and 10% of carrying capacity. To account for this range, three scenarios of reduced trout carrying capacity were modeled: 1%, 5%, 10%. Applying the 50% avoidance effect to these scenarios results in a total avoidance service loss range of 0.5%, 2.5%, and 5% service loss (calculated by multiplying the 50% trout avoidance incidence by the degree of reduced trout carrying capacity). Calculations were limited to the months of September and October when brown trout would move from tributaries to the main stem of the Arkansas River.

This analysis indicated that avoidance service losses occurred during the period 1981-2107 for Reach 2 and Reach 3 (as defined by the SCR). For Reach 4, avoidance service losses occurred for the period 1981-2004 only.

2.3.2.4 Results of HEA Injury Approach 1 Calculations

The service loss calculations discussed above were used as inputs into a HEA model with a base year of 2006 and a 3% discount rate to calculate the total discounted service acre-years (DSAYs) lost as a result of the aquatic injuries. A summary of service loss values for the different time periods and segments of the 11-mile reach is provided in Table 2-10. Total DSAYs for injuries in the 11-mile reach ranged from 2,950 – 3,200 depending on the assumptions used for behavioral avoidance service loss (Table 2-11).

Table 2-10

Estimated Ecological Service Losses in the 11-Mile Reach of the Arkansas River

		Percent Service Loss		
Area	**Acres**	**1981 - 1992**	**1993 - 1999**	**2000 – 2005**[a]
Reach 1	10.5	95%	70%	35%
Reach 2	36.8	69%	52%	23%
Reaches 3 and 4	57.3	84%	57%	38%

a. For 2006 – 2011, aquatic services were assumed to improve by 20%; For 2012 – 2107, aquatic services were assumed to improve by an additional 10%.

Table 2-11

Quantified Injuries in the 11-Mile Reach of the Arkansas River

		DSAYs[a]		
Area	**Acres**	**Direct Injury**	**Behavioral Avoidance**	**Total (rounded)**
11-mile reach	104.6	2,920	28-277	2,950-3,200

a. DSAY = discounted service acre-year.

2.3.2.5 HEA Injury Approach 2 - Exceedances of TVS Standards

The second HEA injury quantification approach was based on the frequency and magnitude of water quality exceedances of TVSs. The data for each reach for Periods 2 and 3, as well as chronic and acute thresholds based on average measured hardness, were obtained from the SCR.[13] For Period 4, the CDOW report, which includes chronic thresholds, was used to estimate injury. For future service loss, ongoing remedial work was assumed to result in a 20% improvement in water quality for the period from 2006-2011 and an additional 10% improvement in water quality for the period from 2012-2107.

To quantify injury, the frequency of exceedance and hazard quotient was calculated for each analyte, reach, and period based on the appropriate hardness-based TVS. For reaches with exceedances of a single contaminant, service losses due to acute injuries were assigned using the following algorithm in combination with the values in Table 2-12:

Acute Injury = (Frequency of acute TVS exceedance)*(Service Loss for average HQ) (7)

We assign 50 percent service loss for acute threshold exceedances with an average HQ of between 1 and 2, to reflect the fact that acute TVSs are based on LC50s for sensitive aquatic species, of which there are several in the Upper Arkansas River. This value is generally consistent with the expectation of a serious impact to the aquatic system. Service loss is increased to 75 percent when the average acute HQ is between 2 and 3, to 90 percent when the average acute HQ is between 3 and 5, and to 100 percent when the average acute HQ is greater than 5, which reflects the increasing loss as magnitude of exceedance increases. Service loss estimates are multiplied by the percent of samples which exceed the acute TVS to adjust for frequency of exceedance. Because the frequency of exceedance can reflect spatial and or temporal variability within a reach, we adopt the conservative approach of multiplying service loss by frequency. In fact, low exceedance frequencies can be associated with high levels of service loss, because of the substantial long-lasting effects that can be associated with even a single exceedance.

Table 2-12
Relationship Between Acute Hazard Quotient and Ecological Service Loss

Acute HQ	Ecological Service Loss
HQ < 1	0
1 ≤ HQ 2	50%
2 ≤ HQ <3	75%
3 ≤ HQ < 5	90%
5 ≤ HQ	100%

In reaches where there are exceedances of multiple contaminants, we follow the same process, but sum the HQs for the different metals based on relative frequency. Metals are assumed to have an additive toxic effect in biota. We assume that the exceedances of different metals are correlated within samples (i.e. that samples with an acute TVS exceedance for one metal are more likely to have acute TVS exceedances for other metals) so the HQ is summed for the metals present in that percent of the samples.[14] This is a conservative calculation which

---

[13] As a visual demonstration of the exceedances, Appendix 1 presents the water quality results and average-hardness-corrected chronic and acute thresholds for Period 2. These present the same data as Tables 2-8 and 2-14.

[14] For illustrative purposes, consider a reach which has 4% Cd exceedance with an average HQ of 1.2 and 9% Zn exceedance with an average HQ of 2.5. We assume that in 4% of the samples both Cd and Zn acute TVS are exceeded, with an average HQ of 3.7 (sum of Zn and Cd HQs), and that in 5% of samples (9% - 4%) only the Zn acute TVS is exceeded, with an average HQ of 2.5.

assumes that the aquatic injury occurs in the minimum number of samples. The percentage of samples associated with each HQ are multiplied by the appropriate service loss from Table 2-12 and summed to give an acute service loss for the reach and period.

The effects of chronic exceedances of the TVS are also considered. Chronic effects may manifest as delayed growth and reproduction, low recruitment, or other population-dampening effects. Exceedances of the chronic TVS for a particular metal (an HQ ≥ 1) are estimated to cause a 25 percent service loss. This loss is calculated for the percentage of samples in a reach that are above chronic thresholds but below acute thresholds (an adjusted chronic exceedance frequency). As with the acute injury, threshold exceedances for different metals are presumed to be correlated. Therefore, since the service loss for all chronic HQs above 1, the highest percentage of samples with an adjusted chronic exceedance is multiplied by the 25 percent service loss to give a chronic service loss for the reach and period.

Total service loss for each reach and period is calculated as the sum of acute and chronic service losses. For future service loss, ongoing remedial work was assumed to result in a 20% improvement in water quality for the period from 2006-2011 and an additional 10% improvement in water quality for the period from 2012-2107. Service levels are likewise presumed to increase by 20% from 2006-2011 and by an additional 10% from 2012-2107, or until 100% service levels are obtained.

2.3.2.6 Results of HEA Injury Approach 2 Calculations

The service loss calculations discussed above were used as inputs into a HEA model with a base year of 2006 and a 3% discount rate to calculate the total discounted service acre-years (DSAYs) lost as a result of the aquatic injuries. A summary of service loss values for the different time periods and segments of the 11-mile reach (Reaches 1 – 4) is provided in Table 2-13. Total DSAYs for injuries for this area are 3,800 DSAYs, including both chronic and acute injuries (Table 2-13).

Table 2-13

Approach 2: Estimated Ecological Service Losses in the 11-Mile Reach of the Arkansas River

Area	**Percent Service Loss**				
	Acres	**1981 - 1992**	**1993 - 1999**	**2000 – 2005[a]**	**DSAYs (rounded)**
Reach 1	10.5	85%	82%	62%	500
Reach 2	36.8	92%	80%	60%	1,800
Reaches 3 and 4	57.3	69%	67%	25%	1,500
Total	**104.6**				**3,800**

a. Services improve linearly between 2000 – 2005 to the listed service loss. For 2006 – 2011, aquatic services were assumed to improve by 20%; For 2012 – 2107, aquatic services were assumed to improve by an additional 10%.

2.3.2.7 HEA Restoration Calculations

With respect to restoration project benefits, the Trustees have investigated opportunities for physical habitat improvement within the 11-mile reach. In some areas, major restoration (including habitat and geomorphology improvements) likely could substantially improve the river's capacity to support ecological communities (potentially on the order of a 70 percent increase relative to baseline ecological service levels). In other areas, minor reconstruction (including habitat improvements only) likely could result in more moderate benefits (potentially on the order of a 45 percent increase relative to baseline). Finally, some areas would not benefit from instream habitat enhancement and bank stabilization projects. Throughout the entire 11-mile reach, preliminary damage calculations assume a 40 percent increase in service levels relative to baseline capacity.[15] While the timing of restoration project implementation is unknown, preliminary calculations assume project initiation in 2008, with full benefits achieved in 2013 (assuming linear improvement in intervening years), and continuing for 100 years.[16]

HEA calculations using the inputs identified above, in combination with the standard annual discount rate of three percent used in natural resource damage analyses, indicate that 11-mile reach instream habitat enhancement and bank stabilization projects are not sufficient to offset 11-mile reach injuries. More specifically, in present value (2006) terms, restoration benefits total approximately 1,170 DSAYs: roughly forty to forty-five percent of the amount needed to offset injuries in the 11-mile reach. This result is not surprising given the basic facts of the situation: from a natural resource damage perspective, future restoration benefits need to offset substantial past loss over the previous 25 years (since 1981), as well as some amount of future loss. Natural resource damage regulations require the use of discounting to account for differences in the timing of injuries and restoration. As a result, past losses are compounded at a three percent annual rate, while future losses and gains are discounted at the same rate. These factors combine to result in a substantial restoration requirement needed to offset natural resource injuries documented in the past and continuing over multiple decades. As previously stated, the purpose of this simplified, preliminary analysis is to develop an initial estimate of the approximate magnitude of damages associated with injuries to the 11-mile reach. The analysis presented above clearly simplifies complex processes and issues. While there are uncertainties inherent in the choice of input variables and values, reasonable variation in these inputs is unlikely to alter the basic conclusion: 11-mile reach instream restoration, while beneficial, is insufficient to fully offset contamination-related ecological service degradation in this resource.[17] The magnitude of shortfall is potentially on the order of sixty percent of the total requirement.

While a variety of supplemental restoration approaches could be used to address this shortfall, detailed evaluation of the benefits and costs of generating resource service improvements at other streams and/or tributaries in the region is beyond the scope of this document. For PED purposes the Trustees make the simplifying assumption that sufficient

---

[15] The preliminary estimates of potential service improvements discussed in this paragraph assume that water quality and other conditions are sufficient to realize expected gains in ecological productivity.

[16] Although project benefits may accrue beyond 100 years, due to the effects of discounting the present value of benefits realized beyond 100 years is small. It is also possible that project benefits will be realized for a period less than 100 years.

[17] The Trustees have not committed to specific natural resource restoration projects at this time. While instream restoration in the 11-mile reach conceptually makes sense to offset injuries sustained to it, and is a reasonable focus of PED analyses, additional evaluation of 11-mile reach and other potential projects will occur before final project decisions are made.

additional instream restoration projects similar in type and per-acre cost to 11-mile reach instream restoration are available. While restoration benefits and costs are likely to vary due to site-specific considerations, such a simplified approach provides a reasonable, general approximation of total restoration project costs. Cost estimates may be updated in the future to reflect additional information about potential restoration benefits and costs associated with other streams, as such information becomes available.

A conceptual, planning-level estimate of the expected costs of 11-mile reach restoration is provided in Table 2-14 below. Estimates of the type and number of treatments are based on Trustee reconnaissance of the 11-mile reach. Unit cost estimates reflect the underlying cost of machinery, labor and raw materials needed to place treatments, based on Trustee experience with similar restoration projects at other sites. Inclusion of a 35 percent materials cost contingency is reasonable at this preliminary costing stage. Project design and management estimates are consistent with EPA experience at the California Gulch Superfund Site. Because project benefits are assumed to accrue over a 100 year period, a modest annual monitoring and maintenance budget of $15,000 (less than 0.5% of project design, management and construction) is included throughout the period to help ensure continued, maximized project performance over time. During the five-year construction phase, an annual oversight budget of $15,000 is included.

Table 2-14

Preliminary Estimate of 11-Mile Reach Restoration Project Costs

Treatment	Unit Cost	Number of Units	Total Cost
Boulder cluster	$768	404	$310,272
Boulder vane	$836	183	$152,988
Cross vane	$2,954	15	$44,310
Half cross vane	$1,477	13	$19,201
Excavate pool	$1,056	149	$157,344
J-hook	$2,485	77	$191,345
Log vane	$1,297	19	$24,643
Random boulder	$209	104	$21,736
Root wad	$823	55	$45,265
Single boulder deflector	$318	100	$31,800
Riparian bench	$3.15/sq ft	14,890 sq ft	$46,904
Willow planting	$1.72/sq ft	1,178 sq ft	$2,026
Cobble placement	$70/cu yd	13,086 cu yd	$916,020
Materials Cost Subtotal			$1,963,854
Materials Cost Contingency (35%)			$687,349
Total Materials Cost			$2,651,203
Project Design (8%)			$212,096
Project Management (5%)			$132,560
Construction Management (6%)			$159,072
Total Design and Management Cost			$503,728
Present Value (3% interest rate) of Annual Monitoring & Maintenance Expense ($15,000 annually throughout assumed 100 year project benefit period)			$473,984
Present Value (3% interest rate) of Construction Oversight by State ($15,000 annually through 5 year construction beginning in 2008)			$66,695
Total Project Cost			$3,695,610

As indicated in Table 2-14, 11-mile reach restoration is expected to cost approximately $3.7 million. Based on a comparison of service loss and projected service gains, this project provides between 37 and 40 percent (depending on the avoidance scenario used) of the estimated ecological compensation required to fully offset contamination-related ecological service degradation in this resource, as calculated in Approach 1. Additional projects are assumed to have a similar scope and cost to the 11-mile reach restoration. This implies a total restoration cost on the order of $9.3 to $10.1 million to fully offset post-1981 natural resource service impairment in the 11-mile reach. Using Approach 2, the 11-mile reach restoration would provide approximately 31 percent of the estimated ecological compensation required to fully offset contamination-related ecological service degradation in this resource. Given the same calculations as with Approach 1, this results in a total restoration cost on the order of $12.1 million for Approach 2.

2.4 UPPER ARKANSAS RIVER: DOWNSTREAM OF 11-MILE REACH

The "downstream" section of the Upper Arkansas River, defined as the 500-year floodplain from downstream of the 11-mile reach at Two Bit Gulch to, and including, Pueblo Reservoir. As shown in Figure 2-4, six sub-reaches are defined within the downstream section:

a) Reach 5 - Confluence of Two-Bit Gulch to confluence of Lake Creek (2.2 RM); 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.

b) Reach 6 - Lake Creek to junction of Chalk Creek at the upstream extent of Browns Canyon (29.5 RM); 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.

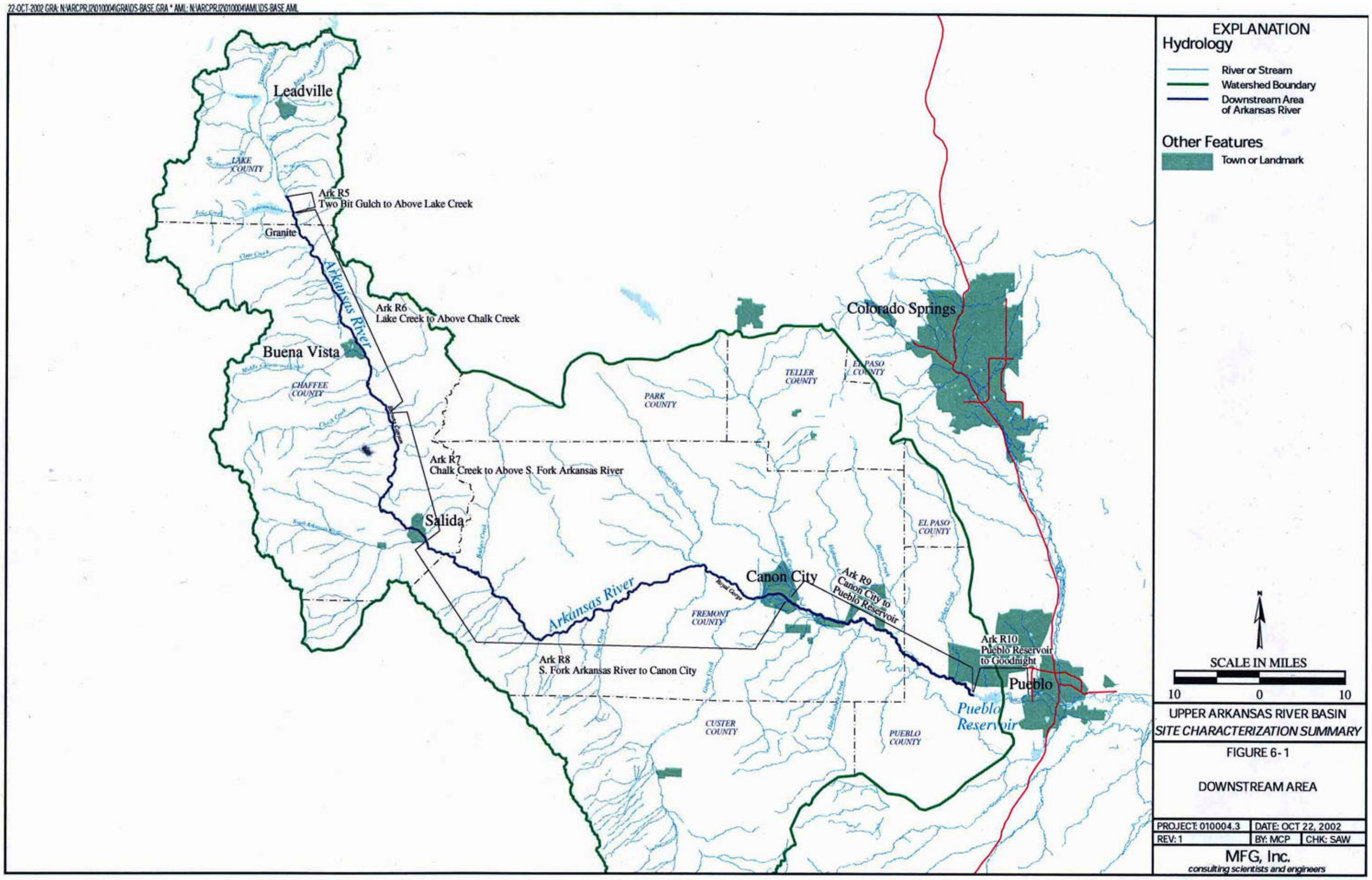
c) Reach 7 - Chalk Creek to the junction of the South Fork Arkansas River (21.2 RM); The upstream limit is determined by the geomorphic control of Browns Canyon, and the downstream limit is determined by the discharge contribution of South Fork Arkansas River. The river is in a deep canyon (Browns Canyon) 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.

d) Reach 8 - South Fork Arkansas River to Cañon City (58.1 RM); 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.

e) Reach 9 - Cañon City to upstream end of Pueblo Reservoir (29 RM); This reach is characterized by an open valley with a floodplain. The change from canyon to open valley at Cañon City is dramatic.

f) Reach 10 - Pueblo Reservoir, including the Arkansas River downstream of the reservoir to approximately 1.5 miles downstream of Pueblo Dam (8.1 RM) (SCR 2002, p. 6-9).

Figure 2-4



Source: SCR 2002.

2.4.1 Evidence of Injury

2.4.1.1 Water Quality (Ecological Use)

Tables 2-15 and 2-16 summarize documented exceedances downstream of the 11-mile reach of water quality criteria established by the State of Colorado for the protection of aquatic life. Table 2-15 presents data from June 1981 through February 1992 (referred to as "Period 2"); Table 2-16 presents data from February 1992 through September 2001 (referred to as "Period 3") As shown in these tables, numerous exceedances of acute and chronic water quality criteria have been documented in Reaches 6, 7 and 8 throughout the 1981-2001 period, during high and low flow conditions, for several metals (cadmium, copper, lead and zinc). Required data were not available for Reach 5 prior to 1992, but were available post-2002 and indicate threshold exceedances during that timeframe. Exceedances in Reaches 9 and 10 have been documented in the pre-1992 period, but not subsequently.

Based on the mean concentration 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 1-4 (SCR 2002, p. 6-13). Citing information from various investigators, the SCR states the following:

> [Ortiz et al. 1988] reported that drainage from the 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 conclusions of Ortiz et al. (1988). 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) (SCR 2002, p. 6-14).

Table 2-15
Summary Statistics for Dissolved Metals Concentrations(mg/L) in Surface Waters of the Downstream Area during Period 2, Table Value Standards (TVS), and Exceedances 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

Source: SCR 2002.

Table 2-15 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.

Source: SCR 2002.

Table 2-16
Summary Statistics for Dissolved Metals Concentrations(mg/L) in Surface Waters of the Downstream Area during Period 3, Table Value Standards (TVS), and Exceedances 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

Source: SCR 2002.

Table 2-16 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

Source: SCR 2002.

2.4.1.2 Benthic Communities

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. Because water quality in Reach 5 is similar to that observed in Reach 3 (where injury was observed) and because metals 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 (SCR 2002, Chapter 6 Matrix Summary p. 23).

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 generally are similar to those values measured in Reach 0. Zinc levels in periphyton measured in Reach 6 in 1995 and 1996 were also within the range of values observed in Reach 0. Results of the 1998 microcosm experiments indicate that metals concentrations similar to those found in Reach 6 had no effect on community composition, species richness of mayflies, or abundance of metal-sensitive species (SCR 2002, Chapter 6 Matrix Summary p. 24).

Few data are available for Reaches 7, 8, 9 and 10. The 1998 microcosm experiments indicate that metals concentrations similar to those found in 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 these reaches (SCR 2002, Chapter 6 Matrix Summary p. 26).

2.4.1.3 Fish

Although data are generally limited prior to remediation of the Leadville Mine Drainage Tunnel and California Gulch, the SCR indicates that some research conducted in the downstream areas indicated impairments to fish populations:

> Historically, there was an absence of large brown trout downstream of the 11-mile reach, 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 (SCR 2002, p. 6-32).

More recent data indicate that 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 metals injuries (SCR 2002, Chapter 6 Matrix Summary, p. 27). Although the brown trout population in Reach 6 was characterized by reduced overall abundance but somewhat larger individuals compared to the reference reach, evaluating the importance of metals relative to other habitat features is difficult 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 (SCR 2002, Chapter 6 Matrix Summary, p. 28).

The significant improvement in biomass and abundance of brown trout in Reach 8 and similarity to the reference reach suggests that there may not be current injury to brown trout in this reach. Conditions within Reach 7 (e.g., water quality) are essentially the same as Reach 8, and improve in the downstream reaches (SCR 2002, Chapter 6 Matrix Summary, p. 29). The SCR notes, however, that natural longitudinal changes in the physicochemical and habitat characteristics of the Arkansas River complicate comparisons with upstream reaches (SCR 2002, Chapter 6 Matrix Summary, p. 30). The appropriateness of Reach 0 as a reference for downstream aquatic populations diminishes as the distance from that Reach increases and the river evolves into a river that is, among other things, at a lower altitude, warmer, larger and slower.

2.4.1.4 Migratory Birds

The USFWS sampled blood and livers from American dippers at 12 sites downstream of the 11-mile reach between 1995 and 1998. Blood and liver samples were analyzed for metals, and blood was also analyzed for ALAD. Citing relevant studies (Archuleta et al. 2000 and Custer et al. 2003 in press), the SCR states that injury is occurring to American dippers from lead exposure in Reaches 5 and 6 (between Granite and Balltown). ALAD activity is suppressed in American dippers by approximately 50 percent compared to the reference area. At sites downstream of Reaches 5 and 6, ALAD activity is suppressed in American dippers (25-48 percent compared to a reference area) indicating lead exposure is occurring, but below injury thresholds. For tree swallows, ALAD activity is suppressed in the downstream area (1-35 percent compared to a reference area), again indicating lead exposure, but below injury thresholds. 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 (SCR 2002, p. 6-37).

2.4.1.5 Human Use

The Arkansas River is an important recreational resource. The Arkansas River Outfitters Association describes its rafting appeal as follows:

> The Arkansas River is the most popular rafting river in America! From its headwaters at the historic mining area around Leadville, Colorado; through scenic mountain towns like Buena Vista and Salida, Colorado; to the breathtaking Royal Gorge and beyond ... Colorado's Arkansas River has some of the nation's most exciting whitewater and amazing mountain views. From highly technical Class IV & V rapids (the Numbers near Granite & Buena Vista, Colorado and The Royal Gorge near Cañon City), to relaxing & scenic calm-water float trips, the Arkansas has it all (http://www.aroa.org/arkansas-river.htm accessed 13 January 2005).

Fishing is also popular. The website flyfishingconnection.com describes the River as follows:

> The most heavily fished and popular section of the Arkansas is from Buena Vista to Cañon City. This section of the river, which is approximately 75 miles long, has beautiful pocket water, pools, riffles and runs holding an excellent population of browns and a good population of rainbows. The river averages from 70-100 feet wide in most areas with boulders, bends and deep seams creating superb habitat for the trout that reside here. Trout in the Arkansas average approximately 13-15 inches although fish to 18 inches and better are not that uncommon (http://www.flyfishingconnection.com/arkansas.html, accessed 13 January 2005).

Readily available information is not sufficient to evaluate the extent to which these and other recreational uses of the downstream area have been diminished by metals contamination since 1981. The Trustees may undertake future analyses to more fully examine potential recreational use injuries.

2.4.2 Downstream of 11-Mile Reach Preliminary Estimate of Damages

For PED purposes, the potential magnitude of damages is assessed through HEA-based development of preliminary estimates of the cost of restoration projects potentially appropriate to offset the resource service degradation observed downstream of the 11-mile reach. Consistent with the 11-mile reach analysis, the Trustees have implemented two HEA approaches to provide a robust assessment of the approximate magnitude of potential restoration scale (and cost). The first (HEA Injury Approach 1) derives quantitative loss estimates through evaluation of direct injury to brown trout as well as behavioral avoidance of otherwise suitable habitat. The second (HEA Injury Approach 2) is derived from the frequency and magnitude of exceedances of TVS standards, using data provided in the SCR. More detailed analysis and/or alternative approaches may be undertaken as part of future assessment activities.

2.4.2.1. HEA Approach 1 - Direct Injury to Brown Trout and Behavioral Avoidance

The aquatic HEA in the first approach included two components: direct injury to brown trout (based on brown trout fry mortality), and injury to brown trout through behavioral avoidance of otherwise suitable habitat. Review of readily available water quality data provided evidence of aquatic injury in the Arkansas River at least as far downstream as the USGS-Shavano sampling station near the town of Salida (approximately 60 miles downstream of the confluence with California Gulch).

2.4.2.2 Service Loss Based on Direct Injuries to Brown Trout

For sites downstream of the 11-mile reach, direct injury to brown trout was based on estimates of predicted trout fry mortality because of limited biological data and concern over appropriate comparisons to reference sites above the 11-mile reach.

Trout fry mortality is dependent on water quality, particularly during spring/early summer high-flow conditions (May-July) when metals concentrations in the Arkansas tend to be highest. Available water quality data for the Arkansas River for May-July from 1981 to 2005 were used to estimate annual trout fry mortality based on acute toxicity tests for brown trout fry exposed to zinc or cadmium (CDOW, 2006). The maximum predicted mortality for zinc or cadmium was used as the estimate of trout fry mortality for a particular year because the maximum mortality for the year is what determines the proportion of the trout fry population able to survive and potentially develop into adult brown trout. For example, in a year where the concentration of zinc or cadmium is high enough at some point during the spring to kill all of the trout fry (100% predicted mortality), there would be no recruitment of trout into the adult population at that location. Calculations of predicted trout fry mortality were based on equations developed by Steve Brinkman (CDOW, 2006). Equations predicting trout fry mortality were presented in Section 2.3.2.2 for the 11-mile reach.

For sampling stations downstream of the 11-mile reach, water quality data were more limited than for the 11-mile reach. Available data were used as the basis for a linear interpolation between sampling stations to estimate likely concentrations of zinc. These estimated concentrations account for expected dilution in contaminant concentrations from upstream to downstream. In other words, service loss calculations were based on the assumption that contaminant concentrations would decrease at a constant rate with distance downstream. Averaged inputs were used for 1981-1992, 1993-1999, and 2000-2005.

For the section of the Arkansas River downstream of the 11-mile reach to the USGS-Station at Shavano, the maximum calculated service loss was 50% for the upstream portion of this reach for the period 1981-1992. Service loss declined over time and with distance downstream, with no service loss after 1999 for the most downstream section of the reach.

2.4.2.3 Service Loss Based on Brown Trout Behavioral Avoidance

Brown trout behavioral avoidance injury was based on studies demonstrating that brown trout will avoid Zn when concentrations exceed certain threshold levels. Because behavioral avoidance may reduce the numbers of trout that occupy otherwise viable habitat in the Arkansas River, we assumed that the ecological consequence of avoidance responses is to reduce the carrying capacity of the available habitat for trout. An avoidance threshold of 50 μg Zn/L was used based on Woodward et al. (1997) with the assumption of a constant level of 50% avoidance when concentrations exceed the threshold. The degree of ecological impact was estimated to be between 1% and 10% of carrying capacity. To account for this range, three scenarios of reduced trout carrying capacity were modeled: 1%, 5%, 10%. Applying the 50% avoidance effect to these scenarios results in a total avoidance service loss range of 0.5%, 2.5%, and 5% service loss (calculated by multiplying the 50% trout avoidance incidence by the degree of reduced trout carrying capacity). Calculations were limited to the months of September and October when brown trout would move from tributaries to the main stem of the Arkansas River.

Mean monthly Zn concentrations for September and October were used to calculate brown trout behavioral avoidance. Downstream of the 11-mile reach, water quality data are unavailable for 1981-1990. Therefore, zinc and cadmium concentrations from 1994-1998 were increased by 50% to estimate behavioral avoidance for the earlier period. Downstream of the 11-mile reach, there were avoidance service losses downstream to Shavano for the period 1981-1995, with no service losses after that date.

2.4.2.4 Results of HEA Approach 1 Injury Calculations

The service loss calculations discussed above were used as inputs into a HEA model with a base year of 2006 and a 3% discount rate to calculate the total discounted service acre-years (DSAYs) lost as a result of the aquatic injuries. A summary of service loss values for the different time periods and segments of downstream section (Reaches 5 – 7) is provided in Table 2-17. Total DSAYs for injuries for this area ranged from 3,000 – 3,500 depending on the assumptions used for behavioral avoidance service loss (Table 2-18).

Table 2-17

Approach 1: Estimated Ecological Service Losses Downstream of the 11-Mile Reach in the Arkansas River

	Percent Service Loss		
Area	**1981 - 1992**	**1993 - 1999**	**2000 – 2005[a]**
Reach 5	55%	25%	4%
Reach 6	40%	18%	4%
Reach 7	11%	3%	0%

a. For 2006 – 2011, aquatic services were assumed to improve by 20%; For 2012 – 2107, aquatic services were assumed to improve by an additional 10%.

Table 2-18

Approach 1: Quantified Injuries Downstream of the 11-Mile Reach in the Arkansas River

		DSAYs[a]		
Area	**Acres**	**Direct Injury**	**Behavioral Avoidance**	**Total (rounded)**
Downstream to USGS-Shavano sampling station	540.8	2,947	60-599	3,000-3,500

a. DSAY = discounted service acre-year.

2.4.2.5 HEA Injury Approach 2 - Exceedances of TVSs

The second HEA injury quantification approach was based on the frequency and magnitude of water quality exceedances of TVSs. The data for each reach for Periods 2 and 3, as well as chronic and acute thresholds based on average measured hardness, were obtained from the SCR.[18] For Period 4, the CDOW report, which includes chronic thresholds, was used to

---

[18] As a visual demonstration of the exceedances, Appendix 1 presents the water quality results and average-hardness-corrected chronic and acute thresholds for Period 2. These present the same data as Tables 2-8 and 2-14.

estimate injury. As described in Section 2.3.2.5 above, ecological service loss was calculated based on water quality exceedances of chronic and acute TVS. For future service loss, ongoing remedial work was assumed to result in a 20% improvement in water quality for the period from 2006-2011 and an additional 10% improvement in water quality for the period from 2012-2107.

For the area downstream of the 11-mile reach, we include Reach 5 through Reach 8. In the SCR, these reaches are characterized as having water quality exceedances sufficient to cause injury in both Period 2 and Period 3.[19] We do not include Reaches 9 and 10; while some small injury may be attributed during Period 2, the level of uncertainty precludes inclusion in this injury estimation.

2.4.2.6 Results of HEA Injury Approach 2 Calculations

The service loss calculations discussed above were used as inputs into a HEA model with a base year of 2006 and a 3% discount rate to calculate the total discounted service acre-years (DSAYs) lost as a result of the aquatic injuries. A summary of service loss values for the different time periods and segments of the area downstream of the 11-mile reach (Reaches 5 – 8) is provided in Table 2-19. Total DSAYs for injuries for this area are 5,700 DSAYs, including both chronic and acute injuries (Table 2-19).

Table 2-19

Approach 2: Estimated Ecological Service Losses and Quantified Injuries Downstream of the 11-Mile Reach of the Arkansas River

		Percent Service Loss			
Area	**Acres**	**1981 - 1992**	**1993 - 1999**	**2000 – 2005[a]**	**DSAYs (rounded)[b]**
Reach 5	20.9	50%	43%	17%	400
Reach 6	282.4	31%	26%	0%	2,800
Reach 7	198.7	17%	9%	0%	900
Reach 8	554.4	11%	4%	0%	1,600
Total	**1,056.4**				**5,600**

a. Services improve linearly between 2000 – 2005 to the listed service loss. For 2006 – 2011, aquatic services were assumed to improve by 20%; For 2012 – 2107, aquatic services were assumed to improve by an additional 10%.
b. DSAY values do not sum to total due to rounding.

2.4.2.7 HEA Restoration Calculations

The purpose of this preliminary analysis is to develop an initial estimate of the approximate magnitude of damages for the Arkansas River downstream of the 11-mile reach. While there are uncertainties inherent in the choice of input variables and values, reasonable variation in these inputs is unlikely to alter the basic conclusion: although readily available data

---

[19] Reach 5 does not have data reported for Period 2, but results from Period 3 indicate levels of injury midway between those of Reach 3 and Reach 6.

suggests that there may not be current, metals-related degradation of resource condition in downstream areas, the magnitude of past injuries (1981 to 2000) likely exceeds combined past and future injuries estimated for the 11-mile reach.

With respect to potential restoration projects, based on readily available information it appears that downstream areas provide limited instream restoration potential. The Trustees therefore have not developed estimates of restoration benefits and costs specific to this area. In the absence of such information, 11-mile reach restoration costs are applied to develop the preliminary estimate of damages. Total cost for the 11-mile reach restoration project, which provides 1,170 DSAYs, is $3.7 million. Based on the preliminary calculations described above in Approach 1, the total magnitude of injuries to downstream areas is approximately 3,000 - 3,500 DSAYs, indicating an estimated $9.5 to $11.1 million dollars as a restoration cost-based preliminary damage estimate for downstream areas.[20] Based on Approach 2, preliminary calculations indicate that the total magnitude of injuries to downstream areas is approximately 5,700 DSAYs, indicating an estimated $17.8 million dollars as a restoration cost-based preliminary damage estimate for downstream areas.

2.5 SUMMARY OF PRELIMINARY ESTIMATE OF UPPER ARKANSAS RIVER AQUATIC DAMAGES

Based on the preliminary analyses presented in this chapter, the cost of restoration projects needed to offset post-1981 natural resource service impairment in the 11-mile reach is expected to be on the order of approximately $9.3 – $12.1 million. Similar calculations suggest that the total magnitude of injuries to downstream areas is approximately $9.5 - $17.8 million, for a total of $18.8 – $29.9 million dollars as a restoration cost-based preliminary damage estimate (see Table 2-20).

Table 2-20

Summary of Preliminary Estimate of Damages for Upper Arkansas River

		Approach 1: Brown Trout				**Approach 2: TVS Exceedance**	
		Lower estimate for avoidance		**Higher estimate for avoidance**			
	Estimated Cost per DSAY*	**Injury DSAYs**	**Estimated Cost ($M)**	**Injury DSAYs**	**Estimated Cost ($M)**	**Injury DSAYs**	**Estimated Cost ($M)**
11-mile reach (Reaches 1-4)	$3,162	2,950	$ 9.3	3,200	$ 10.1	3,800	$12.1
Downstream of 11-mile reach (Reach 5 – 10)	$3,162	3,000	$ 9.5	3,500	$ 11.1	5,600	$17.8

*DSAYs expected to be generated by 11-mile Reach Instream Restoration Project: 1,170
Estimated Project Cost: $3,700,000
Estimated Cost Per DSAY: $3,162 (equal to 1,170 DSAY benefit / $3,700,000 cost of 11-mile Reach project)

---

[20] For example, (3,000 DSAYS / 1,170 DSAYS) * $3.7 million ≈ $9.5 million.

UPPER ARKANSAS RIVER TERRESTRIAL RESOURCES CHAPTER 3

3.1 INTRODUCTION

This chapter summarizes readily available information concerning potential injuries to terrestrial resources and resource services in the UARB. It also provides a preliminary estimate of the magnitude of restoration project costs needed to offset these injuries. Consistent with existing analyses, this chapter presents information addressing the following terrestrial resources:

a) 11-Mile Reach: Irrigated Meadows;

b) 11-Mile Reach: Riparian Habitat;

c) 11-Mile Reach: Mine Waste Deposits in Fluvial Habitat;

d) California Gulch (OUs 4 and 8) Mine Waste Deposits in Fluvial Habitat; and

e) On-Site Mine Waste Rock Piles (OUs 4, 5, 7, 8, and 10).

This chapter focuses primarily on potential contamination-related injuries to vegetation resources (through phytotoxicity). While data suggest that injuries to wildlife and livestock (through food chain exposures and direct soil contact) may exist in the study area (e.g., hazard quotients in excess of 900 have been documented in fluvial tailings, based on ingestion of lead by birds (Weston *et al*. 1997, Appendix D-3)), in the Trustees' judgment insufficient wildlife data have been collected to allow evaluation of the potential extent, severity and duration of such injuries. Future assessment activities may include additional evaluation of wildlife (and vegetation) injuries, as well as potential injuries to agricultural, recreational and other human uses of contaminated terrestrial resources.

In addition, metals concentrations and pH in these geological resources also may be sufficient to contribute to injuries to surface water and groundwater resources within the study area; if so, such resources would be considered injured pursuant to DOI NRD regulations (43 CFR 11.62(e)(11)). Potential aquatic and ground and surface water injuries are addressed in Chapter 2 of this document.

The study area includes lands owned by a variety of private and public entities. The Trusteeship interest in private land occurs due to the potential injury to wildlife due to decreased forage, shelter and similar habitat services on private, undeveloped lands, and due to potential adverse effects from exposure to metals through soil ingestion and food chains. Impacts to livestock are relevant to Trustee NRD efforts to the extent livestock graze on land owned by the government.[1] Further, contamination of many terrestrial areas resulted from the deposition of stream sediments during flood events. NRD regulations include sediments as surface water resources (43 CFR 11.14), and authorize Trustees to evaluate potential injuries to these resources.

3.2 IRRIGATED MEADOWS

The Trustees have identified 1,096 acres of meadows within the 11 Mile Reach 500-year floodplain affected by deposition of hazardous substances due to irrigation with water from California Gulch or the Upper Arkansas River (SCR 2002, p. ES-6). Contaminated water from California Gulch and the Upper Arkansas River is the source of elevated metals and low pH in soils in the irrigated meadows (ROD OU11 2005, Section 5.4.1). California Gulch was (and continues to be) the major source of metals to the Arkansas River, with concentrations of lead and cadmium negligible above the confluence (ROD OU1 1988, p. 5; CDOW 2006, p. 5).

3.2.1 Evidence of Injury

Soil and flora studies undertaken as part of the USEPA 2003 Ecological Risk Assessment Addendum evaluate the potential magnitude of contamination-related impairment of irrigated meadows in the Upper Arkansas River floodplain. More specifically, the 2003 ERA Addendum evaluated data collected in 2001-2002 to assess the potential for mine-waste related phytotoxicity as well as risks to herbivorous mammals that may feed in the area, and is the primary source of information cited in this subsection.[2] The addendum includes the following statement on ecological risks:

> An initial evaluation of risks to terrestrial receptors at the site (Weston et al. 1997) included a consideration of potential risks to a number of different taxa of terrestrial species, including birds, mammals, plants and soil-dwelling organisms. Based on the data available at the time, the risk assessment concluded that overall risks to raptors and game mammals were expected to be minimal, and risks to small mammals and birds were above a level of concern. Primary contributors to predicted risks for wildlife were arsenic, cadmium, lead and zinc. Predicted risks to plants and soil fauna were found to be above a level of concern across the entire site, with the highest risks in the riparian flood plains of California Gulch and the upper Arkansas River. Primary contributors to risks to plants included arsenic, copper, lead, manganese, selenium, silver, and zinc. At the time of the baseline risk assessment, only limited data were available on contaminant levels in the upper Arkansas River floodplain downstream of the confluence with California Gulch. Likewise, few data were available for contaminant

---

[1] Potential impacts to livestock grazing on privately owned land may be pursued by affected private parties.

[2] Data from the Ecological Risk Addendum were not available in time for inclusion in SCR 2002. Information in the ERA Addendum is included in the evaluation presented in the Restoration Alternatives Report (2003).

concentrations in plants in this area, so risks to herbivores did not include an estimation of risk from plant ingestion (USEPA 2003, p. ES-2).

The 2003 ERA Addendum study area encompasses terrestrial areas adjacent to the Arkansas River beginning at the confluence with California Gulch and extending to a distance approximately 11 miles downstream, including the 500 year floodplain plus areas outside the floodplain that are known to have been irrigated (USEPA 2003, p. ES-2). Portions of this analysis relevant to irrigated meadows were subsequently updated in the Record of Decision for OU11 (ROD OU11 2005). Key findings expected to be relevant to the determination of injury under natural resources damage regulations are summarized below. More detailed information can be found in the ERA Addendum and ROD.

3.2.1.1 Phytotoxicity

A total of 126 sites in the study area were sampled by EPA, including 71 from irrigated meadows (see Figure 3-1). A phytotoxicity model was developed from bulk soil chemistry and laboratory data including measurements of several plant growth endpoints (from plants grown in soils collected at 20 of these sites, including 11 from the irrigated meadows (see Figure 3-2).[3] Species diversity and plant density models were also constructed from field-based site observations and bulk soil chemistry. These results were extrapolated to give a mean phytotoxicity score (MPS) for the additional 106 sites in the study area where bulk soil chemistry data were collected, but not phytotoxicity or plant community data. Ranges in mean phytotoxicity scores were associated by EPA with differing degrees of potential phytotoxicity impairment, as indicated in Table 3-1. The results of EPA's phytotoxicity analysis are summarized visually in Figures 3-3 (predicted spatial pattern of phytotoxicity) and 3-4 (spatial patterns of primary contributors to predicted phytotoxicity). In terms of sample numbers, 43 of the 71 irrigated meadow sample locations were predicted to be non- or mildly phototoxic while 17, 8 and 3 sites were predicted to be moderately, highly and severely phytotoxic, respectively. Of the 28 irrigated meadow sites predicted to be moderately, highly or severely phytotoxic, metals were the primary contributor to toxicity at 17 locations. Metals and pH were both believed to be primary contributors at 4 locations, while calcium levels were the primary cause at 7 locations (USEPA 2003, pp. ES-5 and ES-6).

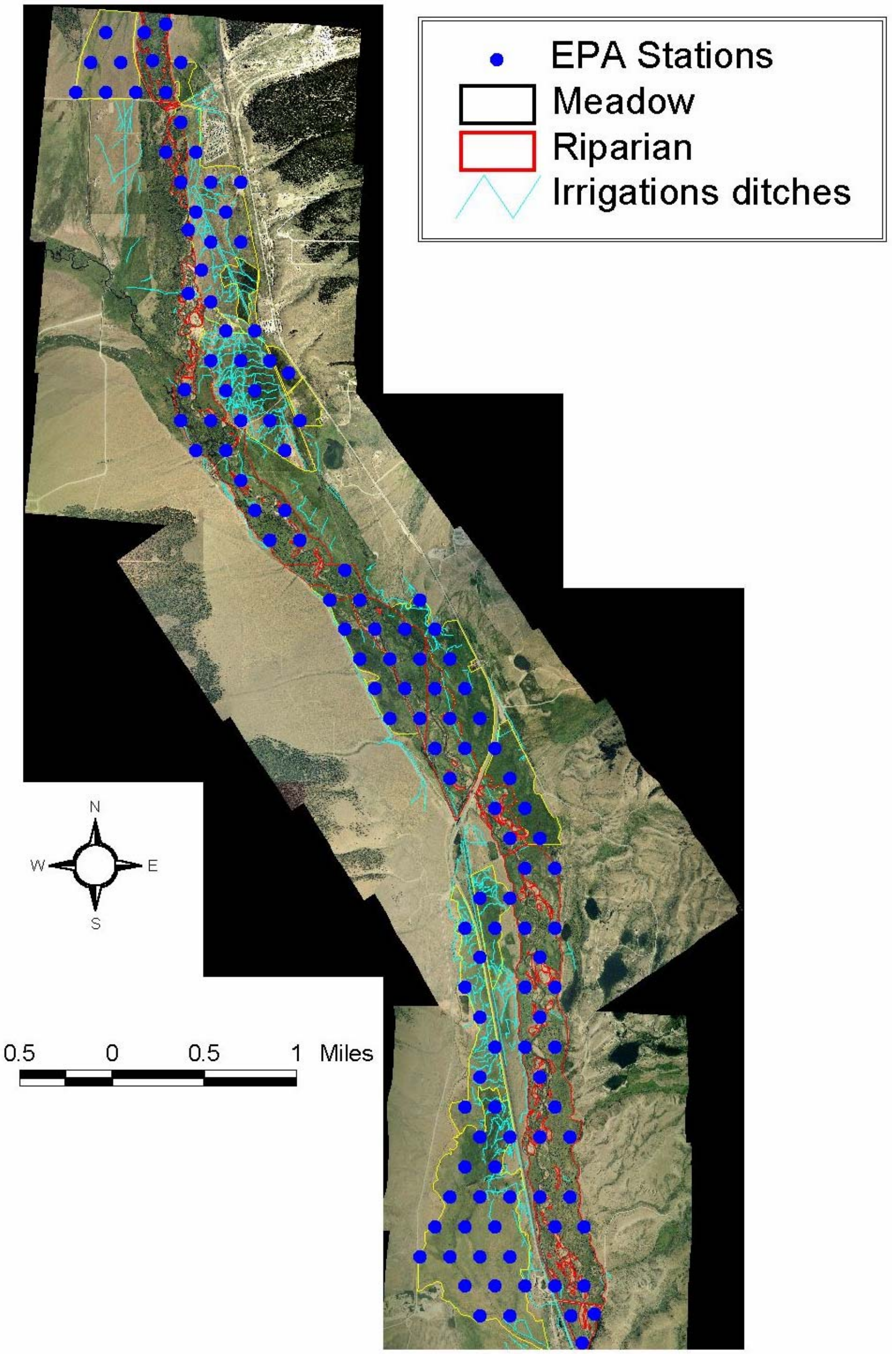
Subsequently, EPA expanded the calculations described above to include soil data from 28 additional sampling stations in the Irrigated Meadows (mainly in the upper portion of OU11). These results are presented in Table 3-2. As shown in the table, many sampling stations are predicted to exceed an MPS score of 0.5 (mild phytotoxicity). For irrigated meadows, the frequency of exceedances and mean MPS scores are highest in the upper portion of OU11, mainly in River Miles 1 and 2, although exceedances are found further downstream and maximum MPS scores don't exhibit a clear spatial trend.

---

[3] Suitable data for evaluation were collected at 19 of the 20 sites. Metals and metalloids included in the phytotoxicity studies are arsenic, cadmium, copper, lead, zinc, and mercury.

Figure 3-1

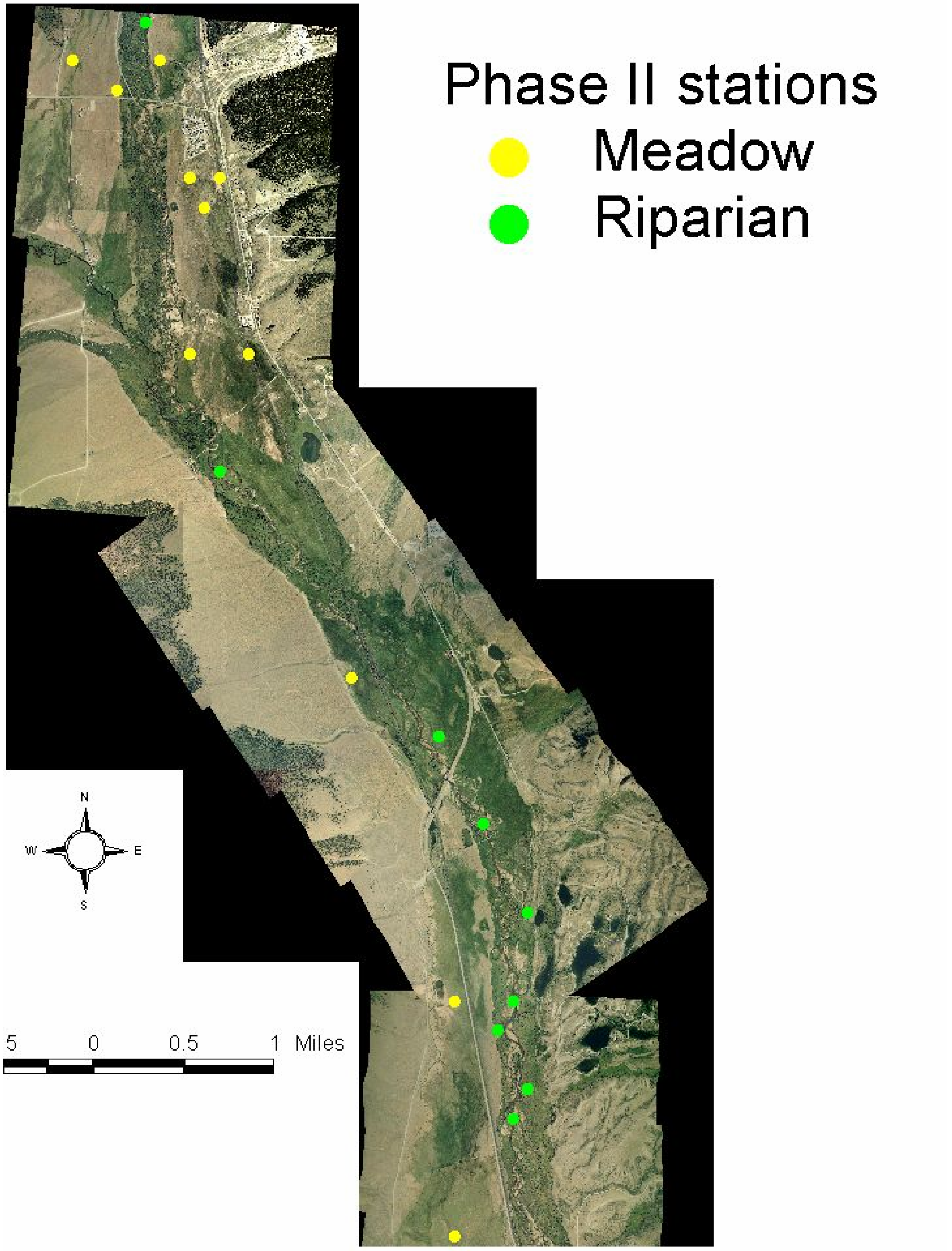
Phase I Sampling Stations
(N = 126)



Source: USEPA 2003.

Figure 3-2

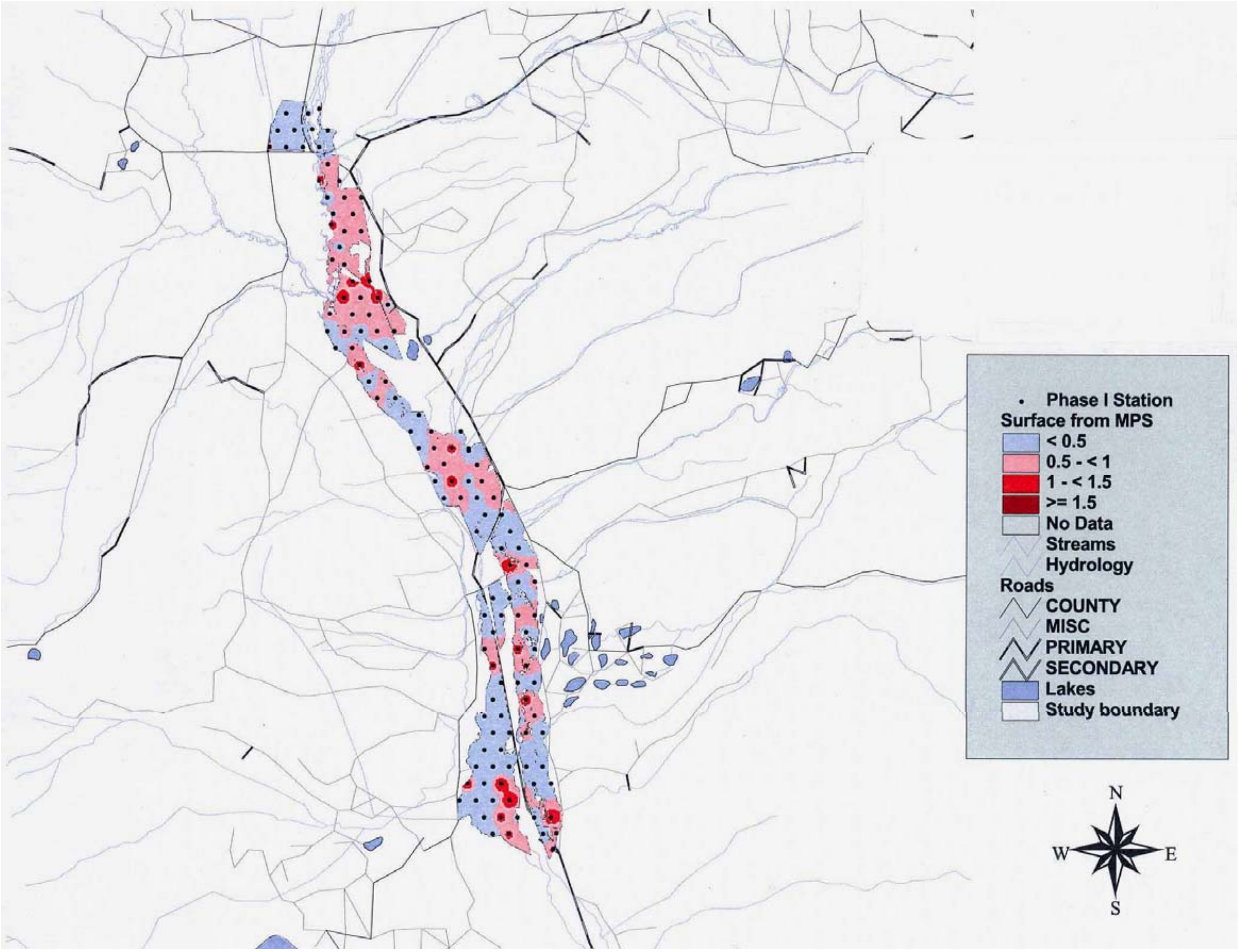
Phase II Sampling Stations
(N=20)



Source: USEPA 2003.

Figure 3-3

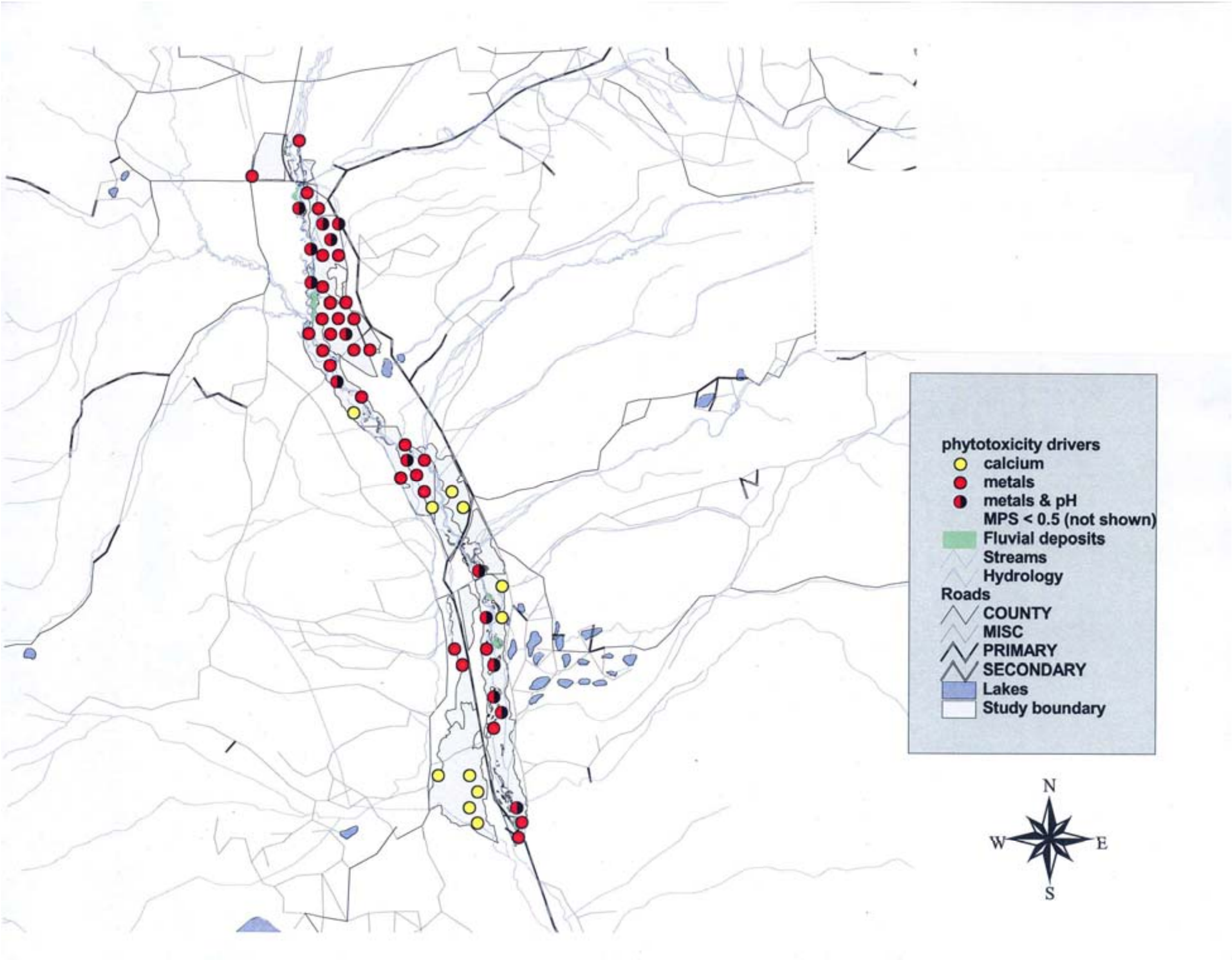
Predicted Spatial Pattern of Phytotoxicity



Source: USEPA 2003.

Figure 3-4

Spatial Patterns of Primary Contributors to Predicted Phytotoxicity



Source: USEPA 2003

Table 3-1

Index Values for Phytotoxicity Scores

Magnitude of Endpoint Response (as % Control)	% Reduction in Ecological Services	Phytotoxicity Score (for Species)	Mean Phytotoxicity Score (for Station)	Description
>90%	0%	0	0.00-0.24	Non-phytotoxic
>75-90%	11-25%	0.5	0.25-0.50	Mildly phytotoxic
>50-75%	26-50%	1.0	0.51-1.00	Moderately phytotoxic
>25-50%	51-75%	2.0	1.01-2.00	Highly phytotoxic
0-25%	75%	4.0	>2.00	Severely phytotoxic

Source: USEPA 2003, p. 4-4.

Table 3-2

Phytotoxicity Model Results

Station Type	River Mile	Number of Stations with MPS > 0.5	Mean MPS	Max MPS
Meadow	Upstream	1	0.16	0.62
	1	7	0.63	0.99
	2	10	0.70	1.34
	3	0	-0.07	0.20
	4	3	0.33	1.02
	5	0	0.17	0.45
	6	2	0.24	0.93
	7	5	0.33	1.71
Riparian	Upstream	1	0.30	0.92
	1	3	0.89	1.36
	2	3	0.34	0.66
	3	4	0.52	0.99
	4	5	0.65	1.40
	5	3	0.59	1.55
	6	4	0.59	1.34
	7	4	0.37	1.46

Source: Data from USEPA 2003

For natural resource damage purposes, Figure 3-5 summarizes the Trustee's preliminary characterization of the level of toxicity for each station (and the area associated with that station), separated into riparian and non-riparian (irrigated meadows) areas.[4] Based on this preliminary evaluation, mild, moderate and high risks of phytotoxicity are predicted for 234, 408 and 40 irrigated meadow acres, respectively. EPA analysis suggests that the remaining 414 acres are non-phytotoxic.

Thus, readily available data suggest that metals concentrations in irrigated meadows are sufficient to adversely affect vegetation. More specifically, EPA's phytotoxicity model is focused on potential growth impacts, although species diversity and plant density also may be affected. For PED purposes, preliminary estimates of service loss reflect expected reductions in vegetative cover, based on modeled Mean Phytotoxicity Scores, field observations and Trustee judgment. Preliminary, quantitative estimates of service loss and recovery time for this potential irrigated meadow resource injury are addressed in the final section of this chapter.

3.2.1.2 Risks to Herbivores and Other Wildlife

As noted previously, irrigated meadow resources may be affected by contamination in other ways (e.g., through a compromised ability to support wildlife communities, due to the transfer of contaminants at levels sufficient to harm such receptors). Any such injuries would be in addition to the potential phytotoxicity impacts discussed above. Readily available information concerning potential risks to herbivores is summarized below, although in the Trustees' judgment insufficient data have been collected to allow evaluation of the potential extent, severity and duration of injuries to herbivores or other wildlife exposed to contaminated soils and/or vegetation directly or indirectly through prey.

Risks to herbivores in the floodplain of the 11-Mile Reach also are evaluated in the 2003 ERA Addendum. Risks were estimated for a number of different herbivorous receptors, including horses, cattle, deer, and vole. Estimated risks are based on a model of metal uptake in plants using soil chemistry and phytotoxicity studies in the Upper Arkansas 500-year floodplain and expected doses from plant and soil ingestion (USEPA 2003, executive summary). Toxicity reference values were derived from published toxicity studies.

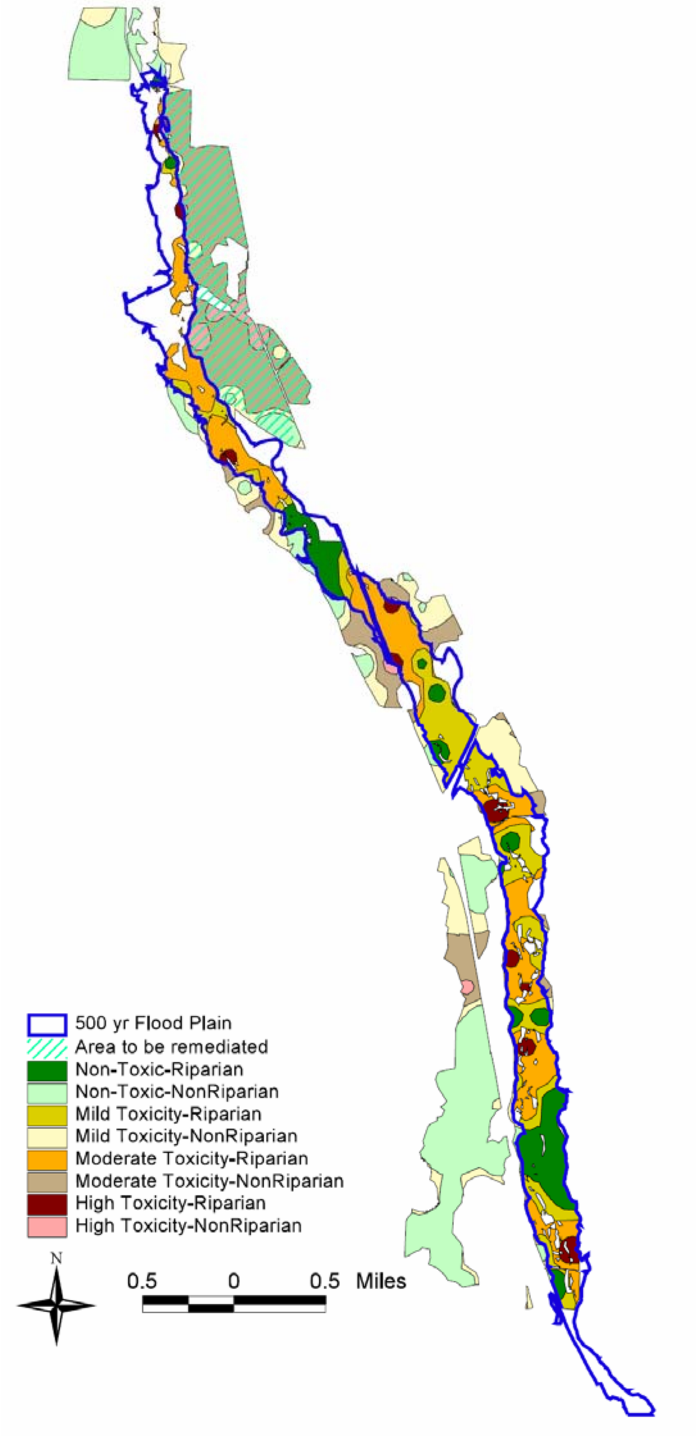
Model results are summarized in Tables 3-3 and 3-4. As indicated in Table 3-3, at most stations HQ values are below a level of concern for all chemicals and all receptors (i.e., $HQ \leq 1$). However, at 11 sampling locations, HQ values are above 1 for one or more receptors, with values ranging from 2 to 20. These stations are located mainly in River Mile 1 and 2.

---

[4] The stations for which calcium is identified as the primary contributor to phytotoxicity are omitted from Figure 3-5.

Figure 3-5

Upper Arkansas River 500-year Floodplain: Regions of Phytotoxicity



Source: Trustee Analysis of USEPA 2003 results

Table 3-3
Risks to Herbivores

Receptor	Location	Count of Maximum HQ Values					
		Max HQ ≤ 1		Max HQ = 2 -4		Max HQ ≥ 5	
		Count	%	Count	%	Count	%
Horse	Riparian	49 / 55	89%	6 / 55	11%	0 / 55	0%
	Meadow	66 / 71	93%	4 / 71	6%	1 / 71	1%
	Total	115 / 126	91%	10 / 126	8%	1 / 126	1%
Cattle	Riparian	53 / 55	96%	2 / 55	4%	0 / 55	0%
	Meadow	68 / 71	96%	2 / 71	3%	1 / 71	1%
	Total	121 / 126	96%	4 / 126	3%	1 / 126	1%
Deer	Riparian	54 / 55	98%	1 / 55	2%	0 / 55	0%
	Meadow	69 / 71	97%	1 / 71	1%	1 / 71	1%
	Total	123 / 126	98%	2 / 126	2%	1 / 126	1%
Vole	Riparian	55 / 55	100%	0 / 55	0%	0 / 55	0%
	Meadow	67 / 71	94%	2 / 71	3%	2 / 71	3%
	Total	122 / 126	97%	2 / 126	2%	2 / 126	2%
Overall	Riparian	50 / 55	91%	3 / 55	5%	2 / 55	4%
	Meadow	65 / 71	92%	6 / 71	8%	0 / 71	0%
	Total	115 / 126	91%	9 / 126	7%	2 / 126	2%

Max HQ = maximum of the chemical-specific HQs within a station
(the chemical-specific HQ at a station includes both soil and plant ingestion exposures)

Table 3-4

Predicted Risks for Large Home Range Receptors
Based on Average Exposure Across River Miles

Station Type	**River Mile**	**Hazard Quotient (HQ)**		
		Cattle	**Horse**	**Deer**
Meadow	upstream	9.6E-02	2.4E-01	1.4E-01
	1	1.6E-01	4.0E-01	2.3E-01
	2	4.0E-01	8.4E-01	8.6E-01
	3	6.5E-02	1.3E-01	8.4E-02
	4	6.6E-02	1.2E-01	9.2E-02
	5	7.1E-02	1.6E-01	9.5E-02
	6	1.2E-01	3.0E-01	1.8E-01
	7+	6.7E-02	7.4E-02	9.7E-02
Riparian	upstream	1.1E-01	2.8E-01	1.6E-01
	1	5.9E-01	1.2E+00	9.4E-01
	2	9.0E-02	2.1E-01	1.4E-01
	3	1.6E-01	3.6E-01	2.1E-01
	4	2.2E-01	5.8E-01	3.3E-01
	5	2.9E-01	6.0E-01	3.5E-01
	6	2.8E-01	6.3E-01	3.6E-01
	7+	2.7E-01	6.2E-01	3.6E-01

HQ = maximum (across chemicals) of the average chemical-specific HQ (across stations)

EPA HQ calculations assume a home range of one mile for herbivore receptors. The Trustees have concerns that this simplifying assumption may not accurately characterize contaminant exposure to these receptors. Additional consideration of this issue, as well as more precise delineation of contaminated areas that may result in injuries to Trustee resources will be conducted during design and implementation of the OU 11 remedy. In the absence of more complete data, the PED relies on literature and professional judgment that indicates metal concentrations are at levels that may harm ecological receptors, and adopts the simplified assumption that risks to herbivores and other wildlife track phytotoxicity.

3.3 RIPARIAN HABITAT

The Trustees have identified approximately 700 acres of riparian areas potentially affected by metals contamination within the 11 Mile Reach 500 year floodplain, based on the USEPA 2003 Ecological Risk Assessment Addendum. California Gulch was (and continues to be) the major source of metals to the Arkansas River, with concentrations of lead and cadmium negligible above the confluence (ROD OU1 1988, p. 5; CDOW 2006, p. 5). Elevated metals concentrations in floodplain sediment deposits may impact soil function and contribute to phytotoxicity. Reduced vegetative productivity of riparian areas also reduces habitat suitability through loss of shade and increased bank erosion (SCR 2002, p. ES-4). Fluvial mine waste deposits in the 11-mile reach, which resulted from historic mining and mineral processing activities upstream, in particular from the Leadville Mining District, continue to affect the riparian habitat (ROD OU11 1995, Section 5.4.2). Floodplain soils peripheral to the mine-waste deposits have elevated metals concentrations, due to transport during flood events (SCR 2002, p. ES-6).

3.3.1 Evidence of Injury

Soil and flora studies undertaken as part of the USEPA 2003 Ecological Risk Assessment Addendum provide evidence of injury to riparian areas in the Upper Arkansas River 500-year floodplain. As noted above, the 2003 ERA Addendum evaluates data collected in 2001-2002 and is the primary source of information cited in this subsection, along with the Record of Decision for OU11 (ROD OU11 2005). Key findings expected to be relevant to the determination of injury under natural resources damage regulations are summarized below. More detailed information can be found in the ERA Addendum and ROD.

3.3.1.1 Phytotoxicity

EPA uses the same phytotoxicity model described for irrigated meadows to evaluate ecological impacts in study area riparian zones. The study area includes 126 sites, including 55 from riparian areas (see Figure 3-1). The results of EPA's phytotoxicity analysis are summarized in Figures 3-3 (predicted spatial pattern of phytotoxicity) and 3-4 (spatial patterns of primary contributors to predicted phytotoxicity). In terms of sample numbers, 27 of the 55 riparian sample locations were predicted to be non- or mildly phytotoxic while 16, 10 and 2 sites were predicted to be moderately, highly and severely phytotoxic, respectively. As shown in Table 3-2, the frequency with which riparian sampling stations exceed an MPS score of 0.5 (mild phytotoxicity) is relatively constant along the length of OU11. Maximum MPS scores also are relatively consistent spatially. Mean MPS scores are highest along River Mile 1.

For natural resource damage purposes, Figure 3-5 summarizes the Trustee's preliminary characterization of the level of toxicity for each station (and the area associated with that station), separated into riparian and non-riparian (irrigated meadows) areas.[5] Based on this preliminary evaluation, mild, moderate and high risks of phytotoxicity are predicted for 209, 305 and 39 riparian acres, respectively. EPA analysis suggests that the remaining 146 acres are non-phytotoxic.

Thus, readily available data suggest that metals concentrations in riparian habitat are sufficient to adversely affect vegetation. As previously noted, EPA's phytotoxicity model is focused on potential growth impacts, although species diversity and plant density also may be affected. Reduced vegetative growth and cover in turn will lead to reduced forage, shelter and similar services provided to the wildlife and livestock communities dependent on this habitat.

---

[5] The stations for which calcium is identified as the primary contributor to phytotoxicity are omitted from Figure 3-5.

For PED purposes, preliminary estimates of service loss reflect expected reductions in vegetative cover, based on modeled Mean Phytotoxicity Scores, field observations and Trustee judgment. Preliminary, quantitative estimates of service loss and recovery time for this potential riparian habitat injury are addressed in the final section of this chapter.

3.3.1.2 Risks to Herbivores and Other Wildlife

Irrigated meadow resources also may be affected by contamination in other ways (e.g., through a compromised ability to support wildlife communities, due to the transfer of contaminants at levels sufficient to harm such receptors). Any such injuries would be in addition to the potential phytotoxicity impacts discussed above. However, in the Trustees' judgment insufficient data have been collected to allow evaluation of the potential extent, severity and duration of injuries to herbivores or other wildlife exposed to contaminated soils and/or vegetation directly or indirectly through prey. In the absence of more complete data, the PED relies on literature and professional judgment that indicates metal concentrations are at levels that may harm ecological receptors, and adopts the simplified assumption that risks to herbivores and other wildlife track phytotoxicity.

3.4 MINE WASTE DEPOSITS IN 11 MILE REACH FLUVIAL HABITAT

The Trustees have identified approximately 65 acres of fluvial mine waste deposits within the 11-Mile Reach 500-year floodplain (see Figures 3-6, 3-7 and 3-8). Over 150 deposits resulted from historic mining and mineral processing activities upstream, in particular from the Leadville Mining District (ROD OU11 2005, p. DS-11), including erosion from tailings and waste rock piles along California and Oregon Gulch. Fluvial habitat mine waste deposits have low pH (3 or below), are highly mineralized, and can be significant sources of metals to surrounding habitats.

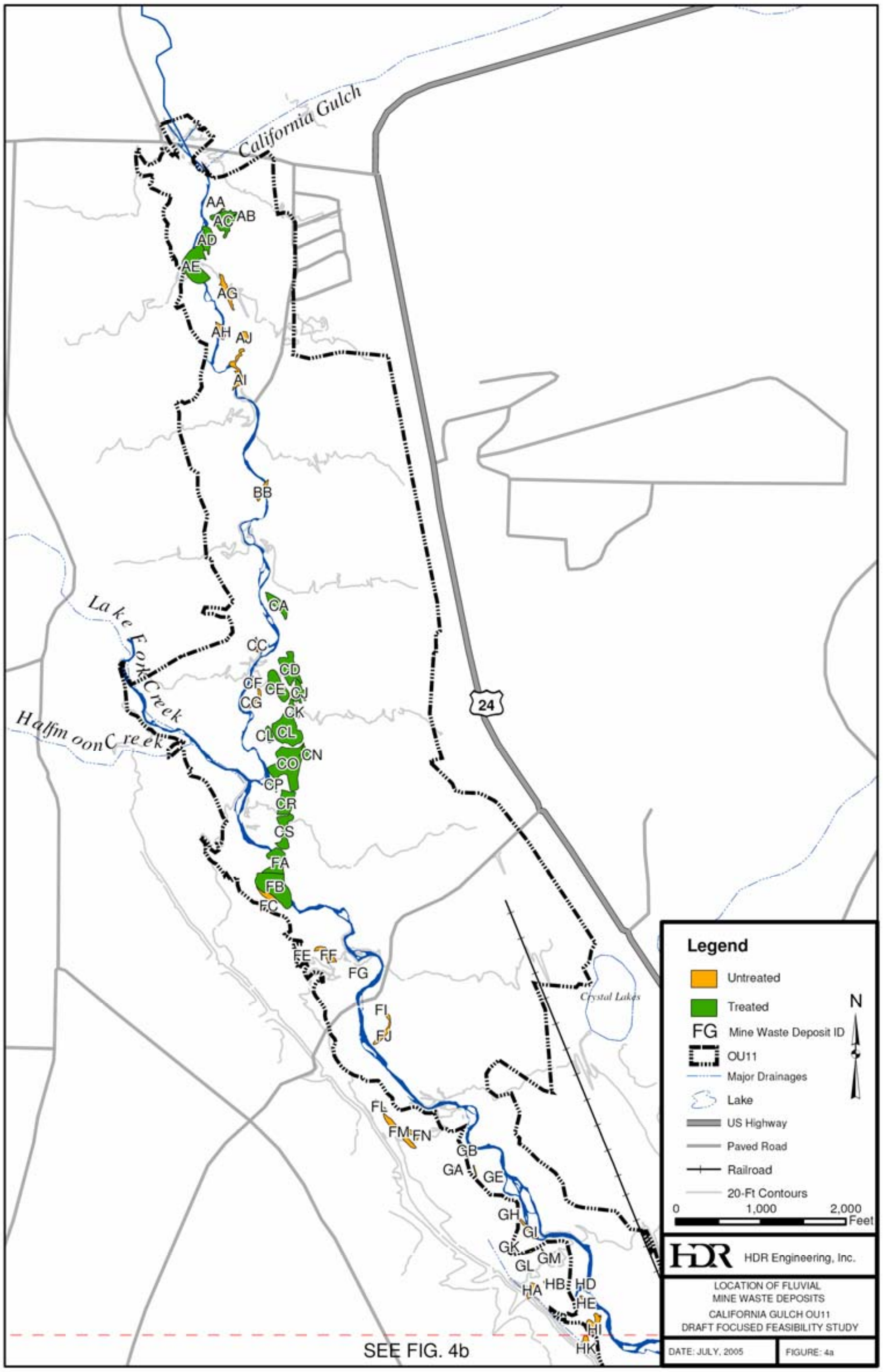
3.4.1 Evidence of Injury

Readily available data suggest the potential for injuries to Trustee resources resulting from mine waste deposits. The SCR and the ROD for OU11 compile and evaluate key data available through 2003. Key findings are summarized below. More detailed information can be found in the source documents.

Removal actions have been implemented at some of these locations. Descriptions of these actions are provided in subsequent sections of this chapter. Because natural resource damage regulations allow Trustees to pursue damages for past injuries to natural resources and/or resource services, characterization of conditions prior to remediation is appropriate for natural resource damage assessment purposes. Preliminary damage estimates presented at the end of this chapter account for improvements in resource condition over time due to remedial activities and natural recovery processes.

Figure 3-6

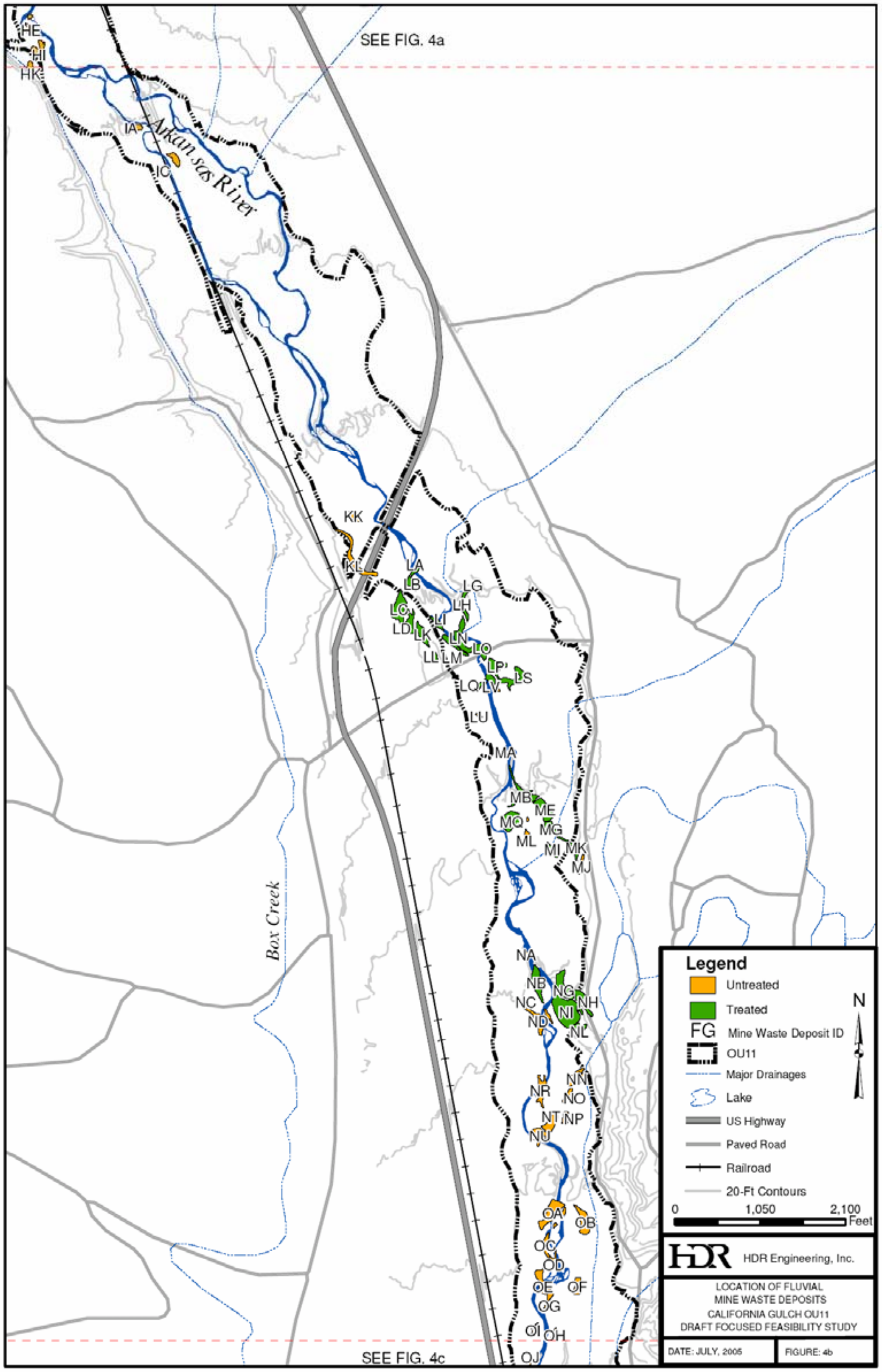
Location of Fluvial Mine Waste Deposits



Source: ROD OU11 2005

Figure 3-7

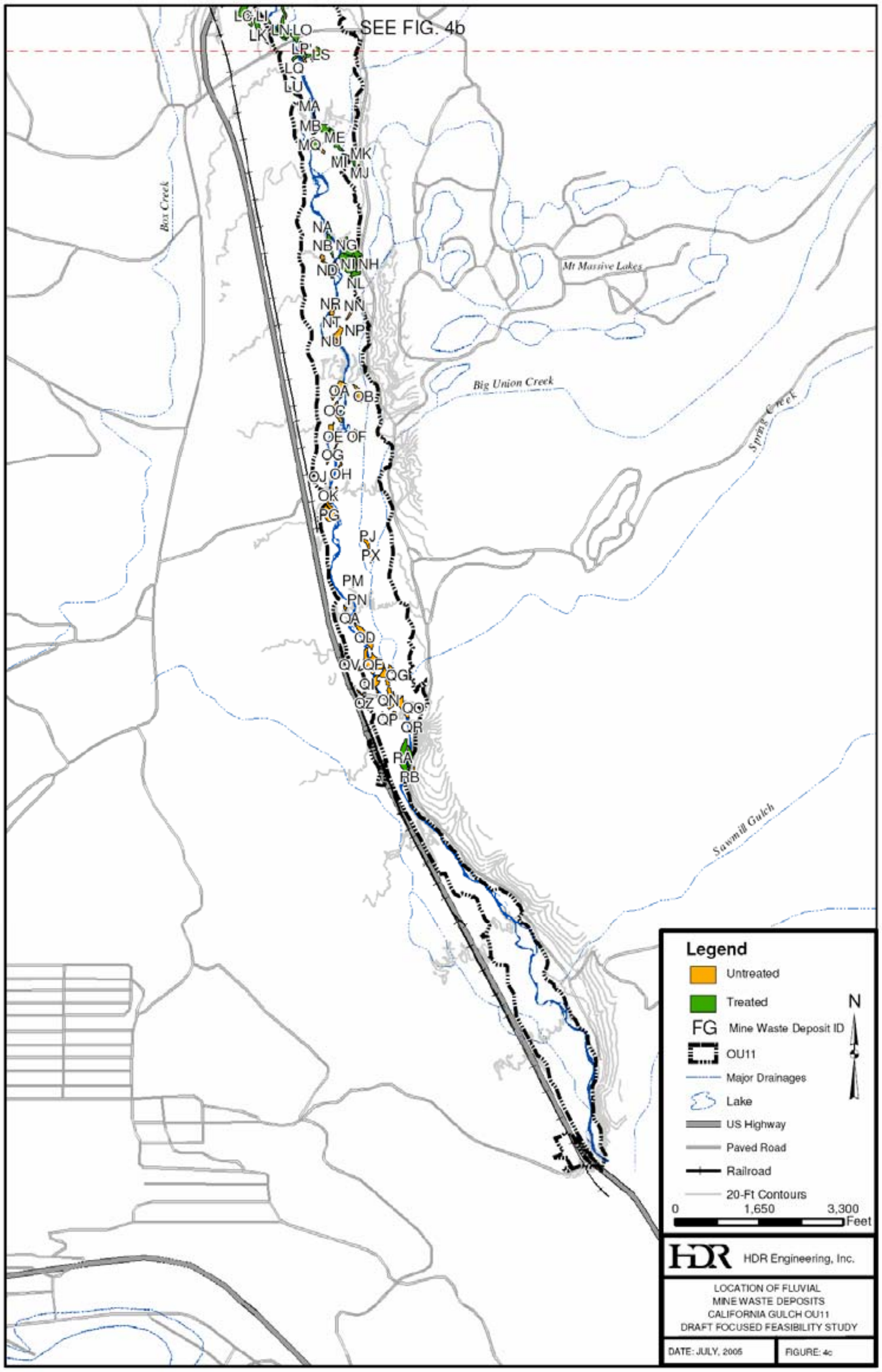
Location of Fluvial Mine Waste Deposits



Source: ROD OU11 2005

Figure 3-8

Location of Fluvial Mine Waste Deposits



Source: ROD OU11 2005

3.4.1.1 Phytotoxicity

Low pH, elevated metal concentrations, and poor substrate result in decreased vegetative cover and consequent impaired habitat in the areas of mine waste deposits. More specifically, for Reaches 1, 2 and 3 the SCR states that “soils where mine-waste deposits occur are considered to be injured. Total metal concentrations exceed toxicity thresholds and plant growth has been substantially impacted on most sites where mine-waste deposits have been identified” (SCR 2002, Chapter 3 Summary Matrix pp. 20-22). For Reach 4, the SCR states that “with respect to mine-waste deposits, not enough information exists to draw direct conclusions about injury. However, only a few small barren or sparsely vegetated areas consistent with mine-waste deposits could be identified. It is inferred that soils in those small areas are injured due to the presence of mine-waste” (SCR 2002, Chapter 3 Summary Matrix p. 23).

The 2003 ERA Addendum study does not predict phytotoxicity potential for fluvial mine waste deposits because the conditions in these deposits are significantly different than in irrigated meadow and riparian area soils, and the phytotoxicity model is not calibrated to be reliable for this type of medium. However, EPA notes that “it is evident that the Fluvial Mine Waste deposits are phytotoxic, since Fluvial Mine Wastes are characterized by sparse or absent plant growth” (ROD OU11 2005, p. DS-16). Table 3-5 shows mine waste deposits by reach, with number, area, and vegetative coverage. Cover is determined from aerial photographs of the region (SCR 2002, Appendix H). Just over four acres of the 65 have good vegetative cover (>50 percent).

Table 3-5

11-Mile Reach Fluvial Deposits (OU11)
Mine Waste Deposit Size and Vegetative Cover

	No. of Deposits	**Volume (cy)**	**Area (acres)**	**Past Remediation (Acres)**	**Future Remediation Plans (Acres)**	**Number of Deposits with Specified Vegetative Cover (and acreage)**	
						Poor to Fair (10-50%)	**Good (>50%)**
Reach 1	24	32,844	18.01	15.3	2.71	23 (17.91)	1 (0.1)
Reach 2	35	8,644	9.32	0	5.1	21 (7.2)	14 (2.1)
Reach 3	94	58,456	37.62	16.8	15	82 (35.67)	12 (1.95)
Total	**153**	**99,944**	**64.95**	**32.1**	**22.81**	**126 (60.78)**	**27 (4.15)**

Note: A small number of uncatalogued mine waste deposits are also present in Reach 4, constituting an estimated two acres. Trustees assume remediation of these sites in Reach 4.
Source: RAR 2003

Thus, readily available data suggest that metals concentrations in 11 Mile Reach fluvial habitat are sufficient to adversely affect the ability of vegetation to establish and sustain itself as would be expected in the absence of such contamination. For PED purposes, preliminary estimates of service loss reflect expected reductions in vegetative cover, based on field observations and Trustee judgment. Preliminary, quantitative estimates of service loss and recovery time for this potential irrigated meadow resource injury are addressed in the final section of this chapter.

3.4.1.2 Risks to Livestock and Wildlife

Readily available data do not address potential risks to livestock and wildlife arising from mine waste deposits in fluvial habitat. The Trustees may further assess such potential injuries as part of future natural resource damage assessment activities.

3.5 FLUVIAL MINE WASTE DEPOSITS IN CALIFORNIA GULCH (OUS 4 AND 8)[6]

Fluvial mine waste deposits also are prevalent in the 500-year floodplain of the California Gulch. In the Upper and Lower California Gulch (OUs 4 and 8), where Resurrection is the Remediation Lead, roughly 70 acres of mine waste deposits were identified and considered for remediation under Superfund authorities. More specifically, the deposits were divided into six fluvial tailing sites, one in OU4 (FTS4) and five in OU8 (FTS1, FTS2, FTS3, FTS6, and FTS8). The fluvial tailing waste volume in OU4 was estimated at 102,000 cubic yards over 10 acres, extending from 20 to 100 feet out across the valley floor, along 1.5 miles of the Upper California Gulch (ROD OU 4 1998, p. DS-1). In OU8, the five sites encompass an estimated 60.6 acres with 71,100 cubic yards of tailings (ROD OU8 2000, pp. DS-10 to DS-12). Table 3-6 provides additional detail on the area, depth, and volume of each FTS.

Table 3-6

Fluvial Mine Waste Deposits in OU4 and OU8

	Location	Volume (cy)	Area (acres)	Average Depth (ft)	Unvegetated Portion of Site	Vegetation on Remaining Site
FTS 1	OU8	5,500	3.4	1	65%	Grasses
FTS 2	OU8	5,200	3.2	1	Most	Isolated grasses
FTS 3	OU8	38,800	4.8	5	75%	Sagebrush, grasses, marshy near channel
FTS 4	OU4	102,000	10	6	75%	Grasses and lodgepole pine
FTS 6	OU8	3,400	4.2	0.5	60%	Sparse grasses with isolated pine trees
FTS 8	OU8	18,200	45	0.25	<80%	20% is well vegetated with dense grasses and shrubs.
TOTAL		**173,100**	**70.6**	**1.5**	**74%**	

Note: FTS8 extends beyond the 500-year floodplain of California Gulch, outside OU8. Overall the tailings encompass 115 acres at a depth of 4 inches, for roughly 46,000 cubic yards of material (ROD OU8 2000, p. DS-12). For total unvegetated calculation, used 90% for FTS 2 and 75% for FTS 8.

Remedial actions have been implemented at some of these locations. Descriptions of these actions are provided in subsequent sections of this chapter. Because natural resource damage regulations allow Trustees to pursue damages for past injuries to natural resources and/or resource services, characterization of conditions prior to remediation is appropriate for natural resource damage assessment purposes. Preliminary damage estimates presented at the end of this chapter account for improvements in resource condition over time due to remedial activities and natural recovery processes.

---

[6] Fluvial mine waste deposits also are present in other OUs, although readily available information is insufficient to include them in the analysis presented below.

3.5.1 Evidence of Injury

Vegetation is severely limited throughout the tailings sites. Between the six fluvial tailings sites in OU4 and OU8, nearly 75 percent of the surface area is completely unvegetated (Table 3-6). Elevated levels of arsenic, cadmium, lead, and zinc are prevalent throughout the tailing deposits at potentially phytotoxic levels (Table 3-7). The Record of Decision for OU8 provides the following summary of the pre-remediation condition of vegetation at fluvial tailing subsites:

- Fluvial Tailing Site 1 - Vegetation is variable with no vegetation over approximately 65% of the site. The remaining 35% of FTS1 is vegetated with grasses (ROD OU8 2000, p. DS-10);

- Fluvial Tailing Site 2 - Portions of FTS2 are devoid of vegetation with only isolated grasses on the tailing deposit. Dense vegetation is present in the area immediately adjacent to the channel (ROD OU8 2000, p. DS-10);

- Fluvial Tailing Site 3 - Approximately 25% of FTS3 is vegetated with sagebush, grasses and marshy areas near the channel. Tailing deposits and areas containing recently deposited fill are generally devoid of vegetation (ROD OU8 2000, p. DS-11);

- Fluvial Tailing Site 6 - Vegetation in FTS6 ranges from sparse grasses with isolated pine trees to unvegetated (approximately 60% of the site) (ROD OU8 2000, p. DS-11); and

- Fluvial Tailing Site 8 - Vegetation in FTS8 ranges from non-existent to dense grasses and shrubs located adjacent to the California Gulch channel. Approximately 20% of FTS8 is well vegetated (ROD OU8 2000, p. DS-12).

Thus, readily available data suggest that metals concentrations in OU 4 and 8 fluvial habitat are sufficient to adversely affect the ability of vegetation to establish and sustain itself as would be expected in the absence of such contamination. For PED purposes, preliminary estimates of service loss reflect expected reductions in vegetative cover, based on field observations and Trustee judgment. Preliminary, quantitative estimates of service loss and recovery time for this potential irrigated meadow resource injury are addressed in the final section of this chapter.

Table 3-7

Metal Concentrations in FTS and Waste Rock Piles in OU4 and OU8

Site	Arsenic (mg/kg)	Cadmium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)
FTS1	214	12.7	250	5780	2,290
FTS2	NA	19.5	NA	NA	NA
FTS3	172	17.4	437	3,220	4,170
FTS4	248	516	271	13,200	11,300
FTS6	108	45.9	263	3,250	6,710
FTS8	193	55	344	7,750	6,320

Source: ROD OU4 1998, ROD OU8 2000.

3.6 ON-SITE MINE WASTE ROCK PILES (OUs 4, 5, 7, 8, AND 10)

Tailing impoundments, smelter waste, and waste rock piles are distributed throughout the Site. The piles are the waste products from various mining operations throughout the history of the Leadville Mining District. Trustee analysis of maps of the Superfund Site indicate a total of 145 acres of waste rock distributed in various sized parcels among OUs 4, 5, 7, 8, and 10 (see Figure 3-9). OU4 contains the greatest portion, with 86.8 acres of waste rock, primarily in evergreen forest areas.

3.6.1 Evidence of Injury

These waste sites have represented major sources of contamination that have contributed to the injury of surface and groundwater as well as beds and banks and wildlife; therefore, they are considered injured geological resources. Table 3-8 presents acreages and descriptions of mine waste in OUs 4, 5, 7, 8 and 10. The abundance and diversity of vegetation is severely limited or absent on and near waste rock pile locations, as shown in Figure 3-9.

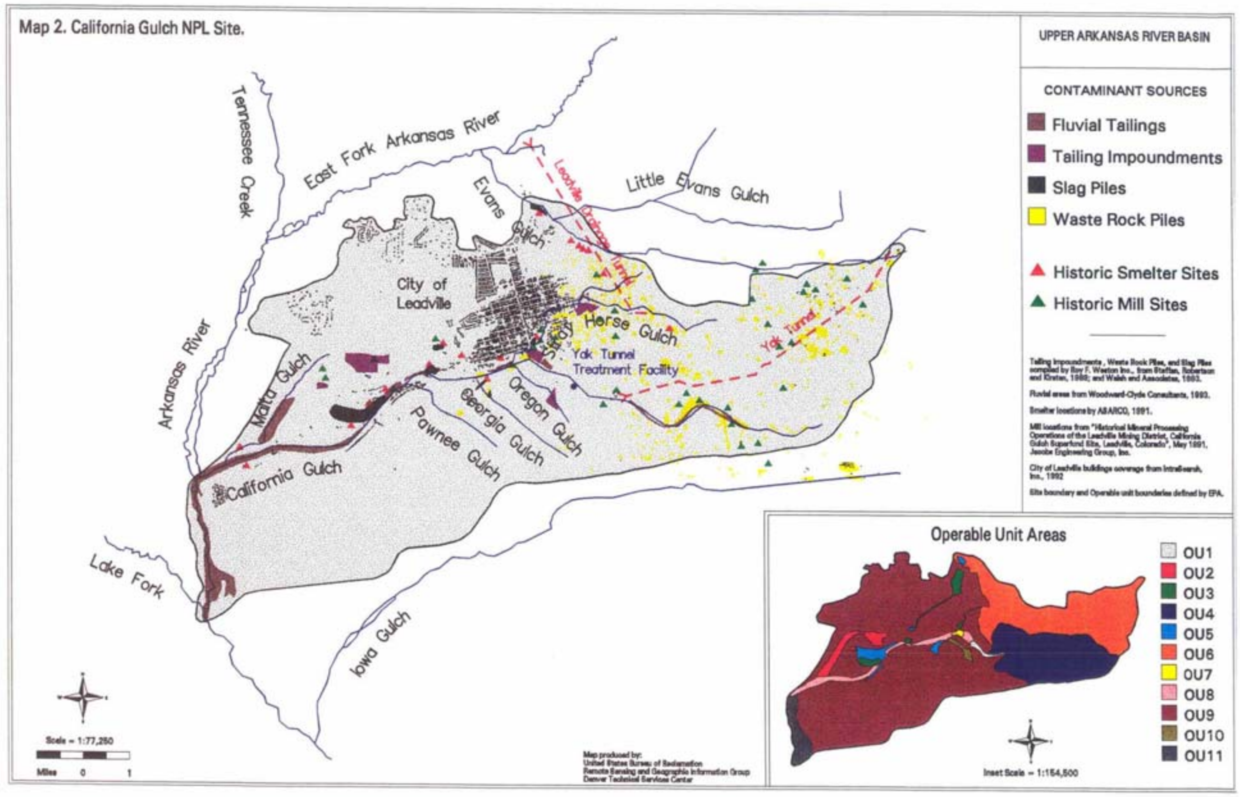
Table 3-8

Waste Rock Coverage in OUs 4, 5, 7, 8, 10

Operating Unit	Waste Rock (acres)	Key Sites
OU 4	87	Garibaldi, Agwalt, Printer Girl mine waste sites
OU 5	28	Elgin, Grant/Union, Western Zinc, Arkansas Valley Slag/Smelter Sites; Arkansas Valley/ Colorado Zinc-Lead (AV/CZL) site
OU 7	14	North and Main Impoundments
OU 8	6	CZL Tailing Impoundment
OU 10	10	Oregon Gulch Tailing Impoundment
Total	**145**	

Figure 3-9

Unvegetated Waste Rock Piles in OUs 4, 5, 7, 8, and 10



Thus, readily available data suggest that waste rock piles in OUs 4, 5, 7, 8 and 10 are adversely affecting the ability of vegetation to establish and sustain itself, as would be expected in the absence of the piles. For PED purposes, preliminary estimates of service loss reflect expected reductions in vegetative cover, based on field observations and Trustee judgment. Preliminary, quantitative estimates of service loss and recovery time for this potential irrigated meadow resource injury are addressed in the final section of this chapter.

Additional waste rock piles may be present in the study area (e.g., Stray Horse Gulch and Evans Gulch). Readily available information is insufficient to include such additional areas in the preliminary estimates of damages presented in this document. The Trustees may collect and evaluate additional data as part of future natural resource damage assessment activities.

3.7 SUPERFUND ACTIONS

In response to observed metals contamination and associated human health and ecological risk concerns, EPA and Responsible Parties implemented a variety of response actions in the past and plan to undertake more in the future. Superfund OUs for the site and associated remediation actions are briefly described in Chapter 2. As the preliminary natural resource damage estimates relate to injuries that precede and are residual to the completion of response activities, such activities are described briefly below. Preliminary damage estimates presented at the end of this chapter account for improvements in resource condition over time due to these remedial activities and natural recovery processes.

3.7.1 Summary of Relevant OU 11 Remedial Actions

Beginning in 1998, USEPA began a series of response actions within OU11, including:

- Revegetation of select mine waste deposits along the banks of the Arkansas River;
- A stream bank stabilization project (ROD OU11 2005, p. D-2).

Currently available information indicates that USEPA will implement additional response actions, including:

- Treatment and maintenance of Irrigated Meadows Areas A and B (see Figure 3-10). Initial treatment will consist of lime amendment for Area A and lime/organic amendment for Area B, deep tilling followed by seeding;

- Continued maintenance of Fluvial Mine Waste Deposits treated during prior response actions. Maintenance will include inspections and periodic application of lime and/or organic amendments;

- Treatment and maintenance of remaining untreated Fluvial Mine Waste Deposits. Initial treatment will consist of lime and organic amendment, deep tilling followed by seeding to physically stabilize the mine wastes through the establishment of vegetation; and

- No active remediation of the Riparian Areas (ROD OU11 2005, p. D-3).

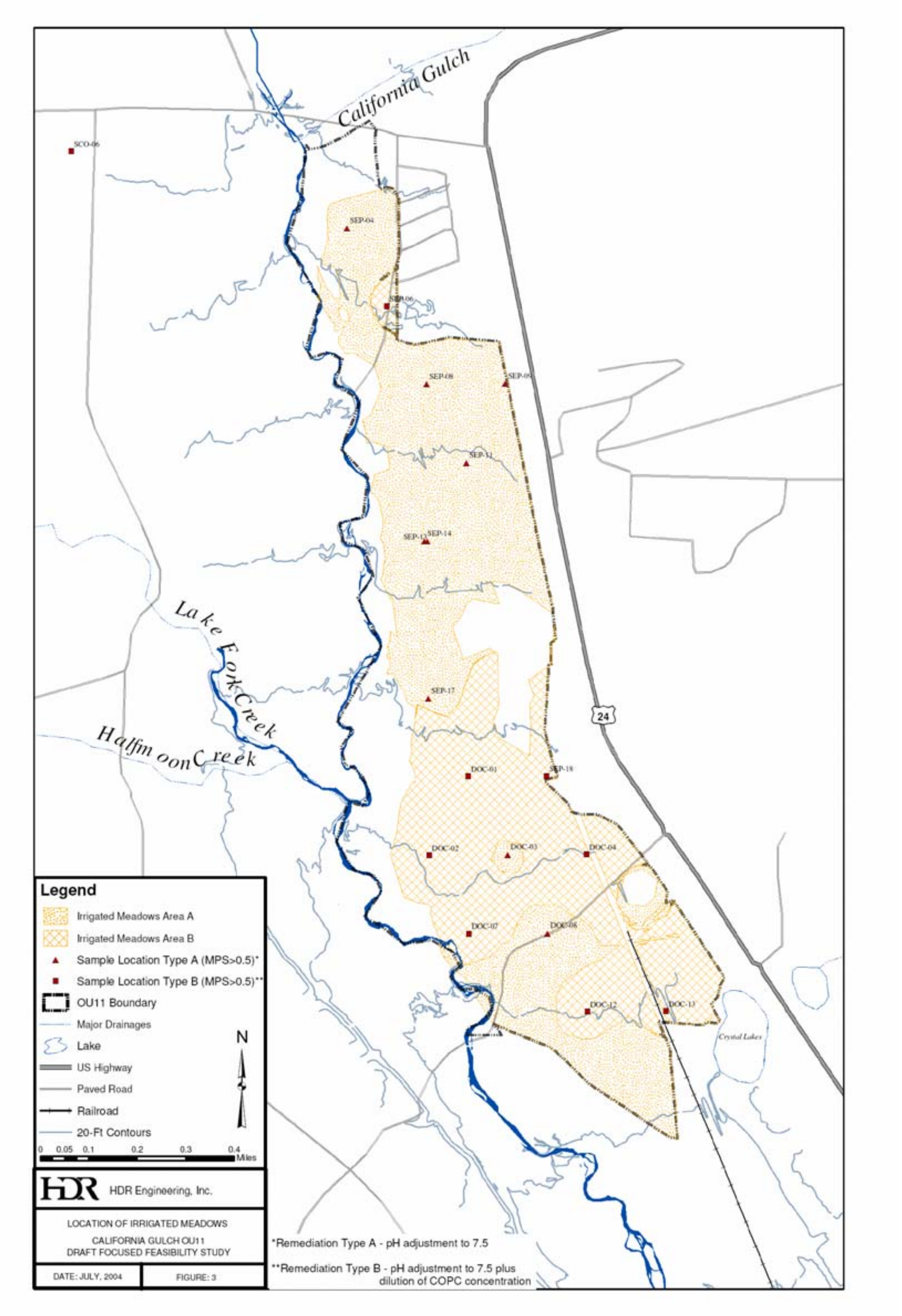
3.7.2 Summary of Relevant OU 4 and 8 Fluvial Tailings Remedial Actions

As part of an interim removal action, in 1998 approximately 5,794 cubic yards of fluvial tailing were excavated from poorly vegetated, erosion-prone areas within OU8 (specifically, FTS2, FTS3, FTS6, and FTS8). The excavated tailing was transported and placed on the Oregon Gulch Tailing Impoundment (OU10). Of the approximately 60 acres of fluvial tailing in OU8, approximately 11.5 acres of wetland and 13.3 acres of upland have been identified for this revegetation. Wetland areas will be revegetated with the same native wetland plant species that currently dominate the California Gulch wetlands. The upland areas will be regraded and vegetation established with soil amendments, as needed, including lime, nutrients and organic matter. In addition, erosion-prone areas will be protected with riprap and a suitable filter fabric" (ROD OU8 2000, p. DS-43).

The decision of whether to remediate OU4/Oro City will be made during evaluations conducted for OU12, site-wide surface and groundwater (ESD OU4 2004, p. 5).

Figure 3-10

Location of Irrigated Meadows



Source: ROD OU11 2005

3.7.3 Summary of Relevant OU 4, 5, 7, 8 and 10 Waste Pile Remedial Actions

Various remedial actions have been undertaken on mine waste piles outside of fluvial regions. The three basic categories of actions are removal, diversion of water flow, and containment/capping. Removals have primarily consisted of consolidation of smaller waste piles into the larger tailings impoundments (e.g. into the Main Impoundment in OU7 or the Oregon Gulch Tailings Impoundment in OU10). Diversions include redirection of surface water around piles and interception of groundwater, with the intent of reducing aqueous transport of contaminants from the piles. Containment projects include regrading, capping, soil amendment, and revegetation. For example, the Oregon Gulch Impoundment has a multi-layer composite cover, including a geosynthetic infiltration barrier covered with 18 inches of soil. The soil surface was graded, amended, and vegetated with grasses and forbs (ROD OU10 2004, p. DS-41). Waste pile remediation projects began in the mid-1990s and have continued since that time. Several vegetation projects have required repeated follow-up actions (USEPA 2005).

3.8 PRELIMINARY ESTIMATE OF DAMAGES

Similar to the aquatic resource analysis presented in Chapter 2, for PED purposes the potential magnitude of terrestrial damages is assessed through development of preliminary estimates of the cost of restoration and/or habitat protection projects potentially appropriate to offset terrestrial resource injury. Restoration and/or habitat protection project costs are a commonly used measure of natural resource damages, and appropriate in this case for several reasons. For this preliminary PED analysis, the Trustees assume that natural resource damage restoration efforts will focus on the purchase of conservation easements intended to prevent future loss and/or degradation of ecologically important and sensitive terrestrial habitats near the Arkansas River and/or other surface water resources as opportunities allow.

The Trustees have undertaken an initial evaluation of placing a conservation easement on the Moyer Ranch, which encompasses 3,261 acres of terrestrial habitat, including 775 acres of wetlands. Undeveloped, the Moyer Ranch provides a land bridge between public lands to the north and south, and to the east and west sides of the Arkansas River valley, forming migration corridors between Mosquito and Sawatch Ranges. The easement would also provide a buffer between Leadville and some interspersed private lands and the public lands of the San Isabel Forest, while protecting and enhancing wildlife, recreational and scenic values of over 8,000 acres of surrounding open space.

The habitat that would be protected by an easement includes a range of terrestrial habitat types, from Alpine tundra and coniferous and aspen forests to graminoid wetlands, shrublands and grasslands. Approximately one mile of Arkansas River, four tributaries – two perennial and two intermittent – and 9.5 miles of tributary riparian habitat add to the diversity of the ecosystem. The ranch provides critical winter range for mule deer and a herd of over 300 elk, habitat for elk calving and deer fawning, and summer range for these large mammals as well as mountain goats and bighorn sheep. Water rights would accompany the protected land.

Maintenance of these rights for current uses would help ensure a healthy aquatic and riparian system along Empire Gulch.

Consistent with PED objectives, the Trustees provide a preliminary HEA analysis to help assess the approximate magnitude of potential restoration scale (and cost). More detailed analysis and/or alternative approaches may be undertaken as part of future assessment activities.

3.8.1 HEA Inputs and Results

Consistent with standard practice in natural resource damage assessments, calculation of service losses begins in 1981. Preliminary, simplified assumptions regarding the areal extent, magnitude and timing of service losses are summarized below and in Table 3-9:

- <u>Irrigated Meadows</u> – Areas predicted to be mildly (234 acres), moderately (408 acres) and highly (41 acres) phytotoxic (based on the 2003 ERA Addendum) are assigned service losses of 18 percent, 38 percent, and 63 percent, respectively.[7] These levels of loss are assumed to begin in 1981, and held constant through 2006. Readily available information suggests that as part of the CERCLA Superfund process, 324 and 32 acres of moderately and highly phytotoxic irrigated meadows, respectively, will be treated by lime or organic amendments, followed by deep tilling and seeding with native grasses, likely beginning in 2007. Based on Trustee revegetation experience and professional judgment, service loss in treated areas is assumed to decrease by 50 percent by 2012, by 80 percent by 2057, and by 100 percent by 2107, with linear improvements between each point. Service loss estimates for untreated areas are held constant for the entire 1981 through 2106 period, reflecting preliminary Trustee judgment that natural recovery processes are unlikely to improve resource condition for many decades.

- <u>Riparian Areas</u> – Areas predicted to be mildly (209 acres), moderately (305 acres) and highly (39 acres) phytotoxic (based on the 2003 ERA Addendum) also are assigned service losses of 18 percent, 38 percent, and 63 percent, respectively. These levels of loss are assumed to begin in 1981 and held constant through 2106, reflecting the Trustees' expectation that remediation will not be undertaken at these locations and preliminary judgment that natural recovery processes are unlikely to improve resource condition for many decades.

- <u>OU11 Fluvial Mine Waste Deposits</u> – Fluvial mine waste deposits are assigned a service loss of 100% based on the severely reduced quantity and quality of vegetation, and reflect a complete loss of ecological services normally provided by this habitat. These levels of loss are assumed to begin in 1981, and are held constant through 2006, reflecting Trustees' observation of slow recovery of these areas even with initial implementation of remediation (*in situ* treatments and revegetation) in the late 1990s. Additional remediation plans, encompassing tilling, soil amendment, and revegetation with native

---

[7] Phytotoxicity categories are assigned to a range of percent reduction in services based on comparison to plant growth at reference stations (USEPA 2003, p. 4-4). These are 11-25 percent for mildly phytotoxic, 26-50 percent for moderately phytotoxic, and 51-75 percent for highly phytotoxic. The mid-point of the range is used in calculations.

grasses, are expected to start in 2007. Based on Trustee revegetation experience and professional judgment, service loss is estimated to be reduced by 50 percent after five years (2012), 80 percent after fifty years (2057) and 100 percent after one hundred years (2107).

- OUs 4 and 8 Fluvial Mine Waste Deposits – Similar to OU11 fluvial mine waste deposits, the deposits in OU4 and 8 fluvial habitats are assigned a service loss of 100%, based on the low vegetative cover and elevated metals concentrations. These levels of loss are assumed to begin in 1981, and are held constant through 2006.[8] Roughly 25 acres of deposits have been revegetated, and are expected to improve on a similar schedule to that described above for OU 11 fluvial deposits. Service loss estimates for untreated areas (approximately 45.8 of the 76 acres of OU 4 and 8 fluvial deposits) are held constant for the entire 1981 through 2106 period. These estimates of service loss do not include potential impacts associated with remedial activities (e.g., impacts to riparian vegetation along channel with riprap).

- OUs 4, 5, 7, 8 and 10 Waste Rock Deposits – Waste rock piles are assigned an initial service loss of 75 percent, reflecting limited quantity and quality of vegetation in and near these areas. While *in situ* remediation actions have been implemented at some deposits, and vegetated covers have or will be installed over several waste impoundments, existing vegetated covers do not support a high quantity or diversity of plant life. This level of loss is assumed to begin in 1981, and held constant through 2106, reflecting the Trustees' expectation that removal of contaminants will not be undertaken at these locations and preliminary judgment that natural recovery processes are unlikely to improve resource condition for many decades.

---

[8] While a 1998 Action Memorandum resulted in excavation of tailing deposits at several fluvial sites in OU8, vegetative cover remains low.

Table 3-9

Preliminary Calculation of Service Loss for Terrestrial Injuries
Input Parameters and Service Acre-Years (Discounted to 2006)

	Area (acres)	1981-2007	2012	2057	2107	Discounted Loss (Acre-Yrs)
Irrigated Meadows - 11-mile Reach						
mildly PT, no treatment	234	18%	18%	18%	18%	2,956.9
moderately PT, no treatment	84	38%	38%	38%	38%	2,240.9
moderately PT, revegetated	323.5	38%	19%	8%	0%	6,286.4
highly PT, no treatment	8.76	63%	63%	63%	63%	387.4
highly PT, revegetated	31.6	63%	32%	13%	0%	1,018.1
Riparian Areas - 11-mile Reach						
mildly PT, no treatment	209.2	18%	18%	18%	18%	2,643.5
moderately PT, no treatment	304.7	38%	38%	38%	38%	8,128.5
highly PT, no treatment	39.34	63%	63%	63%	63%	1,739.9
Fluvial Tailing Deposits						
11-mile Reach, revegetated	65	100%	50%	20%	0%	3,324.0
OUs 4 and 8, revegetated	24.8	100%	50%	20%	0%	1,268.2
OUs 4 and 8, no treatment	45.8	100%	100%	100%	100%	3,215.3
OU 4,5,7,8,10 mine waste piles, no treatment	145	75%	75%	75%	75%	7,634.5
					TOTAL	**40,843.6**

Note: Revegetation presumes soil amendment, tilling, and planting of native grasses.

As described above, the Trustees have identified the purchase of an easement on the Moyer property (3,261 acres) as a reasonable restoration project that will protect and preserve wildlife habitat similar to wildlife habitat injured by the responsible parties. Specifically, the easement will protect the habitat from future development and encroachment, and will maintain and improve ecological services through preservation of water supply and enhanced grazing management. Benefits were calculated separately for irrigated meadows and upland habitat associated with the Moyer property. In addition to the easement on the Moyer property, the Trustees also identified riparian revegetation as a reasonable restoration project that would restore riparian wildlife habitat similar to riparian habitat that was injured by the responsible parties, including areas injured by fluvial tailings.

The following methods were used to calculate the benefits associated with purchasing an easement for irrigated meadow habitat on the Moyer property. The service gain associated with the conservation easement is the avoided loss of habitat value if the current habitat were degraded in the future. In this case, the service gain is the difference in habitat value between the irrigated meadows currently maintained using the Moyer's senior water rights and dry sagebrush habitat that would likely replace the irrigated meadows if the water rights were purchased separately from the land and transferred to a municipality or other entity. This potential loss of habitat value would be avoided if the conservation easement were put in place and the transfer of water rights did not occur. The service gain was estimated to be 58% for the irrigated meadows, based on a documented increase in bird species number for irrigated meadows compared to dry sagebrush habitat (McAdoo, 1999). The service difference was assumed to occur over the period of 2007-2012 to reflect the likely quick loss of water rights if the property were sold without an easement in place.

The following methods were used to calculate the benefits associated with purchasing an easement for upland habitat on the Moyer property. The service gain associated with the conservation easement is the avoided loss of habitat value where the uplands currently associated with a large ranching operation converted to “exurban” residential use (35-acre minimum lot size). This potential loss of habitat value would be avoided if the conservation easement were put in place. For each potential homestead avoided through a conservation easement on the Moyer property, the estimated area of habitat benefit extends across a 180 m radius surrounding the development. Across this area (approximately 25 acres per homestead site), a service difference of 50% was assigned based on the estimated avoided loss for sensitive birds that experience a decline in density for 180 m near exurban development (Odell and Knight, 2001). The service difference was phased in over the period of 2007-2033 to reflect the likely pace of development that would occur if an easement were not put in place. The service gain associated with the easement was assumed to be maintained through 2107.

The following methods were used to calculate the benefits associated with riparian revegetation. The service gain associated with riparian revegetation is based on the estimated difference in habitat value between highly degraded riparian areas and areas replanted successfully with native willow and other native riparian species. Planting of native vegetation in degraded riparian areas was assumed to increase habitat services by 75%, based on an estimated increase in vegetation cover between degraded and restored areas. The area of service gain was based on a strip of revegetated riparian vegetation 2.5 feet wide and an estimated 25-foot buffer area behind the revegetated strip. This buffer area accounts for an area of increased riparian services as the revegetation areas grow and mature. The service gain was phased in over the period of 2007-2016 based on the time required for willows to grow and mature at high elevations. The service gain associated with riparian revegetation was assumed to be maintained through 2107.

Table 3-10 provides quantitative estimates of service benefits associated with the restoration projects described above.

Table 3-10
Calculation of Potential Ecological Benefits Related to Proposed Restoration Projects (discounted to 2006)

Habitat Type	Discounted Service Acre-Years (DSAYs) of Benefit Per Acre Restored
Irrigated Meadows Habitat Easement	17.3
Upland Habitat Easement	10.9
Riparian Habitat Revegetation	20.7

Cost estimates for the three habitat types (irrigated meadows, upland, and riparian) were based on unit costs to implement the restoration projects described above. These unit costs (costs per DSAY) were multiplied by the total number of injured DSAYs to estimate the likely costs needed to offset preliminary estimates of quantified injuries.

For irrigated meadows, the unit price for a conservation easement protecting land and associated water rights in Lake County was derived from an appraisal of the Moyer property (Sartucci, 2006). The value of a conservation easement for a wet meadow parcel with irrigation is $8,315 per acre, based on data presented by Sartucci (2006). Because each acre generates 17.3 DSAYs of credit, the cost per DSAY is $482. The estimated debit of contaminated irrigated meadows is 12,890 DSAYs. This debit would not be compensated by the 9,400 DSAYs (rounded) that would be provided by the preservation of 542 acres of irrigated meadow acreage available on the Moyer property, at a total cost of $6.2 million.

For upland habitats, the unit price for a conservation easement protecting land from development was derived from the same appraisal of the Moyer property used above (Sartucci, 2006). The value of a conservation easement for upland acreage is $2,144 per acre, based on data presented by Sartucci (2006). Because each acre generates 10.9 DSAYs of credit, the cost per DSAY is $197. The estimated debit of 7,635 DSAYs of injured upland habitat resulting from on-site mine waste rock piles would be compensated by an easement of 700 acres of upland acreage available on the Moyer property, for a total cost (rounded) of $1.5 million.

For riparian habitats, the unit price for riparian revegetation was estimated to cost $1.89 per square foot or $82,300 per acre (Rod Van Velson, Colorado Division of Wildlife, personal communication, with costs updated to 2006 dollars using the produced price index). These costs are consistent with riparian revegetation costs (soil amendments plus native plants) developed for the Coeur d'Alene Natural Resource Damage Assessment (LeJeune et al., 2004), which estimated costs at $1.91 per square foot or $83,308 per planted acre. A planted area of 1 acre would generate 207 DSAY credits over an area of 10 acres as the revegetated areas grow and mature and the vegetation footprint expands over time, generating a cost per DSAY of $400. The estimated debit of 20,307 DSAYs for the combined injured riparian and fluvial tailings habitats would be compensated by revegetating 981 acres of riparian habitat for a total cost (rounded) of $8.1 million.

In addition, for preliminary evaluation purposes, the Trustees assume a modest annual budget of $15,000 over the 100-year project period to allow for regular monitoring of the property's ecological condition, administration, and enforcement. In present value terms, this adds approximately $0.5 million to the cost of the project. This brings the total estimated costs of terrestrial restoration to over $16.3 million.

REFERENCES

CDOW. 2006. Arkansas River Research Study Final Report for Period April, 1994 to December 30, 2005. Colorado Division of Wildlife. Submitted to: Bureau of Reclamation. April.

CDOW. 1990. Use Attainability Study, California Gulch, Colorado. Colorado Division of Wildlife.

Chadwick Ecological Consultants, Inc. 2005. The Aquatic Biological Monitoring Program for the Upper Arkansas River 1994-2004.

Chadwick Ecological Consultants. 2003. Preliminary report on the biological data of the Upper Arkansas River, 1994-2002. Chadwick Ecological Consultants, Inc.

Chadwick Ecological Consultants, Inc. 1998. Aquatic biological assessment data for the Upper Arkansas River Basin near Leadville, Colorado (1995-1998).

Engineering-Science, Inc. February 29, 1986 Yak Tunnel/California Gulch Remedial Investigation Report.

ESD OU4. 2004. Explanation of Significant Differences, Upper California Gulch Operable Unit 4, California Gulch Superfund Site, Leadville, Colorado.

Golder Associates. 1996. Hydrogeologic remedial investigation report, California Gulch Site, Leadville, CO. Volume I. May.

HDR. 2006. Draft remedial investigation, Operable Unit 12. California Gulch Superfund Site, Leadville, CO. March.

HDR. 2003. Draft remedial investigation

Pivonka, L.J. 2006. Letter to Stan Christensen, U.S. EPA, re: Draft remedial investigation, Operable Unit 12. California Gulch Superfund Site, Leadville, CO.

Pivonka, Lee and Mike Wireman, August 22, 2003, Memorandum to Stan Christensen and Angus Campbell "Proposed Well Locations in Operable Unit 12, California Superfund Site”

RAR. 2003. Restoration Alternatives Report for the Upper Arkansas River Basin. Prepared by the Memorandum of Understanding Parties Consulting Team.

RMC. 2006. OU12 Conceptual Surface Water Model (presentation).

RMC. 2001

ROD OU1. 1988. Record Of Decision, Operable Unit 1, California Gulch Superfund Site, Leadville, Colorado.

ROD OU10. 2004. Record Of Decision, Oregon Gulch Operable Unit 10, California Gulch Superfund Site, Leadville, Colorado.

ROD OU11. 2005. Record Of Decision, Operable Unit 11, California Gulch Superfund Site, Leadville, Colorado.

ROD OU4. 1998. Record Of Decision, Upper California Gulch Operable Unit 4, California Gulch Superfund Site, Leadville, Colorado.

ROD OU8. 2000. Record Of Decision, Lower California Gulch Operable Unit 8, California Gulch Superfund Site, Leadville, Colorado.

Sartucci, P.E. 2006. Real Estate Appraisal: Complete Appraisal & Summary Report of: Three Conservation Easement Alternatives On the Moyer Ranch, Parts of Townships 9 & 10 South, Ranges 79 & 80 West, 6th P.M., Lake County, Colorado. Prepared for Mr. Ron Carlson of Carlson, Carlson, & Dunkleman, LLC. September 21.

SCR. 2002. Site Characterization Report for the Upper Arkansas River Basin. Prepared by the Memorandum of Understanding Parties Consulting Team.

Tetra TechT/RMC. 2004. California Gulch Superfund Site, site-wide groundwater sampling, summer 2005. Prepared by Tetra Tech Rocky Mountain Consultants for Colorado Department of Public Health and Environment. December.

Thompson, M. 2005. Colorado Gulch Metals Loading Analysis and Mine Waste Characterization, 2002 – 2004. Prepared for the Lake Fork Watershed Working Group.

Tweto, O. 1968. Leadville District. In Graton, L.C. and Sales, R.H. (eds.), Ore Deposits of the United States, 1933-1967; American Institute of Mining Metallurgical, and Petroleum Engineers, Inc, New York. Volume 1.

USEPA. 2001. Second Five-Year Review Report for California Gulch.

USEPA. 2003. Ecological Risk Assessment for the Terrestrial Ecosystem California Gulch NPL Site Leadville, Colorado. *ADDENDUM:* Evaluation of Risks to Plants and Herbivores in the Upper Arkansas River Flood Plain.

USEPA. 2005. December 2005 update for California Gulch Superfund Site.

USGS. 2005. Water Resources of the Upper Arkansas River Basin. Map accessed at http://co.water.usgs.gov/projects/TurqLake/html/mappage.html, December 15, 2005.

Weston and Terra Technologies. 1997. Ecological Risk Assessment for the Terrestrial Ecosystem, California Gulch NPL Site, Leadville, Colorado. DCN 4800-32-0118. January, 1997.