2.0 NATURE AND EXTENT OF CONTAMINATION (11-MILE REACH)

This section provides a summary of the data that are available to define the nature and extent of contamination and resource conditions within the 500-year floodplain of an 11-mile section of the Arkansas River, extending from the confluence of California Gulch to Two-Bit Gulch. Presentation of the data focuses on the presence and/or distribution of metals in the environment, examination of the existing data relative to the previously described definitions of injury, and any relevant benchmarks where appropriate, summary statistics are provided. This section also includes a characterization of the baseline condition for an upstream section of the Arkansas River, from the confluence of Tennessee Creek and the East Fork of the Arkansas River downstream to California Gulch (Reach 0). Quantitative analyses of spatial and temporal trends are presented where data allow. Spatial trends are used to delineate the geographic extent of an injury. Temporal trends are used to describe the history of conditions and to provide a better understanding of resource recovery. Interpretation and discussion of the results are presented in Chapter 3.0.

In order to provide a more complete assessment of the mining impacts to the UARB, data have been collected from numerous studies and databases. These data sources have been compiled into a Bibliographic Database, from which the specific studies containing pertinent data have been used to characterize the system (Appendix A). For some of the resources, a large amount of information was available. An electronic database of numeric information for different media has been developed to more effectively manage and analyze the data, as well as to provide a record of the information used in the environmental characterization of the 11-mile reach (see Appendices C_1, C_2 and C_3). The project electronic database contains a subset of relevant data entered from sources listed in the project Bibliography database.

Media evaluated include soil, surface water and sediment, groundwater, and biota. Because this is a fluvial system, the hydrology and geomorphology of the river are also important components in assessing the nature and extent of contamination. Four primary metals have been selected: cadmium, copper, lead, and zinc, as indicators of metal contaminants. Reasons for selecting these metals are based on:

- Review of the existing studies and data;
- Basic understanding of the mining history and ore bodies;
- Toxicity considerations; and
- Predominance of these metals in the fluvial system of the UARB.

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.

In summary, this section of the report provides a record of the information/data available regarding metal concentrations in the media described above, possible sources, the condition of resident biota, and the existing fluvial characteristics that may influence transport. The following provides a brief overview of the most significant types of information utilized for this characterization. A complete listing is provided in Appendix A.

Hydrology /Geomorphology

USGS flow records from gaging stations located in the 11-mile reach have been compiled to assess the changing conditions of flows in the Arkansas River. Very few gaging stations are present within the 11-mile reach (Figure 2-1). The Leadville Junction gage (07081200) is located just downstream of the East Fork Arkansas and Tennessee Creek confluence. This gage provides data on flows in Reach 0, upstream of California Gulch. Two additional gages are located in close proximity to the Highway 24 Bridge crossing of the Arkansas River. The Arkansas River near Malta gage (07083700) was located at the Highway 24 Bridge crossing, while the Arkansas River below Empire Gulch (07083710) is located just downstream of Empire Gulch. The next closest gaging station is at Granite, CO, which is substantially downstream of the 11-mile reach and includes heavy flow augmentation from Lake Creek. While individual, short-term studies collected flow data from the river at various locations within the reach, those data provide at best, only a snap-shot of flows at a specific point and time. Gaged flow data with several years of records are necessary to characterize flow conditions.

These data, as well as hydrological studies by universities and agencies such as the Bureau of Reclamation, which manages much of the water in the basin, were considered. Assessment of high and low flow conditions in the basin is provided to gain a better understanding of how the hydrology of the system affects metals transport. Additional information that describes the water management in the UARB, which includes many trans-basin diversions that ultimately affects the hydrology of the system, is also presented (Figure 1-7).

As typical with Rocky Mountain river systems, the Arkansas River experiences annual seasonal snowmelt conditions resulting in high flows (beginning about late April to early May and continuing until about early to mid August) followed by a period of lower flow (typically in August and September) that may be elevated during precipitation events sufficient to cause runoff (Figure 2-2). The geomorphology of the river is directly influenced by the water flows in the system and land uses in the basin, as well as other natural and anthropogenic factors. Fluvial geomorphology of this system was characterized by InterFluve (1999) and by review of historical aerial photographs that help to establish the changes in the river's morphology, by field reconnaissance and discussions with local landowners.

Surface Water and Sediments

Water quality data presented in the following sections have been compiled from numerous sources into an electronic database. Sources include both published and unpublished data, from both electronic and hardcopy sources. Studies include those by Davies et al. (1997 and 2000), Walton-Day et al. (1999), and Nelson and Roline (1999). Other data sources include Colorado State University Water Resources program, USFWS, Bureau of Reclamation, Colorado State University, Colorado Division of Wildlife's River Watch Program, the USGS, and USEPA's STORET. Because of the number of different data sources, summarizing the methods for the different data collection efforts is not practical.

Only a small number of studies have been conducted on riverine sediments in the Arkansas River. The lack of studies on streambed sediments may be due to the characteristics of the river. Because the 11-mile reach is located in the upper portions of the drainage basin, the riverbed tends to be coarse gravel and cobble, with little fine-grained material present. Seasonal high flows entrain and transport the finer grained sediments downstream, where they tend to be deposited on the upper banks and in the bars of the braided channels during high flows. Historical entrainment and transport has resulted in the fluvial deposition of fine-grained mine-wastes along the floodplain of the 11-mile reach.

The surface water and sediment portion of the electronic database was continually updated with new information as it became available. Data entered into the database was suspended at the beginning of September 2001. Thus, the analyses and summaries of data presented as of this site characterization include all data that has been made available to that point. It is believed that the existing data have framed the geographic and temporal extent of injury. Unless the magnitude of the chemical concentrations are significantly different from what is presently in the database, the summary statistics for any one parameter in a given time period is not expected to change dramatically. This is particularly true for Period 3 (1992 to September 2001), because of the large amount of relatively consistent data.

Several independent studies have been conducted by agencies, some of the data from which are included in the database related to water quality or sediment quality in one or more Arkansas River reaches of interest. A listing of studies obtained and reviewed for the preparation of this SCR is presented as part of Appendix A. On occasion, these studies focus on a particular area or a period in time that sometimes provides a greater level of detail.

Water quality data included in the database span an approximate period of record from 1965 to 2000. This range is not consistent for all parameters or for all reaches. Summary statistics calculated from data in the database are grouped by three time periods that coincide with major changes in water quality and quantity within the basin. Time periods include:

- Period 1 – Prior to June 1981 when the Mt. Elbert conduit began transporting water from Turquoise Lake to power stations north of Twin Lakes Reservoir;

- Period 2 – June 1981 to before February 1992, a period following diversion of water into the Mt. Elbert conduit and prior to treatment of mine waters at the Leadville Mine Drainage Tunnel (LMDT), which discharges to the East Fork of the Arkansas River, and the Yak Tunnel, which discharges to California Gulch; and

- Period 3 – February 1992 to September 2001, a period following treatment at the above-mentioned facilities. While it is clear that there have been numerous water development projects and other influences on water quality and quantity in the UARB, it is believed that these two modifications have most greatly influenced the surface water quantity and quality of the system, and therefore provide logical temporal break points as well as points of comparison.

Discussion of the 11-mile reach of the river has been divided into the previously described reaches. Information on water quality in Reach 0, the Arkansas River from the confluence of Tennessee Creek and the East Fork of the Arkansas River to CR 300 upstream of California Gulch, is also presented as a point of comparison. Because Reach 0 is used as a baseline point of comparison for downstream reaches, care was taken, specifically in the analysis of surface water quality data, to assure that California Gulch influences were not included in this reach. Samples designated as AR-2 or those with different site designations in close geographic proximity to AR-2 were not included with water quality data for Reach 0, as concentrations of metals at these sites were on a few occasions elevated above the concentrations of metals observed in upgradient sites. The AR-2 sites are described as being about 300 feet upstream of the confluence of California Gulch with the Arkansas River; however, uncertainties about the positional accuracy of these locations, as well as the potential influence of California Gulch on these locations justified removal of the AR-2 sites from the Reach 0 analysis. Thus, for the purposes of the surface water discussions, Reach 0 begins as described above and extends to 1,000 feet upstream of the CR 300 bridge over the Arkansas River. Changes in water quality that may result due to inputs from tributaries within a reach are discussed in the context of how they influence water quality in the four primary reaches.

After reviewing the data in some detail, a few issues become clear relative to the distribution of the information across time and space. For most all metals data in each reach, total metals provide the clearest picture of temporal trends because these data were more consistently collected prior to the mid to late 1980s, where as dissolved metal data does not generally become available until after this time. The sampling frequency generally increases after about 1990, thus the distribution of metals data during high and low flow becomes more clearly defined. Because of these observations, the following discussions focus on two distinct aspects of the data. First, the overall temporal trend for each metal in each reach during the entire period of record (POR) is discussed based on total metals. Second, a closer look at metals data available for Period 3 during high and low flows in each reach is provided. This discussion focuses on dissolved metals only as these concentrations are directly comparable to the TVSs. Focusing in on Period 3 provides a closer examination of the last 10 years of metals data to assess the current potential for injury, sources, and current temporal and spatial trends.

Summary statistics, including the number of sampling stations, number of samples, minimum, maximum, average, and standard deviation are presented for each metal, period, and reach combination. These summary statistics are further divided by high and low flow. The summary statistics included all non-zero values and samples from locations identified as ambient river samples (i.e., no outfall, discharge, effluent, springs or seeps, etc., were included). Data reported as less than detection limits were included in the summary statistics as one-half the detection limit. Minimum values for some of the metals in each reach are therefore one-half the detection limit. In some cases, the reported detection limits are greater than the State of Colorado's TVSs. This is particularly true for samples collected in Period 1.

Because data sets from multiple studies were combined into a single database, there were occasions in which data were reported in more than one of the study data sets. The water quality statistics presented in the report are based on unique data occurrences only. Duplicate values were filtered from the analysis data set by a custom Visual Basic program, which identifies and flags duplicate records. Duplicate records are defined as two or more records reporting the same location, date, analytical parameter, and similar result value. For the purpose of this report, values within 0.75 percent of each other were considered identical for duplicate-flagging purposes. Exact result values could not be used to identify duplicates primarily because of how different investigators report their data.

Positional data reported in the various data sets varied significantly in accuracy and precision. Different sample station naming conventions were used by the various sampling agencies. As a result, two data sets may report the same station in slightly different locations, or may refer to the same location using different station identifiers. These inconsistencies were also assessed in the duplicate identification process by using GIS-generated spatial data instead of absolute locations. Stations occurring on the same water body within 100 meters of each other and not potentially separated by a tributary input were considered as the same station for duplicate identification purposes. Analytical parameter names and reporting units also differed across the various data sets. Analyte names and reporting units were standardized prior to duplicate identification and data analysis.

Finally, a statistical test for outliers was conducted on each metal for each form of the metal (e.g., total vs. dissolved cadmium) for the entire period of record across all reaches and tributaries. This approach is considered conservative, as only the most extreme outliers from the population of data would be identified. Such an approach was considered appropriate given the composite nature of the data (i.e., different sampling methods, detection limits, and collecting agencies/individuals). Outliers were identified as those measurement data that were greater than four standard deviations of the mean value for the population mean. Any data identified as an outlier were flagged in the database with an "O," and a selective query and review excluded these data from the analysis. A complete description of data handling, duplicate flagging, and outlier testing is provided in Appendix C.

Summary statistics are calculated for total and dissolved cadmium, copper, lead, and zinc. For each period, the number of data points collected within each reach for a parameter that exceeds the Colorado Table Value Standard (TVS) (CDPHE 2000) is reported (Table 2-1). Because the TVSs are based on concentrations of dissolved metal, the comparisons reported are all for dissolved metals. Further, because the TVSs for these metals are hardness-dependent, standards were calculated using the mean hardness for a Reach during the flow (e.g., high or low) condition represented for a specific time period. The number of exceedances is presented, followed by the percentage of exceedances in parentheses, which is based on the number of exceedances divided by the number of samples.

<u>Groundwater</u>

Consistent with the hydrogeology and definitions of injury, groundwater quality information was grouped into two fundamental categories: a) data from shallow wells (0-10 feet below ground surface) recently placed by USEPA and USGS primarily to evaluate any impacts from mine-waste deposits to surface water and groundwater, and b) deeper valley fill groundwater (screened interval typically more than 10 feet below ground surface) collected from existing domestic water supply wells, and a single deeper, monitoring well. Correspondingly, within this document, the analysis of groundwater will be divided into discussions for Shallow Monitoring Well (SMW) data and Domestic Water Supply (DWS) data. Generally, shallow monitoring wells are constructed with minimal screening and little development, whereas domestic water supply wells tend to have more extensive and deeper screening and with more development. Consequently, data obtained from the deeper water supply wells likely characterizes the groundwater that is less influenced by river fluctuation, perched water lenses, and surface erosion, than the shallow monitoring wells. There were also a few groundwater samples from springs that were summarized independently of the SMW and DWS categories. Data sources used in the groundwater characterization include:

Sources of Domestic Water Supply (DWS) groundwater data:

- 1983 Surface and Groundwater data, Cal Gulch/Arkansas River area, compiled by Ecology & Environment, Inc.;
- 1983-1988 California Gulch Water Quality Data, compiled by ISSI;
- 1955-1997 USEPA STORET data, compiled by USEPA (Only very limited data from 1972 available for the 11-mile reach);
- 1989 Groundwater & Surface Water Data, compiled by Water, Waste and Land;
- 1963-2000 USGS Upper Arkansas Basin Semi-Annual Well Network Water Levels, compiled by USGS; and
- 1984-2000 CDPHE GW Data compiled by CDPHE.

Sources of Shallow Monitoring Well (SMW) groundwater data:

- 1995 and 1996 GW data compiled by USGS (Walton-Day et al. 2000); and
- 1998-2000 Upper Arkansas Monitoring Well Data, compiled by USEPA/URS.

Summary statistics, including the number of samples, minimum, maximum, mean, and standard deviation are presented for each metal and reach combination for Period 3 for SMW groundwater data and individual data records can be found in Appendix E. The same time periods as those used to categorize surface water are also used for groundwater. Summary statistics for the DWS data are presented for Periods 1, 2 and 3 combined and individual data records can be found in Appendix E. The data presented in the summary tables included all non-zero values and samples from locations identified as wells. Data reported as less than detection were included in the summary statistics as one-half the detection limit. As in the surface water section, since multiple studies were combined into a single database, any occurrence where the same data were reported in multiple studies, only unique occurrences of the data were used for groundwater quality statistics. Unlike surface water quality data, an outlier test was not done for groundwater data due to the limited quantity of data available; however, values were reviewed individually for discrepancies.

For SMW groundwater, data are only available for Period 3 (February 1992 to present) and, within that time frame, most groundwater data are from 1998 and 1999 (Appendix E). Most of the shallow wells are screened 1-6 ft below ground surface and are located close to the Arkansas River (approximately 50ft- 750ft). All but two of the shallow monitoring wells are within the 500-year floodplain. Data from shallow wells outside the 500-year floodplain are extremely limited.

DWS data are temporally sparse, however, the spatial distribution covers Reach 0 and most of the 11 mile Reach, though there are no DWS groundwater data available in Reach 4. Generally, groundwater quality data are presented for dissolved cadmium, copper, lead, and zinc. However, since only total metals data were available from the CDPHE Safe Drinking Water Information System, statistics for this data set are also included. Similar to the surface water quality discussion, mean (minimum, maximum) concentrations are presented. Given the limited quantity of temporal information, data from all time periods are combined for the DWS category (Appendix E).

Floodplain Soils

A number of studies, including those conducted by Keammerer (1987), Colby (1988), Swyers (1990), Sommers et al. (1991), Levy et al. (1992), Woodward Clyde (1993), URS (1998) and BLM (2000) cover portions of the 11-mile reach and provide physical and chemical data for soils and fluvial mine-waste deposits that are found in the overbank portions of the Arkansas River floodplain.

Available data are presented for Arkansas River reaches of interest, and are also part of the overall electronic database developed for this investigation. Specific data used for characterization include total and plant-available metal concentrations in soils from locations along the 11-mile reach and upstream of the confluence of California Gulch and the Arkansas River. In addition, total metal concentrations in fluvial mine-waste deposits along the 11-mile reach were included in the Site Characterization. The metals reported in this characterization include cadmium, copper, lead, and zinc. For the summarized data, no data were reported as less than detection and no outliers were identified.

In contrast to the other more limited studies referenced above, Keammerer (1987) sampled soils within and adjacent to the 500-year floodplain along most of the 11-mile reach and upstream of the confluence of California Gulch and the Arkansas River. Soils were sampled at 39 locations, including five locations along California Gulch, 9 locations upstream of the confluence of California Gulch and the Arkansas River, and 25 sites along the 11-mile reach. Soil samples were collected from the upper 6 inches and analyzed for total and plant-available (DTPA extractable) cadmium, copper, lead, and zinc.

The Superfund Technical Assessment and Response Team (START) was tasked by the Environmental Protection Agency (USEPA) to locate and characterize mine-waste deposits along 10 miles of the Arkansas River, with the confluence of the Arkansas River with California Gulch being the northern boundary. The study focused on mine-waste deposits within 100 feet of the river. Field work was conducted in the fall of 1996 and 1997 (URS 1997 and 1998). URS Operating Services collected data on each deposit location, depth of the deposit, and area of the deposit. They also sampled the deposits to evaluate the concentration of metals. Using these data, the Consulting Team paired the location information with the aerial photographs using a GIS to obtain a more accurate estimate of the area. Instead of using maximum concentrations as used in the USEPA START reports, average concentrations were used. Together, the area, depth and location data were used to more accurately define where and how much mine-waste deposits were in the 11-mile reach as well as assess the concentrations of metals in those deposits that may be available for transport under high flow conditions. Data summarizing the volume, area, depth, characteristics, and metals concentrations of each deposit are presented in Appendix D.

Biota -- Terrestrial Vegetation

Sommers et al. (1991) and Levy et al. (1992) collected and analyzed plant samples for metal concentrations on the Seppi Ranch (Reach 1) in 1988. There was one principal study, conducted by Keammerer (1987), that provides plant cover and production information for non-mine-waste areas along the 11-mile reach and upstream of the confluence of California Gulch and the Arkansas River. Sample locations were the same as those used for soil sampling within and adjacent to the 500-year floodplain of the Arkansas River. Some of the plant metal data were analyzed on a species level, and some data were grouped into major life-form types, such as grasses and forbs. The metals included in these analyses were cadmium, copper, lead, and zinc. In summarizing the plant tissue data, there were no data reported as less than detection, and no outliers were identified for removal.

Biota -- Habitat: Terrestrial

NRCS (1997) conducted vegetation mapping and described vegetative community types along the 11-mile reach of the Arkansas River. Generally, habitat data for the terrestrial ecosystem along the Arkansas River has been well characterized by CDOW (1988). Habitat types and specific features have been identified for much of the 11-mile reach.

Biota -- Habitat: Aquatic

CDOW collected aquatic habitat data in 1989 and 1990 using the USEPA's Rapid Bioassessment Protocols (RBPs) (Woodling 1990). Chadwick Ecological Consultants, Inc (1998 and 1999) conducted studies of the fish population, benthic community, and fish habitat in the Arkansas River from 1994 through 1999. Habitat quality assessments were made in 1994 and 1998 using the U.S. Forest Service's (USFS) R1/R4 inventory methods, USEPA's RBPs, and the Habitat Quality Index (HQI) methods to assess quality and quantity of habitat at the selected survey sites.

USFS's R1/R4 inventory methods are a standardized inventory and quantification process developed to determine the quantity of habitat in assessment areas. The inventory was designed to define structure, pattern, and dimensions of fish habitat; describe species compositions, distributions, and relative abundance of salmonid species; and facilitate the calculation of summary statistics for habitat descriptors (Overton et al. 1997).

USEPA's RBPs provide a systematic method for rating habitat quality in stream and river systems. Ratings are based on three levels of physical features (each of which contains several categories of rating) that are scored based on observations of the various physical characteristics in the field. Scores based on individual parameter ratings are usually generated using subjective observations rather than measurement data.

The HQI model predicts trout standing crop based on physical, chemical, and biological characteristics of the stream. Output from this model provides a quantitative estimate of fish biomass based on the quality of the stream characteristics. Predicted trout biomass derived from the HQI are presented; however, the biomass estimates are presented as a point of comparison between reaches, not as absolute trout biomass that should be present at any one site or reach.

The U.S. Bureau of Land Management (USBLM) prepared an Arkansas River Water Needs Assessment Report (Smith and Hill 1999) to identify the water resource values of significance and importance. Part of this report identified the water quantity necessary to support the brown trout fishery in a study area extending from Leadville to near Pueblo. Physical Habitat Simulation (PHABSIM) modeling was used to quantify weighted usable area (WUA) based on water depth and velocity, and substrate for life stages of brown trout, including spawning, fry, juvenile, and adult fish. PHABSIM is a predictive modeling tool used to quantify an index to the amount of microhabitat available for different life stages at different flow levels. Variables used in the model include measurements of water depth, velocity, substrate material, and cover. The model uses these variable together with fish suitability curves to arrive at a weighted useable area of habitat available for a given life stage of fish species.

Each of the assessment tools described above provides mechanisms by which aquatic habitat quality can be evaluated. PHABSIM is largely predicting the amount of suitable habitat available for a fish life stage at varying flow levels. The RBPs are providing a rating of overall habitat quality based on instream features, channel features, and near stream features. HQI is providing a predicted fish biomass estimated based on the quality of habitat. Each provides a relative means by which sites can be compared, however, direct comparison of the outputs from the different models/scoring mechanisms is not appropriate.

Biota -- Aquatic Community: Benthic Community

Clements (unpublished data), Chadwick Ecological Consultants (1998 and 1999), and Nelson and Roline (1999) conducted studies spanning several years on the benthic macroinvertebrate community and populations at several sites along the Arkansas River.

A 10-year research program investigating the impact of heavy metals on benthic macroinvertebrate communities was conducted in the Arkansas River from 1989 to 1999 (Clements unpublished data). Portions of this research have been published previously (Clements 1994; Clements and Kiffney 1994; Clements et al. 2002). This assessment included: 1) quantitative measurements of benthic community composition along a 70 km reach of the upper Arkansas River between Climax and Buena Vista; 2) measurements of heavy metal concentrations in water and other physicochemical characteristics; 3) measurement of heavy metal concentrations in invertebrates, sediment, and periphyton; 4) an assessment of genetic diversity of organisms collected from upstream and downstream from metal inputs; and 5) a series of stream microcosm experiments to assess routes of exposure and to quantify concentration-response relationships between heavy metals and benthic community structure.

Spatial and temporal variation in benthic community composition was compared to changes in water quality over a ten-year period to assess the influence of improvements in water quality below the

LMDT and California Gulch. Measurement of heavy metals in abiotic (water, sediment) and biotic (periphyton, benthic macroinvertebrates) compartments quantified routes of exposure and provided insight into potential transfer of metals to higher trophic levels. Genetic studies examined the effects of long-term exposure to heavy metals on genetic diversity of the mayfly *Baetis tricaudatus*. The mechanistic basis for heavy metal tolerance in this species was investigated through analysis of metallothionein, a metal binding protein responsible for metal regulation. Community-level toxicity tests examined benthic invertebrate responses to heavy metals microcosm experiments, and examined concentration-response relationships between benthic community structure and metal levels.

Biota -- Aquatic Community: Periphyton

Sediment and periphyton samples were collected from 5 sites on the Arkansas River at four time points (August 1995, June 1996, August 1996, and July 1998) for metals analyses (Harrahy 2000). Periphyton samples were collected in August 1992 from Reaches 0, 1, and 4 to measure diatom community composition (Medley and Clements 1998). All samples were collected from cobble substrate (128-256 mm) in shallow, unshaded riffle areas (~50 cm deep) with similar current velocity, substrate composition, and canopy cover.

Biota -- Aquatic Community: Fish Populations

Fish species and populations in the Arkansas River have been characterized as far back as 1889 (Jordan). In more recent times, because of their management responsibility for the resource, CDOW personnel have conducted the most comprehensive study of the Arkansas River fish populations. USFWS, CSU, and the U.S. Bureau of Reclamation (USBOR) have also conducted studies in the basin. A 1993 document prepared for the USBOR by the USFWS presents an assessment of the status of brown trout populations in the Arkansas River, and possible causal factors for the observed population characteristics. Chadwick Ecological Consultants surveyed the river for fish in 1994, 1996, 1997, and 1998.

Fish were collected by Aquatic Associates (1993) at sample sites in the Arkansas River and tributaries in 1992 for estimating trout populations. Two fish from each site were retained for tissue residue analysis.

A recently published report by Nehring & Policky (2002) evaluates trends in trout populations over the last 16 years. This report indicates continued improvement in brown trout fishery.

Biota – Terrestrial Vertebrates: Small Mammals

Small mammals were studied as part of three ecological risk assessments (ERAs) conducted for the California Gulch Superfund site (Woodward Clyde 1993; Stoller 1996; USEPA 1997), but only Woodward Clyde (1993) included sampling along the Arkansas River. The Woodward Clyde study was developed by the Biological Technical Assistance Group, which included the Federal and State Trustees, USEPA, Asarco, and Resurrection. While the Stoller (1996) study did not include work in the 11-Mile Reach, they sampled small mammals from various habitats covering a range of contamination and contaminant sources. The USEPA (1997) study did not include collection of data, but rather evaluated risk to small mammals using the data from Woodward Clyde and Stoller as well as scientific literature. Each of the ERAs described above presents a conceptual model that describes the sources of contamination, the pathways by which exposure could occur, and a list of potential receptors.

Woodward Clyde (1993) conducted small mammal trapping and small mammal tissue sampling on the California Gulch NPL Site including the first 2 miles of the 11-Mile Reach. In addition to small mammals, they sampled soils and vegetation at the same sites where small mammals were trapped. They selected reference sites in Reach 0 wetlands (Tennessee Creek and the upper Arkansas River) and they selected a site in Reach 2 (Smith Ranch) to represent the "worst case scenario" for fluvial mine-waste deposits. They trapped small mammals at each site to determine relative abundance and collect tissues for histopathology (evaluation of tissues for microscopic changes) and analysis of metal concentrations in liver, kidney, and bone. Co-located soils and vegetation samples were also collected and analyzed for metals. While Woodward Clyde presents relative abundance based on their trapping effort, one sampling event is not sufficient to determine the abundance of the small mammal community (Fitzgerald et al. 1994 and Lancia et al. 1994). In addition, it is not apparent that Woodward Clyde considered disturbances due to events other than mining or differences in habitat quality when they selected their sample sites. Therefore, we present the total number of each small mammal species trapped at each site as an indication of the small mammal species present, but not as a reliable estimate of abundance (Table 2-2). Samples collected for histopathology and metal residue analysis should represent site-specific exposure and data are presented as reported by Woodward Clyde.

Stoller (1996) conducted small mammal trapping and tissue sampling in upper California Gulch on the NPL Site and in Iowa Gulch. All of their sample sites were in upland areas as compared to wetlands and they did not have any sites located in the 11-mile reach. However, they did collect tissue data for histopathology and residue data from habitats representing a gradient of metals contamination. This data is useful for comparing bioavailability, exposure, and effect of metals from various media at differing concentrations.

USEPA (1997) had an ecological risk assessment conducted for the terrestrial ecosystem on the California Gulch NPL site. They evaluated the potential for adverse effects on biological receptors exposed to soil, sediment, slag, waste rock, tailings, and water within the NPL site. Their assessment relied on existing information, including the Woodward Clyde and Stoller data, and did not include the collection of additional data. They developed hazard quotients for various receptors throughout the NPL site.

Biota – Terrestrial Vertebrates: Large Mammals

There are a variety of large mammals that utilize the 11-mile reach including elk, deer, coyotes and fox, however, the riparian and meadow habitats represent only a portion of the range for most large mammals. Neither tissue metals data nor histopathology data are available for large mammals from Reach 0 or the 11-Mile Reach. Only the USEPA (1997) ERA evaluated potential risk to large mammals. The ERA utilized existing soils and vegetation data and evaluated risk based on modeling of potential exposure, but did not include the collection of injury-specific data.

In the absence of data on histopathology or metal residues in tissues, the potential for injury can be estimated using risk assessment techniques. Data on metal content in food and other ingested materials is used along with estimates of the daily intake of each medium (Alldredge et al. 1974; USEPA 1993 and 1997; Beyer et al. 1994). The potential for injury to large mammals in Reach 0 and throughout the 11-Mile Reach was characterized by comparing the potential metals exposure of large mammals to ecotoxicologically-based benchmarks. This was conducted using two approaches: (1) comparing metal concentrations in forage plants to benchmarks from the scientific literature and (2) estimating daily intake of metals from forage foods and soils, and comparing the intakes to Toxicity Reference Values which represent rates corresponding to known levels of toxicity and injury (USEPA 1993 and 1997; Eisler 2000).

Large mammals of greatest concern in the 11-Mile Reach are elk and mule deer. Elk and mule deer use the 11-Mile Reach seasonally during fall and winter, but generally migrate to higher elevations in spring and summer. However, a few individuals may remain through spring and summer. Elk feed both by grazing on grasses and forbs, and browsing on woody vegetation (Fitzgerald et al. 1994). Deer are primarily browsers, but opportunistically feed on some grasses and forbs (Fitzgerald et al. 1994). Ungulates could be exposed to metals in forage plants, incidentally ingested soils, and, to a lesser extent, in surface waters. Data on metal content of grasses, forbs, and shrubs (e.g., willows) are available from Reach 0, 1, 2 and 3; grass and forb data are available from more downstream areas. Vegetation data are from Keammerer (1987) and were collected from locations in the floodplain, but distinct from mine-waste deposits. Soils in these areas contain elevated metals concentrations, which tend to decrease with distance downstream from Reach 1.

Carnivorous mammals such as the coyote, red fox, North American badger, and short-tailed weasel also inhabit the 11-Mile Reach. Individual fox and coyote occupy large areas ranging from several hundred to over 3,000 hectares (USEPA 1993; Fitzgerald et al. 1994). Badgers and weasels have more restricted home ranges and individuals may spend a large proportion of their time in the 11-Mile Reach. Coyotes, badgers, fox, and weasels are primary carnivorous, feeding on small mammals and birds. Small mammal whole-body data from California Gulch (Stoller 1996; USEPA 1997) and other mine sites suggest that metals are not effectively translocated to the primary prey of these species, thus bioaccumulation is low, limiting the potential for metals exposure to predators.

Because there are no specific large mammal studies available, there are no data reported under the Large Mammal sections for individual reaches in the remainder of this chapter. However, potential injury to large mammals will be evaluated in Chapter 3 based on the approach discussed above.

Biota – Terrestrial Vertebrates: Birds

The U.S. Fish and Wildlife Service conducted studies of American dippers nesting along the Arkansas River (Archuleta et al. 2000). American dippers feed primarily on aquatic insects by diving into the stream and walking along the bottom picking invertebrates from rocks and other substrate. Because of their dependence on aquatic life, dippers can be exposed to similar dietary metals concentrations as fish. American dippers nest above the stream on cliffs, boulders, or bridges. Archuleta et al. (2000) collected adult and nestling dippers and analyzed blood for aminolevulinic acid dehydratase (ALAD), an enzyme whose production is suppressed when an organism is exposed to lead, and metals concentrations. They analyzed liver for metallothionein activity (a liver enzyme important in detoxification) and metals concentrations. They also collected co-located invertebrate samples from each of their sample sites and analyzed them for metals. Their sample sites included Reach 0 (the upper East Fork) and several sites in Reaches 2 and 3.

There are no studies of raptors or terrestrial feeding birds for the 11-mile reach although USEPA (1997) did evaluate potential risk to raptors and terrestrial feeding birds based on modeling of exposure to different media.

The U.S. Geological Survey (Custer et al. 2003 In Press) conducted a tree swallow study along the Arkansas River. Trees swallows forage on emerging aquatic insects and are dependent upon the aquatic environment. In metals contaminated streams, aquatic invertebrates can sequester metals and concentrations can remain elevated in emerging life stages creating a significant route of exposure to invertebrate predators such as tree swallows. Tree swallows are colonial cavity nesters and will utilize nest boxes. Custer et al. (2003 In Press) established nest box colonies at 6 sites along the Arkansas River from the Upper East Fork downstream to Pueblo Reservoir. They used data collected from the Aggassiz National Wildlife Refuge in Minnesota as their Study Reference. There have been no known mining or metal producing activities in the vicinity of the Refuge. Blood and liver samples were collected from twelve-day-old nestlings for evaluation of metals exposure and physiological effects using blood ALAD. Twelve-day old nestlings were used to represent the metals exposure in the immediate vicinity of the nesting colony. Egg survival and nest success were evaluated and eggs were collected for metals analysis from some boxes, however, none of the metals of concern were elevated in eggs and that data are not presented here. Stomach contents were collected from 12-day old nestlings and analyzed for metals to evaluate dietary exposure. In addition, food boli were collected to identify dietary components. Boli are the conglomeration of insects fed to the nestlings by the adult. The boli contained 86 percent aquatic insects with the two dominant insect taxa being mayflies (Ephemeroptera) and true flies (diptera). Within the 11-mile reach, their study included sample sites in Reach 0 (Colorado Belle Property and near the Leadville Mine Drainage Tunnel), Reach 2 (Smith Ranch), and Reach 3 (near County Road 55).

2.1 Reach 0: Above California Gulch

Reach 0 includes portions of Tennessee Creek and the East Fork of the Arkansas River upstream of their confluence, and the Arkansas River extending downstream to just upstream of the confluence of California Gulch. Both of the upstream drainages that form the Arkansas River have experienced historic mining. The primary mining activity in the Tennessee Creek drainage occurred in St. Kevin's Gulch, but there are also other abandoned mines in the Tennessee Creek drainage. Mining has occurred at numerous locations in the East Fork, but the primary mining influence has likely been the discharge of water from the Leadville Mine Drainage Tunnel (LMDT). This upstream reach is being characterized as a point of comparison to establish the baseline conditions for the river, fully recognizing that this reach has been affected by point and non-point sources of mine-wastes. Studies on floodplain soils were conducted in Reach to characterize total and plant-available metal concentrations. Terrestrial vegetation, small mammal and bird studies were also conducted in this Reach. Studies on water quality and the condition of the aquatic biological resources indicate significant recovery of the system since treatment of the LMDT discharge began in 1992 (Figure 1-4). Because of the level of recovery and because Reach 0 incorporates an area upstream of the influence of California Gulch, it provides a realistic point of comparison to evaluate the effects of mining in California Gulch on the remainder of the Arkansas River.

There is a large amount of surface water and aquatic community data available from several stations in Reach 0, especially station AR-1 immediately downstream from the confluence of Tennessee Creek and the east Fork of the Arkansas River. A long-term (>11-year) survey of water quality and benthic macroinvertebrate communities was initiated in 1989 and is currently underway in Reach 0. In addition, numerous fish surveys have been conducted at several sites within the reach. A variety of experiments have been conducted in this reach investigating the direct effects of metals on benthic communities. Finally, a gaging station is located at station AR-1, immediately downstream from the confluence of Tennessee Creek and the East Fork of the Arkansas River.

2.1.1 Hydrology/Geomorphology

InterFluve (1999) established Subreach 1, which extends upstream from California Gulch approximately one river mile to an old railroad crossing. The InterFluve subreach does not extend the entire length of Reach 0, but has sufficient length to characterize the geomorphic conditions upstream of California Gulch. The reach has not been impacted by substantial mine-waste deposition, but does experience flow augmentation. Vegetation cover within the 500-year floodplain is relatively dense. Floodplain width averaged 900 feet, and the channel sinuosity (ratio of channel length to valley length) was 1.3. The subreach is characterized by multiple channels with frequent overbank flows. Flows are contained within 1 to 3 distinct channels that are highly sinuous and experience active relocation. InterFluve suggests that the multi-channeled pattern observed in Subreach 1 would probably represent that of downstream reaches prior to the impacts of development. The gradient of the reach is steep (Table 2-3), but is less steep than Reach 1. It is probable that the introduction of large quantities of sediment from California Gulch in the past caused aggradation and overbank flooding in Reach 0. This would have promoted marshy conditions, dense willow growth, and multiple channels. Therefore, although this reach can be used as baseline for comparison with Subreaches 1-4, the morphology of the reach is somewhat different from that of the four downstream reaches.

InterFluve (1999) reported changes in channel width for the river upstream of California Gulch using aerial photography. In 1939 the width was estimated to be 26 feet, in 1957 and 1998 it was estimated at 30 feet. Changes in width and channel condition are due to many factors, among them, flow augmentations. The Ewing and Wurtz Ditch and the Wurtz Ditch convey transbasin flows to the Arkansas River via Tennessee Creek, while the Columbine Ditch conveys flows to the East Fork of the

Arkansas River. Combined, these ditches have contributed from 10-15 percent of the total annual flow recorded just downstream at the USGS Leadville Junction gage and, during peak flows, the ditches have contributed as much as 22 percent of the total stream flow (Studzinski 1997 as cited in InterFluve 1999). These ditches began augmenting flows as early as 1908.

Independent examination of 1973, 1979, 1988, and 1997 aerial photography revealed that there were multiple channels in 1973 and 1979, but in 1988, one channel appeared to carry the most flow, and this condition persisted in 1997, suggesting that eventually a single channel will exist in this reach.

The Leadville Junction gage, located downstream of the confluence of Tennessee Creek and the East Fork of the Arkansas River, provides good flow information from 1967 to 1983 and from 1990 to 1998 for Reach 0 (Figure 2-2). Mean monthly flows generated from these records indicate that flows from October to March decrease from 26 cfs to about 15 cfs. The rising limb of the hydrograph begins in April, where mean monthly flows averaged 29 cfs. May through about mid-June flows continue to increase during snowmelt and runoff with mean monthly flows of 168 and 360 cfs, respectively. The descending limb of the hydrograph begins sometime in June depending upon snow pack and temperature. July, August, and September tend to represent the descending limb of the hydrograph with mean monthly flows of 139 cfs, 62 cfs, and 35 cfs, respectively. Flows measured at this gage reflect the combined inputs of the East Fork of the Arkansas River and Tennessee Creek, including the above-described diversions of trans-basin water.

2.1.2 Surface Water

Tables 2-4, 2-5, and 2-6 present the summary statistics for the four metals in surface waters in Reach 0, for each of the three time periods. Table 2-7 presents summary statistics for total metals in Reach 0 during each of the three time periods. Surface water sample locations are shown in Figure 2-3.

Entire Period of Record

Water quality is Reach 0 is generally good. There are some dissolved metals concentrations that exceed TVSs. Mean discharge in this reach ranged from about 25 cfs during low flows to 205 cfs during high flows. During high flows, hardness ranged from 32 mg/L to 107 mg/L, while during low flows hardness ranged from 55 to 174 mg/L. Specific conductivity ranged from as low as 56 µmhos to 1,650 µmhos and is undoubtedly affected by changes in discharge. Likewise pH, ranged from 6 SU to 10 SU, with lower pH predominating during high flows and higher pH predominating during low flows.

<u>Cadmium</u>

For total cadmium data, the POR extends from 1968 to 2000. The highest total cadmium measured during the POR was 0.0103 mg/L recorded during high flows, while the maximum low flow total cadmium concentration was 0.007 mg/L. Much of the more recent total cadmium data from about 1990 on is found to be present at values less than detection. Over the entire POR, it appears that total cadmium concentrations in Reach 0 have decreased slightly in more recent years. Mean total cadmium concentrations in each period and flow condition further support this trend.

<u>Copper</u>

Total copper data in Reach 0 have been collected since about 1968, although the majority of the data were collected after 1975. The highest total copper concentration observed was 0.75 mg/L measured during high flows, whereas the highest low flow concentration of total copper observed was 0.036 mg/L. On average, total copper concentrations are lower during low flows. During both high and low flows, total copper in Reach 0 shows a decreasing trend in concentrations in recent years.

<u>Lead</u>

Total lead data are available from 1975 to 2000. During high flows total lead was always less than 0.05 mg/L; however, it increases during low flows with a maximum concentration of 0.081 mg/L observed. Total lead does not exceed 0.1 mg/L during high flows. Despite the increased concentrations observed during low flows, total lead shows a consistently decreasing trend during both flow conditions.

<u>Zinc</u>

Total zinc data are available from 1968 to 2000. The highest total zinc concentration observed was 2.4 mg/L observed during high flows while the highest low flow concentration observed was 1.4 mg/L. On average, low flow concentrations of zinc are greater than high flow concentrations. Examining total zinc data across all time periods shows a clear decreasing trend with time, as concentrations of zinc are lower in recent years.

Period 3 (After February 1,1992)

Cadmium

Dissolved cadmium samples were collected from between 5 (high flow) to 6 (low flow) sites during Period 3, representing about 140 individual measurements. Hardness values during high flows averaged 57.6 mg/L and increased to 100 mg/L during low flows. Mean dissolved cadmium concentrations were 0.001 and 0.0007 mg/L during high and low flows, respectively. Dissolved cadmium was highest during high flows (0.009 mg/L) while during low flows maximum dissolved cadmium was 0.0027 mg/L. During the approximate 8-year time frame of Period 3, dissolved cadmium shows no temporal trends.

Copper

Dissolved copper samples were collected from between 5 (high flow) to 6 (low flow) sites during Period 3 representing about 136 individual measurements. Hardness values were the same as indicated above for cadmium. Mean dissolved copper concentrations were 0.003 and 0.002 mg/L during high and low flows, respectively. Dissolved copper was highest during high flows (0.015 mg/L) while during low flows maximum dissolved copper was 0.008 mg/L. During the approximate 8-year time frame of Period 3, dissolved copper shows no apparent trends of increase or decrease. During high flows, acute TVSs were exceeded by 4 sample concentrations, and chronic TVSs were exceeded by 8 sample concentrations. During low flows, no exceedances of the TVSs occurred. Based on the summary statistics, the ratios of average and maximum concentrations to TVSs were considerably higher during high flows relative to low flows.

Lead

Dissolved lead samples were collected from between 5 (high flow) to 6 (low flow) during Period 3 representing about 121 individual measurements. Hardness values were the same as indicated above for cadmium. The mean dissolved lead concentration was 0.001 mg/L during both high and low flows. Dissolved lead was highest during high flows (0.01 mg/L), while during low flows maximum dissolved lead was 0.005 mg/L. During the approximate 8 year time frame of Period 3, dissolved lead shows an apparent decreasing trend in concentrations.

<u>Zinc</u>

Dissolved zinc samples were collected from between 5 (high flow) to 6 (low flow) sites during Period 3 representing about 139 individual measurements. Hardness values were the same as presented for cadmium above. Mean dissolved zinc concentrations were 0.108 and 0.0971 mg/L during high and low flows, respectively. Dissolved zinc was highest during high flows (0.87 mg/L) while during low flows maximum dissolved zinc was 0.47 mg/L. During the approximate 8-year time frame of Period 3, dissolved zinc shows a slight decreasing trend in concentrations.

2.1.3 Sediments

Sediment data for Reach 0 are limited. Numerous sources were pursued to augment the database; however, few researchers consistently collected sediment data over a long period of time. As indicated by Table 2-8, often only 1 or 2 sites with sediment data for Reach 0 were found. Data from prior to Period 3 were almost non-existent for this reach. See Figure 2-4 for stream sediment locations.

2.1.4 Groundwater

There are no shallow monitoring well (SMW) data available to characterize Reach 0.

At present, only a single deeper well, GW205, has groundwater quality data to characterize the domestic water supply (DWS) conditions in Reach 0. Groundwater data at this location are only available for Period 2, and were collected in 1983 by Ecology and Environment, Inc. (EEI) for USEPA. GW205 is a 50-foot deep monitoring well located near the Arkansas River, downstream of the confluence of Tennessee Creek and the East Fork Arkansas River (Figure 2-5). Because of the depth of the groundwater sampled from this well, the data are used to characterize the deeper DWS category of groundwater data even though the well is not currently used as a domestic water supply. Table 2-9 provides a summary of the water quality in this well for dissolved cadmium, copper lead, and zinc. Detailed data records for Reach 0 DWS groundwater can be found in Appendix E.

Cadmium

Domestic Water Supply (DWS)

The single DWS groundwater sample collected in Reach 0 at GW205 (Figure 2-5) in 1983 (Period 2) by EEI was analyzed for dissolved cadmium, but none was detected. Therefore, for statistical comparison purposes, one half of the detection limit of this sample is used to characterize Reach 0 DWS groundwater as having 0.0025 mg/L dissolved cadmium. This concentration of dissolved cadmium does not exceed the MCL (0.005 mg/L).

Copper

Domestic Water Supply (DWS)

For the single DWS groundwater sample collected at GW205 (Figure 2-5) in 1983 (Period 2) by EEI, dissolved copper was detected at 0.007 mg/L in Reach 0. Although there is no MCL for copper, the value measured for DWS groundwater in Reach 0 does not exceed the Colorado Drinking Water Standard for dissolved copper (1.3 mg/L).

Lead

Domestic Water Supply (DWS)

The single DWS groundwater sample collected at GW205 (Figure 2-5) in 1983 (Period 2) by EEI was analyzed for dissolved lead, but none was detected. Therefore, for statistical comparison purposes, one half of the detection limit of this sample is used to characterize Reach 0 DWS groundwater as having 0.015 mg/L dissolved lead. Although there is no MCL for lead, the value measured for DWS groundwater in Reach 0 does not exceed the Colorado action level for dissolved lead (0.015 mg/L).

Zinc

Domestic Water Supply (DWS)

For the single DWS groundwater sample collected at GW205 (Figure 2-5) in 1983 (Period 2) by EEI, dissolved zinc was detected at 0.02 mg/L in Reach 0. This concentration of dissolved zinc does not exceed the MCL (5.0 mg/L).

2.1.5 Floodplain Soils

There are no fluvial mine-waste deposits within Reach 0. The results from the work by Keammerer (1987) relative to Reach 0 are summarized in Table 2-10, which presents soils data for 9 sampling locations upstream of the confluence of California Gulch and the Arkansas River (Figure 2-6). These data may be used to represent baseline conditions for the 11-mile reach (Figures 2-7 to 2-10).

Total concentrations for cadmium averaged 3.3 mg/Kg, with a range of 0.8 to 6.1 mg/Kg; copper averaged 29.9 mg/Kg, with a range of 12 to 82 mg/Kg; lead averaged 238 mg/Kg, with a range of 97 to 464; and zinc averaged 428 mg/Kg, with a range of 184 to 857 mg/Kg (Table 2-10). The maximum concentrations reported by Keammerer were higher than those reported by Levy et al. (1992) for copper and zinc at the one location they sampled in Tennessee Park. Plant-available metal concentrations were substantially lower than totals, with cadmium averaging 1.4 mg/Kg, copper averaging 3.9 mg/Kg, lead averaging 23.7 mg/Kg, and zinc averaging 73.9 mg/Kg.

Woodward Clyde (1993) presented soils data for 5 locations in Tennessee Park. Total concentrations for cadmium averaged 1.6 mg/Kg, with a range of 1.5 to 3.9 mg/Kg; copper averaged 66 mg/Kg, with a range of 28 to 121 mg/Kg; lead averaged 249 mg/Kg, with a range of 40 to 629 mg/Kg; and zinc averaged 591 mg/Kg, with a range of 50 to 1,700 mg/Kg.

BLM recently conducted soil sampling in Reach 0 (BLM 2000). Results from this sampling were as follows: total concentrations of lead averaged 161 mg/Kg, with a range of 20 to 884 mg/Kg; zinc averaged 438 mg/Kg, with a range of 61 to 1,574 mg/Kg.

2.1.6 Biota

2.1.6.1 Terrestrial Vegetation

The plant community was inventoried by Keammerer (1987) for plant cover and aboveground production at 39 locations. These locations included 9 sites upstream of the confluence of California Gulch and the Arkansas River. Plant samples were also collected of the dominant grasses and forbs at each site, and analyzed for tissue concentrations for cadmium, copper, lead, and zinc.

The results from the work by Keammerer (1987) are summarized in Tables 2-11 and 2-12. Sample locations are shown on Figure 2-11. Table 2-11 presents plant cover and production data for sampling locations upstream of the confluence of California Gulch and the Arkansas River. These data may be used to represent baseline conditions for the 11-mile reach. Total plant cover averaged approximately 52 percent across 9 sampling locations, and aboveground production averaged 137 g/m^2 (Table 2-12). Cover and production values reflect land use impacts of cattle and horse grazing at a number of the sample locations. Keammerer reported that grazing ranged from 0 to 35 percent forage utilization.

Table 2-12 presents plant tissue metal concentrations for sampling locations upstream of the confluence of California Gulch and the Arkansas River. These data may be used to represent baseline conditions for the 11-mile reach. Plant metal concentrations for grasses averaged 0.8 mg/Kg for cadmium, 5.1 mg/Kg for copper, 0.1 mg/Kg for lead, and 82 mg/Kg of zinc. Plant metal concentrations for forbs averaged 3.8 mg/Kg for cadmium, 11.2 mg/Kg for copper, 2.9 mg/Kg for lead, and 255 mg/Kg for zinc. Woodward Clyde (1993) analyzed plant samples from Tennessee Park for metal concentrations. All metal concentrations were similar or slightly higher than the concentrations reported by Keammerer.

2.1.6.2 Habitat

2.1.6.2.1 Terrestrial

This reach is dominated by a riparian shrub community consisting primarily of willow species, and is interspersed with open water wetlands and grasses. The uplands are dominated by herbaceous riparian vegetation consisting of sedges, rushes, and mesic grasses representative of moist soils. These areas are interspersed with upland grasses (CDOW 1988) (Figure 2-12).

2.1.6.2.2 Aquatic

Existing data are available on the hydraulic and geomorphic character of the Arkansas River. These characteristics, as well as others, ultimately influence the quality and quantity of physical habitat available for fish. Jordan (1889) examined both the Lake Fork and the Arkansas River upstream of California Gulch. He found that the Lake Fork and Arkansas River were very similar in size and character, which he described as moderate current, shaded by willows, occasional deep holes in the bends, about 15 feet wide with gravel bottoms. Today's Arkansas River upstream of California Gulch as characterized by InterFluve (1999), is comprised of a large proportion of split flows and active channel relocation and dense vegetation. From Jordan's description, it is difficult to determine whether this split channel condition was present when and where he examined the river.

PHABSIM modeling conducted by the USBLM was used to quantify weighted usable area (WUA) based on water depth and velocity, and substrate for life stages of brown trout, including spawning, fry, juvenile, and adult fish. Because flow dynamics affect each of these variables, the model uses flow to estimate the suitability of area for each life stage. PHABSIM is limited because of the focus on discharge measurements to estimate available habitat. However, the model provides a quantitative estimate of optimal flow conditions during different seasons and for different life stages of brown trout. Table 2-13 illustrates the results of their analysis for transect data collected between Leadville and Granite, which includes Reaches 1 through 4 of this report, and Table 2-14 presents the mean monthly flows measured at these two gages.

Using these data, it is possible to estimate the flows that provide the optimal conditions for each stage of brown trout during their development, based on flow conditions in the river. For example, about 100 cfs provides optimal conditions for brown trout spawning as long as it occurs during the period when brown trout spawn. Optimization of flows for success of each brown trout life stage must occur at the correct time of year, as illustrated in the Table 2-13.

Compared to Arkansas River mean monthly flows at the Leadville (POR = >30 years) and Granite (POR = 90 years) gaging stations, it is possible to estimate whether flows suitable for the different life stages of brown trout are present in the river, especially because of the extensive water augmentation and diversion system in the basin. Plotting the optimal flows for the various life stages against the recorded mean monthly flows from these two gage stations illustrates that for certain life stages, flows are potentially limiting. For example, at the Leadville gaging station and river sections downstream to a point where flows are increased due to tributary inflows, the WUA for brown trout spawning and egg incubation is considerably less than estimated for optimal spawning and egg incubation. Likewise, the peak and descending flows occur at a period when, at least for adults, a more moderate base flow would be more desirable (Figure 2-13).

Chadwick Ecological Consultants' study sites AR-1, AR-12, and AR-2 fall within Reach 0. Table 2-15 summarizes the fish habitat inventory data. Site AR-1 was dominated by low gradient riffles and runs (>70 percent), site AR-12 was dominated by low gradient riffles (83 percent), and site AR-2 was dominated by runs (46 percent). Cobble and willow were the dominant instream substrate and near-stream vegetation at all sites, respectively. These inventory data suggest that important habitat components such as pools are largely absent from Reach 0. Details of the data summarized in Table 2-15 are provided in Table 2-16.

RBP scoring conducted by Chadwick Ecological Consultants (1998) (Table 2-17) indicates good to excellent scores for all sites in the 11 mile reach and relatively little variation among reaches. Excellent/optimal scores were reported for sites AR-1 and AR-12 during both 1994 and 1998. AR-2 was scored as good in 1994 and optimal in 1998. The habitat inventory data indicate that a large proportion of the available habitat types consist of riffles and runs. The RBP scores, which consider a larger assessment of the habitat, channel, and near-stream conditions suggest that habitat quality is good. PHABSIM data suggest that under different flow scenarios, habitat for certain life stages of trout can be limiting.

Woodling (1990) surveyed the Arkansas River upstream of the California Gulch confluence. Average wetted width was 22.4 feet, ranging from 15 to 32 feet. Depth ranged from one inch on the banks to 2-3 feet in pools. Stream substrate ranged from cobble to boulder 1.5 feet in diameter, with sand deposits downstream of the larger substrates. Backwaters held more fines, while the free flowing waters were free from silts. Near stream vegetation was composed of grasses, sedges, and willows. Overhanging vegetation was present, adjacent to many of the pools. RBP habitat scores for this section of river totaled 99 out of the possible 135. Woodling's assessment of habitat using the RBPs showed a slightly lower score than identified by Chadwick, but this score still rates habitat quality as good.

The Habitat Quality Index (HQI) was developed to predict trout biomass in Rocky Mountain streams based on a suite of physical (e.g., stream flow, water temperature, substrate composition, cover, stream morphology), chemical (e.g., nutrients concentrations, total dissolved solids), and biological (e.g., stream bank vegetation, prey abundance) variables (Binns and Eiserman 1979). The index was developed by relating trout biomass in a large number of streams (n=36) to these environmental attributes. The model was tested by comparing predicted to observed trout biomass. A highly significant relationship was observed, suggesting that the HQI is a reasonable approach for estimating potential fish standing stock in Rocky Mountain streams.

Figure 2-14 shows the relationship between predicted (based on the HQI) and observed trout biomass in Reaches 0, 1, 2, and 3 of the Arkansas River. Mean dissolved zinc concentrations (μ/L) are also shown in the figure. Observed brown trout biomass (pounds per acre) in Reach 0 exceeded values predicted by the HQI.

HQI ratings are presented in Table 2-18. Late summer stream flows are rated completely adequate for all sites in Reach 0, where as annual stream flow variation was rated as limited. Water temperature was rated moderate, nitrate ranged from moderate to limited. Cover ranged from inadequate to very limited. Stream bank erosion ranged from completely adequate to limited. Substrate ranged from limited to very limited. Water velocity ranged from completely adequate to moderate, and stream width ranged from moderate to completely adequate. Predicted trout biomass for AR-1 was 97 lbs/acre, for AR-12 it was 76 lbs/acre, and for AR-2 it was 62 lbs/acre.

2.1.6.3 Aquatic Community

2.1.6.3.1 Benthic Community

Over the period of record (1989-1999), total macroinvertebrate abundance in Reach 0 (EF5, AR-1) was generally between 300-500 individuals per 0.1 m^2, with greater abundance observed at station AR-1 (Figure 2-15). Statistical analyses (one-way ANOVA) of these data that test for differences among reaches are shown in Table 2-19. Results showed that for most benthic community measures, abundance and richness were greatest in Reach 0 compared to the downstream reaches. The key exceptions were abundance and species richness of caddisflies and dipterans, which were greater downstream. Benthic communities in this reach were dominated by EPT taxa (mayflies, stoneflies, and caddisflies). Mean abundance (across all sampling dates) of EPT taxa in Reach 0 ranged from 200-300 individuals per 0.1 m^2, and these organisms consisted primarily of mayflies (Ephemeroptera). Mayfly assemblages in Reach 0 were dominated by two families: Heptageniidae and Baetidae (Figures 2-16 and 2-17). Stoneflies in this reach consisted primarily of Chloroperlidae and Nemouridae, whereas caddisflies (Trichoptera) were dominated by Rhyacophilidae. Other major groups collected from this reach included elmid beetles (Coleoptera: Elmidae) and chironomids (Diptera: Chironomidae).

Mean species richness (all dates combined) in Reach 0 ranged from 22-27 species per sample (Figure 2-18). As with abundance, EPT taxa were most common in benthic samples and accounted for most of the species richness. Species richness of mayflies ranged between 6-7 species per sample, followed by stoneflies (4.7) and caddisflies (4.5).

Similar patterns for abundance and species richness of benthic communities in Reach 0 were reported by Chadwick Ecological Consultants (Figures 2-19 and 2-20). Mayflies dominated the benthic community in Reach 0, and mean species richness of mayflies ranged from 5.4 to 6.2 species. Temporal variation in benthic communities in Reach 0 reflected seasonal and long-term changes in metal levels in the Arkansas River. Statistical analyses (two-way ANOVA) of these data that tested for differences before and after remediation of LMDT and California Gulch are shown in Table 2-20. Total macroinvertebrate abundance and abundance of mayflies, stoneflies, and other organisms (primarily elmid beetles) at station EF5 significantly increased after remediation of the LMDT in 1992 (Figures 2-21 and 2-22). In contrast, there was relatively little change in abundance of caddisflies and dipterans. The exception to this pattern was for the Rhyacophilidae (Trichoptera), which increased over time. Increased abundance of mayflies and stoneflies resulted primarily from the response of Baetidae, Heptageniidae, and Chloroperlidae. For example, heptageniid mayflies at station EF5 were rare or absent in spring samples prior to 1992, but increased dramatically between 1992 and 1999. Patterns of species richness were similar to abundance, with greatest improvements in richness of mayflies and stoneflies (Figure 2-23). For example, mean species richness of mayflies at station EF5 ranged from 1.0 to 4.8 prior to 1992, but increased by approximately 2 times between 1992 and 1999 (Period 3). Total species richness and the number of EPT taxa also increased after 1992. In contrast, there were relatively little changes in species richness of caddisflies and dipterans.

Temporal changes in benthic communities at station AR-1 due to improvements in water quality were similar to those observed at EF5 (Table 2-20; Figure 2-24). Although there was considerable seasonal variation, total abundance of mayflies was greater after treatment of the LMDT (Figure 2-24). In contrast, total abundance of caddisflies and dipterans did not show any consistent long-term trends. Increased abundance of mayflies and stoneflies resulted primarily from recovery of Heptageniidae and Chloroperlidae (Figure 2-25). The caddisfly Rhyacophilidae and elmid beetles also showed gradual improvement following reductions in zinc levels observed at station AR-1. Other caddisflies (Brachycentridae and Hydropsychidae) and dipterans (Chironomidae and Simuliidae) showed relatively little change in abundance over time. Temporal patterns of species richness at station AR-1 showed less improvement than those observed at EF5 (Figure 2-26). Although there was gradual improvement in species richness of mayflies, EPT, and total species richness, these changes were modest compared to those observed at station EF5.

Canonical discriminant analysis (CDA) was employed to examine spatial and temporal changes in benthic communities. CDA is a multivariate technique that examines separation and overlap of sites based on linear combinations of a large number of variables. For graphical display, these multiple variables are reduced to a smaller number of canonical variables (generally 1-3) that explain most of the differences among sites. Variables used in this analysis were the 15 dominant taxa sampled in the Arkansas River between 1989 and 1998. The proximity of points in 2-dimensional space is a reflection of the overall similarity among the communities at each location. Thus, benthic communities at stations that group close together in canonical space are more similar to each other than sites that are separated. To illustrate this, Figure 2-27 shows the distribution of Arkansas River sampling locations before remediation (1989-1992). During most years, station AR-3 (Reach 1) was distinct and separated from all other stations in the Arkansas River, indicating that benthic communities were quite different at this location. This was especially evident in 1989, 1990, and 1991. It is important to note that the distribution of points in canonical space is a reflection of the relative similarity of benthic communities among stations. For example, in 1990 the overlap of stations AR-1 and AR-8 (Reach 6) simply indicates that benthic communities at AR-1 are more similar to AR-8 than to AR-3.

Results of multivariate analyses showed significant spatial and temporal variation in benthic community composition between 1989 and 1998. In general, the two stations in Reach 0 (EF5 and AR-1) showed considerable overlap and grouped together during most years before (Figure 2-27) and after (Figure 2-28) remediation of LMDT. The only exception to this pattern occurred in 1993 when benthic communities at station AR-1 were distinct from those at EF5. These data indicate that benthic communities at the two control stations in Reach 0 were generally similar.

A summary of the long-term changes in benthic communities at these two Reach 0 stations is shown in Figure 2-29. The length of the arrows is an indication of the amount of change observed at each station before and after remediation. Although station EF5 was more similar to station AR-3 prior to remediation, benthic communities changed significantly after 1993 and became more similar to station AR-1. These changes reflect an increase in abundance of metal-sensitive taxa, especially Heptageniidae and *Pericoma*, and a decrease in abundance of metal-tolerant taxa (*Brachycentrus*, Hydropsychidae, and Chironomidae).

Previous studies of benthic communities and water quality from Reach 0 were similar to those described above and have also reported dramatic improvement in water quality following remediation of the LMDT. Nelson and Roline (1999) observed recovery of metal sensitive taxa and increased species richness after remediation. The rapid increase in metal-sensitive species described above indicates the potential for recovery of the Arkansas River and that Reach 0 is an appropriate target for restoration.

<u>Tissue Concentrations of Metals in Benthic Macroinvertebrates</u>

Exposure of benthic macroinvertebrates to heavy metals in the Arkansas River between 1990 and 1999 was assessed by measuring concentrations of cadmium and zinc in the caddisfly *Arctopsyche grandis* (Trichoptera: Hydropsychidae). *Arctopsyche* is a relatively large, widely distributed caddisfly found in many Rocky Mountain streams. Caddisflies from Reach 0 (stations EF5 and AR-1), Reach 1 (station AR-3), and Reach 4 (station AR-5) were collected using either a D-frame net (1990-1995) or a small seine (1996-1999) and transported to the laboratory on ice. Metal levels (cadmium and zinc) were measured using atomic adsorption spectrophotometry.

Concentrations of cadmium in *Arctopsyche grandis* collected from Reach 0 were generally less than 10 µg/g and declined between 1990 and 1999 (Figure 2-30). Zinc levels in *Arctopsyche* collected from Reach 0 were generally less than 500 µg/g.

In addition to these long-term data on metal concentrations in *Arctopsyche*, field experiments were conducted in the Arkansas River to measure uptake of metals by *Brachycentrus americanus* (Trichoptera: Brachycentridae). In May 1992 caddisflies were collected from the Cache la Poudre River, a non-mining impacted reference stream located approximately 70 km northwest of Fort Collins, Colorado. Organisms were transferred to small, cylindrical tubes (30 cm x 5 cm) covered with a coarse mesh (2.0 mm) and placed immediately upstream (Reach 0) and downstream (Reach 1) from California Gulch (10 organisms per cage). Two cages were removed from each station after 6, 12, 24, 36, 48, 72, and 212 hours and organisms were analyzed for cadmium and zinc as described above.

Cadmium and zinc concentrations in *Brachycentrus* measured at the end of the experiment were similar to those in *Arctopsyche* collected from Reach 0 (Figure 2-31). Concentrations of cadmium and zinc in *Brachycentrus* from Reach 0 (station AR-2) at the end of the experiment were similar to those at the start of the experiment, indicating that there was relatively little accumulation of metals by these organisms.

<u>Sediment Toxicity and Bioaccumulation</u>

Several investigators have measured toxicity and bioavailability of heavy metals from sediments to benthic invertebrates in the Arkansas River. Experiments conducted by U.S. EPA (Willingham unpublished data) in September 1993 showed relatively little toxicity of sediments collected from Reach 0 (Table 2-21). Frugis (1995) examined effects of heavy metals on chironomids exposed to sediments collected from a reference site (Cache la Poudre River) and several metal-impacted sites in the Arkansas River. In general toxicity of sediments was greater in Reach 0 of the Arkansas River compared to the Cache la Poudre River. The greater toxicity of Reach 0 sediments observed in these experiments was expected. Because experiments were conducted in 1993, soon after initiation of remediation activities in the Leadville Mine Drainage Tunnel, it is likely that metal levels in sediments had not responded to improvements in water quality. Although toxicity of sediments varied among other Arkansas River stations, effects differed among dates and were not consistently related to metal contamination (Figure 2-32).

Figure 2-33 shows results of a laboratory experiment in which chironomids (*Chironomus tentans*) were exposed to sediments collected from the Cache la Poudre River, an uncontaminated reference stream, and several stations in the upper Arkansas River. Because the Cache la Poudre River is located within an area of relatively low mineralization, the lower metal uptake observed in chironomids exposed to sediments from this stream was expected. In general, metal concentrations in chironomids were lower than concentrations in sediments.

Levels of Metallothionein in *Baetis tricaudatus*

To examine a possible mechanistic basis for tolerance to metals, concentrations of metallothionein, a metal-binding protein, were compared in mayflies with different metal exposure histories. Eight-hundred *B. tricaudatus* (four replicates of 200 mayflies) were collected from Reaches 0, 1and 4 on the Arkansas River. Mayflies were also collected from an unpolluted site on the Cache la Poudre River (PR3). Each sample was homogenized and subsampled to determine total metals, total metallothionein, and metal-bound metallothionein. Concentrations of metallothionein were determined using a cadmium saturation technique.

Concentrations of total cadmium, total metallothionein, and cadmium natively-bound to metallothionein were significantly greater in mayflies collected from Reach 0 than from the Cache la Poudre River (Figure 2-34). Elevated levels of metallothionein in mayflies indicated that mayflies from Reach 0 were exposed to heavy metals.

Periphyton

Results showed that concentrations of cadmium and zinc in sediment and periphyton collected from Reach 0 (stations EF5 and AR-1) were generally elevated compared to samples collected from streams in less mineralized watersheds (Figure 2-35). In general, cadmium and zinc levels were between 3-10 times greater in periphyton than in sediment.

Periphyton samples were collected in August 1992 from Reaches 0, 1, and 4 to measure diatom community composition (Medley and Clements 1998). All samples were collected from cobble substrate (128-256 mm) in shallow, unshaded riffle areas (~50 cm deep) with similar current velocity, substrate composition, and canopy cover. Individual stones were removed from the stream and periphyton samples were collected using a neoprene-cuffed sampler (7.1 cm^2), which was pressed firmly on the smooth upper surface of the substrate. Three samples were collected from each site.

Diatom species richness and diversity showed relatively little variation among the three stations within Reach 0 (Table 2-22). The number of species ranged from 23 to 26.3 and the proportion of *Achnanthes minutissima*, a metal-tolerant diatom species, ranged from 0.31 to 0.35.

Toxicology

Numerous experiments have been conducted with fish and macroinvertebrates to investigate toxicity of metals in the Arkansas River. Experiments conducted with fathead minnows in 1991 (Clements unpublished data) showed significant acute toxicity of water collected from Reach 0 (Figure 2-36). Although there was relatively little toxicity observed at low concentrations of Arkansas River water (< 25 percent), treatments at higher concentrations were acutely toxic. Chronic toxicity tests conducted in fall 1990 and spring 1991 with *Ceriodaphnia dubia* showed that organisms exposed to water from Reach 0 were affected by metals (Clements and Kiffney 1994) (Figure 2-36).

Results of Period 2 toxicity tests conducted by U.S. EPA in September 1987 found significant effects of heavy metals in Reach 0 (Willingham Unpublished) (Table 2-23). Significant mortality (100 percent) of cladocerans (*Ceriodaphnia dubia*) was observed at most stations in Reach 0. Effects on fathead minnows (*Pimephales promelus*) were less severe, and 100 percent mortality was observed only at station AR-2 in this reach.

Results of acute (48 hour) toxicity tests reported by the U.S. EPA spanning Periods 2 and 3 between 1991 and 1993 were quite different from these patterns (Table 2-23). Although samples collected directly from the LMDT in 1991 were acutely toxic (generally 30-50 percent mortality), organisms exposed to water collected from Reach 0 exhibited little acute toxicity. These data also showed the effectiveness that remediation at the LMDT has had on acute toxicity. Percent mortality decreased from 50 percent to 10 percent following remediation in 1992.

2.1.6.3.2 Fish Populations

Jordan (1889) provides perhaps the earliest qualitative information about the condition of the fishery during this time period. Placer mining and agricultural irrigation are cited as the two primary factors impacting the trout fishery in the Arkansas River, as well as in many other Colorado rivers. Species found during the investigation include the primary native species green-back trout (*Salmo mykiss stomias*), as well as introduced species such as brook trout and rainbow trout.

Results of fish surveys conducted in Reach 0 by CDOW during fall and spring of 1990 are shown in Table 2-24. Brown trout biomass ranged from 123 to 152 lbs/acre, and the number of fish collected ranged from 759 to 1,005 individuals per acre. Results of the 1990 surveys were compared to more spatially extensive analyses of brown trout populations conducted from 1994 to 1999 by CDOW. Because fish were sampled after installation of water treatment plants at the LMDT, these data also provide an opportunity to evaluate potential recovery of brown trout populations in the Arkansas River.

Field surveys of brown trout showed both spatial (upstream versus downstream) and temporal (annual, seasonal) variation in population abundance and length-frequency distributions (Table 2-24). Data collected from 1994 to 1999 showed that brown trout population estimates, abundance, and biomass (lbs per acre) were generally similar at the three sampling stations in Reach 0 (EF2, EF5, and AR-1) (Figures 2-37 to 2-40). Brown trout biomass measured at the upstream station in 1990 was similar to values measured between 1994 and 1999. Figure 2-41 summarizes data collected from stations that were sampled in September 1994, August 1997, April 1998, and September 1999. Brown trout biomass measured at Reach 0 in 1990 (123-152 lbs/acre) was similar to values measured between 1994 and 1999. Note that observed values for trout biomass exceed those predicted by the Habitat Quality Index for Reach 0 (Table 2-18).

Length-frequency distributions of brown trout populations reveal 2 (sometimes 3) year classes in the Arkansas River; however, population structure varies strongly among sampling stations (Figures 2-42 to 2-45). Sampling data from August (1997) and September (1994 and 1999) consistently indicate the presence of age 1 fish (e.g., those that hatched the preceding fall) in Reach 0. Age 1 fish were most abundant at stations AR-1 and AR-2, and slightly less abundant in the East Fork stations.

Reach 0 includes sites AR01 and AR02 from the Aquatic Associates study (1993). Metal concentrations in fish collected from locations in Reach 0 were < 0.1 mg/Kg cadmium, 0.4 to 0.6 mg/Kg copper, 0.2 mg/Kg lead, and 5.9 to 8.0 mg/Kg zinc. The zinc concentration in fillets at site AR02 (just upstream of California Gulch) was higher than measured in fish collected from site AR01. Of the available data, highest zinc concentrations were measured at a site in the East Fork Arkansas River (9.3 mg/Kg).

Nehring (1986) compared metal levels in age 1, 2, and 3 brown trout collected from a reference site (Ossmann) and from stations located both upstream and downstream from the LMDT and California Gulch. Cadmium and zinc levels in brown trout from Reach 0 were generally greater than in fish from the reference stream (Figure 2-46). There was also considerable variation in metal levels with fish age.

Cadmium and copper concentrations generally increased with age, whereas patterns for zinc were inconsistent.

Clements and Rees (1997) examined the effects of heavy metals on prey abundance, feeding habits, and metal bioaccumulation of brown trout (*Salmo trutta*) collected from Reach 0 (station AR-1) and Reach 4 (station AR-5). Although community composition of benthic macroinvertebrates varied seasonally, benthic communities in Reach 0 were dominated by metal-sensitive mayflies (Ephemeroptera) and black flies (Diptera: Simuliidae). The feeding habits of brown trout reflected the availability of these prey organisms (Figure 2-47). Concentrations of heavy metals in dominant prey taxa and brown trout stomach contents from Reach 0 are shown in Figure 2-48.

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

2.1.6.4 Terrestrial Vertebrates

2.1.6.4.1 Small Mammals

Woodward Clyde (1993) sampled the small mammal community in wetland habitats on Tennessee Creek and on the upper Arkansas River between the California Gulch and Tennessee Creek confluences**.** They collected liver, kidney and bone tissues from voles for trace element analysis and tissues for histopathology examination (Table 2-25). For metals analysis, one individual vole was collected at the Tennessee Creek Site while 26 voles were collected at the upper Arkansas River site. At the Upper Arkansas River site, Woodward Clyde combined individual tissue and bone samples to make up 3 composite samples of 10, 10, and 6 individuals. Ideally, composite samples should represent the mean value of the individuals in the sample; however, this method of sampling does not provide an estimate of the variance for the individuals. Composite samples should not be statistically compared to individual samples, thus the values for both individual and composite samples are presented.

None of the metal concentrations in kidney or liver exceeded literature-based benchmarks. The histopathology examination revealed no significant lesions or other tissue damage that could be associated with metal toxicity. It should be noted that while the work plan (Woodward Clyde 1993) called for submission of the kidney, there were no histopathology results reported for kidney tissue (Woodward Clyde 1993). However, kidney metal concentrations reported by Woodward Clyde do not exceed literature-based benchmark concentrations that are associated with pathological changes. Dr. Terry Spraker, DVM Colorado State University Veterinary Hospital, conducted the histopathological evaluation and indicated that kidney tissue damage would not be expected at the metal concentrations reported. The tissue residue data for all metals of concern are considered representative of the baseline condition for the metal concentrations in voles and other herbivorous small mammals.

2.1.6.4.2 Large Mammals

There are no known large mammal (i.e., deer and elk) studies or sampling efforts for this reach.

2.1.6.4.3 Birds

Archuleta et al. (2000) collected blood and liver from American dippers on the upper East Fork. They analyzed blood for metals concentrations and ALAD activity and liver for metals and metallothionein concentrations (Table 2-26). Aquatic invertebrate samples (dipper food items) were also collected from the stream at or near dipper sample locations and analyzed for metals (Table 2-27). They collected samples from the Poudre River west of Fort Collins, Colorado as their Study Reference site. The Poudre River is outside of the Colorado Mineral Belt and has had no known metal mining activities besides exploration.

Average ALAD activity from Reach 0 measured was lower than ALAD activity from the Study Reference, but there was not a significant difference ($P<0.05$). The production of ALAD is inhibited by exposure to lead thus; lower ALAD values are generally associated with increased lead exposure. Metallothionein levels were higher in Reach 0 then the Study Reverence, but not significantly different ($p<0.05$). Metallothionein production is increased in response to a variety of stressors including metals, thus higher metallothionein values are generally associated with increased metals exposure.

For almost all metals, the dipper tissue concentrations for Reach 0 are higher than those reported for the Study Reference, however, there was not a statistically significant difference ($p > 0.05$) for any tissue for any metal between the two sites and data from both sites are below literature-based benchmark values. Because American dippers migrate from low elevations in spring to higher elevations in summer, it is not appropriate to assume that birds sampled in Reach 0 are exposed only in Reach 0. Birds sampled in Reach 0 have migrated from downstream reaches and unless they are nestlings or nesting adults, the period of time that they have been in Reach 0 is unknown and they may have accumulated tissue burden as they migrated upstream. Therefore, the out-of-basin Study Reference will be used for benchmark comparison as well as data from Reach 0.

In aquatic invertebrates collected near dipper sample sites, cadmium was below the literature-based benchmark, but lead and zinc exceeded this benchmark. All of the metals in invertebrate samples from Reach 0 exceeded the concentrations from the Study Reference site (Table 2-27). The invertebrate data from Reach 0 are representative of baseline conditions for the 11-mile Reach and will used as the comparative benchmark for downstream samples.

The USGS conducted a study of tree swallows along the Arkansas River (Custer et al. 2003 In Press). In this reach, nesting colonies were established on the upper East Fork (Colorado Belle Property) and near the Leadville Mine Drainage Tunnel. They collected 12 –day old nestlings and sampled blood for ALAD activity and livers for metals concentrations. Liver samples from Reach 0 had higher cadmium and lead concentrations than the Study Reference, but all metals were below literature-based benchmark values (Table 2-28). ALAD activity was 36 percent less than the Study Reference.

Stomach contents were collected from nestlings and analyzed for metals to evaluate exposure via the diet of tree swallows. Only zinc exceeded the dietary benchmark and Custer et al. (2003 In Press) did not report stomach content data from their Study Reference (Table 2-29).

During one year of the two-year study, the colony at the Leadville Mine Drainage Tunnel had a lower probability of egg survival compared to all other sites except Reach 2 (Smith Ranch). Nest success was 100 percent at the Colorado Belle site for both years of the study. Nest success at the Leadville Mine Drainage site was 77.4 percent and 76.1 percent in 1997 and 1998 respectively which was below the 86.9 percent nationwide average for tree swallows calculated by Robertson et al. (1992).

2.2 Reach 1: California Gulch Confluence to Lake Fork Confluence

2.2.1 Hydrology/Geomorphology

This reach is about 8,850 feet long, and extends from California Gulch to the confluence of Lake Fork (Figure 2-49). This is a steep, cobble-bed reach, that is InterFluve Reach 2 (Table 2-3). InterFluve Reach 1 is upstream of California Gulch. Sinuosity in this reach has been relatively constant, ranging from 1.18 to 1.21 over 57 years. Low-flow width for a straight reach increased 22 percent since 1939 from 35 to 45 feet, although there was zero change between 1939 and 1957 (InterFluve 1999).

Study of aerial photographs of the river, maps of the distribution of mine-waste deposits, and the longitudinal profile prepared by InterFluve (1999) (Figure 2-50) permit the identification of three geomorphic subreaches in this reach (Figure 2-49).

Subreach 1A extends from the junction of California Gulch to about 2,250 feet downstream. This subreach is steep (Figure 2-50), and contains a relatively active channel. The subreach contains numerous mine-waste deposits that total 317,294 cubic feet. There are 141 cubic feet of mine-waste per linear foot of banks, but only 13 percent of banks expose mine-waste (Table 2-30).

Through examination of 1973, 1979, 1988, and 1997 aerial photography, it was observed that Subreach 1A had the following geomorphic characteristics. In 1973, the channel was wide and braided, and cutoffs indicate an active channel. In 1979, the channel was better defined. It appeared to be less active, and braiding was less. By 1988 and in 1997, the subreach contained a well-defined single channel. Based on the review of 24 years of record, this channel appears to have adjusted to a period of reduced sediment loads, and has become less active.

The steep gradient should have transported the mine-waste downstream, but, in fact, the marked change of gradient from California Gulch (0.025) to the Arkansas River (0.008) caused deposition of mine-waste throughout the floodplain of Subreach 1A.

Subreach 1B is about 3,000 feet long. It is steep (Table 2-3), and it contains only one mine-waste deposit (Table 2-30). Its gradient is sufficient to allow transport of mine-waste downstream to Subreach 1C. There are only 3.2 cubic feet of mine-waste per linear foot of banks in this relatively stable subreach, and only 5 percent of the banks expose mine-waste. During the period 1973 to 1988, the channel in Subreach 1B was well defined and braided. In 1997, braiding was less obvious, suggesting increased channel stability.

Subreach 1C is 3,600 feet long above the junction of Lake Fork. The gradient is gentler than Subreach 1B, and mine-waste transported through steep Subreach 1B was in part deposited above the junction of Lake Fork. There are 560,003 cubic feet of mine-waste in this subreach. The gentler gradient and the possible effect of backwater from Lake Fork results in 156 cubic feet of mine-waste per linear foot of bank, and 15 percent of the banks expose mine-waste. In the past, the channel has been very active in this subreach, perhaps as a result of the deposition of substantial amounts of mine-waste. Numerous irrigation ditches in this reach may have diverted water containing elevated metals concentrations.

Aerial photography shows that in 1973 there was a fan-like deposit in Subreach 1C with many channels spreading across its surface, suggesting deposition of sediment upstream of the junction with Lake Fork. This feature became less obvious, and a better-defined channel crossed it in 1979, 1988, and 1997, suggesting increased channel stability.

No USGS stream flow gages are located in Reach 1 on the Arkansas River. Very limited flow data are available for California Gulch at its mouth from 1991 to 1992. Available data suggest that contributory flows from California Gulch generally ranged from less than 1 cfs to a maximum of 4.1 cfs. However, discharges of California Gulch water have been measured as high as 20 cfs during peak high flow periods. Mean monthly flow in California Gulch ranged from about 1 cfs to about 2.1 cfs.

2.2.2 Surface Water

Summary statistics for surface water quality in Reach 1 are presented in Tables 2-4 through 2-6. These tables also summarize TVS exceedances during the high and low flow conditions. Table 2-31 presents total metal concentrations for Reach 1 during each period. In Reach 1, California Gulch is the only major tributary to the Arkansas River (Figure 2-51). Mean dissolved concentrations of metals from 1992 to 1999 measured at the mouth of California Gulch for high and low flow periods illustrate the levels of metals entering Reach 1 after treatment at the Yak Tunnel and remediation efforts had begun. Over Period 3, cadmium averaged from 0.076 to 0.010 mg/L, copper averaged from 0.172 to 0.008 mg/L, lead averaged from 0.238 to 0.003 mg/L, and zinc averaged from 15.7 to 5 mg/L during high and low flows, respectively. These mean concentrations are substantially elevated in one or both flow conditions relative to the concentrations observed in Reach 1.

Entire Period of Record

California Gulch discharge to the Arkansas River in Reach 1 dramatically alters water quality. California Gulch mean discharges range from less than 1 cfs during low flows to about 2.1 cfs during high flows. Mean hardness in Reach 1 is 82 mg/L during high flows while during low flows mean hardness increases to about 148 mg/L. Specific conductivity ranges from 67 to 783 µmhos, and the pH range is highly altered from that in Reach 0 ranging from 3.7 to 8.9.

California Gulch at its mouth has a high flow mean hardness of 472 mg/L and a low flow mean hardness of 423 mg/L. Conductivities range from 99 to 22,600 µmhos, and pH ranges from 2.7 to 8.2.

The discharge of treated mine waters from the YAK tunnel treatment system likely moderated more acidic contributions.

Cadmium

Total cadmium data in Reach 1 are available from 1983 to 2000. Ten stations have been sampled for a total of 331 samples over the POR. The highest total cadmium measured during the POR was 0.036 mg/L recorded during high flows, while the maximum low flow total cadmium concentration was 0.032 mg/L. Due to the large range of total cadmium concentrations that occur during both flow periods, no trends are obvious. Mean total cadmium concentrations are very similar between high flows (0.0036 mg/L) and low flows (0.0035 mg/L).

California Gulch at its mouth had an average total cadmium concentration of 0.099 and 0.041 mg/L during high and low flows, respectively, while maximum total cadmium observed was 0.48 mg/L during high flows and 0.698 mg/L during low flows. Mean concentrations of total cadmium further upstream in California Gulch are greater, but not substantially so, as the mean high flow concentration was 0.132 mg/L and the low flow mean was 0.043 mg/L.

Copper

Total copper data in Reach 1 spans from 1974 to 2000. Eleven stations have been sampled for a total of 318 samples over the POR. The highest total copper measured during the POR was 0.132 mg/L recorded during high flows, while the maximum low flow total copper concentration was 0.092 mg/L. A large spike in concentrations of total copper appeared in about 1994. Based on the distribution of all the data over the POR, no trends are evident. Based on the mean values for total copper in each Period, both high and low flow means indicate a slight decrease in copper concentrations from past to present.

California Gulch at its mouth had total copper concentrations that averaged 0.339 mg/L during high flow and 0.243 mg/L during low flow. The highest total copper concentrations observed during high flow were 2.56 mg/L and 6.87 mg/L during low flows. Mean total copper from sites higher up in the gulch are considerably greater with a high flow mean concentration of 0.959 mg/L, while the low flow mean is similar at 0.258 mg/L.

Lead

Total lead data in Reach 1 spans from 1974 to 2000. Ten stations were sampled resulting in a total of 289 samples over the POR. Maximum total lead was observed during high flows at 0.301 mg/L while at lows flows the highest total lead observed was 0.205 mg/L. Similar to copper, there was a large concentration spike in 1994. Mean total values during both high and low flows indicated decreasing total lead concentrations from past to present.

California Gulch at its mouth had total lead concentrations that averaged 0.805 mg/L during high flows and 0.598 mg/L during low flows. Highest total lead concentrations observed were 16.1 mg/L and 25.3 mg/L during high and low flows respectively. Mean total lead higher in the California Gulch drainage averaged 1.6 mg/L during high flows and 0.605 mg/L during low flows. Total lead concentrations in California Gulch show a similar pattern to that observed for copper.

Zinc

Total zinc data in Reach 1 spans from 1973 to 2000. Nine (high flow) and ten (low flow) stations were sampled resulting in a total of 327 samples over the POR. Maximum total zinc was observed during high flows at 5.9 mg/L while at lows flows the highest total zinc observed was 5.63 mg/L. For total zinc, two concentration spikes occur over the POR. There was a large concentration spike about 1994 during high flows and another in about 1974 during low flows. Although concentrations are still elevated, there appears to be a slight decreasing concentration over the POR. Mean total zinc concentrations for both the high and low flow periods support this observation.

California Gulch at its mouth had a mean total zinc concentration that averaged 20.6 mg/L during high flows and 16.9 mg/L during low flows. Maximum total zinc observed during high flows was 82 mg/L while during lows flows a measurement of 342 mg/L was observed. For sites higher in the California Gulch drainage, mean total zinc was 27.1 mg/L during high flow and 12.6 mg/L during low flow. High flow mean zinc is considerably greater further up in the drainage then at the mouth, but low flow zinc is considerably higher at the mouth relative to locations higher in the drainage.

Period 3 (After February 1,1992)

Hardness values during high flows averaged 83.5 mg/L and increased to 150 mg/L during low flows. In general, water quality in Reach 1 is improved in Period 3 relative to prior periods. Treatments of the Leadville and Yak Tunnel discharges have benefited water quality in Reach 1.

<u>Cadmium</u>

Dissolved cadmium samples were collected from 7 sites during Period 3 representing more than 200 individual measurements. Mean dissolved cadmium concentrations were 0.0017 and 0.0018 mg/L during high and low flows, respectively. Dissolved cadmium was highest during high flows (0.014 mg/L) while during low flows maximum dissolved cadmium was 0.012 mg/L. During high flows, acute TVSs were exceeded by 17 samples and 24 samples exceeded the chronic TVS, while during low flows only 5 samples exceeded the acute TVSs and chronic TVSs were exceeded by 14 samples. Based on the summary statistics, the ratios of average and maximum concentrations to TVSs are higher during high flows than for low flows. During the approximate 8 year time frame of Period 3, dissolved cadmium shows a slight decreasing trend during high flows; however no apparent trends of increase or decrease are evident during low flows. Mean dissolved cadmium in Reach 1 is elevated above mean dissolved cadmium observed in Reach 0 during both high and low flows.

At the mouth of California Gulch, dissolved cadmium averaged 0.076 mg/L during high flows and 0.010 mg/L during low flows. These concentrations are substantially greater than those observed in Reach 1.

<u>Copper</u>

Dissolved copper samples were collected from 8 (high flow) and 7 (low flow) sites during Period 3 representing about 230 individual measurements. Mean dissolved copper concentrations were 0.0052 and 0.0030 mg/L during high and low flows, respectively. Dissolved copper was highest during high flows (0.036 mg/L) while during low flows maximum dissolved copper was 0.012 mg/L. During high flows, acute TVSs were exceeded by 20 samples and 22 samples exceeded the chronic TVS, while during low flows no acute or chronic TVSs were exceeded. Based on the summary statistics, the ratios of average and maximum concentrations to TVSs were higher during high flows. During the approximate 8-year time frame of Period 3, dissolved copper shows a slight decreasing trend during high flows; however, no apparent trends of increase or decrease are evident during low flows. Mean dissolved copper in Reach 1 is elevated above mean dissolved copper observed in Reach 0 during both high and low flows.

At the mouth of California Gulch, dissolved copper averaged 0.172 mg/L during high flows and averaged 0.008 mg/L during low flows. The high flow mean was considerably greater than observed in Reach 1; however, the low flow mean was only slightly higher. Total copper averaged 0.165 (0.0004, 1.3) mg/L (n = 84) across the three stations sampled.

<u>Lead</u>

Dissolved lead samples were collected from 7 sites during Period 3 representing about 210 individual measurements. Mean dissolved lead concentrations were 0.0037 and 0.0031 mg/L during high and low flows, respectively. Dissolved lead was highest during high flows (0.14 mg/L) while during low flows maximum dissolved lead was 0.05 mg/L. During high flows, the acute TVS was exceeded once, and 18 samples exceeded the chronic TVS, while during low flows only the chronic TVS was exceeded in 11 samples. Based on the summary statistics, the ratios of average and maximum concentrations to TVSs were higher during high flows. During the approximate 8-year time frame of Period 3 and except for a single sample, dissolved lead showed a decreasing trend during high flows and low flows. Mean dissolved lead in Reach 1 was elevated above mean dissolved lead observed in Reach 0 during both high and low flows.

California Gulch at its mouth had a mean dissolved lead concentration during high flows of 0.431 mg/L and 0.012 mg/L during low flows. The high flow mean concentration was considerably higher in California Gulch than in Reach 1; however, the low flow mean in Reach 1 was only marginally lower than observed in the gulch.

<u>Zinc</u>

Dissolved zinc samples were collected from 7 sites during Period 3 representing about 220 individual measurements. Mean dissolved zinc concentrations were 0.403 and 0.559 mg/L during high and low flows, respectively. Dissolved zinc was highest during low flows (2.23 mg/L) while during high flows maximum dissolved zinc was 2.15 mg/L. During high flows, the acute and chronic TVSs were exceeded in 112 samples, and the acute and chronic TVSs were exceeded in 81 samples during low flows. The ratios of average concentrations to TVSs were similar during high flows and low flows. Ratios of maximum values to TVSs indicate high flow ratios were substantially larger than for low flow. During the approximate 8-year time frame of Period 3, dissolved zinc showed a decreasing trend during low flows; however, there was not a discernible trend during high flows. Mean dissolved zinc in Reach 1 was substantially higher than mean dissolved zinc observed in Reach 0.

Dissolved zinc in California Gulch at the mouth averaged 15.7 mg/L during high flow and decreased considerably during low flow to 5 mg/L. These concentrations are substantially greater than those observed in Reach 1.

2.2.3 Sediments

As indicated by Table 2-32, only a few sites with sediment data for Reach 1 were found (Figure 2-52). Data prior to Period 3 were almost non-existent for this reach. Concentrations of copper, lead, and zinc in sediments from Reach 1 are elevated over those found in Reach 0. Mean concentrations of copper, lead, and zinc are 1.9, 5.9, and 3.6 times greater, respectively, in Reach 1 sediments compared to Reach 0 sediments.

2.2.4 Groundwater

The eight shallow monitoring well (SMW) groundwater-monitoring locations in Reach 1 consist of wells installed by USEPA. The SMW locations in this reach are generally 1 to 6 feet deep, with minimal screening and little development and are located close to the Arkansas River (approximately 50-300 feet) adjacent to, or entirely within, mine-waste deposits (Figure 2-53). Two of the SMW groundwater monitoring locations in Reach 1, UMW14 and UMW15 (located adjacent to deposits CN, and within deposit CR respectively), have paired wells, with identifiers A and B included in the site names. Table 2-33 provides a summary of the water quality in the SMW wells for dissolved cadmium, copper lead, and zinc. Detailed data records for Reach 1 SMW groundwater can be found in Appendix E.

For the DWS groundwater locations in Reach 1 (Figure 2-53), dissolved metals concentration data were available for Period 2 from two NW-14 locations (a pair of wells which feed a blend tank at the Lake Fork Mobile Home Park) and from GW211 (a tap off of a storage tank in the Lake Fork Mobile Home Park well house). The three DWS groundwater sampling locations in Reach 1 that have dissolved metals data are located several hundred feet to the east of the 500-year floodplain, and south of California Gulch. In 1983, GW211 was sampled by Ecology and Environment, Inc. (EEI) for USEPA, and the NW-14 locations were sampled in 1989 by Water, Waste and Land, Inc. (WWL).

There are also two additional DWS groundwater sample locations, 133100-001 and 133400-001, within Reach 1 (Figure 2-53) for which total cadmium, total copper, and total lead data are available. The total metals data were collected by CDPHE between 1984 and 2000 (Periods 2 and 3). DWS groundwater monitoring location 133100-001 is the Lake Fork Mobile Home Park blend tank and corresponds to GW211 discussed above. It appears that the locations recorded by the respective agencies that sampled GW211 and 133100-001 are slightly different, perhaps due to differing accuracy, or differing methods of recording sample location between the two agencies. DWS groundwater location 133400-001 is well #1 (approximately 60 feet deep) at the Mt Elbert Trailer Park, and based on the location information available, appears to be located within the 500-year floodplain.

Summary statistics for Reach 1 DWS groundwater are presented for both total and dissolved metals in Table 2-9 and data for individual records can be found in Appendix E.

For comparative purposes, groundwater data from California Gulch near the Arkansas River confluence are also presented in this section. At present, only a single well, UMW19, is located such that it provides an indication of SMW groundwater quality associated with the mouth of California Gulch, and at present, two wells GW210 (39 feet deep, screened from 27 to 39 feet) and GW218 (depth unknown) provide an indication of DWS groundwater quality associated with California Gulch near the Arkansas River confluence (Figure 2-53). Individual data records for the SMW and DWS locations associated with California Gulch near the Arkansas River confluence can be found in Appendix E.

Cadmium

Shallow Monitoring Well (SMW)

The mean dissolved cadmium concentration in Reach 1 SMW groundwater was 0.0099 (0.0001, 0.187) mg/L (n = 91) across the eight locations sampled. The maximum dissolved cadmium concentration occurred at UMW15A, above the mouth of Lake Fork/Halfmoon Creek. Data are available for Period 3 only.

For SMW groundwater at the mouth of California Gulch near the Arkansas River confluence, for Period 3, the location UMW19 had a mean dissolved cadmium concentration of 0.075 (0.0005, 0.238) mg/L (n = 9).

Domestic Water Supply (DWS)

The mean dissolved cadmium concentration in Reach 1 DWS groundwater was 0.0033 (0.0025, 0.005) mg/L (n = 3) across the three locations sampled in Period 2. Data for this average came from the following: in 1983, Ecology and Environment, Inc. did not detect dissolved cadmium at GW211 hence the value 0.0025 mg/L (one half of the detection limit) was used; in 1989, Water, Waste and Land, Inc. (WWL) did not detect dissolved cadmium in June, hence the sample was assigned a value of 0.0025 mg/L, and in November WWL detected dissolved cadmium at 0.005 mg/L.

The mean total cadmium concentration in Reach 1 DWS groundwater was 0.00049 (0.00005, 0.0012) mg/L (n = 6) across the two locations sampled by CDPHE during Periods 2 and 3.

The maximum total cadmium and maximum dissolved cadmium values for Reach 1 were at or below the MCL (0.005 mg/L). Dissolved cadmium concentration in Reach 1 DWS groundwater appears to be very slightly higher, but within the same magnitude, as values in Reach 0.

The mean dissolved cadmium concentration in DWS groundwater in the vicinity of California Gulch near the Arkansas River confluence, 0.0025 mg/L, was approximately the same magnitude as the concentrations observed in Reach 1, and were below the MCL (0.005 mg/L).

<u>Copper</u>

Shallow Monitoring Well (SMW)

The mean dissolved copper concentration in Reach 1 SMW groundwater was 0.003 (0.0003, 0.084) mg/L (n = 91) across the eight locations sampled. The maximum dissolved cadmium concentration occurred at UMW15A, above the mouth of Lake Fork/Halfmoon Creek. Data are available for Period 3 only.

For SMW groundwater at the mouth of California Gulch near the Arkansas River confluence, for Period 3, the location UMW19 had a mean dissolved copper concentration of 0.0062 (0.00075, 0.0413) mg/L (n = 9).

Domestic Water Supply (DWS)

The mean dissolved copper concentration in Reach 1 DWS groundwater was 0.005 (0.0025, 0.01) mg/L (n = 3) across the three locations sampled in Period 2. Data for this average came from the following: in 1983, Ecology and Environment, Inc. detected dissolved copper at GW211 at 0.01 mg/L; in 1989, Water, Waste and Land, Inc. (WWL) did not detect dissolved cadmium in June, hence 0.0025 mg/L is used for statistical comparison purposes, nor did WWL detect dissolved copper in November, therefore 0.0025 mg/L was used for this sample for statistical purposes.

The mean total copper concentration in Reach 1 DWS groundwater was 0.1273 (0.009, 0.35) mg/L (n = 3) across the two locations sampled by CDPHE during Period 3.

Although there is no MCL for copper, the total and dissolved concentrations measured for DWS groundwater in Reach 1 do not exceed the Colorado Drinking Water Standard (1.3 mg/L). The mean dissolved copper concentration in Reach 1 DWS groundwater is slightly lower than the dissolved copper concentration for Reach 0.

The mean dissolved copper concentration in DWS groundwater in the vicinity of California Gulch near the Arkansas River confluence, 0.0205 mg/L, was higher than the concentrations observed in Reach 1, however, still below the Colorado Drinking Water Standard (1.3 mg/L).

<u>Lead</u>

Shallow Monitoring Well (SMW)

The mean dissolved lead concentration in Reach 1 SMW groundwater was 0.0056 (0.0005, 0.0162) mg/L (n = 89) across the 8 locations sampled. The maximum dissolved lead concentration occurred at UMW15A, above the mouth of Lake Fork/Halfmoon Creek. Data are available for Period 3 only.

For SMW groundwater at the mouth of California Gulch near the Arkansas River confluence, for Period 3, the location UMW19 had a mean dissolved lead concentration of 0.0134 (0.0008, 0.0238) mg/L (n = 9).

Domestic Water Supply (DWS)

The mean dissolved lead concentration in Reach 1 DWS groundwater was 0.0067 (0.0025, 0.015) mg/L (n = 3) across the three locations sampled in Period 2. Data for this average came from the following: in 1983, Ecology and Environment, Inc. did not detected dissolved lead at GW211, hence for statistical purposes, one half of the detection limit, or 0.015 mg/L, was used; and in 1989, Water, Waste and Land, Inc. (WWL) did not detect dissolved lead in June, nor in November, hence 0.015 mg/L is used for statistical comparison purposes for both dates.

The mean total lead concentration in Reach 1 DWS groundwater was 0.0086 (0.0005, 0.024) mg/L (n = 4) across the two locations sampled by CDPHE during Periods 2 and 3.

The total dissolved lead concentration measured for DWS groundwater in Reach 1 did not exceed the Colorado action level for dissolved lead (0.015 mg/L). The mean dissolved lead concentration in Reach 1 DWS groundwater is slightly lower than the dissolved lead concentration for Reach 0.

The mean dissolved lead concentration in DWS groundwater in the vicinity of California Gulch near the Arkansas River confluence, 0.015 mg/L, was slightly higher than the concentrations observed in Reach 1, however, still below the Colorado action level for dissolved lead (0.015 mg/L).

Zinc

Shallow Monitoring Well (SMW)

The mean dissolved zinc concentration in Reach 1 SMW groundwater was 4.36 (0.00045, 29.7) mg/L (n = 91) across the eight locations sampled. The maximum dissolved zinc concentration occurred at UMW03, above the mouth of Lake Fork/Halfmoon Creek. Data are available for Period 3 only.

For SMW groundwater at the mouth of California Gulch near the Arkansas River confluence, for Period 3, the location UMW19 had a mean dissolved zinc concentration of 19.7 (1.99, 55.9) mg/L (n = 9). The concentration of dissolved zinc at the mouth of California Gulch is substantially higher than in Reach 1.

Domestic Water Supply (DWS)

The mean dissolved zinc concentration in Reach 1 DWS groundwater was 0.598 (0.063, 1.1) mg/L (n = 3) across the three locations sampled in Period 2. Data for this average came from the following: in 1983, Ecology and Environment, Inc. detected dissolved zinc at GW211 at 0.063 mg/L; and in 1989, Water, Waste and Land, Inc. (WWL) detected dissolved zinc in June at 0.63 mg/L and in November WWL detected dissolved zinc at 1.1 mg/L.

The mean dissolved zinc concentration in Reach 1 DWS groundwater did not exceed the MCL (5.0 mg/L). The mean dissolved zinc concentration in Reach 1 DWS groundwater is somewhat higher than the dissolved zinc concentration for Reach 0.

The mean dissolved zinc concentration in DWS groundwater in the vicinity of California Gulch near the Arkansas River confluence, 0.9795 mg/L, was slightly higher than the concentrations observed in Reach 1, however, still below the MCL (5.0 mg/L).

2.2.5 Floodplain Soils

Work by Levy et al. (1992) and Sommers et al. (1991) on the Seppi Ranch (Reach 1) characterized physical and chemical properties of soils that were reported to be contaminated by mine drainage and sediment from California Gulch (Figure 2-54). Metal concentrations in soils were quantified by depth for total, organically bound, iron-manganese oxide bound, exchangeable, and water-soluble forms of cadmium, copper, lead, and zinc. A total of five locations were sampled at six depth increments between 0 and 12 inches.

The greatest concentration of total metals was found either in the surface horizons or in hydraulically deposited sand layers that were buried at a number of locations. Copper was predominantly associated with the organic fraction at most locations, while cadmium, lead, and zinc were mainly bound to iron and manganese oxides at all locations. The range of concentrations reported for cadmium was 4-51 mg/Kg, copper was 21-236 mg/Kg, lead was 67-2,822 mg/Kg, and zinc was 139-5,663 mg/Kg (Sommers et al. 1991). These concentrations were much higher than the maximum concentrations reported for the control site for this study, which was located in Reach 0 north of the confluence between the East Fork of the Arkansas River and Tennessee Creek. Maximum total concentrations in Reach 0 were approximately 13 mg/Kg for cadmium, 36 mg/Kg for copper, 342 mg/Kg for lead, and 172 mg/Kg for zinc.

Colby (1988) sampled soils on the Seppi Ranch (Reach 1) on pastureland south of Colorado Highway 300 and west of U.S. Highway 24 (Figure 2-54). This site has most likely been irrigated with Arkansas River water. A total of 25 samples were collected at depths that varied, depending upon the sample location. Sampling depths varied from 0-12 inches to 0-22 inches. There was no explanation provided for the ranges of depth used in the study. Samples were analyzed for total concentrations of cadmium, copper, lead, and zinc and there was also a measure of concentrations in the soil solution. The report does not present details on analytical methods and we can only assume that the soil solution measurements are in some way related to the bioavailable fraction. The range of total concentrations for cadmium was 5 to 72 mg/Kg, copper was 46 to 388 mg/Kg, lead was 2.5 to 245 mg/Kg, and zinc was 178 to 4,720 mg/Kg. The range of soil solution concentrations for cadmium was 0.09 to 1.43 mg/Kg, copper was 0.9 to 7.8 mg/Kg, lead was 0.05 to 5 mg/Kg, and zinc was 3.6 to 94 mg/Kg.

A third study on the Seppi Ranch (Reach 1) by Swyers (1990) involved soil sampling in two meadows approximately one mile south of Colorado Highway 300 and one-quarter mile west of U.S. Highway 24 (Figure 2-54). As with the Colby study, these meadows have most likely been irrigated with water from the Arkansas River. A total of 36 sites were sampled in one meadow, and 25 sites in a second meadow. Soil sampling was done to a depth of 8 to 10 inches and total concentrations of cadmium, copper, lead, and zinc were determined. The range of concentrations reported for cadmium was 5-113 mg/Kg, copper was 21-409 mg/Kg, lead was 2.5-1,112 mg/Kg, and zinc was 178-8,722 mg/Kg. The fact that Swyers (1990) and Colby (1988) both report identical minimum values for total cadmium, lead, and zinc raises some concern as to the independence of these studies.

The results from the work by Keammerer, relative to Reach 1, are shown in Table 2-34, which presents soils data for seven sampling locations between the confluence of California Gulch and Lake Fork (Figure 2-54). Total concentrations of cadmium averaged 13.5 mg/Kg, with a range of 1.6 to 45 mg/Kg; copper averaged 192 mg/Kg, with a range of 7 to 870; lead averaged 3,990 mg/Kg, with a range of 76 to 25,150 mg/Kg; and zinc averaged 3,142 mg/Kg, with a range of 84 to 17,400 mg/Kg. Plant-available metal concentrations were substantially lower, with cadmium averaging 2.96 mg/Kg, copper averaging 12.7 mg/Kg, lead averaging 51.4 mg/Kg, and zinc averaging 158 mg/Kg (Figures 2-7 to 2-10).

BLM conducted soil sampling in Reach 1 in 2000. Sampling was conducted at 29 separate locations at a depth interval of 0 to 1 inch at each location. Results from this sampling were as follows: total concentrations of lead averaged 223 mg/Kg, with a range of 20 to 1,824 mg/Kg; and zinc averaged 543 mg/Kg, with a range of 41 to 3,390 mg/Kg.

A total of 24 mine-waste deposits were selected for study along the stretch of river between the confluence of California Gulch and the confluence of Lake Fork Creek (URS 1997 and 1998) (Figure 2-55). The deposits were identified and selected from landowner's input and from observations of tailing material on cut banks, dead vegetation, and/or metal salts on the soil surface. Some deposits were observed but not studied because they were small, had vegetation cover, and/or were away from the riverbank. Other deposits were not investigated because of access limitations. All mine-waste samples were analyzed for total metal concentrations using X-Ray Fluorescence spectrometry (XRF). A total of 24 mine-waste deposits were identified and characterized by USEPA in 1996 and 1997 (URS 1997 and 1998). Among these deposits, there are a total of approximately 887,000 ft^3 of mine-waste, covering a surface area of approximately 785,364 ft^2 in Reach 1. The average depth of the mine-waste deposits is

1.1 feet and no deposits that averaged greater than 2 feet in depth were found. Total metal concentrations averaged 177 mg/Kg for cadmium, 446 mg/Kg for copper, 4,228 mg/Kg for lead, and 7,271 mg/Kg for zinc. See Appendix D for a more detailed physical and chemical description of these deposits.

2.2.6 Biota

2.2.6.1 Terrestrial Vegetation

In 1997, the Natural Resource Conservation Service (NRCS) completed vegetation mapping of the 11-mile reach of the UARB. The assessment was designed to map vegetation communities adjacent to the river. A total of five major community types were identified along the 11-mile reach. Three of these types were mapped within the reach, between California Gulch confluence and Lake Fork confluence. The types are wet meadow, subirrigated, and riparian subirrigated.

Levy et al. (1992) and Sommers et al. (1991) collected and analyzed plant samples for metal concentrations on the Seppi Ranch (Reach 1) in 1988 (Figure 2-56). A total of four locations were sampled, including a control site in Tennessee Park. Table 2-35 summarizes the data from this sampling effort. Sedges, rushes, grasses, forbs, and shrubs were sampled and analyzed for tissue concentrations of cadmium, copper, lead, and zinc. Cadmium concentrations ranged from 0.1 to 13 mg/Kg, copper concentrations ranged from 4 to 13 mg/Kg, lead concentrations ranged from 0.25 to 12 mg/Kg, and zinc concentrations ranged from 26 to 630 mg/Kg.

The results from the work by Keammerer are summarized in Tables 2-36 and 2-37. Table 2-36 presents plant cover and production data for sampling locations between the confluence of California Gulch with the Arkansas River and the Lake Fork confluence (Figure 2-56). Total plant cover averaged 63 percent across seven sampling locations along the Arkansas River between the confluence of California Gulch and Lake Fork (Table 2-36). Aboveground production averaged 256 g/m^2 for the same stretch of river.

Table 2-37 presents plant tissue metal concentrations for sample sites along the Arkansas River between the confluence of California Gulch and Lake Fork. Reach 1 plant metal concentrations for grasses averaged 2.2 mg/Kg for cadmium, 4.6 mg/Kg for copper, 12.2 mg/Kg for lead, and 153 mg/Kg for zinc. Plant metal concentrations for forbs averaged 4.6 mg/Kg for cadmium, 10.3 mg/Kg for copper, 19.8 mg/Kg for lead, and 248 mg/Kg for zinc. Recall that for Reach 0, plant metal concentrations for grasses averaged 0.8 mg/Kg for cadmium, 5.1 mg/Kg for copper, 0.1 mg/Kg for lead, and 82 mg/Kg of zinc. Plant metal concentrations for forbs averaged 3.8 mg/Kg for cadmium, 11.2 mg/Kg for copper, 2.9 mg/Kg for lead, and 255 mg/Kg for zinc.

2.2.6.2 Habitat

2.2.6.2.1 Terrestrial

This reach is dominated by a riparian shrub community consisting primarily of willow species. It is interspersed with open water wetlands and herbaceous riparian vegetation consisting of sedges and rushes representative of saturated soils. There are areas of unvegetated mine-waste deposits and unvegetated sandbars throughout. The uplands are dominated by herbaceous riparian vegetation consisting of sedges, rushes, and mesic grasses representative of moist soils (Figure 2-57). These areas are interspersed with upland grasses (CDOW 1988). Agricultural activities influence the composition and productivity of vegetation in Reach 1.

2.2.6.2.2 Aquatic

Chadwick site AR-3 falls within Reach 1 (Figure 2-58). Table 2-15 summarizes the fish habitat inventory data. Site AR-3 was dominated by runs (53 percent) and low gradient riffles (47 percent). Cobble and willow were the dominant instream substrate and near stream vegetation at all sites, respectively.

Details of the inventory are presented in Table 2-16, where specific conditions by habitat type for each reach are presented. Wetted widths averaged from 25 to 36 feet. Average depths ranged from 0.6 to 1.4 feet. Average percent surface fines ranged from 15 to 33 percent and the average amount of cut banks ranged from 3 to 33 percent.

RBP scores developed by Chadwick Ecological Consultants (1998) (Table 2-17) indicate good habitat for site AR-3 during 1994 and optimal habitat during 1998.

Woodling (1990) evaluated physical habitat at two locations downstream of the California Gulch confluence with the Arkansas River, with one site located in the mixing zone of the California Gulch discharge to the river and one site located 0.5 miles downstream of the confluence. Habitat in the mixing zone was described as follows: average width was 26.5 feet ranging from 21.5 to 34 feet, depth ranged from one inch along the banks to 2-3 feet in the deeper pools, substrate ranged from gravel to boulders 1.5

feet in diameter, with sand deposits behind the larger substrates, substrates had a distinct coating of iron deposits, as well as a white scummy film. Waters were not completely mixed at this site as evidenced by the high turbidity on the east side of the river, and turbidity was reduced but present on the west side of the river. Riparian vegetation was comprised of grasses, sedges, and willows that overhung the banks. The valley in this section of the river was primarily pasture. At low flows, the river was separated from the banks by rubble substrate bars. RBP habitat scores for this reach of river totaled 74 out of the possible 135.

About one-half mile downstream, the riverine habitat was similar to the mixing zone habitat. Wetted width averaged 39 feet and ranged from 26 to 50 feet. Depths ranged from one inch to 3-4 feet in the pools. Substrate ranged in size from sand to boulder about 1.5 feet in diameter. Sands and silts covered the substrates in the areas of lower water velocity. Riparian vegetation was also similarly comprised of grasses, sedges, and willows that grew up to the banks. Some of the river banks in this reach were described as deeply cut creating steep banks several feet high. RBP habitat scores for this reach of the river totaled 70 out of the possible 135.

Habitat Quality Index (HQI) ratings are presented in Table 2-18. Late summer stream flows are rated completely adequate, whereas annual stream-flow variation was rated as limited. Water temperature was rated as moderate, and nitrate as limited. Cover was rated as inadequate, stream bank erosion rated as completely adequate, substrate rated as very limited, water velocity rated as completely adequate, and stream width rated as moderate. Predicted trout biomass for Reach 1 just upstream from Lake Fork (AR-3) was 49 lbs/acre.

2.2.6.3 Aquatic Community

2.2.6.3.1 Benthic Community

Benthic communities in Reach 1 immediately downstream from California Gulch were quite different from those collected from the upstream reach (Figures 2-15, 2-16, 2-17, and 2-45). Results of statistical analyses (one-way ANOVA) testing for differences among locations are shown in Table 2-19. Mean macroinvertebrate abundance was less than 300 organisms per 0.1 m^2, and mean EPT abundance was reduced by 40-55 percent compared to Reach 0. The greatest difference between Reach 1 and the upstream reference section was for abundance of mayflies, which was reduced by 60-75 percent. In contrast, total abundance of caddisflies and dipterans was similar or greater in Reach 1 compared to Reach 0. Benthic communities in Reach 1 were dominated by chironomids, which accounted for approximately 35 percent of the total abundance. Heptageniid mayflies were generally eliminated from Reach 1, whereas baetid mayflies and elmid beetles were significantly lower in this reach compared to Reach 0.

Patterns of species richness in Reach 1 were similar to those for total abundance (Figure 2-18). Total species richness was less than 20 species per sample, and species richness of mayflies was reduced by 40-50 percent compared to Reach 0. In contrast, species richness of caddisflies and dipterans was similar to Reach 0.

Patterns in benthic communities observed in Reach 1 were similar to those reported by Chadwick Ecological Consultants (Figure 2-19 and 2-20). Although total abundance was similar to Reach 0, abundance of mayflies was lower in this reach and heptageniids were essentially eliminated from Reach 1. In addition, total species richness was similar between Reaches 0 and 1; however, species richness of mayflies was reduced by approximately 50 percent.

Patterns of long-term temporal variation in total abundance and abundance of major groups in Reach 1 are shown in Figure 2-59. Statistical analyses (2-way ANOVA) of these data testing for responses to remediation and seasonal variation are shown in Table 2-20. In general, abundance of most groups increased significantly after 1993. In particular, elmid beetles showed a gradual increase between 1992 and 1999 (Figure 2-60). Another consistent pattern observed in these data was the large amount of seasonal variation. Abundance of many of the groups was very low during spring, and increased greatly in the fall.

Most measures of species richness also showed some evidence of improvement following treatment at the Yak Tunnel (Figure 2-61). In particular, mayfly richness increased from 3.2 species per sample in fall 1989 to 6.0 species per sample in fall 1998. Similarly, total species richness increased from 13.6 to 25.0 species per sample during this same period ($p=0.0005$). There was also significant seasonal variation in measures of species richness, as most measures were greater in fall than in spring.

Results of multivariate analyses showed significant temporal variation in benthic community composition in Reach 1 (station AR-3) between 1989 and 1998 (Figures 2-27 and 2-28). During most years, benthic communities in Reach 1 were separated from Reach 0 reference stations (EF5 and AR-1). This was especially obvious between 1989 and 1992, prior to remediation. Benthic communities from Reach 1 following remediation were generally more similar to those from Reach 0, especially in the later years of the survey (1997-1998). However, important exceptions occurred in 1994 and 1995 when station AR-3 was distinct from all other sampling locations.

Temporal changes in benthic communities in Reach 1 were relatively minor compared to those observed at stations EF-5 and AR-1 in Reach 0. Figure 2-29 shows a summary of these multivariate analyses that compares changes in community composition before and after remediation of LMDT and California Gulch. The length of the arrows is an indication of the amount of change observed at each station during this period. Overall, benthic communities in Reach 1 after 1993 were characterized by small increases in abundance of metal-sensitive Heptageniidae and *Pericoma*.

Concentrations of cadmium and zinc in *Arctopsyche grandis* were consistently higher in Reach 1 than in Reach 0 (Figure 2-30). In particular, concentrations were greatly elevated in spring 1996, which corresponded to a peak in aqueous zinc concentrations on this same date. Other seasonal variation in metal bioaccumulation by *Arctopsyche* was not consistent with temporal changes in aqueous levels, and there was relatively little evidence of reduced metal uptake by caddisflies following treatment at the Yak and Leadville Mine DrainageTunnels. These data suggest that other sources of metal exposure in addition to water were important for caddisflies. Because *Arctopsyche* is a filter-feeding organism, it is likely that uptake of metals from seston and other particulate material was an important source of exposure.

Results of a field experiment showing metal uptake by *Brachycentrus* in Reach 1 are shown in Figure 2-31. Cadmium and zinc concentrations in *Brachycentrus* measured at the end of the experiment were similar to those in *Arctopsyche* and reflected differences in aqueous concentrations between Reach 0 and Reach 1. Although the duration of this experiment was relatively short (9 days), the shape of the uptake curve indicates that metal levels in caddisflies approached equilibrium conditions. In addition, metal levels in *Brachycentrus* at the end of the experiment were similar to those in organisms collected in the field. Mean concentrations of cadmium and zinc in water measured during the 9-day experiment were elevated in Reach 1 (cadmium: 4.1-10.2 µg/L; zinc: 1,633-6,240 µg/L) compared to Reach 0 (cadmium: below detection; zinc: 52-97 µg/L). Concentrations of cadmium and zinc in *Brachycentrus* in Reach 1 increased over time and were 2-6 times greater compared to Reach 0. These differences in metal levels between Reach 0 and Reach 1 were statistically significant.

Experiments conducted by U.S. EPA (Willingham unpublished data) in September 1993 showed significant toxicity of sediments collected from California Gulch and Reach 1 (Table 2-21). Lower toxicity was observed at station AR-3A, which was located on the west side of the river outside of the influence of California Gulch. Experiments conducted by Frugis (1995) showed elevated toxicity of sediments from Reach 1; however, effects differed across sampling dates (Figure 2-32).

Results of an experiment in which chironomids (*Chironomus tentans*) were exposed to sediments from Reach 1 are shown in Figure 2-33. Results showed that levels of cadmium, copper, lead, and zinc in sediment and chironomids were greatly elevated in Reach 1 compared to Reach 0. In general, levels of metals in chironomids were lower than concentrations in sediments.

Periphyton

Concentrations of cadmium and zinc in sediment and periphyton collected from Reach 1 (station AR-3) were greatly elevated compared to samples collected from Reach 0 (Figure 2-35).

Diatom species richness and diversity in Reach 1 were similar to values observed in Reach 0 (Table 2-22). In addition, the proportion of *Achnanthes minutissima* was similar in Reaches 0 and 1.

Toxicity

Toxicity tests conducted with cladocerans and fathead minnows showed that water from California Gulch, the Yak Tunnel, and Reach 1 was acutely toxic (Tables 2-38 and 2-39). Mean LC_{50} values for invertebrates measured in Reach 0 ranged from 40 to 47 percent (Table 2-38). Experiments conducted by ENSR Consulting, Inc. (Weston 1994) reported LC_{50} values for invertebrates and fish exposed to water collected from California Gulch and the Arkansas River (Table 2-39). Results showed that water from California Gulch and stations in Reach 1 were highly toxic to invertebrates (LC_{50} = 1-5 percent). In contrast, there was relatively little acute toxicity to fish in these experiments.

2.2.6.3.2 Fish Populations

Jordan (1889) reported that, between Leadville and Granite, the river was affected by placer mining, which introduced solids into the river. Fish were reported to exist, albeit in reduced numbers, while tributaries still had a high abundance of fish.

Results of fish surveys conducted in 1990 showed reduced abundance (#/acre) and biomass (lbs/acre) of brown trout collected from Reach 1 compared to Reach 0 (Table 2-24). Although the number of fish collected varied between seasons, brown trout abundance and biomass was 74-81 percent lower at the downstream station compared to the upstream station.

Results of a more spatially extensive survey of brown trout populations conducted from 1994 to 1999 by the Colorado Division of Wildlife (CDOW) are shown in Figures 2-37 through 2-40. Field surveys of brown trout showed both spatial (upstream versus downstream) and temporal (annual, seasonal) variation in population abundance and length-frequency distributions. Data collected on all sampling occasions showed that brown trout abundance (number per acre, number per mile) and biomass (lbs per acre) were greatly reduced in Reach 1 compared to Reach 0. Between 1994 and 1999, brown trout biomass in Reach 1 (station AR-3) ranged from 12.8 to 31.0 lbs/acre. The greatest values for brown trout abundance and biomass in Reach 1 were observed in September 1999. These values are similar to those reported in 1990 (fall: 22.7 lbs/acre; spring: 37.6 lbs/acre).

The length-frequency distribution of brown trout in Reach 1 was difficult to interpret because of the small number of fish collected (Figures 2-42 through 2-45). In particular, the abundance of age 1 fish was significantly lower at Reach 1 compared to Reach 0. Age 1 trout were absent from samples in Reach 1 during 1994 and were 25-80 percent less abundant compared to Reach 0 between 1997 and 1999. Age 2 trout were present in Reach 1 on all sampling occasions; however, abundance of this age class was consistently lower compared to Reach 0. Age 3 trout were too rare to identify strong trends, but were consistently absent from Reach 1.

Aquatic Associate's (1993) site AR03 falls within Reach 1. Metal concentrations in fish collected from the locations in Reach 1 were < 0.1 mg/Kg cadmium, 0.5 mg/Kg copper, 0.2 mg/Kg lead, and 8.9 mg/Kg zinc.

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

2.2.6.4 Terrestrial Vertebrates

2.2.6.4.1 Small Mammals

There are no terrestrial mammal studies or sampling efforts for this reach.

2.2.6.4.2 Large Mammals

There are no terrestrial mammal studies or sampling efforts for this reach.

2.2.6.4.3 Birds

There are no avian studies or sampling efforts for this reach.

2.3 Reach 2: Lake Fork Confluence to Highway 24 Bridge

2.3.1 Hydrology/Geomorphology

Reach 2 is about 18,000 feet long, and extends from the confluence of Lake Fork downstream to Highway 24 (Figure 2-62). This reach can be divided into 2 subreaches (InterFluve 1999) (Table 2-3). ***Subreach 2A*** is about 11,000 feet long, and extends from the confluence of Lake Fork to just upstream of the railroad Bridge at mile 4 near Iowa Gulch. It contains 154,388 ft^3 of mine-waste, 13.9 ft^3 per linear foot of channel (Table 2-30), and 14 percent of the banks expose mine-waste. It is a steep reach, and the upstream 4,000 feet of this reach is steeper than the remainder. The steeper portion is upstream of the Smith Bridge, and the channel on the 1997 aerial photographs is wide and braided. Sinuosity has been almost constant since 1939, decreasing slightly from 1.31 to 1.29. Low-flow channel width in a straight reach increased 37 percent since 1939; with only 6 percent of that taking place after 1957 (InterFluve 1999), suggesting increased channel stability.

Through examination of 1973, 1979, 1988, and 1997 aerial photography, it was observed that Subreach 2A had the following geomorphic characteristics. In 1973, the channel in Subreach 2A was wide and actively braiding. In 1979, discharge contributions from Lake Fork maintained a wide channel. In 1988, the channel appeared to have narrowed, and numerous point bars were exposed. Nevertheless, the contribution of discharges from Lake Fork was substantial. The channel in 1997 was well-defined with exposed point bars. This reach is less active than Reach 1 upstream, although aerial photographs show evidence of cutoff and avulsion.

Subreach 2B is about 8,000 feet long, and extends from upstream of the railroad bridge at mile 4 to the Highway 24 Bridge. The subreach contains 79,001 ft^3 of mine-waste, or 10.1 ft^3 of mine-waste per linear foot of banks, and only 1 percent of the banks expose mine-waste. The gradient is gentler than the upstream Subreach 2A, but is similar to the downstream Subreach 3A. At the upstream limit of the reach, the Arkansas River bifurcates into two channels. The channels rejoin midway through the reach, but immediately separate again until they join just upstream of the Highway 24 Bridge. Sinuosity increased in this reach since 1939 from 1.11 to 1.31**.**

Examination of the aerial photography found that the channel in Subreach 2B was braided in 1973 and had two main branches at the railroad. In 1979, the western branch appeared to be most active, and it conveyed more water than the eastern branch. In 1988, flow appeared to be equal in the two anabranches, but in 1997, the east channel was conveying the most discharge.

No USGS gage stations are located on the Arkansas River in Reach 2. However, since about June 1981, an average of 50 percent of all native Lake Fork flows and over 95 percent of all Fryingpan Arkansas Project water and water from other importers has been delivered from Turquoise Reservoir through the Mt. Elbert Conduit to the Mt. Elbert power plant at Twin Lakes Reservoir. Hydrologic influences of the discharges of these creeks to Reach 2 are described in Reach 3, where sufficient flow records are present at two of the USGS's gaging stations.

2.3.2 Surface Water

Extending from the Lake Fork confluence with the Arkansas River downstream to the Highway 24 Bridge (Figure 2-63), tributaries in Reach 2 include Lake Fork Creek, Halfmoon Creek, Iowa Gulch and Thompson Gulch. There is one large agricultural diversion ditch (Derry Ditch No. 1) that appears to collect water on the western side of the river and conveys water to the floodplain within this reach. Other agricultural irrigation ditches are also present (Figure 1-6). Tables 2-4 through 2-6 present the summary statistics for surface water quality in Reach 2 and summarize the criteria exceedances for dissolved metals during each of the periods. Total metals concentrations for Reach 2 are presented in Table 2-40.

Entire Period of Record

Water quality in Reach 2 shows some general improvements over that observed in Reach 1, although there are metals concentrations that exceed TVSs. Mean discharge in this reach ranged from about 121 cfs during low flows to 508 cfs during high flows. There is a clear influence of Lake Fork on discharge noticed in this reach. During high flows, hardness ranged from 26 mg/L to 242 mg/L, while during low flows hardness ranged from 32 to 184 mg/L. Specific conductivity ranged from as low as 50 µmhos to 942 µmhos and is undoubtedly affected by changes in discharge. Likewise pH, ranged from 5 to 9.3, with lower pH predominating during high flows and higher pH during low flows. However, these pH values are not as variable as observed upstream in Reach 1.

Cadmium

Total cadmium data in Reach 2 were collected from 1974 to present at five sites. The highest total cadmium measured during the POR was 0.04 mg/L recorded during low flows, while the maximum high flow total cadmium concentration was 0.02 mg/L. During both the high and low flow conditions, total cadmium concentrations show a definite trend of decreasing concentrations in this reach. Mean total cadmium concentrations are very similar between high flows (0.0029 mg/L) and low flows (0.0034 mg/L). Compared to upstream reaches, mean total cadmium in Reach 2 is only slightly lower than in Reach 1 and still greater than in Reach 0.

Copper

Total copper data were available from 1973 to 2000 from five sites, although the majority of data was found primarily for the period after 1992. The highest total copper observed was 0.06 mg/L during low flows while the maximum high flow concentration was 0.025 mg/L. During both the high and low flow conditions, total copper concentrations show a slight decreasing trend in concentrations in this reach, particularly during the most recent few years. Mean total copper concentrations are very similar between high flows (0.011 mg/L) and low flows (0.009 mg/L). Compared to upstream reaches, mean total copper in Reach 2 is slightly lower than in Reach 1 and only slightly greater than in Reach 0.

Lead

Total lead data in Reach 2 were available from 1974 to 2000 from five sites. The highest total lead observed was 0.3 mg/L during high flows while the maximum low flow concentration was 0.2 mg/L. During both the high and low flow conditions, total lead concentrations show a decreasing trend in concentrations in this reach, particularly during the most recent few years. Mean total lead concentrations are similar between high and low flows (0.027 mg/L). Compared to upstream reaches, mean total lead in Reach 2 is lower than in Reach 1 during high flows but greater during low flows. Both concentrations are greater in Reach 2 than in Reach 0.

Zinc

Total zinc data in Reach 2 are available from 1973 to 2000 at five sites. The highest total zinc observed was 1.6 mg/L during low flows while the maximum high flow concentration was 1.5 mg/L. During only low flow conditions, total zinc concentrations show a decreasing trend in concentrations in this reach, particularly during the most recent few years. Mean total zinc concentrations are similar between high (0.425 mg/L) and low flows (0.439 mg/L). Compared to upstream reaches, mean total zinc in Reach 2 is considerably lower than in Reach 1, but still greater than in Reach 0.

Period 3 (After February 1, 1992)

Hardness values during high flows averaged 63.3 mg/L and increased to 86.6 mg/L during low flows.

Cadmium

Dissolved cadmium samples were collected from 3 sites during Period 3 representing 55 individual measurements. Mean dissolved cadmium concentrations were 0.0017 and 0.0006 mg/L during high and low flows, respectively. Dissolved cadmium was highest during high flows (0.0068 mg/L) while during low flows maximum dissolved cadmium was 0.0025 mg/L. During high flows, acute and chronic TVSs were exceeded by 8 samples, while during low flows only 1 sample exceeded the chronic TVSs. Based on the summary statistics, the ratios of average and maximum concentrations to TVSs were higher during high flows relative to low flows. During the approximate 8-year time frame of Period 3, dissolved cadmium shows a decreasing trend during both high and low flows. Mean dissolved cadmium in Reach 2 is only slightly elevated above mean dissolved cadmium observed in Reach 0 during high flows and during lows flows dissolved cadmium is lower in Reach 2 than in Reach 0.

Copper

Dissolved copper samples were collected from 3 sites during Period 3 representing 56 individual measurements. Mean dissolved copper concentrations were 0.007 and 0.004 mg/L during high and low flows, respectively. Maximum dissolved copper observed during both high and low flows was the same (0.025 mg/L). During high flows, acute and chronic TVSs were exceeded in 6 and 9 samples, respectively, while during low flows only 1 sample exceeded the acute and chronic TVSs. Based on the summary statistics, the ratios of average and maximum concentrations to TVSs were higher during high than low flows. During the approximate 8-year time frame of Period 3, dissolved copper shows a decreasing trend during both high and low flows. Mean dissolved copper in Reach 2 is only slightly elevated above mean dissolved copper observed in Reach 0 during high and low flows.

Lead

Dissolved lead samples were collected from 3 sites during Period 3 representing 55 individual measurements. Mean dissolved lead concentrations were 0.003 and 0.0007 mg/L during high and low flows, respectively. Dissolved lead was highest during high flows (0.0171 mg/L) while during low flows maximum dissolved lead was 0.0025 mg/L. During high and low flows, chronic TVSs were exceeded by 13 samples and 1 sample, respectively. Based on the summary statistics, the ratios of average and maximum concentrations to TVSs were higher during high flows. During the approximate 8-year time frame of Period 3, dissolved lead shows a slight decreasing trend during both high and low flows. Mean dissolved lead in Reach 2 is only slightly elevated above mean concentrations observed in Reach 0 during high flows. During lows flows dissolved lead is lower in Reach 2 than in Reach 0.

Zinc

Dissolved zinc samples were collected from 3 sites during Period 3 representing 57 individual measurements. Mean dissolved zinc concentrations were 0.313 and 0.187 mg/L during high and low flows, respectively. Dissolved zinc was highest during high flows (1.15 mg/L) while during low flows maximum dissolved zinc was 0.63 mg/L. During high flows, acute and chronic TVSs were exceeded in 25 samples, while during low flows, 21 samples exceeded the acute and chronic TVSs. Based on the summary statistics, the ratios of average and maximum concentrations to TVSs were higher during high flows. During the approximate 8 year time frame of Period 3, dissolved zinc shows a decreasing trend during high flow, but a similar trend is not found during low flows. Mean dissolved zinc in Reach 2 is elevated above mean concentrations observed in Reach 0 during both high and low flows.

2.3.3 Sediments

Sediment data for Reach 2 are limited. As indicated by Table 2-41, often only a few sites with sediment data for Reach 2 were found. Data prior to Period 3 are almost non-existent for this reach. Concentrations of metals in sediments from Reach 2 are elevated over those found in Reach 0. Mean concentrations of cadmium, copper, lead, and zinc are 2.8, 7.2, 9.7, and 7.7 times greater, respectively, in Reach 2 compared to Reach 0. Figure 2-64 shows sediment sample locations within this reach.

2.3.4 Groundwater

The four shallow monitoring well (SMW) groundwater monitoring locations in Reach 2 consist of wells installed by USEPA for the purposes of monitoring shallow groundwater. The SMW locations in this reach are generally 1 to 6 feet deep, with minimal screening and little development, are located close to the Arkansas River (approximately 50-400 feet) and are adjacent to, or entirely within, mine-waste deposits FA, FB and FC (Figure 2-65), near the upstream portion of Reach 2. All of the SMW locations within Reach 2 are within the 500-year floodplain. Table 2-33 provides a summary of the water quality in the SMW wells for dissolved cadmium, copper lead, and zinc. Detailed data records for Reach 2 SMW groundwater can be found in Appendix E.

For the DWS deeper groundwater locations in Reach 2 (Figure 2-65), dissolved metals concentration data were available for Periods 2 and 3 from a single well, GW203, which has a total depth of 32 feet, and a screened interval from 20 to 32 feet, located approximately 700 feet west of the Arkansas River. GW203 was sampled in 1983 by Ecology and Environment, Inc. (EEI), for USEPA, and again in 2001 by URS, for USEPA. There are no CDPHE total metals data available in Reach 2. Summary statistics for Reach 2 DWS groundwater are presented for dissolved metals in Table 2-9 and data for individual records can be found in Appendix E.

A pair of spring pools, GW201 and GW201 (Figure 2-65), used for watering farm stock, were also sampled by Ecology and Environment, Inc. in 1983 and analyzed for dissolved cadmium, copper, lead, and zinc. Data from these locations are also included here in the DWS section for Reach 2.

<u>Cadmium</u>

Shallow Monitoring Well (SMW)

The mean dissolved cadmium concentration in Reach 2 SMW groundwater was 0.0092 (0.0001, 0.036) mg/L (n = 44) across the four locations sampled. The maximum dissolved cadmium concentration occurred at UMW09, below the mouth of Lake Fork/Halfmoon Creek. Data are available for Period 3 only.

Domestic Water Supply (DWS)

The mean dissolved cadmium concentration in Reach 2 DWS groundwater was 0.0015 (0.0005, 0.0025) mg/L (n = 2) at location GW203. In 1983 (Period 2), EEI did not detect dissolved cadmium at GW203, resulting in a value of 0.0025 mg/L for statistical comparison purposes; and in 2001 (Period 3), URS/USEPA did not detect dissolved cadmium at GW203, resulting in a value of 0.0025 mg/L for statistical comparison purposes. The dissolved cadmium concentrations in DWS groundwater in Reach 2 did not exceed the MCL (0.005 mg/L).

For the spring pool samples collected by EEI in 1983, dissolved cadmium was not detected at GW201 (0.0025 mg/L used for statistical comparison purposes), but was detected at GW202 at 0.009 mg/L.

Copper

Shallow Monitoring Well (SMW)

The mean dissolved copper concentration in Reach 2 SMW groundwater was 0.0017 (0.0003, 0.011) mg/L (n = 44) across the four locations sampled. The maximum dissolved copper concentration occurred at UMW08, below the mouth of Lake Fork/Halfmoon Creek. Data are only available for Period 3.

Domestic Water Supply (DWS)

The mean dissolved copper concentration in Reach 2 DWS groundwater was 0.0023 (0.002, 0.0025) mg/L (n = 2) at GW203. In 1983 (Period 2), EEI did not detect dissolved copper at GW203, resulting in a value of 0.0025 mg/L for statistical comparison purposes; and in 2001 (Period 3), URS/USEPA did not detect dissolved cadmium at GW203, resulting in a value of 0.002 mg/L for comparison purposes. Although there is no MCL for copper, the maximum dissolved copper did not exceed the Colorado action level for copper (1.3 mg/L).

For the spring pool samples collected by EEI in 1983, dissolved copper was not detected at GW201, nor at GW202, hence 0.0025 mg/L was used for statistical comparison purposes at both locations.

Lead

Shallow Monitoring Well (SMW)

The mean dissolved lead concentration in Reach 2 SMW groundwater was 0.0106 (0.0005, 0.096) mg/L (n = 44) across the four locations sampled. The maximum dissolved lead concentration occurred at UMW08, below the mouth of Lake Fork/Halfmoon Creek. Data are only available for Period 3.

Domestic Water Supply (DWS)

The mean dissolved lead concentration in Reach 2 DWS groundwater was 0.01 (0.005, 0.015) mg/L (n = 2) at GW203. In 1983 (Period 2), EEI did not detect dissolved lead at GW203, resulting in a value of 0.0025 mg/L for comparison purposes; and in 2001 (Period 3), URS/USEPA did not detect dissolved lead at GW203, resulting in a value of 0.005 mg/L for comparison purposes. The concentrations measured in DWS groundwater in Reach 2 do not exceed the Colorado action level for dissolved lead (0.015 mg/L).

For the spring pool samples collected by EEI in 1983, dissolved lead was not detected at GW201, nor at GW202, hence 0.015 mg/L was used for comparison purposes at both locations.

Zinc

Shallow Monitoring Well (SMW)

The mean dissolved zinc concentration in Reach 2 SMW groundwater was 3.13 (0.00045, 9.82) mg/L (n = 45) across the four locations sampled. The maximum dissolved zinc concentration occurred at UMW08, below the mouth of Lake Fork/Halfmoon Creek. Data are only available for Period 3.

Domestic Water Supply (DWS)

The mean dissolved zinc concentration in Reach 2 DWS groundwater was 0.193 (0.0022, 0.383) mg/L (n = 2) at GW203. In 1983 (Period 2), EEI detected dissolved zinc at GW203 at 0.383 mg/L, and in 2001 (Period 3), URS/USEPA detected dissolved zinc at GW203 at 0.0022 mg/L. The mean dissolved zinc concentration in Reach 2 DWS groundwater does not exceed the MCL (5.0 mg/L).

For the spring pool samples collected by EEI in 1983, dissolved zinc was detected at GW201 at 0.036 mg/L, and dissolved zinc was detected at GW202 at 0.025 mg/L.

2.3.5 Floodplain Soils

Work by Sommers et al. (1991) and Levy et al. (1992) on the Smith Ranch characterized physical and chemical properties of soils that were reported to be contaminated by mine drainage and sediment from California Gulch (Figure 2-66). Metal concentrations in soils were quantified by depth for total, organically bound, iron-manganese oxide bound, exchangeable, and water-soluble forms of cadmium, copper, lead, and zinc. A total of two locations were sampled at six depth increments between 0 and 12 inches.

The greatest concentrations of total metals were found either in the surface horizons or in hydraulically deposited sand layers that were buried at a number of locations. Copper was predominantly associated with the organic fraction at most locations, while cadmium, lead, and zinc were mainly bound to iron and manganese oxides at all locations. The range of total concentrations reported for cadmium was 30-325 mg/Kg, copper was 100-1,176 mg/Kg, lead was 463-48,708 mg/Kg, and zinc was 2,499-12,819 mg/Kg (Sommers et al. 1991). These concentrations were much higher than the maximum concentrations reported for the control site for this study, which was located in Tennessee Park, north of the confluence between the East Fork of the Arkansas River and Tennessee Creek. Maximum total concentrations in Tennessee Park were approximately 18 mg/Kg for cadmium, 48 mg/Kg for copper, 490 mg/Kg of lead, and 126 mg/Kg for zinc. Woodward Clyde (1993) also presented soils metals data for the Smith Ranch. The highest concentrations reported in the Woodward Clyde report were below the highest concentrations reported by Levy et al. (1992).

Keammerer (1987) sampled soils at eight locations along the Arkansas River between Lake Fork and Highway 24 Bridge (Table 2-42 and Figure 2-66). Total concentrations of cadmium averaged 15.4 mg/Kg, with a range of 1.6 to 33 mg/Kg; copper averaged 51.4 mg/Kg, with a range of 16 to 121 mg/Kg; lead averaged 675 mg/Kg, with a range of 150 to 2,033 mg/Kg; and zinc averaged 1,180 mg/Kg, with a range of 78 to 3,718 mg/Kg. Plant-available concentrations were substantially lower, with cadmium concentrations averaging 2.6 mg/Kg, copper averaging 2.5 mg/Kg, lead averaging 24.5 mg/Kg, and zinc averaging 121 mg/Kg (Figures 2-7 to 2-10).

URS (1998) identified and sampled 35 mine-waste deposits between Lake Fork confluence and Highway 24 Bridge (Figure 2-67). Among these deposits, there are a total of approximately 233,389 ft^3

of mine-waste, covering a surface area of approximately 405,936 ft^2 in Reach 2. The average depth of the deposits is 0.6 feet and no deposits that averaged greater than 1.5 feet in depth were found. Total metal concentrations averaged 153 mg/Kg for cadmium, 200 mg/Kg for copper, 3,266 mg/Kg for lead, and 3,438 mg/Kg for zinc. See Appendix D for a more detailed physical and chemical description of these deposits.

2.3.6 Biota

2.3.6.1 Terrestrial Vegetation

The vegetation mapping conducted by NRCS in 1997 identified five community types along this stretch of river: wet meadow, subirrigated, riparian subirrigated, irrigated pasture, and upland.

Sommers et al. (1991) and Levy et al. (1992) collected and analyzed plant samples for metal concentrations from the Smith Ranch in 1988 where two locations were sampled (Figure 2-66). Table 2-43 is a summary of the data from this sampling effort. Sedges, rushes, grasses, and forbs were sampled and analyzed for tissue concentrations of cadmium, copper, lead, and zinc. Cadmium concentrations ranged from 2 to 21 mg/Kg, copper concentrations ranged from 5 to 21 mg/Kg, lead concentrations ranged from 13 to 52 mg/Kg, and zinc concentrations ranged from 403 to 593 mg/Kg.

Plant cover along the Arkansas River between Lake Fork and Highway 24 Bridge averaged 77 percent across eight sample locations in 1987 (Keammerer 1987). The range in plant canopy cover was 38 to 92 percent (Table 2-44). Aboveground production averaged 242 g/m^2, with a range of 115 to 400 g/m^2. Plant tissue metal concentrations for the same sample locations (Figure 2-68) are shown in Table 2-45 (Keammerer 1987). Plant metal concentrations for grasses averaged 1.6 mg/Kg for cadmium, 4.9 mg/Kg for copper, 9.0 mg/Kg for lead, and 147 mg/Kg for zinc. Plant metal concentrations for forbs averaged 3.4 mg/Kg for cadmium, 7.7 mg/Kg for copper, 13.1 mg/Kg for lead, and 186 mg/Kg for zinc.

Woodward Clyde collected plant samples on the Smith Ranch for plant tissue metal analysis in 1992 (Woodward Clyde 1993). Plant samples included grasses, sedges, and willows, and metal analysis was done for cadmium, copper, lead, and zinc. All concentrations reported were within the range of values reported by both Keammerer (1987) and Levy et al. (1992). The site sampled by Woodward Clyde was selected as a "worst-case fluvial tailings sample location, based on previous soil sampling and its semi-barren vegetative condition."

Mine-waste material from the Smith ranch was collected in 1997 for a greenhouse study to determine the effect of lime and organic matter amendments on plant growth and metal uptake (Fisher 1999). Geyer willow was planted in lysimeters filled with mine-waste amended with lime, organic matter, or lime plus organic matter. Each amendment was incorporated to three different depths (0-20, 0-40, and 0-60 cm). Aboveground growth of willow in treatments with lime was more than eight times greater than from willow grown in treatments that did not contain lime. In addition, deeper depths of incorporation supported more plant growth than shallower depths of mixing. The addition of organic matter to the lime amendment provided some additional benefit to plant growth. Willows from all treatments accumulated metals (cadmium and copper), but concentrations were lower in treatments amended with lime.

Fisher (1999) also conducted a field study on mine-waste deposits located on the Smith Ranch. The purpose of the study was to determine the effects that soil amendments (lime, organic matter, and phosphorus) had on establishment of tufted hairgrass, creeping bentgrass, and Geyer willow. The results of the study indicated that plant growth was improved with the addition of lime and organic matter. Willows grown in treatments with lime had 60 percent more leaders than those grown without lime. The length of willow leaders was two and a half times greater in lime plus organic matter than control treatments without any amendments. The density and cover of grasses also responded favorably to lime, but not to organic matter. There was no phosphorus effect found in this study, and the primary conclusion was that lime was an essential amendment for successful plant establishment on these mine-waste deposits.

2.3.6.2 Habitat

2.3.6.2.1 Terrestrial

The upper half of this reach is dominated by a riparian shrub community consisting of willow species, and herbaceous riparian vegetation consisting of sedges and rushes, and with areas of open standing water. The area is interspersed with unvegetated mine-waste deposits and unvegetated sandbars (Figure 2-69).

The lower half of this reach is dominated by riparian herbaceous vegetation consisting primarily of sedges and rushes indicative of saturated soils. The uplands are dominated by herbaceous riparian vegetation consisting of sedges, rushes, and mesic grasses representative of moist soils. The area is interspersed with unvegetated mine-waste deposits and unvegetated sandbars.

2.3.6.2.2 Aquatic

Table 2-15 summarizes the fish habitat inventory data. Site AR-4 (Figure 2-70) was dominated by runs (54 percent) and low gradient riffles (41 percent). Cobble and willow were the dominant instream substrate and near-stream vegetation at all sites, respectively.

Details of the inventory are presented in Table 2-16 where specific conditions by habitat type for each reach are presented. Wetted widths averaged from 39 to 58 feet. Average depths ranged from 0.9 to 1.1 feet. Average percent surface fines ranged from 10 to 50 percent and the average amount of cut banks ranged from 0 to 50 percent.

Rapid Bioassessment Protocol (RPB) scoring conducted by Chadwick Ecological Consultants (1998) (Table 2-17) indicates good habitat for site AR-4 during 1994 and optimal habitat during 1998.

Habitat Quality Index (HQI) ratings are presented in Table 2-18. Late summer stream flows were rated completely adequate whereas annual stream flow variation was rated as moderate. Water temperature was rated as moderate, and nitrate was rated as limited. Cover was rated as very limited, stream bank erosion was rated as limited, substrate was rated as moderate, water velocity was rated as completely adequate, and stream width was rated as moderate. Predicted trout biomass for Reach 2 was 178 lbs/acre, the highest of the reaches assessed.

2.3.6.3 Aquatic Community

2.3.6.3.1 Benthic Community

Chadwick Ecological Consultants collected benthic macroinvertebrates from Reach 2 (station AR-4), located below the confluence of Lake Fork on the Smith Ranch. Total macroinvertebrate abundance at this station (all dates combined) was 1,090 individuals per m^2, which was greater than abundances at either Reach 0 or Reach 1 (Figures 2-19 and 2-20). Although total mayfly abundance and number of heptageniid mayflies increased compared to Reach 1, these measures were reduced compared to Reach 0. Similar patterns were observed for species richness of macroinvertebrates in Reach 2. Although total species richness in Reach 2 was similar to that observed in Reach 0, species richness of mayflies was lower than the reference reach.

Toxicology

Results of acute toxicity tests conducted with water collected from Reach 2 in 1987 showed 100 percent mortality to *Ceriodaphnia* (Table 2-23). Experiments conducted in subsequent years reported less mortality, and LC50 values ranged from 37-56 percent (Table 2-23).

2.3.6.3.2 Fish Populations

The CDOW and Chadwick Ecological Consultants conducted surveys of brown trout populations in Reach 2 (station AR-4) between 1994 and 1999. On two of the four sampling occasions (September 1994 and 1999), brown trout populations showed significant improvement compared to Reach 1, and were similar to those collected from Reach 0 (Figure 2-37 through 2-40). In contrast, brown trout populations in August 1997 and April 1998 were reduced compared to Reach 0.

Length-frequency data of brown trout collected in Reach 2 showed some evidence of recovery; however, these patterns were dependent on season and year (Figure 2-42 through 2-45). For example, in September 1994, the age distribution of brown trout in Reach 2 was very similar to Reach 0. In contrast, length-frequency distributions indicated a dramatic reduction of younger age classes in 1998 and 1999.

Aquatic Associates' (1993) site AR04 falls within Reach 2. Metal concentrations in fish collected from the locations in Reach 2 were < 0.1 mg/Kg cadmium, 0.2 mg/Kg copper, 0.2 mg/Kg lead, and 3.5 mg/Kg zinc. A substantial decrease in zinc tissue concentration is present at this site when compared to the upstream site, although the other metals remain relatively unchanged. The observed decrease coincides with the increased discharge within the reach, where substantial flow augmentation occurs.

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

2.3.6.4 Terrestrial Vertebrates

2.3.6.4.1 Small Mammals

Small mammal trapping was conducted in Reach 2 on the Smith Ranch by Woodward Clyde (1993). Based on soil sampling data, the Smith Ranch site was selected to represent "worst-case" fluvial mine-waste exposure conditions for wildlife. The sampling locations were pastures irrigated with Arkansas River water and near fluvial mine-waste deposits. They collected liver, kidney, and bone tissues from voles and weasels for trace element analysis and various tissues for histopathological examination.

Woodward Clyde (1993) collected 2 individual vole liver samples and one composite sample made up of 4 individuals. They collected 1 individual vole kidney sample and one composite vole kidney sample made up of 4 individuals. Three bone samples were collected which included 2 individual samples and one composite sample made up of 4 individuals (Table 2-46). Woodward Clyde (1993) collected 2 individual weasel liver and kidney samples for trace element analysis. The average concentrations for the 2 individual liver samples were 1.3 mg/Kg wet weight for cadmium, 12.6 mg/Kg wet weight for copper, 0.4 mg/Kg wet weight for lead, and 31.8 mg/Kg wet weight for zinc. The average concentrations for the 2 individual kidney samples were 3.3 mg/Kg wet weight for cadmium, 20.4 mg/Kg wet weight for copper, 1.4 mg/Kg wet weight for lead, and 39.0 mg/Kg wet weight for zinc. They collected one weasel bone sample with a lead concentration of 16.3 mg/Kg wet weight.

None of the liver or kidney concentrations reported for Reach 2 exceed literature- based benchmark values. Some liver and kidney metal concentrations from Reach 2 are slightly higher than concentrations reported for Reach 0. However, the histopathology examination revealed no significant lesions or other tissue damage that would be associated with metal toxicity.

2.3.6.4.2 Large Mammals

There are no known terrestrial mammal studies or sampling efforts for this reach.

2.3.6.4.3 Birds

Archuleta et al. (2000) collected blood and liver samples from American dippers at 3 locations in Reach 2 (Smith Ranch, near Iowa Gulch confluence, and Hwy. 24 bridge). They analyzed blood for metals and ALAD activity and liver for metals and metallothionein concentrations.

None of the blood or liver concentrations exceeded literature-based benchmark values. With the exception of lead, all blood metal concentrations were less than those from Reach 0 (Table 2-47). Lead and zinc concentrations in both blood and liver were higher in Reach 2 than concentrations from the Study Reference. Metallothionein was 50 percent higher in Reach 2 compared to Reach 0 and 82 percent higher than the Study Reference. ALAD activity was reduced by 18 percent in Reach 2 compared to Reach 0 and by 47 percent compared to the Study Reference site.

Invertebrate concentrations for all metals of concern were higher in Reach 2 compared to Reach 0 and the Study Reference. Cadmium, lead, and zinc concentrations in invertebrates from Reach 2 all exceeded the literature-based benchmark values (Table 2-48).

Custer et al. (2003 In Press) established a nesting colony of tree swallows on the Smith Ranch and collected 12 –day old nestlings. They sampled blood for ALAD activity and livers and stomach contents for metals analysis. With the exception of lead, all liver concentrations from Reach 2 were similar to those from Reach 0 (Table 2-49). Although the average liver concentration for lead from Reach 2 was 3 times the average concentration from Reach 0, it was far below the literature-based benchmark. ALAD activity in tree swallows was 35 percent less than the Study Reference but only 2 percent less than Reach 0.

Average concentrations for cadmium and lead in tree swallow stomach contents were higher in Reach 2 than Reach 0 and lead and zinc exceeded literature –based benchmarks (Table 2-50).

During one year of the study, the colony in Reach 2 had a lower probability of egg survival compared to all other sites except the Leadville Mine Drainage Tunnel. The colony in Reach 2 had a nest success of 70.5 percent and 65.3 percent compared to the 86.9 percent nationwide average for tree swallows calculated by Robertson et al. (1992). Reach 2 nest success was significantly less than the Reach 0 Colorado Belle site ($p<0.05$) and slightly less than the Reach 0 Leadville Mine Drainage Tunnel site. Nest success in the Reach 2 colony was the lowest of any colony sampled on the Arkansas River. Custer et al. (2003 In Press) attributed reduced hatching success in Reach 2 to nest abandonment or death of adults at the nest box.

2.4 Reach 3: Highway 24 Bridge to Narrows just downstream of County Road 55 Bridge

2.4.1 Hydrology/Geomorphology

Reach 3 extends from the Highway 24 Bridge to a short distance downstream of County Road 55 (Figure 2-71) and is about 19,000 feet long. The channel appears to have been relatively active, and the reach contains numerous mine-waste deposits. Based primarily upon differences of gradient, the reach can be divided into 2 subreaches (InterFluve 1999) (Table 2-3). Low-flow channel width in a straight reach increased 9 percent since 1939, but only one percent took place after 1957 (InterFluve 1999).

Subreach 3A is about 11,400 feet long and extends from the Highway 24 Bridge to mile 8, where the Narrows constricts the alluvial valley. The gradient is similar to that of Subreach 2B upstream (Table 2-3). The 1997 aerial photograph shows what appears to be an active channel with some divided flow reaches and evidence of numerous cutoffs. In the downstream half of the reach, the longitudinal profile is irregular, displaying two concavities. Sinuosity decreased slightly since 1939 from 1.25 to 1.18.

The amount of mine-waste in this reach is high (1,053,518 ft^3) with 92.4 cubic feet of mine-waste per linear foot of banks (Table 2-30), and 15 percent of the banks expose mine-waste. The channel shows past evidence of bend growth, cutoffs, and avulsion.

Based upon examination of 1973, 1979, 1988, and 1997 aerial photography, the geomorphological characteristics of Subreach 3A indicate that in 1973, the main channel was braided with numerous side channels. This condition persisted to 1979, but in 1988, there were fewer side channels. In 1997, the side channels were abandoned, and a well-defined single braided channel conveyed the flow, suggesting increased channel stability.

Subreach 3B is about 7,400 feet long and extends from the confluence of Big Union Creek to the Narrows, 1,500 feet downstream of County Road 55. It contains 524,793 ft^3 of mine-waste or 71.4 ft^3 per linear foot of banks, but only 9 percent of the banks expose mine-waste. Sinuosity decreased significantly since 1939, from 1.35 to 1.12, indicating a relatively active channel. Low-flow channel width in a straight reach increased 14 percent since 1939, but the entire increase occurred after 1957 (InterFluve 1999).

This is a steep active subreach with abundant evidence of bend migration, cutoffs, and avulsion. The InterFluve report suggests that part of the pattern is the result of human relocation of the main channel. According to InterFluve (1999), the Arkansas River channel is perched above the valley floor, and an avulsion to the east is possible. This appears to be a subreach of sediment storage upstream of a constriction that could produce backwater effects.

The aerial photographs indicate that in 1973, the channel in Subreach 3B was wide and braided. In 1979, the channel was braided, with multiple channels at both upstream and downstream portions of the subreach. This condition persisted in 1988, but by 1997, there was a single, well-defined channel in this subreach, suggesting relative channel stability.

The USGS gage just downstream of the Hwy 24 Bridge crossing (#7083700) had a 20-year period of record from 1964 to 1984, providing a good flow record for Reach 3. Mean monthly flows generated from these records indicate that from November to March, mean monthly flows decrease from 129 cfs to about 100 cfs (Figure 2-2). The rising limb of the hydrograph begins in April, where mean monthly flows averaged 155 cfs. May through about mid-June flows continue to increase during snowmelt and runoff with mean monthly flows of 359 and 721 cfs, respectively. The descending limb of the hydrograph begins sometime in June, depending upon snow pack and temperature. July, August, and September tend to represent the descending limb of the hydrograph with mean monthly flows of 545 cfs, 282 cfs, and 151 cfs, respectively.

The change in flows measured at this station versus those measured at Leadville Junction illustrate the magnitude of influence the augmented flows have on Reach 2 and 3 of the river. Figures 2-72 and 2-73 further illustrate the differences in flows measured between the two stations, both prior to 1981 and after 1981. This record is augmented by flows measured at another gage from 1990 to 1993 located just downstream of Empire Gulch (#7083710), but within close proximity to the Hwy 24 stations. For time periods when there were overlapping data prior to water being diverted through the Mt. Elbert conduit (1974 to 1981), the magnitude of peak flows as well as the duration of sustained higher flows during the low flow periods is obvious. From 1990 to 1993, flows compared between the Leadville Junctions gage and the Empire Gulch gage further illustrate the change in flows between the two gages after the Mt. Elbert Conduit was placed in operation. Although only three years of continuously monitored flow data are available for the Empire Gulch station, it provides a good estimate of the amount of change, as well as a more recent record of the flow conditions that are likely occurring in Reach 3.

2.4.2 Surface Water

Tributaries to Reach 3 include Empire Gulch, Dry Union Gulch, drainage from the Mount Massive Lakes area located downstream of Dry Union Gulch, and Spring Creek (Figure 2-74). Table 2-51 presents the summary statistics for surface water quality in Reach 3, and Tables 2-4 through 2-6 summarize the criteria exceedances for dissolved metals during each of the periods.

Entire Period of Record

Water quality in Reach 3 shows some general improvements over that observed in Reach 1, although metals concentrations exceed TVSs. Mean discharge in this reach ranged from about 72 cfs during low flows to 329 cfs during high flows. During high flows, hardness ranged from 39 mg/L to 107 mg/L, while during low flows hardness ranged from 76 to 140 mg/L. Specific conductivity ranged from as low as 69 µmhos to 2,990 µmhos, which is a substantial change in the range from upstream Reaches. Likewise pH, ranged from 4.8 to 8.9, again a shift from upstream reaches.

Cadmium

Total cadmium data in Reach 3 were collected from 1990 to 2000 at ten sites. The highest total cadmium measured during the POR was 0.038 mg/L recorded during high flows, while the maximum low flow total cadmium concentration was 0.005 mg/L. During both the high and low flow conditions, total cadmium concentrations show no clear trends. Mean total cadmium concentrations are similar between high flows (0.0027 mg/L) and low flows (0.0013 mg/L). Compared to upstream reaches, mean total cadmium in Reach 3 was only slightly lower than in Reach 2 during both flow conditions, but mean low flow cadmium was lower in Reach 3 than in Reach 0.

Copper

Total copper data in Reach 3 were collected from 1972 to 2000 at ten sites. The highest total copper measured during the POR was 0.025 mg/L recorded during both high and low flows. During both the high and low flow conditions, total copper concentrations appear to show a slight decreasing trend in more recent times. Mean total cadmium concentrations were very similar between high flows (0.014 mg/L) and low flows (0.009 mg/L). Compared to upstream reaches, mean total copper in Reach 3 was slightly higher than in Reach 2 during high flow but similar during low flow conditions. However, both high and low flow total copper was higher in Reach 3 than in Reach 0.

<u>Lead</u>

Total lead data in Reach 3 were collected from 1972 to 2000 at ten sites. The highest total lead measured during the POR was 0.121 mg/L recorded during high flow and during low flows maximum lead was 0.108 mg/L. During both the high and low flow conditions, total lead concentrations show no clear increasing or decreasing trends. Mean total lead concentrations were higher during high flows (0.024 mg/L) relative to low flows (0.014 mg/L). Compared to upstream reaches, mean total lead in Reach 3 was slightly lower than in Reach 2, but still elevated compared to Reach 0.

<u>Zinc</u>

Total zinc data in Reach 3 were collected from 1972 to 2000 at eleven sites. The highest total zinc measured during the POR was 2.3 mg/L recorded during high flow and during low flows maximum zinc was 1.3 mg/L. Mean total zinc concentrations were higher during high flows (0.385 mg/L) relative to low flows (0.282 mg/L). During both the high and low flow conditions, total zinc concentrations showed a decreasing trend. Compared to upstream reaches, mean total zinc in Reach 3 was considerably lower during high and low flows than in Reach 2. Compared to Reach 0, Reach 3 mean total zinc was higher during high flows but lower during low flows.

Period 3 (After February 1, 1992)

Hardness values during high flows averaged 69.5 mg/L and increased to 100.8 mg/L during low flows.

<u>Cadmium</u>

Dissolved cadmium samples were collected from 7 sites during Period 3 representing 148 individual measurements. Mean dissolved cadmium concentrations were 0.0018 and 0.0012 mg/L during high and low flows, respectively. Dissolved cadmium was highest during high flows (0.006 mg/L) while during low flows maximum dissolved cadmium was 0.0025 mg/L. During high flows, the acute TVS was exceeded by 5 samples and the chronic TVS was exceeded by 44 samples, while during low flows, no acute exceedances occurred and 24 samples exceeded the chronic TVS. The ratios of average and maximum concentrations to TVSs were higher during high flows. During the approximate 8-year time frame of Period 3, dissolved cadmium showed a decreasing trend during high flows, but no trend was apparent during low flows. Mean dissolved cadmium in Reach 3 was only slightly elevated above mean dissolved cadmium observed in Reach 0 during high and low flows.

Copper

Dissolved copper samples were collected from 7 sites during Period 3 representing 150 individual measurements. Mean dissolved copper concentrations were 0.013 and 0.008 mg/L during high and low flows, respectively. The maximum dissolved copper concentration (0.025 mg/L) was observed during both high and low flows. During high flows, the acute TVS was exceeded by 39 samples and the chronic TVS was exceeded by 42 samples, while during low flows acute and chronic exceedances occurred in 18 samples each. The ratios of average and maximum concentrations to TVSs were higher during high flows. During the approximate 8-year time frame of Period 3, dissolved copper shows a decreasing trend during high and low flows. Mean dissolved copper in Reach 3 was elevated above mean dissolved copper observed in Reach 0 during high and low flows.

Lead

Dissolved lead samples were collected from 7 sites during Period 3 representing 136 individual measurements. Mean dissolved lead concentrations were 0.0033 and 0.0020 mg/L during high and low flows, respectively. Dissolved lead was highest during high flows (0.045 mg/L) while during low flows maximum dissolved lead was 0.027 mg/L. During high flows, the chronic TVS was exceeded by 46 samples and during low flows 2 samples exceeded the chronic TVS. The ratios of average and maximum concentrations to TVSs were higher during high flows. During the approximate 8 year time frame of Period 3, dissolved lead showed no apparent increasing or decreasing trends during either flow condition. Mean dissolved lead in Reach 3 was only slightly elevated above mean dissolved lead observed in Reach 0 during high and low flows.

Zinc

Dissolved zinc samples were collected from 7 sites during Period 3 representing 161 individual measurements. Mean dissolved zinc concentrations were 0.240 and 0.172 mg/L during high and low flows, respectively. Dissolved zinc was highest during high flows (1.04 mg/L) while during low flows maximum dissolved zinc was 0.637 mg/L. During high flows, the acute and chronic TVS was exceeded by 56 samples and during low flows by 46 samples. The ratios of average and maximum concentrations to TVSs were higher during high flows. During the approximate 8-year time frame of Period 3, dissolved zinc showed a slight decreasing trend during both flow conditions. Mean dissolved zinc in Reach 3 was elevated above mean dissolved zinc observed in Reach 0 during high and low flows.

2.4.3 Sediments

As indicated by Table 2-52, only a few sites with sediment data for Reach 3 were found. Stream sediment sample locations are shown on Figure 2-75. Data prior to Period 3 were almost non-existent for this reach. Concentrations of metals in sediments from Reach 3 are elevated over those in sediments found in Reach 0. Mean concentrations of cadmium, copper, lead, and zinc are 1.3, 1.2, 4.4, and 3.3 times greater, respectively, in Reach 3 compared to Reach 0. Metals in sediments from Reach 3 are not nearly as elevated as those in Reach 2.

2.4.4 Groundwater

The twenty-six shallow monitoring well (SMW) locations in Reach 3 consist of six wells installed by USEPA and twenty installed by USGS for the purposes of monitoring shallow groundwater. The SMW locations in this reach are generally 1 to 6 feet deep, with minimal screening and little development, are located close to the Arkansas River (approximately 50-400 feet) and are adjacent to, or entirely within, mine-waste deposits (Figure 2-76). The USEPA SMW locations are distributed in the upper portion of Reach 3, from below Empire Gulch to below Dry Union Gulch, and the USGS SMW locations are in the middle of the Reach 3, below Dry Union Gulch, near the "N" group of mine-waste deposits. All of the SMW locations in Reach 3 are within the 500-year floodplain. One of the USEPA SMW groundwater monitoring locations in Reach 3, UMW17, has a pair of wells (UMW17A and UMW17B). Table 2-33 provides a summary of the water quality in the SMW wells for dissolved cadmium, copper lead, and zinc. Detailed data records for Reach 3 SMW groundwater can be found in Appendix E.

For the DWS deeper groundwater locations in Reach 3 (Figure 2-76), dissolved zinc data was available from STORET for location 390746106190200 (west of County Road 55, at Kobe) in 1972 (Period 1); and dissolved cadmium, copper, lead, and zinc data were available from Ecology and Environment, Inc. (EEI) for 1983 (Period 2) from GW204, a hand dug, 5-foot diameter well, total depth unknown, located approximately 700 feet west of the Arkansas River. There are no CDPHE total metals data available in Reach 3. Summary statistics for Reach 3 DWS groundwater are presented for dissolved metals in Table 2-8 and data for individual records can be found in Appendix E.

Cadmium

Shallow Monitoring Well (SMW)

The mean dissolved cadmium concentration in Reach 3 SMW groundwater was 0.0184 (0.0001, 0.249) mg/L (n = 155) across the 26 locations sampled. The maximum dissolved cadmium concentration occurred at AWT2-4, below the mouth of Dry Union Gulch. Data are available for Period 3 only.

Domestic Water Supply (DWS)

At GW204, the one location sampled in Reach 3 by EEI, in 1983 (Period 2) for USEPA, dissolved cadmium in DWS groundwater was not detected, hence for statistical comparison purposes, a concentration of 0.0025 mg/L was assigned to the reach. The dissolved cadmium concentration in DWS groundwater in Reach 3 did not exceed the MCL (0.005 mg/L).

Copper

Shallow Monitoring Well (SMW)

The mean dissolved copper concentration in Reach 3 SMW groundwater was 0.0331 (0.0003, 0.442) mg/L (n = 153) across the 26 locations sampled. The maximum dissolved copper concentration occurred at AWT2-4, below the mouth of Dry Union Gulch. Data are only available for Period 3.

Domestic Water Supply (DWS)

At GW204, the one location sampled in Reach 3 by EEI, in 1983 (Period 2) for USEPA, dissolved copper in DWS groundwater was not detected, hence for statistical comparison purposes, a concentration of 0.0025 mg/L was assigned to the reach. Although there is no MCL for copper, the dissolved copper concentration did not exceed the Colorado action level for copper (1.3 mg/L).

Lead

Shallow Monitoring Well (SMW)

The mean dissolved lead concentration in Reach 3 SMW groundwater was 0.016 (0.0005, 0.476) mg/L (n = 154) across the 26 locations sampled. The maximum dissolved lead concentration occurred at AWT1-3, below the mouth of Dry Union Gulch. Data are only available for Period 3.

Domestic Water Supply (DWS)

At GW204, the one location sampled in Reach 3 by EEI, in 1983 (Period 2) for USEPA, dissolved lead in DWS groundwater was not detected, hence for statistical comparison purposes, a concentration of 0.015 mg/L was assigned to the reach. Although there is no MCL for lead, the concentration measured for DWS groundwater in Reach 3 did not exceed the Colorado action level for dissolved lead (0.015 mg/L).

Zinc

Shallow Monitoring Well (SMW)

The mean dissolved zinc concentration in Reach 3 SMW groundwater was 2.35 (0.00045, 16.203 mg/L (n = 158) across the 26 locations sampled. The maximum dissolved zinc concentration occurred at AWT4-3, below the mouth of Dry Union Gulch. Data are only available for Period 3.

Domestic Water Supply (DWS)

The mean dissolved zinc concentration in Reach 3 DWS groundwater was 0.081 (0.032, 0.13) mg/L (n = 2). Data for this average came from the following: In 1972 (Period 1), the USGS detected 0.13 mg/L dissolved zinc at station 390746106190200 (near Kobe); and in 1983 (Period 2), Ecology and Environment, Inc. detected dissolved zinc at GW204 at 0.032 mg/L. The mean dissolved zinc concentration in Reach 3 DWS groundwater did not exceed the MCL (5.0 mg/L).

2.4.5 Floodplain Soils

Keammerer (1987) sampled soils at 8 locations (Figure 2-77) along the Arkansas River between Highway 24 Bridge and Narrows below CR 55 Bridge (Table 2-53). Total concentrations of cadmium averaged 7.4 mg/Kg, with a range of 1.6 to 13.8 mg/Kg; copper averaged 58.5 mg/Kg, with a range of 7 to 269 mg/Kg; lead averaged 626 mg/Kg, with a range of 35 to 3,675 mg/Kg; and zinc averaged 959 mg/Kg, with a range of 61 to 3,615 mg/Kg. Plant-available concentrations were substantially lower, with cadmium concentrations averaging 3.1 mg/Kg, copper averaging 8.6 mg/Kg, lead averaging 11.8 mg/Kg, and zinc averaging 175 mg/Kg (Figures 2-7 to 2-10).

URS (1998) identified and sampled 94 mine-waste deposits between Highway 24 Bridge and the Narrows below CR 55 Bridge (Figure 2-78). Among these deposits, there are a total of approximately 1,578,311 ft^3 of mine-waste, covering a surface area of approximately 1,638,612 ft^2 in Reach 3. The average depth of the deposits is 1 foot. Seven deposits were found to be over 2 feet in depth, with one deposit having an average depth of 3 feet. Total metal concentrations averaged 153 mg/Kg for cadmium, 301 mg/Kg for copper, 3,517 mg/Kg for lead, and 5,212 mg/Kg for zinc. See Appendix D for a more detailed physical and chemical description of these deposits.

2.4.6 Biota

2.4.6.1 Terrestrial Vegetation

The vegetation mapping conducted by NRCS (1997) identified four community types along this stretch of river: subirrigated, riparian subirrigated, wet meadow, and upland.

Plant cover along the Arkansas River between Highway 24 Bridge and the Narrows below CR 55 Bridge averaged 65 percent across eight sample locations (Figure 2-79) in 1987 (Keammerer). The range in plant canopy cover was 42 to 80 percent (Table 2-54). Aboveground production averaged 136 g/m^2, with a range of 63 to 263 g/m^2.

Plant tissue metal concentrations for the same sample locations are shown in Table 2-55 (Keammerer 1987). Plant metal concentrations for grasses averaged 1.6 mg/Kg for cadmium, 6.4 mg/Kg for copper, 4.5 mg/Kg for lead, and 239 mg/Kg for zinc. Plant metal concentrations for forbs averaged 6.4 mg/Kg for cadmium, 18.9 mg/Kg for copper, 0.1 mg/Kg for lead, and 394 mg/Kg for zinc.

2.4.6.2 Habitat

2.4.6.2.1 Terrestrial

This reach is dominated by riparian herbaceous vegetation consisting primarily of sedges and rushes indicative of saturated soils with areas of open standing water (Figure 2-80). The area is interspersed with riparian shrub vegetation consisting of willow species. There are large areas of unvegetated mine-waste deposits and unvegetated sandbars.

2.4.6.2.2 Aquatic

Table 2-15 summarizes the fish habitat inventory data. Site AR-5 (Figure 2-81) was dominated by runs (59 percent) and low gradient riffles (41 percent). Cobble and willow were the dominant in-stream substrate and near stream vegetation at all sites, respectively.

Details of the inventory are presented in Table 2-16, where specific conditions by habitat type for each reach are presented. Wetted widths averaged from 42 to 56 feet. Average depths ranged from 1 to 1.4 feet. Average percent surface fines ranged from 5 to 13 percent, and the average amount of cut banks ranged from 2 to 10 percent.

RBP scores conducted by Chadwick Ecological Consultants (1998) (Table 2-17) indicate excellent habitat for station AR-5 during 1994 and optimal habitat during 1998.

Habitat Quality Index (HQI) ratings are presented in Table 2-18. Late summer stream flows are rated completely adequate, whereas annual stream flow variation was rated as moderate. Water temperature was rated as moderate, and nitrate as moderate. Cover was rated as inadequate, stream bank erosion rated as limited, substrate rated as limited, water velocity rated as limited, and stream width rated as moderate. Predicted trout biomass for AR-5 was 81 lbs/acre.

2.4.6.3 Aquatic Community

2.4.6.3.1 Benthic Community

Extensive benthic macroinvertebrate data have been collected from this reach, primarily from station AR-5 located near Kobe downstream of County Road 55. Results of statistical analyses of these data are shown in Table 2-19. Total macroinvertebrate abundance generally exceeded 700 individuals per 0.1 m^2, and was significantly greater in this reach compared to other upstream reaches (Figure 2-15). Increased abundance in this section of the Arkansas River resulted primarily from a large increase in abundance of caddisflies and dipterans, which accounted for greater than 50 percent of the benthic community. Total abundance of mayflies and stoneflies was also similar to upstream reaches.

Improvements in this reach are evident, but abundance of other metal-sensitive macroinvertebrates remained low in Reach 3. In particular, abundances of heptageniid mayflies, rhyacophilid caddisflies, elmid beetles, and some dipterans (e.g., *Pericoma*) were lower in Reach 3 than in Reach 0 (Figure 2-16).

Patterns of species richness in Reach 3 were similar to those for macroinvertebrate abundance (Figure 2-17). Total species richness and the number of EPT taxa improved compared to Reach 1 and were similar to those observed in the reference reach; however, species richness of mayflies was 36-46 percent lower in Reach 3 compared to Reach 0 ($p<0.0001$).

Spatial patterns of benthic macroinvertebrates in Reach 3 described above were similar to those reported by Chadwick and Associates (Figures 2-19 and 2-20). Total macroinvertebrate abundance was greater at Reach 3 compared to upstream reaches. In contrast, total abundance of mayflies and abundance of metal-sensitive Heptageniidae were lower in Reach 3 compared to Reach 0. Although total species richness in Reach 3 was similar to Reach 0, species richness of mayflies also remained low.

Temporal patterns of benthic community structure in Reach 3 reflect improvements in water quality following remediation of California Gulch (Figures 2-82, 2-83, and 2-84). Results of statistical analyses of these data are shown in Table 2-20. Although abundance of mayflies and caddisflies showed significant seasonally variability, peak abundances of these groups (generally measured in the fall) increased after 1992. Total macroinvertebrate abundance increased from 1989 until 1995 and then decreased, primarily due to lower in abundance of dipterans (primarily orthoclad chironomids) (Figure 2-82). Several metal sensitive species, which were either rare or absent before 1992, were collected from this reach in subsequent years (Figure 2-83).

Total species richness and the number of EPT taxa at Reach 3 also increased significantly over time (Fig. 2-74). The increase in total number of species was primarily a result of greater richness of mayflies, which increased from 3.6 species per sample in 1989 to 6.0 in fall 1998.

Results of multivariate analyses showed significant temporal variation in benthic community composition in Reach 3 (station AR-5) between 1989 and 1998 (Figures 2-27 and 2-28). Some of this variation is due to natural changes in community composition while other changes are likely attributed to improvements in water quality. During most years, benthic communities in Reach 3 were distinctly separated from Reach 0 reference stations (EF5 and AR-1). This was especially obvious between 1989 and 1992, prior to remediation. There was somewhat greater overlap between Reach 3 and Reach 0 communities following remediation, especially in the later years of the survey (1997-1998). However, important exceptions occurred in 1994 and 1995 when station AR-5 was separated from all other sampling locations.

Figure 2-29 shows a summary of these multivariate analyses that compares changes in community composition before and after treatment of discharge from LMDT and California Gulch. The length of the arrows is an indication of the amount of change observed at each station during this period. Overall, benthic communities in Reach 3 remained distinct from Reach 0 communities after remediation because of greater abundance of *Brachycentrus*, Hydropsychidae, and Chironomidae. However, Reach 3 was also characterized by increased abundance of metal-sensitive Heptageniidae.

Kiffney and Clements (1993) reported that concentrations of cadmium, copper, and zinc were significantly elevated in benthic macroinvertebrates collected in Reach 3 compared to upstream reference stations. In addition to variation in metal levels among stations, differences among species were also reported from Reach 3. The highest levels of metals were measured in grazing mayflies (*Baetis*) feeding directly on periphyton (Figure 2-85).

Long-term analyses of metal concentrations in *Arctopsyche grandis* showed that levels of cadmium and zinc were lower in Reach 3 compared to Reach 1 (Figure 2-30). However, metal levels in organisms from Reach 3 were consistently greater than in those from Reach 0. Although there was considerable temporal variation in metal levels, there was some evidence of reduced metal uptake by caddisflies following treatment of discharge from California Gulch and the LMDT.

Sediment toxicity tests conducted by U.S. EPA (Willingham unpublished data) and by Frugis (1995) showed that acute toxicity was reduced in Reach 3 compared to Reach 1 (Table 2-21; Figure 2-

32). Results of an experiment in which chironomids (*Chironomus tentans*) were exposed to sediments from Reach 3 are shown in Figure 2-33. Results showed that levels of cadmium, copper, lead, and zinc in sediment and chironomids were greatly elevated in Reach 3 compared to upstream stations and an uncontaminated reference stream. In general, levels of metals in chironomids were lower than concentrations in sediments. However, in contrast to the spatial pattern observed for sediments, metal levels in chironomids exposed to these sediments did not decrease downstream.

Levels of metallothionein, a metal binding protein, were measured in *Baetis tricaudatus* collected from Reach 3. Concentrations of total cadmium, total metallothionein, and cadmium natively-bound to metallothionein were significantly greater in mayflies collected from Reach 4 than from the Cache la Poudre River (Figure 2-34). Elevated levels of metallothionein indicated that mayflies from Reach 3 were exposed to heavy metals. Despite significantly greater concentrations of total cadmium, total metallothionein in mayflies was less in Reach 3 compared to Reach 0.

<u>Periphyton</u>

Concentrations of cadmium and zinc in sediment and periphyton collected from Reach 3 (station AR-5) were elevated compared to samples collected from Reach 0 (Figure 2-35). Although metal levels in periphyton were lower in Reach 3 compared to Reach 1, concentrations in sediment remained elevated.

Although diatom species diversity was similar in Reach 3 compared to upstream reaches, species richness was lower (Table 2-22). In addition, the proportion of *Achnanthes minutissima* (0.13) was also lower in Reach 3.

<u>Toxicology</u>

Results of acute toxicity tests conducted with water collected from Reach 3 in 1987 showed 100 percent mortality to *Ceriodaphnia* (Table 2-23). Subsequent experiments showed considerably less acute toxicity (Table 2-23).

Experiments conducted with fathead minnows in 1991 (Clements, unpublished data) showed significant acute toxicity of water collected from Reach 3 (Figure 2-36). Although there was relatively little toxicity observed at low concentrations of Arkansas River water, treatments at higher concentrations (50 percent) were acutely toxic.

Chronic toxicity tests conducted in fall 1990 and spring 1991 with *Ceriodaphnia dubia* showed that organisms exposed to water from Reach 3 (station AR-5) were affected by metals (Figure 2-36). These results also showed that chronic toxicity was greater in spring than in fall. In spring experiments the number of offspring produced per female was significantly reduced in the 50 percent dilution and approached zero in the 100 percent dilution. These differences in toxicity reflected seasonal differences in total zinc concentrations.

2.4.6.3.2 Fish Populations

Surveys of brown trout populations in Reach 3 conducted from 1994 to 1999 by CDOW and Chadwick Ecological Consultants generally showed that population abundance and biomass were reduced compared to Reach 0 (Table 2-56; Figures 2-37 through 2-40). Although surveys conducted in August 1997 showed some evidence of recovery in Reach 3, abundance and biomass were considerably less than those in Reach 0. Furthermore, during all four years when biomass estimates were made, the biomass in Reach 3 was always greater than measured in Reach 1.

Inspection of length-frequency data of brown trout populations revealed 2 (sometimes 3) year classes in the upper Arkansas River; however, population structure varies strongly among sampling stations and dates (Figures 2-42 through 2-45). Evaluating age structure of brown trout at downstream Reaches 1-3 is difficult because of the overall reduced density of fish. Sampling data from August 1997, September 1994, and September 1999 consistently indicate the presence of age 1 fish (i.e., those that hatched the preceding fall) at upstream reference stations. Age 1 fish were most abundant at stations AR-1 and AR-2, and slightly less abundant in the East Fork stations. In contrast, the abundance of this age class was much lower in Reaches 1, 2, and 3. Age 1 trout were absent from samples taken at AR-3 and other downstream sites during 1994, 1997, and 1999, age 1 trout were 25-80 percent less abundant downstream of California Gulch than at stations AR-1 and AR-2.

Age 2 trout were the most common age class in Arkansas River samples, but also varied in abundance among stations. Age 2 trout were present at all sampling stations during all years and seasons. However, their abundance was consistently reduced in Reach 3. Age 3 trout were most common in Reach 3.

Bioaccumulation and Food Chain Effects of Heavy Metals on Brown Trout

Metal concentrations measured in benthic macroinvertebrates collected from AR-5 in Reach 3 (Kiffney and Clements 1993) are illustrated in Figure 2-85. For cadmium and zinc, concentrations ranged from higher to lower for the following species: *Baetis*, *Pteronarcella*, *Arctopsyche*, *Skwala*, and *Rhyacophila*. In general, concentrations of metals were highest in organisms closely associated with periphyton and detritus and lowest in predators.

Nehring (1986) compared metal levels in age 1, 2, and 3 brown trout collected from Reach 3 (Figure 2-46). Results showed that cadmium concentrations were generally greater compared to Reach 0, and that levels increased with fish age.

Clements and Rees (1997) examined the effects of heavy metals on prey abundance, feeding habits, and metal bioaccumulation of brown trout (*Salmo trutta*) from Reach 3. In contrast to Reach 0, prey communities in Reach 3 were dominated by metal-tolerant chironomids (Diptera: Chironomidae) and caddisflies (Trichoptera). These differences in prey community composition were reflected in the feeding habits of brown trout, which consumed greater numbers of chironomids and caddisflies in Reach 3 (Figure 2-47).

Concentrations of heavy metals in dominant prey taxa and brown trout stomach contents were greater in Reach 3 compared to Reach 0 (Figure 2-48). In addition, metal levels were significantly elevated in brown trout gill and gut tissue, indicating greater metal exposure from water and diet. However, metal levels in liver and kidney tissue, the primary organs of metal storage and regulation, were either similar or greater in the upstream reach. In addition, brown trout size and condition factors (weight x 100/length^3) were significantly reduced in Reach 0 compared to Reach 3. Finally, although condition factors were significantly correlated with metal levels in liver tissue of fish collected from Reach 0, there was no relationship at Reach 3 (Figure 2-86).

Aquatic Associates' (1993) site AR05 falls within Reach 3. Metal concentrations in fish collected from the locations in Reach 3 were < 0.1 mg/Kg cadmium, 0.3 mg/Kg copper, 0.4 mg/Kg lead, and 5.8 mg/Kg zinc.

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

2.4.6.4 Terrestrial Vertebrates

2.4.6.4.1 Small Mammals

There are no known terrestrial mammal studies or sampling efforts for this reach.

2.4.6.4.2 Large Mammals

There are no known terrestrial mammal studies or sampling efforts for this reach.

2.4.6.4.3 Birds

Archuleta et al. (2000) collected blood and liver samples from American dippers at 2 locations in Reach 3 (Old Highway 24 bridge and County Rd. 55 bridge). They analyzed blood for metals and ALAD activity and liver for metals and metallothionein concentrations. Aquatic invertebrate samples were collected from the Arkansas River near dipper sample locations and analyzed for metals

Reach 3 had the highest mean lead concentrations in both blood and liver samples (Table 2-57). This would be expected based on the lead exposure represented by the invertebrate samples, which was almost 9 times, the lead concentration in Reach 0 and 10 times the literature-based benchmark (Table 2-58). Blood lead was significantly higher than Reach 0 ($p<0.016$), but less than literature-based benchmark values. ALAD activity was depressed by 39 percent compared to Reach 0 and by 62 percent compared to the Study Reference site.

Liver concentrations for lead and zinc were below literature-based benchmark values and none of the liver metal samples were significantly different than Reach 0 ($p<0.05$). However, there was a significant difference between liver lead concentrations from Reach 3 compared to the Study Reference site ($P<0.05$). Average metallothionein concentrations were higher in Reach 3 than Reach 0, but not significantly different ($p<0.05$).

Custer et al. (2003 In Press) collected 12 –day old nestlings and sampled blood for ALAD activity and livers for metals concentrations. In addition they collected stomach contents from nestlings for metals analysis. In this reach, a nesting colony was established near County Road 55 on the Hayden Ranch and on BLM property.

Concentrations for all metals in livers from Reach 3 were similar to those from Reach 0 (Table 2-59). ALAD activity for Reach 3 was only 4 percent lower than Reach 0, but 39 percent less than the Study Reference. Average concentrations for all metals of concern in stomach contents samples were lower than Reach 0 (Table 2-60) which is quite different than concentrations in invertebrate samples reported by Archuleta et al. (2000) for this reach.

2.5 Reach 4: Narrows below CR 55 Bridge to Two-Bit Gulch Confluence

2.5.1 Hydrology/Geomorphology

This reach is about 9,400 feet long and extends from the narrows below County Road 55 to downstream bedrock controls at approximately 700 feet above the junction of Two-Bit Gulch. The gradient is less than Reach 3 (Table 2-3). The main channel lies close to the eastern valley side. At the downstream end of the reach, the channel enters a bedrock canyon.

Sinuosity has changed little since 1939, increasing slightly from 1.09 to 1.14. The channel is basically straight. Low-flow channel width in a straight reach increased 14 percent since 1939 with the entire change occurring after 1957 (InterFluve 1999). This subreach is relatively stable and contains no large mine-waste deposits (Table 2-30). It appears to deliver any mine-waste received from upstream to the canyon downstream.

Based upon examination of 1979, 1988, and 1997 aerial photography, geomorphological characteristics in Reach 4 indicated the following temporal changes. It was not possible to see this reach on the 1973 photograph because of cloud cover, but in 1979, there were multiple channels. In 1988, a well-defined single channel flowed through this reach, and this condition persisted until 1997.

Reach 4 contains the combined flows from all the reaches and tributaries. Figure 2-87 illustrates the changes and flow magnitudes that occur between Leadville Junction and Granite, Colorado, which is downstream of the Lake Creek discharge to the Arkansas River.

2.5.2 Surface Water

Reach 4 includes the following tributaries Box Creek and Sawmill Gulch. Of the data presently integrated into the database, no samples locations are found in this reach.

2.5.3 Sediments

Similar to the surface water quality data, no locations are found in Reach 4 containing sediment data.

2.5.4 Groundwater

No wells have been identified for Reach 4.

2.5.5 Floodplain Soils

There are small deposits of mine-waste along Reach 4. However, no data are available to characterize the physical and chemical characteristics of these deposits.

2.5.6 Biota

2.5.6.1 Terrestrial Vegetation

The vegetation mapping conducted by NRCS (1997) identifies three community types along this stretch of river: subirrigated, riparian subirrigated, and wet meadow.

2.5.6.2 Habitat

2.5.6.2.1 Terrestrial

This reach is dominated by riparian herbaceous vegetation consisting primarily of sedges and rushes indicative of waterlogged soils (Figure 2-88). The reach is interspersed with riparian shrub vegetation, and small areas of unvegetated sandbar and possibly, unvegetated mine-wastes.

2.5.6.2.2 Aquatic

No habitat data were available to assess the quality of habitat in Reach 4.

2.5.6.3 Aquatic Community

2.5.6.3.1 Benthic Community

No studies of benthic macroinvertebrate communities have been conducted in Reach 4.

2.5.6.3.2 Fish Populations

The only data set specific to Reach 4 was collected in 1999. Abundance and biomass were much less than in Reach 0 and were the lowest of all reaches sampled in 1999. Data collected just downstream of Reach 4 are available for 1985, 1988, and 1994. The data for 1985 and 1988 show relatively low numbers and biomass compared to Reach 0. Data for 1994 show higher numbers and biomass compared to Reach 3, and significantly increased numbers and biomass compared to previous years. No fish tissue data were available for this reach.

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

2.5.6.4 Terrestrial Vertebrates

2.5.6.4.1 Small Mammals

There are no known terrestrial mammal studies or sampling efforts for this reach.

2.5.6.4.2 Large Mammals

There are no known terrestrial mammal studies or sampling efforts for this reach.

2.5.6.4.3 Birds

There are no known avian studies or sampling efforts for this reach.

TABLES

Table 2-1

Colorado Table Value Standards (TVSs) [1] Derived for High and Low Flow Conditions in the Arkansas River

Reach	Flow	Average Hardness [2]	Cadmium		Copper		Lead		Zinc	
			Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic
0	High	57.57	0.002	0.002	0.008	0.006	0.035	0.001	0.073	0.074
	Low	100.12	0.004	0.002	0.014	0.009	0.065	0.003	0.117	0.118
1	High	83.54	0.003	0.002	0.011	0.008	0.053	0.002	0.101	0.101
	Low	150.3	0.006	0.003	0.020	0.013	0.100	0.004	0.166	0.166
2	High	63.26	0.002	0.002	0.009	0.006	0.039	0.002	0.080	0.080
	Low	86.62	0.003	0.002	0.012	0.008	0.055	0.002	0.104	0.104
3	High	69.5	0.003	0.002	0.010	0.007	0.043	0.002	0.086	0.087
	Low	100.79	0.004	0.002	0.014	0.009	0.065	0.003	0.118	0.119
4	High	nd	nc	nc	nc	nc	nc	nc	nc	nc
	Low	nd	nc	nc	nc	nc	nc	nc	nc	nc

[1] Acute and chronic TVSs from the State of Colorado's Regulation No. 31 Basic Standards and Methodologies for Surface Waters (5 CCR 1002-31)
[2] Mean high and low flow hardness (mg/L as $CaCO_3$) data during Period 3
nd = no data
nc = not calculated

Table 2-2

Number and Species of Small Mammals Trapped from Wetlands in Reach 0 and Reach 2[1]

Reach	southern red-backed vole[2]	long-tailed vole[3]	deer mouse[4]	short-tailed weasel[5]	montane shrew[6]
Reach 0 (Tennessee Creek)	0	1	1	2	2
Reach 0 (Upper Arkansas River)	26	22	4	2	6
Reach 2 (Smith Ranch)	6	2	15	2	1

[1]From Woodward Clyde 1993
[2]*Clethrionomys gapperi*
[3]*Microtus longicaudus*
[4]*Peromyscus maniculatus*
[5]*Mustela erminea*
[6]*Sorex monticolus*

Table 2-3

Geomorphological Characteristics of Arkansas River Reaches

Committee Subreaches	InterFluve Reaches	Length (ft)	Mine Waste (ft^3/ft of channel)	Channel Slope	Sinuosity	Bankfull Width (ft)	Depth (ft)	Width/ Depth	Split Flow (%)	500-Year Floodplain Width (ft)	Bankfull Discharge (cfs) IM Sites	Bankfull R.I. (yrs) IM Sites
0	1	15,400	0	0.01	1.25	---	---	---	75	900	---	1.1
1A, 1B, 1C	2	8,850	100	0.014	1.21	61	1.5	40	10	700	330	1.1
2A	3	11,100	14	0.0085	1.29	87	1.9	45	32	800	500	1.2
2B	4	7,800	10	0.0067	1.31	104	2.1	49	89	1,200	1,057	4.4
3A	5	11,400	92	0.0067	1.18	109	1.5	73	18	1,200	515	1.2
3B	6	7,350	71	0.011	1.12	---	---	---	---	1,300	---	---
4	7	9,400	5	0.0076	1.14	95	2	48	18	900	792	1.9

Data from InterFluve, 1999

Table 2-4

Summary Statistics for Dissolved Metals Concentrations (mg/L) in Surface Waters from the 11-Mile Reach during Period 1, 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	% Exceedance By Flow Period		% Exceedance Across All Flows	
														%>Acute	%>Chronic	%>Acute	%>Chronic
0	Zn	H	1	6	0.00011	0.23	0.0652	0.103	53.28	NA	NA	NA	NA	NA	NA	NA	NA
		L	2	13	0.00024	0.64	0.1466	0.2338	133.46	NA	NA	NA	NA	NA	NA	NA	NA
2	Cd	H	1	2	0.002	0.002	0.002	0	61.92	0.0022	0.0016	0	2	0.00	100.00	16.67	100.00
		L	1	4	0.002	0.003	0.0023	0.0005	75.16	0.0027	0.0018	1	4	25.00	100.00		
	Cu	H	1	2	0.02	0.021	0.0205	0.0007	61.92	0.0086	0.0059	2	2	100.00	100.00	50.00	66.67
		L	1	4	0.002	0.02	0.009	0.0079	75.16	0.0103	0.007	1	2	25.00	50.00		
	Pb	H	1	2	0.002	0.008	0.005	0.0042	61.92	0.0382	0.0015	0	2	0.00	100.00	0.00	100.00
		L	1	4	0.002	0.004	0.003	0.0012	75.16	0.0473	0.0018	0	4	0.00	100.00		
	Zn	H	1	4	0.016	0.56	0.3115	0.2844	61.92	0.0781	0.0785	3	3	75.00	75.00	90.91	90.91
		L	1	7	0.46	0.87	0.6686	0.1338	75.16	0.092	0.0925	7	7	100.00	100.00		
4	Cd	L	1	1	0.002	0.002	0.002		ND			0	0	ND	ND	ND	ND
	Cu	L	1	1	0.009	0.009	0.009		ND			0	0	ND	ND		
	Pb	L	1	1	0.001	0.001	0.001		ND			0	0	ND	ND	ND	ND
	Zn	L	1	1	0.56	0.56	0.56		ND			0	0	ND	ND		

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.

ND = no data

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

Table 2-5

Summary Statistics for Dissolved Metals Concentrations (mg/L) in Surface Waters from the 11-Mile Reach during Period 2, Table Value Standards (TVS), and Exceedences 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		

Table 2-5 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.

Table 2-6

Summary Statistics for Dissolved Metals Concentrations (mg/L) in Surface Waters from the 11-Mile Reach during Period 3, Table Value Standards (TVS), and Exceedences 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		

Table 2-6 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.

Table 2-7

Total Cadmium, Copper, Lead, and Zinc Concentrations (mg/L) in Reach 0 Surface Waters

Analyte	Period	Flow	StaCnt	n	Min	Max	Avg	Stdev
Cadmium	1	High	2	8	0.001	0.007	0.0031	0.0024
		Low	2	33	0.001	0.006	0.0022	0.0011
	2	High	4	31	0.0002	0.0103	0.0023	0.0024
		Low	5	68	0.0002	0.007	0.0024	0.0013
	3	High	5	37	0.000075	0.0025	0.0009	0.0008
		Low	5	52	0.000005	0.003	0.0006	0.0008
Copper	1	High	1	8	0.008	0.05	0.0231	0.0136
		Low	1	20	0.005	0.035	0.0144	0.0087
	2	High	4	23	0.001	0.027	0.0088	0.007
		Low	4	38	0.0005	0.036	0.0098	0.0092
	3	High	5	36	0.001	0.075	0.0068	0.015
		Low	5	53	0.0003	0.009	0.0023	0.0019
Lead	1	High	1	8	0.001	0.046	0.0218	0.0154
		Low	1	20	0.005	0.054	0.0147	0.0123
	2	High	3	21	0.0009	0.033	0.0109	0.0096
		Low	3	39	0.0005	0.081	0.0158	0.0188
	3	High	5	30	0.0007	0.0107	0.0028	0.0025
		Low	5	44	0.00025	0.0106	0.0012	0.0015
Zinc	1	High	1	12	0.13	1.17	0.4492	0.3577
		Low	1	45	0.2	1.2	0.53	0.2484
	2	High	4	26	0.0575	2.4	0.4328	0.5438
		Low	4	40	0.0725	1.4	0.5459	0.3022
	3	High	5	52	0.014	0.279	0.0797	0.0645
		Low	5	64	0.005	0.096	0.0306	0.0188

Table 2-8

Reach 0 Sediment Data for Period 3 [1]

Analyte (dry weight)	StaCnt	n	Min	Max	Avg	Stdev
Cadmium	2	6	1	23	6.2	8.5
Copper	2	13	3.18	170	24.7	44.5
Lead	1	10	24	510	88.9	152.0
Zinc	2	17	25	2,500	345.0	646.7

[1] Concentrations in mg/L. Data from consulting team database.

Table 2-9

Summary of Domestic Water Supply (DWS) Groundwater Quality Characteristics for Periods 1, 2, and 3[1]

Dissolved Metals

Metal	Reach	No. of Samples (n)	No. of Stations[7]	Mean Dissolved Concentration (mg/L)	Minimum Dissolved Concentration (mg/L)	Maximum Dissolved Concentration (mg/L)	Standard Deviation (mg/L)	Diameter (in)| Total Depth (ft)| Screen (ft)| Well IDs
Cadmium[2]	0[6]	1	1	0.0025	0.0025	0.0025	---	6.5"| 50'| NA[8]| GW205
	1	3	3	0.0033	0.0025	0.005	0.0014	NA| 50'| 10'-50'| NW14; GW211
	2	2	1	0.0015	0.0005	0.0025	0.0014	7"| 32'| 20'-32'| GW203
	3	1	1	0.0025	0.0025	0.0025	---	60"| 5'| NA| GW204
Copper[3]	0[6]	1	1	0.007	0.007	0.007	0.007	6.5"| 50'| NA| GW205
	1	3	3	0.005	0.0025	0.01	0.0043	NA| 50'| 10'-50'| NW14
	2	2	1	0.0023	0.002	0.0025	0.0004	7"| 32'| 20'-32'| GW203
	3	1	1	0.0025	0.0025	0.0025	---	60"| 5'| NA| GW204
Lead[4]	0[6]	1	1	0.015	0.015	0.015	---	6.5"| 50'| NA| GW205
	1	3	3	0.0067	0.0025	0.015	0.0072	NA| 50'| 10'-50'| NW14
	2	2	1	0.01	0.005	0.015	0.007	7"| 32'| 20'-32'| GW203
	3	1	1	0.015	0.015	0.015	---	60"| 5'| NA| GW204
Zinc[5]	0[6]	1	1	0.02	0.02	0.02	---	6.5"| 50'| NA| GW205
	1	3	3	0.598	0.063	1.1	0.519	NA| 50'| 10'-50'| NW14
	2	2	1	0.193	0.0022	0.383	0.269	7"| 32'| 20'-32'| GW203
	3	2	2	0.081	0.032	0.13	0.069	60"| 5'| NA| GW204

Total Metals [9]

Metal	Reach	No. of Samples (n)	No. of Stations[7]	Mean Total Concentration (mg/L)	Minimum Total Concentration (mg/L)	Maximum Total Concentration (mg/L)	Standard Deviation (mg/L)	Well IDs[10]
Cadmium	1	6	2	0.00049	0.00005	0.0012	0.0004	133100; 133400
Copper	1	3	2	0.1273	0.009	0.35	0.193	133100; 133400
Lead	1	4	2	0.0086	0.0005	0.024	0.11	133100; 133400

[1]Data is from consulting team database.
[2]MCL = 0.005 mg/L.
[3]There is no MCL for copper, but it has a drinking water supply standard of 1.3 mg/L in Colorado.
[4]There is no MCL for lead, but it has an action level of 0.015 mg/L in Colorado.
[5]MCL = 5.0 mg/L.
[6]Sample was taken from a 50-foot deep well on undeveloped land (Bureau of Reclamation).
[7]Number of stations is based on location; some agencies use the same location name for multiple wells (e.g., NW14 is a pair of wells). Therefore, the number of stations can sometimes be higher than the number of well IDs. Locations within 2 meters of each other are considered to be the same for station counting purposes.
[8]NA = not available.
[9]Data is from CDPHE 2001.
[10]Well completion information is not available.

Table 2-10

Total and Plant Available Soil Metal Concentrations for Sites Sampled along the Arkansas River above the Confluence of California Gulch [1/2] and Benchmark Concentrations of Total Metals in Soils for Toxicity [3]

Sample Site No.	Cadmium (mg/kg)		Copper (mg/kg)		Lead (mg/kg)		Zinc (mg/kg)	
	Total	PA [4]	Total	PA	Total	PA	Total	PA
LV06	3.9	2.3	82	12.0	464	74	500	61
LV07	2.8	0.8	18	3.0	317	32	295	39
LV08	3.9	2.1	23	4.4	202	39	351	76
LV09	6.1	2.2	38	3.8	338	11	857	141
LV10	2.0	1.1	13	2.3	97	17	223	68
LV24	0.8	1.1	12	2.2	108	14	184	61
LV25	2.8	1.8	27	5.5	139	13	695	158
LV26	2.0	1.0	18	1.4	108	12	306	57
LV38	5.5	0.08	38	1.3	369	1.6	440	4.4
Mean	3.3 (±0.57)	1.4 (±0.25)	29.9 (±7.3)	3.9 (±1.1)	238 (±45)	23.7 (±7.3)	428 (±75)	73.9 (±16)
Benchmark Concentrations [3]	8		125		400		400	

[1] Data from Keammerer 1987 (LNRD-016)

[2] Data for individual sites and means (±1 s.e.) are presented for this stretch of river. Sampling conducted in 1987.

[3] Data from Kabata-Pendias 2001. These concentrations are reported as total concentrations, but are most closely associated with plant-available concentrations measured in field-collected soils.

[4] PA=Plant available using DTPA soil extract.

Table 2-11

Total Plant Cover and Production for Sites Sampled along the Arkansas River above the Confluence with California Gulch (Reach 0) [1]

Sample Site Number	Percent Total Cover	Total Production (g/m^2)
LV06	60	225
LV07	38	43
LV08	68	135
LV09	44	81
LV10	60	244
LV24	38	92
LV25	50	134
LV26	50	139
LV38	64	140
Mean	52.4 (±3.7)	137 (±21.5)

[1] Data for individual sites and means (±1 s.e.) are presented for this stretch of river. Sampling conducted in 1987 by Keammerer.

Table 2-12

Plant Tissue Metal Concentrations for Grasses and Forbs (reported on a dry weight basis) from Sites Sampled along the Arkansas River above the Confluence of California Gulch [1] and Benchmark Concentrations of Plant Tissue for Toxicity to Vegetation [2]

Sample Site No.	Cadmium (mg/kg)		Copper (mg/kg)		Lead (mg/kg)		Zinc (mg/kg)	
	Grasses	Forbs	Grasses	Forbs	Grasses	Forbs	Grasses	Forbs
LV06	0.5	---[3]	6.5	---	0.1	---	35	---
LV07	0.5	---	6.5	---	0.1	---	46	---
LV08	0.5	3.9	8.0	12.0	0.1	0.1	158	341
LV09	1.2	5.4	4.5	5.5	0.1	2.0	154	184
LV10	0.95	7.2	3.5	30	0.1	0.1	82	533
LV24	0.95	2.7	3.5	6.5	0.1	0.1	65	119
LV25	0.95	2.2	---	6.5	---	6.0	---	313
LV26	0.1	1.6	5.0	6.5	0.1	9.5	38	43
LV38	1.6	---	3.5	---	0.1	---	77	---
Mean	0.8 (±1.3)	3.8 (±0.87)	5.1 (±0.6)	11.2 (±3.9)	0.1 (±0)	2.9 (±1.6)	82 (±17.3)	255 (±72)
Benchmark Concentrations [2] (mg/kg)	30		100		300		400	

[1] Data for individual sites and means (±1 s.e.) are presented for this stretch of river. Sampling conducted in 1987 by Keammerer.

[2] Data from Kabata-Pendias 2001. These threshold concentrations represent the upper end of toxicity thresholds for agronomic species. Native perennial plants are known to be more tolerant of metals than agronomic species. These thresholds are therefore considered to be highly conservative (Paschke et al. 2000).

[3] No data available.

Table 2-13

Weighted Usable Area (WUA = ft^2/ 1000 linear ft of stream) for Four Life Stages of Brown Trout at Varying Discharges

Discharge (cfs)	Time Period for Optimized Flows			
	October 15 – March 31	April 1 – May 31	June 1 – July 15	July 16– October 14
	Spawning and Egg Incubation	Fry Emergence and Development	Juvenile	Adult
70	7,588	2,739	24,140	15,334
86	8,611	2,452	24,968	16,434
97	9,285	2,272	25,172	16,868
100	9,444	2,195	25,190	16,944
200	7,843	3,613	19,642	14,212
300	4,488	5,280	12,227	9,587
400	3,747	6,089	7,875	6,968
500	5,360	7,406	5,695	5,951

Table 2-14

Mean Monthly Flows (cfs) Calculated from Measured Daily Flows at Two USGS Gaging Stations with Long Periods of Record

Month	Leadville (Reach 0)	Granite (Downstream of the 11-Mile Reach)
Oct	26.4	157
Nov	21	130
Dec	16.4	107
Jan	14.6	103
Feb	14.3	109
Mar	14.9	128
Apr	29.1	242
May	168	702
Jun	360	1,282
Jul	139	904
Aug	61.5	541
Sep	34.5	246

Table 2-15

Fish Habitat Inventory Measurements for Sites on the Arkansas River Mainstem (Fall 1998)

Parameter		Reach 0			Reach 1	Reach 2	Reach 3
Habitat	**Habitat Type**	**AR-1**	**AR-12**	**AR-2**	**AR-3**	**AR-4**	**AR-5**
Total # Habitat Units		6	7	13	5	7	7
Total Length (ft)		553	711	593	725	915	712
Total Area (ft^2)		15495	22906	10879	21026	42368	33103
% Area Of	HGR	19	0	0	0	0	0
	LGR	48.8	82.8	19.4	47.3	40.5	40.8
	RUN	32.2	13	46.3	52.7	53.5	59.2
	LSP	0	4.2	16.8	0	6	0
	MCP	0	0	17.5	0	0	0
	PP	0	0	0	0	0	0
Dominant Substrate		Cobble	Cobble	Cobble	Cobble	Cobble	Cobble
Dominant Vegetation Type		Willow	Willow	Willow	Grass	Grass	Grass

Data from Chadwick Ecological Consultants 1999
HGR = High Gradient Riffle
LGR = Low Gradient Riffle
RUN = Run
LSP = Lateral Scour Pool
MCP = Mid-Channel Pool
PP = Plunge Pool

Table 2-16

Habitat Inventory Data Using the R1/R4 Procedures for the Arkansas River

Reach	Stn		# Units	Length of Units (ft)	Average Length Units (ft)	Average Wetted Width (ft)	Average Bank Width (ft)	Average Depth (ft)	Average Maximum Depth (ft)	Average % Surface Fines	Average (%) Undercut Banks
0	AR-1	HGR	2	109	55.5	27	37	1	1.5	10	10
		LGR	1	252	252	30	40	0.6	1.4	15	0
		RUN	3	192	64	25.7	36.7	1.2	1.8	22	5
		LSP	0								
		MCP	0								
		PP	0								
	AR-12	HGR	0								
		LGR	4	545	136.3	34.8	37.3	0.8	1.4	10	0
		RUN	2	112	56	26.5	34	1	1.7	13	3
		LSP	1	54	54	18	46	1.5	2.9	10	20
		MCP	0								
		PP	0								
	AR-2	HGR	0								
		LGR	4	96	24	22	31.3	0.7	1.3	13	36
		RUN	5	307	61.4	16.4	40.8	1.2	2.1	21	29
		LSP	2	87	43.5	21	52	1.4	2.6	20	28
		MCP	2	103	51.5	18.5	18.5	1.8	2.8	25	55
		PP	0								
1	AR-3	HGR	0								
		LGR	2	276	138	36	44.5	0.6	1.5	15	3
		RUN	3	449	149.7	24.7	36.3	1.4	2.7	33	33
		LSP	0								
		MCP	0								
		PP	0								
2	AR-4	HGR	0								
		LGR	3	294	98	58.3	82	0.9	1.7	10	0
		RUN	3	577	192.3	39.3	92.7	2.2	3.6	15	40
		LSP	1	44	44	58	139	1.1	2	50	50
		MCP	0								
		PP	0								
3	AR-5	HGR	0								
		LGR	4	242	60.5	55.8	82.8	1	1.5	5	10
		RUN	3	470	156.7	41.7	60.3	1.4	2.8	13	2
		LSP	0								
		MCP	0								
		PP	0								

Data from Chadwick Ecological Consultants 1998

Table 2-17

Rapid Bioassessment Scores during 1994 and 1998 Habitat Assessments of the Arkansas River

Habitat Parameter	1994						1998					
	Reach 0			Reach 1	Reach 2	Reach 3	Reach 0			Reach 1	Reach 2	Reach 3
	AR-1	AR-12	AR-2	AR-3	AR-4	AR-5	AR-1	AR-12	AR-2	AR-3	AR-4	AR-5
Epifaunal Substrate/ Instream Cover	19	18	18	17	19	20	16	16	18	17	17	17
Embeddedness	19	16	16	12	16	19	17	16	16	13	16	19
Velocity/Depth	15	16	17	16	17	17	12	15	18	15	17	16
Sediment Deposition							16	16	17	14	15	16
Channel Flow Status							16	17	16	14	17	15
Channel Alteration	13	13	7	11	11	12	17	17	18	19	16	20
Bottom scour and Deposition	14	13	11	11	11	12						
Frequency of Riffles	9	9	14	15	14	11	19	19	17	18	16	18
Bank Stability	9	9	7	9	5	8	16	17	16	16	17	17
Bank Vegetative Protection	9	9	8	9	8	7	18	18	18	18	18	17
Riparian Zone Vegetative Width	5	7	5	5	4	4	18	16	20	20	18	13
Totals	112	110	103	105	105	110	165	167	174	164	167	168
	1	1	2	2	2	1	1	1	1	1	1	1

Scoring:

	1994	1998
1. Excellent or Optimal	135-111	200-166
2. Good or Suboptimal	102-75	153-113
3. Fair or Marginal	66-39	100-60
4. Poor	30-0	47-0

Data from Chadwick Ecological Consultants 1998

Table 2-18

Habitat Quality Index (HQI) Scores from the Arkansas River, May 1994

Parameter	Location and Habitat Rating					
	Reach 0			Reach 1	Reach 2	Reach 3
	AR-1	AR-12	AR-2	AR-3	AR-4	AR-5
X1 - Later Summer Streamflow	4	4	4	4	4	4
X2 - Annual Streamflow Variation	2	2	2	2	3	3
X3 - Water Temperature	3	3	3	3	3	3
X4 - Nitrate	3	2	2	2	2	3
X7 - Cover	0	0	1	0	1	0
X8 - Eroding Streambank	4	3	2	4	2	2
X9 - Substrate	2	2	1	1	3	2
X10 - Water Velocity	4	4	3	4	4	2
X11 - Stream Width	3	3	4	3	3	3
HQI Score [Predicted Fish Biomass (lbs/acre)]	97.6	75.8	61.9	49.2	179.9	81.7

Rating Criteria: 4 = Best Habitat Rating
0 = Worst Habitat Rating

Data from Chadwick Ecological Consultants 1994

Table 2-19

Results of One-Way ANOVA Showing Differences in Benthic Macroinvertebrate Measures Among Arkansas River Stations (1989-1999) [1]

Variable	EF5	AR1	AR3	AR5	AR8	F (p-value)
Mayfly taxa	B	A	C	C	C	63.94 (<0.0001)
Stonefly taxa	AB	AB	C	A	B	19.75 (<0.0001)
Caddisfly taxa	D	B	C	A	CD	40.10 (<0.0001)
Dipteran taxa	C	A	C	B	B	19.50 (<0.0001)
Other taxa	B	B	B	A	B	17.28 (<0.0001)
EPT taxa	B	A	D	AB	C	39.22 (<0.0001)
Total Taxa	B	A	C	A	C	38.27 (<0.0001)
Mayfly abundance	B	A	C	B	A	43.68 (<0.0001)
Stonefly abundance	A	A	B	A	A	10.31 (<0.0001)
Caddisfly abundance	C	C	C	A	B	56.28 (<0.0001)
Dipteran abundance	C	B	C	B	A	32.50 (<0.0001)
EPT abundance	B	A	C	A	A	31.17 (<0.0001)
Total abundance	C	B	D	A	A	46.11 (<0.0001)
Baetidae	C	A	D	B	AB	35.75 (<0.0001)
Ephemerellidae	A	A	B	C	D	66.06 (<0.0001)
Heptageniidae	A	A	C	B	A	137.39 (<0.0001)
Perlodidae	C	C	D	B	A	140.62 (<0.0001)
Chloroperlidae	A	A	AB	A	B	4.34 (0.0019)
Nemouridae	A	B	B	C	D	48.38 (<0.0001)
Brachycentridae	E	C	B	A	D	167.86 (<0.0001)
Hydropsychidae	B	C	C	A	A	60.81 (<0.0001)
Rhyacophilidae	A	A	B	C	D	117.22 (<0.0001)
Chironomidae	D	C	B	A	A	43.23 (<0.0001)
Elmidae	A	A	B	B	C	132.79 (<0.0001)
Psychodidae	B	A	C	D	D	174.91 (<0.0001)

Data from Clements, unpublished

[1] If ANOVA indicated significant main effects ($p<0.05$), Ryan's Q multiple range test was used to test for differences among stations. Ryan's Q is a conservative test that has been recommended because of its rigorous control of experiment-wise error rates. Stations with the same letter were not significantly different. (EF-5 and AR-1 = Reach 0; AR-3 = Reach 1; AR-5 = Reach 3; AR-8 = Reach 6).

Table 2-20

Results of Two-Way ANOVA Showing Responses to Remediation (before versus after 1993), Seasonal Variation (spring versus fall), and Overall Differences in Macroinvertebrate Communities

Reach (Station)	Variable	Before/After F (p-value)	Season F (p-value)	Overall F (p-value)
Responses of Dominant Macroinvertebrate Families				
Reach 0 (EF-5)	Baetidae	118.47 (<0.0001)	5.47 (0.0214)	61.97 (<0.0001)
	Heptageniidae	178.91 (<0.0001)	37.38 (<0.0001)	108.14 (<0.0001)
	Chloropelidae	53.45 (<0.0001)	8.53 (0.0043)	30.99 (<0.0001)
	Brachycentridae	2.09 (0.1519)	0.12 (0.7341)	1.10 (0.3366)
	Rhacophilidae	53.18 (<0.0001)	1.69 (0.1961)	27.44 (<0.0001)
	Hydropsychidae	2.40 (0.1247)	44.87 (<0.0001)	23.63 (<0.0001)
	Elmidae	37.89 (<0.0001)	5.81 (0.0178)	21.85 (<0.0001)
	Chironomidae	0.44 (0.5099)	64.29 (<0.0001)	32.37 (<0.0001)
Reach 0 (AR-1)	Baetidae	19.46 (<0.0001)	18.59 (<0.0001)	19.02 (<0.0001)
	Heptageniidae	93.84 (<0.0001)	6.14 (0.0149)	49.99 (<0.0001)
	Chloropelidae	44.65 (<0.0001)	0.42 (0.5175)	22.54 (<0.0001)
	Brachycentridae	0.18 (0.6732)	0.04 (0.8438)	0.11 (0.8968)
	Rhacophilidae	21.66 (<0.0001)	9.31 (0.0029)	15.48 (<0.0001)
	Hydropsychidae	1.55 (0.2157)	48.41 (<0.0001)	24.98 (<0.0001)
	Elmidae	58.74 (<0.0001)	26.65 (<0.0001)	42.69 (<0.0001)
	Chironomidae	4.50 (0.0364)	34.68 (<0.0001)	19.59 (<0.0001)
Reach 1 (AR-3)	Baetidae	0.19 (0.6651)	36.85 (<0.0001)	18.52 (<0.0001)
	Heptageniidae	14.14 (0.0003)	0.01 (0.9098)	7.08 (0.0014)
	Chloropelidae	4.88 (0.0295)	1.30 (0.2576)	3.09 (0.0501)
	Brachycentridae	0.18 (0.6733)	26.28 (<0.0001)	13.23 (<0.0001)
	Rhacophilidae	1.13 (0.2901)	16.28 (<0.0001)	8.70 (0.0003)
	Hydropsychidae	24.27 (<0.0001)	22.13 (<0.0001)	23.20 (<0.0001)
	Elmidae	32.73 (<0.0001)	3.86 (0.0524)	18.29 (<0.0001)
	Chironomidae	0.00 (0.9602)	31.55 (<0.0001)	15.78 (<0.0001)

Table 2-20 Continued

Reach (Station)	Variable	Before/After F (p-value)	Season F (p-value)	Overall F (p-value)
Responses of Dominant Macroinvertebrate Families Continued				
Reach 3 (AR-5)	Baetidae	4.54 (0.0358)	88.50 (<0.0001)	46.52 (<0.0001)
	Heptageniidae	50.06 (<0.0001)	32.86 (<0.0001)	41.46 (<0.0001)
	Chloropelidae	18.04 (<0.0001)	0.98 (0.3240)	9.51 (0.0002)
	Brachycentridae	21.49 (<0.0001)	0.28 (0.5988)	10.88 (<0.0001)
	Rhacophilidae	0.84 (0.3628)	9.43 (0.0028)	5.13 (0.0076)
	Hydropsychidae	8.38 (0.0047)	5.80 (0.0179)	7.09 (0.0013)
	Elmidae	86.84 (<0.0001)	1.26 (0.2650)	44.05 (<0.0001)
	Chironomidae	23.23 (<0.0001)	0.17 (0.6773)	11.70 (<0.0001)
Reach 6 (AR-8)	Baetidae	2.61 (0.1095)	12.68 (0.0006)	7.64 (0.0008)
	Heptageniidae	33.23 (<0.0001)	13.52 (0.0004)	23.38 (<0.0001)
	Chloropelidae	53.62 (<0.0001)	18.37 (<0.0001)	35.99 (<0.0001)
	Brachycentridae	28.81 (<0.0001)	10.32 (0.0018)	19.57 (<0.0001)
	Rhacophilidae	23.16 (<0.0001)	12.08 (0.0008)	17.62 (<0.0001)
	Hydropsychidae	0.23 (0.6294)	4.89 (<0.0001)	17.56 (<0.0001)
	Elmidae	9.85 (0.0023)	1.42 (0.2367)	5.63 (0.0048)
	Chironomidae	9.65 (0.0025)	68.49 (<0.0001)	39.07 (<0.0001)
Responses of Species Richness Variables				
Reach 0 (EF-5)	Mayfly richness	0.34 (0.5592)	51.83 (<0.0001)	26.09 (<0.0001)
	Stonefly richness	8.02 (0.0056)	17.50 (<0.0001)	12.76 (<0.0001)
	Caddisfly richness	7.66 (0.0068)	4.47 (0.0370)	6.07 (0.0033)
	Diptera richness	4.37 (0.0391)	10.75 (0.0014)	7.56 (0.0009)
	Other taxa	6.29 (0.0138)	17.39 (<0.0001)	11.84 (<0.0001)
	EPT	5.56 (0.0203	48.10 (<0.0001)	26.83 (<0.0001)
	Total Richness	2.32 (0.1313	48.90 (<0.0001)	25.61 (<0.0001)

Table 2-20 Continued

Reach (Station)	Variable	Before/After F (p-value)	Season F (p-value)	Overall F (p-value)
Responses of Species Richness Variables Continued				
Reach 0 (AR-1)	Mayfly richness	6.98 (0.0096)	1.22 (0.2716)	4.10 (0.0195)
	Stonefly richness	0.19 (0.6613)	12.19 (0.0007)	6.19 (0.0029)
	Caddisfly richness	2.28 (0.1340)	4.02 (0.0477)	3.15 (0.0471)
	Diptera richness	1.15 (0.2856)	31.63 (<0.0001)	16.39 (<0.0001)
	Other taxa	2.14 (0.1470)	9.73 (0.0024)	5.93 (0.0037)
	EPT	0.17 (0.6848)	5.89 (0.0171)	3.03 (0.0530)
	Total Richness	1.42 (0.2361)	0.36 (0.5502)	0.89 (0.4139)
Reach 1 (AR-3)	Mayfly richness	2.76 (0.0999)	25.87 (<0.0001)	14.31 (<0.0001)
	Stonefly richness	0.12 (0.7321)	23.58 (<0.0001)	11.85 (<0.0001)
	Caddisfly richness	13.49 (0.0004)	32.24 (<0.0001)	22.86 (<0.0001)
	Diptera richness	15.48 (0.0002)	9.84 (0.0023)	12.66 (<0.0001)
	Other taxa	12.05 (0.0008)	15.37 (0.0002)	13.71 (<0.0001)
	EPT	6.50 (0.0123)	49.98 (<0.0001)	28.24 (<0.0001)
	Total Richness	13.16 (0.0005)	25.48 (<0.0001)	19.32 (<0.0001)
Reach 3 (AR-5)	Mayfly richness	16.77 (<0.0001)	12.94 (0.0005)	14.85 (<0.0001)
	Stonefly richness	32.24 (<0.0001)	22.87 (<0.0001)	27.55 (<0.0001)
	Caddisfly richness	6.71 (0.0111)	0.29 (0.5936)	3.50 (0.0341)
	Diptera richness	0.20 (0.6587)	16.06 (0.0001)	8.13 (0.0005)
	Other taxa	20.06 (<0.0001)	1.94 (0.1666)	11.00 (<0.0001)
	EPT	48.40 (<0.0001)	21.49 (<0.0001)	34.95 (<0.0001)
	Total Richness	37.95 (<0.0001)	2.30 (0.1328)	20.12 (<0.0001)

Table 2-20 Continued

Reach (Station)	Variable	Before/After F (p-value)	Season F (p-value)	Overall F (p-value)
Responses of Species Richness Variables Continued				
Reach 6 (AR-8)	Mayfly richness	6.80 (0.0106)	21.94 (<0.0001)	14.37 (<0.0001)
	Stonefly richness	0.08 (0.7765)	9.34 (0.0029)	4.71 (0.0111)
	Caddisfly richness	0.70 (0.4064)	46.42 (<0.0001)	23.56 (<0.0001)
	Diptera richness	24.84 (<0.0001)	6.83 (0.0104)	15.84 (<0.0001)
	Other taxa	2.04 (0.1561)	17.18 (<0.0001)	9.61 (0.0002)
	EPT	1.74 (0.1901)	13.80 (0.0003)	7.77 (0.0007)
	Total Richness	9.96 (0.0021)	15.15 (0.0002)	12.56 (<0.0001)
Responses of Major Macroinvertebrate Orders				
Reach 0 (EF-5)	Mayfly abundance	24.39 (<0.0001)	157.92 (<0.0001)	91.15 (<0.0001)
	Stonefly abundance	11.74 (0.0009)	21.53 (<0.0001)	16.64 (<0.0001)
	Caddisfly abundance	28.73 (<0.0001)	12.02 (0.0008)	20.37 (<0.0001)
	Diptera abundance	25.04 (<0.0001)	14.20 (0.0003	19.62 (<0.0001)
	Other abundance	7.36 (0.0079)	42.06 (<0.0001)	24.71 (<0.0001)
	Total Abundance	1.53 (0.2195)	104.07 (<0.0001)	52.80 (<0.0001)
Reach 0 (AR-1)	Mayfly abundance	8.91 (0.0036)	56.81 (<0.0001)	32.86 (<0.0001)
	Stonefly abundance	0.29 (0.5891)	16.06 (0.0001)	8.17 (0.0005)
	Caddisfly abundance	1.60 (0.2087)	5.79 (0.0180)	3.70 (0.0283)
	Diptera abundance	17.82 (<0.0001)	12.89 (0.0005)	15.35 (<0.0001)
	Other abundance	34.85 (<0.0001)	54.10 (<0.0001)	44.48 (<0.0001)
	Total Abundance	0.71 (0.4014)	55.49 (<0.0001)	28.10 (<0.0001)
Reach 1 (AR-3)	Mayfly abundance	66.19 (<0.0001)	2.27 (0.1352)	34.23 (<0.0001)
	Stonefly abundance	8.51 (0.0044)	6.50 (0.0124)	7.51 (0.0009)
	Caddisfly abundance	28.75 (<0.0001)	7.91 (0.0060)	18.33 (<0.0001)
	Diptera abundance	16.95 (<0.0001)	1.28 (0.2610)	9.11 (0.0002)
	Other abundance	16.16 (0.0001)	43.38 (<0.0001)	29.77 (<0.0001)
	Total Abundance	41.00 (<0.0001)	7.01 (0.0095)	24.01 (<0.0001)

Table 2-20 Continued

Reach (Station)	Variable	Before/After F (p-value)	Season F (p-value)	Overall F (p-value)
Responses of Major Macroinvertebrate Orders Continued				
Reach 3 (AR-5)	Mayfly abundance	39.64 (<0.0001)	21.15 (<0.0001)	30.39 (<0.0001)
	Stonefly abundance	6.77 (0.0108)	24.02 (<0.0001)	15.39 (<0.0001)
	Caddisfly abundance	0.17 (0.6774	79.78 (<0.0001)	39.98 (<0.0001)
	Diptera abundance	0.39 (0.5342	25.59 (<0.0001)	12.99 (<0.0001)
	Other abundance	1.45 (0.2322	53.94 (<0.0001)	27.69 (<0.0001)
	Total Abundance	3.65 (0.0590	22.91 (<0.0001)	13.28 (<0.0001)
Reach 6 (AR-8)	Mayfly abundance	14.38 (0.0003	11.07 (0.0012	12.73 (<0.0001)
	Stonefly abundance	48.38 (<0.0001)	36.76 (<0.0001)	42.57 (<0.0001)
	Caddisfly abundance	31.86 (<0.0001)	5.93 (0.0168	18.89 (<0.0001)
	Diptera abundance	1.18 (0.2791	1.47 (0.2282	1.33 (0.2699
	Other abundance	16.31 (0.0001	4.48 (0.0368	10.40 (<0.0001)
	Total Abundance	7.74 (0.0065	4.97 (0.0281	6.36 (0.0025

Data from Clements, unpublished

Table 2-21

Results of Sediment Toxicity Tests Conducted by U.S. EPA in September 1993

Reach	Station	Percent Mortality
0	EF-1	7.5
	EF-2	13.8
	EF-6	10.0
	AR-2	8.8
1	CG-6	100
	AR-3	100
	AR-3A	33.8
4	AR-6	25.0

Table 2-22

Diatom Community Variables Measured at Sampling Stations in the Arkansas River in August 1992

Reach	Station	Species Richness	Diversity H’	Proportion *Achnanthes*
0	EF-5	26.3	2.18	0.35
	AR-1	23.0	1.83	0.51
	AR-2	26.3	1.88	0.50
1	AR-3	27.0	2.02	0.46
3	AR-5	22.7	1.94	0.13
Downstream Area	AR-8	27.0	2.10	0.33

Table 2-23

Results of Acute Toxicity Tests Conducted with *Ceriodaphnia dubia* and *Pimephales promelas* Exposed to Water from the Arkansas River and California Gulch [1]

Reach	Station	*Ceriodaphnia dubia*	*Pimephales promelas*
September 1987			
0	EF-1	0	5
	EF-2	9	0
	LMDT	100	22.7
	EF-4	100	0
	EF-5	100	0
	EF-6	100	5
	AR-1	100	5
	AR-2	100	100
1	AR-3	100	100
2	AR-4	100	15
3	AR-5	100	0
4	AR-6	100	100
September 1991			
0	EF-1	5	0
	EF-2	5	0
	EF-4	9	0
	EF-5	10	0
	AR-1	5	0
	AR-2	20	0
	Yak Tunnel		5
	CG-6		35
1	AR-3W	5	0
	AR-3A	25 (in 50% effluent)	10
2	AR-4		0
3	AR-5	0	0
4	AR-6	20	0
	AR-7	5	0
September 1993			
0	EF-1	10	0
	EF-2	5	0
	EF-4	5	0
	EF-6	0	0
	LMDT	20	
	AR-2	0	0
2	AR-4	15	5
4	AR-6	30	0
	AR-7	15	0

[1]The table reports percent mortality in 100% exposure water

Table 2-24

Fish Survey Data Collected from the Arkansas River during Spring and Fall 1990 [1]

	Fall		Spring	
	Abundance	**Biomass**	**Abundance**	**Biomass**
Upstream	1,005	123.0	759	152.0
Downstream	263	22.7	153	37.6

Data from CDOW 1990

[1] The table shows the abundance (#/acre) and biomass (lbs/acre) of brown trout collected upstream and downstream of California Gulch.

Table 2-25

Average Metal Concentrations in Tissues and Bone Collected from Voles Trapped in Wetlands from Reach 0 (Tennessee Creek and the upper Arkansas River) (ppm wet weight)[1]

	No. of samples	No. in each sample	Cadmium	Copper	Lead	Zinc
Tennessee Creek						
liver	1	1	1.2	6.3	<dl	41.9
kidney	1	1	<dl[2]	<dl	<dl	61.9
bone	1	1	<dl	16.2	<dl	142.0
Upper Arkansas						
liver	3	10,10,6	2.6	5.9	0.7	28.2
kidney	3	10,10,6	5.3	6.4	0.5	24.8
bone	3	10,10,6	<dl	3.1	3.4	120.2

[1]From Woodward Clyde 1993

[2]<dl=less than detection limit

Table 2-26

Average Metals Concentrations in American Dipper Blood and Liver Samples from Reach 0 and the Study Reference (ppm wet weight) [1]

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

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

Table 2-27

Average Metals Concentrations in Aquatic Invertebrates Collected From Reach 0[1] And the Study Reference (ppm wet weight) [2]

	n	Cadmium	Copper	Lead	Zinc
Reach 0	12	1.48	5.62	2.50	119.70
Study Reference[2]	23	0.11	5.08	0.21	40.38
Benchmark	--	2.00	NR	2.00	50.00

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

Table 2-28

Average Metals Concentration in Tree Swallow Livers from Reach 0 and the Study Reference (ppm wet weight)[1]

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

[1]From: Custer et al. (2003 In Press)
[2]Study Reference: Agassiz NWR, Minnesota
[3]less than detection limit

Table 2-29

Average Metals Concentration in Stomach Contents of Tree Swallows from Reach 0 (ppm wet weight)[1]

	n	Cadmium	Copper	Lead	Zinc
Reach 0	4	1.15	11.60	1.75	73.86
Benchmark	--	2.00	NR	2.00	50.00

[1]From: Custer and Custer et al. (2003 In Press)

Table 2-30

Summary of Mine-Waste Deposits in Arkansas River Subreaches

Subreach	Mapped Mine-Waste Deposits[1]	Length of Reach (ft)	Volume of Mine-Waste Deposits[2] (ft^3)	Volume of Mine-Waste per Linear Foot of Channel (ft^3)	Length of Banks[2] Exposing Mine Waste (ft)	Percentage of Banks Exposing Mine Waste (%)
1A	AA-AJ	2,250	317,294	141.0	600	13
1B	BB	3,000	9,517	3.2	300	5
1C	CA-CS	3,600	560,003	155.6	1,080	15
2A	FA-HK	11,100	154,388	13.9	3,140	14
2B	IA-KL	7,800	79,001	10.1	150	1
3A	LA-OH + PA	11,400	1,053,518	92.4	3,480	15
3B	OJ-RE	7,350	524,793	71.4	1,300	9
4	---	9,400	0	0	0	0
TOTAL		**55,900**	**2,698,514**	**48.3**	**10,050**	**9**

[1] Data from CT GIS (Appendix H)
[2] Data from EPA 1998

Table 2-31

Total Cadmium, Copper, Lead, and Zinc Surface Water Concentrations in Reach 1

Analyte	Period	Flow	StaCnt	n	Min	Max	Avg	Stdev
Cadmium	Period 2	High	7	40	0.00042	0.00999	0.0036	0.0026
Cadmium	Period 2	Low	7	50	0.000295	0.0251	0.0056	0.0051
Cadmium	Period 3	High	7	139	0.0002	0.036	0.0036	0.0068
Cadmium	Period 3	Low	7	102	0.00005	0.03172	0.0024	0.0037
Copper	Period 1	High	1	4	0.025	0.06	0.04	0.0178
Copper	Period 1	Low	1	5	0.025	0.06	0.053	0.0157
Copper	Period 2	High	7	23	0.00175	0.0691	0.0155	0.0157
Copper	Period 2	Low	6	50	0.00055	0.092	0.0152	0.0182
Copper	Period 3	High	8	137	0.0005	0.132	0.0112	0.019
Copper	Period 3	Low	7	102	0.0005	0.033	0.0066	0.007
Lead	Period 1	High	1	3	0.025	0.2	0.0833	0.101
Lead	Period 1	Low	1	5	0.025	0.1	0.075	0.0354
Lead	Period 2	High	6	22	0.0005	0.0293	0.0083	0.008
Lead	Period 2	Low	5	34	0.0005	0.2045	0.0101	0.0347
Lead	Period 3	High	8	131	0.0005	0.301	0.0238	0.0529
Lead	Period 3	Low	7	93	0.0005	0.132	0.0159	0.0217
Zinc	Period 1	High	1	4	1.35	5.9	2.6575	2.1695
Zinc	Period 1	Low	1	6	2.4	4.75	3.7767	0.8564
Zinc	Period 2	High	6	23	0.226	2.26	0.9109	0.5029
Zinc	Period 2	Low	6	49	0.139	5.63	1.3745	1.1045
Zinc	Period 3	High	8	141	0.02075	5.39	0.7595	1.1197
Zinc	Period 3	Low	7	104	0.03235	2.89	0.8031	0.639

Table 2-32

Reach 1 Sediment Data for Period 3 [1]

Analyte (dry weight)	StaCnt	n	Min	Max	Avg	Stdev
Cadmium	3	6	1.96	11.1	6.0	3.1
Copper	3	6	15.83	131	46.8	42.5
Lead	2	3	291	922	521.0	348.5
Zinc	3	6	239.7	2072	1251.2	651.4

[1] Concentrations in mg/L. Data from consulting team database.

Table 2-33

Summary of Shallow Monitoring Well (SMW) Groundwater Quality Characteristics for Dissolved Metals in Period 3 [1]

Metal	Reach	No. of Samples (n)	No. of Stations	Mean Dissolved Concentration (mg/L)	Minimum Dissolved Concentration (mg/L)	Maximum Dissolved Concentration (mg/L)	Standard Deviation (mg/L)
Cadmium	1	91	8	0.0099	0.0001	0.187	0.0232
	2	44	4	0.0092	0.0001	0.0359	0.0104
	3	155	26	0.0184	0.0001	0.249	0.0362
Copper	1	91	8	0.003	0.0003	0.0837	0.0091
	2	44	4	0.0017	0.0003	0.011	0.0018
	3	153	26	0.0331	0.0003	0.442	0.066
Lead	1	89	8	0.0056	0.0005	0.0162	0.0056
	2	44	4	0.0106	0.0005	0.0963	0.0197
	3	154	26	0.016	0.0005	0.476	0.0521
Zinc	1	91	8	4.36	0.00045	29.7	6.59
	2	45	4	3.13	0.00045	9.82	3.44
	3	158	26	2.35	0.00045	16.203	3.01

[1] Data from consulting team database.

Table 2-34

Total and Plant-Available Soil Metal Concentrations for Sites Sampled along the Arkansas River between the Confluence of California Gulch and Lake Fork [1/2] and Benchmark Concentrations of Total Metals in Soils for Toxicity to Vegetation [3]

Sample Site No.	Cadmium (mg/kg)		Copper (mg/kg)		Lead (mg/kg)		Zinc (mg/kg)	
	Total	PA [4]	Total	PA	Total	PA	Total	PA
LV22	45.0	8.3	870	40	25150	161	17400	544
LV23	17.0	2.2	148	14	870	55	1085	60
LV28	6.5	0.3	20	1.6	244	6.6	485	10
LV29	1.6	0.9	7	2.2	76	17	150	40
LV30	2.0	0.02	30	0.1	150	0.5	84	2.7
LV34	9.5	4.7	122	11	830	62	1330	251
LV35	13.0	4.4	150	20	610	58	1465	196
Mean	13.5 (±5.7)	2.96 (±1.1)	192 (±115)	12.7 (±5.3)	3990 (±1,212)	51.4 (±21)	3142 (±2,385)	158 (±74)
Benchmark Concentrations[3] (mg/kg)	8		125		400		400	

[1] Data from Keammerer 1987 (LNRD-016)

[2] Data for individual sites and means (±1 S.E.) are presented for this stretch of river. Sampling conducted in 1987.

[3] Data from Kabata-Pendias 2001. These concentrations are reported as total concentrations, but are most closely associated with plant-available concentrations measured in field-collected soils.

[4] PA=Plant available using DTPA soil extract

Table 2-35

Plant Tissue Metal Concentrations (reported on a dry-weight basis) for Cd, Cu, Pb, and Zn in Plants Growing in Meadows at the Seppi Ranch (Reach 1)[1] and Benchmark Concentrations of Plant Tissue for Toxicity to Vegetation [2]

Species	Copper (mg/kg)	Cadmium (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)
Yarrow	7.9	2.2	1.9	30
Wheatgrass	8.1	0.27	1.1	61
Redtop Bent Grass	4.4	0.99	1.2	49
Sedge	4.1-13.3	0.55-3.0	0.92	27
Rush	3.7-7.3	0.77-3.6	0.25-12.0	35-443
Muhly	4.2-5.3	0.21-0.84	1.2-2.5	52-102
Lousewort	4.4-10.0	0.63-3.9	0.98-3.3	42-630
Alpine Timothy	4.2	0.11-0.30	0.45-0.74	39-86
Bluegrass	4.0-6.3	0.22-0.25	0.81-1.2	26-28
Cinquefoil	5.4-6.5	0.47-2.9	1.4-2.8	79-133
Willow	4.4	13.2	2.4	588
Clover	4.4-9.8	0.35-1.5	1.3-1.7	109-209
Dandelion	12.5	2.0-4.2	1.5-1.8	47-196
Benchmark Concentrations[2] (mg/kg)	30	100	300	400

[1] Data collected in 1988 by Levy.

[2] Data from Kabata-Pendias 2001. These threshold concentrations represent the upper end of toxicity threshold for agronomic species. Native perennial plants are known to be more tolerant of metals than agronomic species. These thresholds are therefore considered to be highly conservative (Paschke et al. 2000).

Table 2-36

Total Plant Cover and Production for Sites Sampled along the Arkansas River in Reach 1 (between the Confluence of California Gulch and Lake Fork) [1]

Sample Site Number	Percent Total Cover	Total Production (g/m^2)
LV22	52	222
LV23	48	105
LV28	90	323
LV29	78	411
LV30	72	225
LV34	44	121
LV35	60	384
Mean	63.4 (±6.5)	256 (±46)

[1] Data for individual sites and means (±1 s.e.) are presented for this stretch of river. Sampling conducted in 1987 by Keammerer.

Table 2-37

Plant Tissue Metal Concentrations for Grasses and Forbs (reported on a dry-weight basis) from Sites Sampled along the Arkansas River between the Confluence of California Gulch and Lake Fork [1] and Benchmark Concentrations of Plant Tissue for Toxicity to Vegetation [2]

Sample Site No.	Cadmium (mg/kg)		Copper (mg/kg)		Lead (mg/kg)		Zinc (mg/kg)	
	Grasses	Forbs	Grasses	Forbs	Grasses	Forbs	Grasses	Forbs
LV22	2.2	2.2	5.0	5.0	40	6.0	555	115
LV23	2.2	8.5	5.0	15.0	17	50	83	151
LV28	2.7	1.6	3.5	6.5	9.5	40	18	144
LV29	2.7	3.3	3.5	17.0	13	9.5	29	126
LV30	0.95	---[3]	5.0	---	0.1	---	71	---
LV34	2.7	2.2	3.5	6.5	6.0	13	115	420
LV35	2.2	9.5	6.5	12.0	0.1	0.1	198	530
Mean	2.2 (±0.2)	4.6 (±1.4)	4.6 (±0.4)	10.3 (±2)	12.2 (±5.2)	19.8 (±8.3)	153 (±71)	248 (±74)
Benchmark Concentrations[2] (mg/kg)	30		100		300		400	

[1] Data for individual sites and means (±1 s.e.) are presented for this stretch of river. Sampling conducted in 1987 by Keammerer.

[2] Data from Kabata-Pendias 2001. These threshold concentrations represent the upper end of toxicity threshold for agronomic species. Native perennial plants are known to be more tolerant of metals than agronomic species. These thresholds are therefore considered to be highly conservative (Paschke et al. 2000).

[3] No Data Available

Table 2-38

Results of Acute Toxicity Tests Conducted with *Ceriodaphnia dubia* Exposed to Water from the Arkansas River and California Gulch, September 1992 and 1993

Year	Station	LC_{50}	95% C.I.	
			Lower	Upper
1992	Yak Tunnel	47.54	31.18	72.48
	Reach 1 (AR-3E)	46.45	25.31	85.23
	Reach 2 (AR-4)	55.85	49.66	62.81
1993	California Gulch	2.64	2.05	3.40
	Reach 1 (AR-3)	39.7	27.3	57.6
	Reach 1 (AR-3A)	70.7	58.5	85.5

Table 2-39

Results of Acute Toxicity Tests Conducted with Invertebrates and Fish Exposed to Water from California Gulch (CG) and Arkansas River Stations AR-3 and AR-4 [1]

Station	Invertebrate LC_{50} (% site water)	Fish LC_{50} (% site water)
CG1	1.0	1.3
Reach 1 (AR-3)	5.3	>12.5
Reach 2 (AR-4)	37	>100

[1] The table shows LC_{50} values after 48-hour (invertebrate) and 96-hour (fish) exposure.
From ENSR 1991

Table 2-40

Total Cadmium, Copper, Lead, and Zinc Surface Water Concentrations in Reach 2

Analyte	Period	Flow	StaCnt	n	Min	Max	Avg	Stdev
Cadmium	Period 1	High	1	2	0.02	0.02	0.02	0
Cadmium	Period 1	Low	1	2	0.03	0.04	0.035	0.0071
Cadmium	Period 2	High	1	2	0.00085	0.0015	0.0012	0.0005
Cadmium	Period 2	Low	3	13	0.0004	0.011	0.0042	0.0032
Cadmium	Period 3	High	3	28	0.0002	0.0072	0.0019	0.0019
Cadmium	Period 3	Low	3	27	0.0002	0.0025	0.0007	0.0005
Copper	Period 1	High	2	6	0.02	0.025	0.0233	0.0026
Copper	Period 1	Low	2	9	0.02	0.06	0.0272	0.0125
Copper	Period 2	High	1	2	0.0034	0.00445	0.0039	0.0007
Copper	Period 2	Low	2	12	0.00145	0.0361	0.0069	0.0098
Copper	Period 3	High	3	28	0.001	0.025	0.0086	0.008
Copper	Period 3	Low	3	28	0.001	0.025	0.004	0.0045
Lead	Period 1	High	2	5	0.025	0.3	0.1	0.1159
Lead	Period 1	Low	2	9	0.025	0.2	0.1194	0.0659
Lead	Period 2	High	1	2	0.006	0.0082	0.0071	0.0016
Lead	Period 2	Low	2	12	0.00225	0.0269	0.0113	0.0082
Lead	Period 3	High	3	28	0.00075	0.0656	0.0155	0.016
Lead	Period 3	Low	3	27	0.0005	0.008	0.0042	0.0019
Zinc	Period 1	High	2	6	0.2	1.5	0.76	0.4345
Zinc	Period 1	Low	2	10	0.5	1.6	0.858	0.3146
Zinc	Period 2	High	1	2	0.298	0.344	0.321	0.0325
Zinc	Period 2	Low	2	12	0.2	0.862	0.5899	0.2136
Zinc	Period 3	High	3	29	0.048	1.28	0.3632	0.3367
Zinc	Period 3	Low	3	29	0.112	0.79	0.2316	0.1314

Table 2-41

Reach 2 Sediment Data for Period 3

Analyte (dry weight)	StaCnt	n	Min	Max	Avg	Stdev
Cadmium	5	5	1	33	17.6	13.0
Copper	5	5	10	610	177.7	247.4
Lead	5	5	63	1,900	862.8	764.3
Zinc	5	5	180	5,200	2,669.8	1,930.8

Table 2-42

Total and Plant Available Soil Metal Concentrations for Sites Sampled along the Arkansas River between Lake Fork and Highway 24 Bridge [1/2] and Benchmark Concentrations of Total Metals in Soils for Toxicity to Vegetation [3]

Sample Site No.	Cadmium (mg/kg)		Copper (mg/kg)		Lead (mg/kg)		Zinc (mg/kg)	
	Total	**PA [4]**	**Total**	**PA**	**Total**	**PA**	**Total**	**PA**
LV19	7.0	0.6	36	2.2	495	12	223	17
LV20	17	5.7	22	3.9	150	30	1185	274
LV21	33	9.6	92	4.8	2033	26	3718	535
LV31	27	0.02	121	0.1	1255	1.6	725	2.2
LV32	21	2.5	87	2.7	890	79	750	90
LV33	1.6	2.1	17	4.1	150	40	295	34
LV36	4.3	0.2	16	1.9	275	4.0	78	8.3
LV37	12	0.08	20	0.5	150	3.0	2470	7.1
Mean	15.4 (±3.9)	2.6 (±1.2)	51.4 (±15)	2.5 (±0.6)	675 (±241)	24.5 (±9.3)	1180 (±451)	121 (±67)
Benchmark Concentrations[3] (mg/kg)	8		125		400		400	

[1] Data from Keammerer 1987 (LNRD-016)
[2] Data for individual sites and means (±1 s.e.) are presented for this stretch of river. Sampling conducted in 1987.
[3] Data from Kabata-Pendias 2001. These concentrations are reported as total concentrations, but are most closely associated with plant-available concentrations measured in field-collected soils.
[4] PA=Plant available using DTPA soil extract.

Table 2-43

Plant Tissue Metal Concentrations (reported on a dry-weight basis) for Cd, Cu, Pb, and Zn in Plants Growing in Meadows at the Smith Ranch [1] and Benchmark Concentrations of Plant Tissue for Toxicity to Vegetation [2]

Species	Cadmium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)
Yarrow	7.3	11.0	52.0	517
Sedge	2.0	21.1	26.4	593
Iris	21.0	4.7	23.4	403
Rush	3.5	6.8	12.7	443
Bluegrass	1.9	11.6	43.1	570
Benchmark Concentrations[2] (mg/kg)	100	30	300	400

[1] Data collected in 1988 by Levy.
[2] Data from Kabata-Pendias 2001. These threshold concentrations represent the upper end of toxicity threshold for agronomic species. Native perennial plants are known to be more tolerant of metals than agronomic species. These thresholds are therefore considered to be highly conservative (Paschke et al. 2000).

Table 2-44

Total Plant Cover and Production for Sites Sampled along the Arkansas River between Lake Fork and Highway 24 Bridge [1]

Sample Site Number	Percent Total Cover	Total Production (g/m^2)
LV19	80	263
LV20	74	190
LV21	38	115
LV31	92	400
LV32	90	269
LV33	90	252
LV36	72	273
LV37	80	174
Mean	77 (±6)	242 (±30)

[1] Data for individual sites and means (±1 s.e.) are presented for this stretch of river. Sampling conducted in 1987 by Keammerer.

Table 2-45

Plant Tissue Metal Concentrations for Grasses and Forbs (reported on a dry-weight basis) from Sites Sampled along the Arkansas River between Lake Fork and Highway 24 Bridge [1] and Benchmark Concentrations of Plant Tissue for Toxicity to Vegetation [2]

Sample Site No.	Cadmium (mg/kg)		Copper (mg/kg)		Lead (mg/kg)		Zinc (mg/kg)	
	Grasses	Forbs	Grasses	Forbs	Grasses	Forbs	Grasses	Forbs
LV19	0.95	2.2	6.5	8.1	0.1	0.1	43	106
LV20	2.2	11	8.0	18	0.1	20	265	895
LV21	2.7	---[3]	5.0	---	21	---	662	---
LV31	0.95	0.95	2.5	5.0	6.0	65	23	32
LV32	2.2	3.9	5.0	3.5	9.5	0.1	62	23
LV33	1.6	2.7	5.0	6.5	13	0.1	77	136
LV36	0.1	1.6	3.5	6.5	9.5	0.1	20	47
LV37	2.2	1.6	3.5	6.5	13	6.0	23	62
Mean	1.6 (±0.3)	3.4 (±1.3)	4.9 (±0.6)	7.7 (±1.8)	9.0 (±2.5)	13.1 (±9.1)	147 (±79)	186 (±119)
Benchmark Concentrations[2] (mg/kg)	30		100		300		400	

[1] Data for individual sites and means (±1 s.e.) are presented for this stretch of river. Sampling conducted in 1987 by Keammerer.
[2] Data from Kabata-Pendias 2001. These threshold concentrations represent the upper end of toxicity threshold for agronomic species. Native perennial plants are known to be more tolerant of metals than agronomic species. These thresholds are therefore considered to be highly conservative (Paschke et al. 2000).
[3] No Data Available

Table 2-46
Metal Concentrations in Tissues and Bone Collected from Voles Trapped in Wetlands from Reach 2 (ppm, wet weight) [1]

Media	No. of samples	No. in each composite sample	Cadmium	Copper	Lead	Zinc
liver	2	1	2.7[3]	8.1[3]	<dl[2]	29.6[3]
liver	1	4	7.6	7.5	0.5	29.6
kidney	1	1	11.1	<dl	<dl	79.8
kidney	1	4	11.0	6.7	2.0	26.5
bone	2	1	NA[4]	NA	6.4[3]	88.5[3]
bone	1	4	NA	NA	10.2	189.0

[1] From Woodward Clyde 1993
[2] <dl=less than detection limit
[3] arithmetic mean
[4] NA=Not Analyzed

Table 2-47

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

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

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

Table 2-48

Average Metals Concentrations in Aquatic Invertebrates Collected from Reach 2 (ppm wet weight) [1]

	n	Cadmium	Copper	Lead	Zinc
Reach 2	4	2.77	10.20	13.78	303.00
Reach 0	12	1.48	5.62	2.50	119.70
Study Reference[2]	23	0.11	5.08	0.21	40.38
Benchmark	--	2.00	NR	2.00	50.00

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

Table 2-49

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

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

[1]From: Custer et al. 2003 In Press
[2]Study Reference: Agassiz NWR Minnesota
[3]<dl=less than detection limit
[4]NR=Benchmark not reported

Table 2-50

Average Metals Concentration in Stomach Contents of Tree Swallows from Reach 2 (ppm wet weight)[1]

	n	Cadmium	Copper	Lead	Zinc
Reach 2	3	1.52	9.57	3.87	66.87
Reach 0	4	1.15	11.60	1.75	73.86
Benchmark	--	2.00	NR	2.00	50.00

[1]From: Custer et al. 2003 In Press

Table 2-51

Total Cadmium, Copper, Lead, and Zinc Surface Water Concentrations in Reach 3

Analyte	Period	Flow	StaCnt	n	Min	Max	Avg	Stdev
Cadmium	Period 2	High	3	13	0.001	0.0056	0.0024	0.0015
Cadmium	Period 2	Low	3	13	0.000495	0.003	0.0015	0.0008
Cadmium	Period 3	High	7	78	0.0002	0.038	0.0028	0.0044
Cadmium	Period 3	Low	9	75	0.00005	0.005	0.0013	0.001
Copper	Period 1	High	1	3	0.025	0.025	0.025	0
Copper	Period 1	Low	1	6	0.025	0.025	0.025	0
Copper	Period 2	High	3	13	0.00485	0.0207	0.0097	0.0054
Copper	Period 2	Low	3	12	0.0011	0.008	0.0045	0.0023
Copper	Period 3	High	7	78	0.001	0.025	0.0147	0.0102
Copper	Period 3	Low	8	74	0.00045	0.025	0.0081	0.0097
Lead	Period 1	High	1	3	0.025	0.1	0.05	0.0433
Lead	Period 1	Low	1	6	0.05	0.1	0.0917	0.0204
Lead	Period 2	High	2	9	0.006	0.029	0.015	0.007
Lead	Period 2	Low	2	10	0.0005	0.022	0.0077	0.0066
Lead	Period 3	High	7	77	0.0025	0.121	0.024	0.0264
Lead	Period 3	Low	8	66	0.0017	0.108	0.0088	0.0148
Zinc	Period 1	High	1	3	0.21	1.1	0.6033	0.4539
Zinc	Period 1	Low	1	7	0.28	1.3	0.6557	0.3175
Zinc	Period 2	High	3	17	0.15	1.037	0.4158	0.2426
Zinc	Period 2	Low	3	12	0.13	0.73	0.3138	0.2011
Zinc	Period 3	High	7	86	0.064	2.339	0.3719	0.37
Zinc	Period 3	Low	9	82	0.038	1.3	0.2455	0.2066

Table 2-52

Reach 3 Sediment Data for Period 3

Analyte (dry weight)	StaCnt	n	Min	Max	Avg	Stdev
Cadmium	4	6	3.27	14	8.2	3.9
Copper	4	6	14.24	52.19	30.5	17.5
Lead	3	3	104	601.9	394.0	258.9
Zinc	4	6	398.7	2079	1148.6	783.6

Table 2-53

Total and Plant Available Soil Metal Concentrations for Sites Sampled along the Arkansas River between Highway 24 Bridge and the Valley Constriction below CR 55 Bridge [1/2] and Benchmark Concentrations of Total Metals in Soils for Toxicity to Vegetation [3]

Sample Site No.	Cadmium (mg/kg)		Copper (mg/kg)		Lead (mg/kg)		Zinc (mg/kg)	
	Total	**PA [4]**	**Total**	**PA**	**Total**	**PA**	**Total**	**PA**
LV11	1.6	1.6	32	2.6	35	8	930	274
LV12	13.8	0.21	44	1.3	445	8.6	656	8.8
LV13	0.8	1.2	10	2.5	66	6.6	195	47
LV14	1.6	1.6	7	2.3	118	21	256	84
LV15	23	12	269	43	3,675	11	3,615	608
LV16	4.3	3.2	14	3.8	76	5.9	645	174
LV17	13	4.8	79	12	520	28	1,310	205
LV18	0.8	0.2	13	1.3	76	4.9	61	4.8
Mean	7.4 (±2.9)	3.1 (±1.4)	58.5 (±31)	8.6 (±5.1)	626 (±435)	11.8 (±2.9)	959 (±407)	175 (±71)
Benchmark Concentrations[3] (mg/kg)	8		125		400		400	

[1] Data from Keammerer 1987 (LNRD-016)
[2] Data for individual sites and means (±1 s.e.) are presented for this stretch of river. Sampling conducted in 1987.
[3] Data from Kabata-Pendias 2001. These concentrations are reported as total concentrations, but are most closely associated with plant-available concentrations measured in field-collected soils.
[4] PA = Plant Available Using DTPA Soil Extract

Table 2-54

Total Plant Cover and Production for Sites Sampled along the Arkansas River between Highway 24 Bridge and the Valley Constriction below CR 55 Bridge [1]

Sample Site Number	Percent Total Cover	Total Production (g/m^2)
LV11	78	263
LV12	70	221
LV13	80	63
LV14	54	69
LV15	42	89
LV16	64	135
LV17	68	126
LV18	66	123
Mean	65.2 (±4.4)	136 (±25)

[1] Data for individual sites and means (±1 s.e.) are presented for this stretch of river. Sampling conducted in 1987 by Keammerer.

Table 2-55

Plant Tissue Metal Concentrations for Grasses and Forbs (reported on a dry-weight basis) from Sites Sampled along the Arkansas River between Highway 24 Bridge and the Valley Constriction below CR 55 Bridge[1] and Benchmark Concentrations of Plant Tissue for Toxicity to Vegetation[2]

Sample Site No.	Cadmium (mg/kg)		Copper (mg/kg)		Lead (mg/kg)		Zinc (mg/kg)	
	Grasses	Forbs	Grasses	Forbs	Grasses	Forbs	Grasses	Forbs
LV11	0.5	11	5.0	17	0.1	0.1	93	501
LV12	1.3	8.2	5.5	14.7	0.1	0.1	47	345
LV13	0.5	6.3	8.0	30	0.1	0.1	111	335
LV14	0.5	3.9	6.5	24	6.5	0.1	112	341
LV15	3.3	--- [3]	10	---	23	---	575	---
LV16	2.7	5.3	6.5	20	0.1	0.1	460	787
LV17	2.7	---	5.0	---	6.0	---	481	---
LV18	0.95	3.9	5.0	8.0	0.1	0.1	35	58
Mean	1.6 (±0.4)	6.4 (±1.1)	6.4 (±0.6)	18.9 (±1.6)	4.5 (±2.8)	0.1 (±0)	239 (±79)	394 (±98)
Benchmark Concentrations[2] (mg/kg)	30		100		300		400	

[1] Data for individual sites and means (±1 s.e.) are presented for this stretch of river. Sampling conducted in 1987 by Keammerer.

[2] Data from Kabata-Pendias 2001. These threshold concentrations represent the upper end of toxicity threshold for agronomic species. Native perennial plants are known to be more tolerant of metals than agronomic species. These thresholds are therefore considered to be highly conservative (Paschke et al. 2000).

[3] No Data Available

Table 2-56

Fish Survey Data Collected from the Arkansas River during Fall [1]

	Year	Location	Fish/Acre	Pounds/Acre	Data Source
Reach 0 [2]					
	1979	Upstream of CG-AR2	624	---	Roline & Boehmke [3]
	1985	Upstream of CG-AR2	76	22	Engineering Science
	1986	AR1	194	46	CDOW
	1989	AR1	882	123	CDOW
	1991	AR1	444	87	Aquatics Associates
	1992: LMDT Treatment Plant Goes Online				
	1994	AR1	657	97	CDOW
	1997	AR1	401	111	CDOW
	1999	AR1	342	70	CDOW
Reach 1 [4]					
	1979	Below CG	0	0	Roline & Boehmke
	1985	Below CG	2	0.88	Engineering Science
	1987	Below CG	20	3	ENSR
	1989	Below CG	194	23	CDOW
	1992: Yak Tunnel and LMDT Treatment Plants Go Online				
	1994	Below CG	51	15	CDOW
	1997	Below CG	55	13	CDOW
	1999	Below CG	178	31	CDOW
Reach 2 [5]					
	1985 (Sept)	Smith Ranch	4	0.88	Engineering Science
	1985 (Oct)	Smith Ranch	68	31	CDOW
	1987	Smith Ranch	124	43	ENSR
	1987	3.5 mi Downstream of Lake Fork Confluence	49	8	ENSR
	1991	Smith Ranch	63	31	CDOW/Aquatics Associates
	1992: Yak Tunnel and LMDT Treatment Plants Go Online				
	1994	Smith Ranch	509	102	CDOW/Aquatics Associates
	1997	Smith Ranch	146	44	CDOW/Aquatics Associates
	1999	Smith Ranch	184	72	CDOW/Aquatics Associates
Reach 3 [6]					
	1991	Upstream of Empire Gulch	67	54	CDOW/Aquatics Associates
	1992: Yak Tunnel and LMDT Treatment Plants Go Online				
	1994	Upstream of Empire Gulch	112	40	CDOW/Aquatics Associates
	1997	Upstream of Empire Gulch	115	51	CDOW/Aquatics Associates
	1999	Upstream of Empire Gulch	123	59	CDOW/Aquatics Associates

Table 2-56 Continued

	Year	Location	Fish/Acre	Pounds/Acre	Data Source
Reach 4 [7]					
	1999	0.5 mi Downstream of Co. Rd. 55	80	28	CDOW
Just Downstream of Reach 4					
	1985	Upstream of Lake Creek	64	28	CDOW
	1988	Upstream of Lake Creek	88	---	CDOW
	1992: Yak Tunnel and LMDT Treatment Plants Go Online				
	1994	Upstream of Lake Creek	244	84	CDOW

[1] Number of fish and biomass are presented for each reach.
[2] Confluence of Tennessee Creek and East Fork to California Gulch
[3] From Roline & Boehmke 1988. Data is for all trout; 94% were brown trout.
[4] California Gulch to Lake Fork
[5] Lake Fork to Highway 24 Bridge
[6] Highway 24 Bridge to Valley Constriction Downstream of County Road 55
[7] Valley Constriction to Two Bit Gulch
CG = California Gulch

Table 2-57

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

Blood	n	Cadmium	Copper	Lead	Zinc
Reach 3	11	0.06	0.15	0.22	5.96
Reach 2	17	0.01	0.13	0.16	4.15
Reach 0	14	0.04	0.23	0.11	13.93
Study Reference[2]	27	0.01	0.16	0.04	4.09
Benchmark	--	NR[3]	NR	0.20	60.00
Liver					
Reach 3	5	0.80	7.30	0.58	33.31
Reach 2	6	0.23	5.04	0.53	39.85
Reach 0	4	0.84	5.39	0.19	34.31
Study Reference	14	0.21	6.90	0.01	21.38
Benchmark	--	40.00	NR	2.00	60.00

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

Table 2-58

Average Metals Concentrations in Aquatic Invertebrates Collected from Reach 3 (ppm wet weight) [1]

	n	Cadmium	Copper	Lead	Zinc
Reach 3	4	2.39	7.66	21.90	279.50
Reach 2	4	2.77	10.20	13.78	303.00
Reach 0	12	1.48	5.62	2.50	119.70
Study Reference[2]	23	0.11	5.08	0.21	40.38
Benchmark	--	2.00	NR[3]	2.00	50.00

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

Table 2-59

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

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

[1]From: Custer et al. 2003 In Press
[2]Study Reference: Agassiz NWR Minnesota

Table 2-60

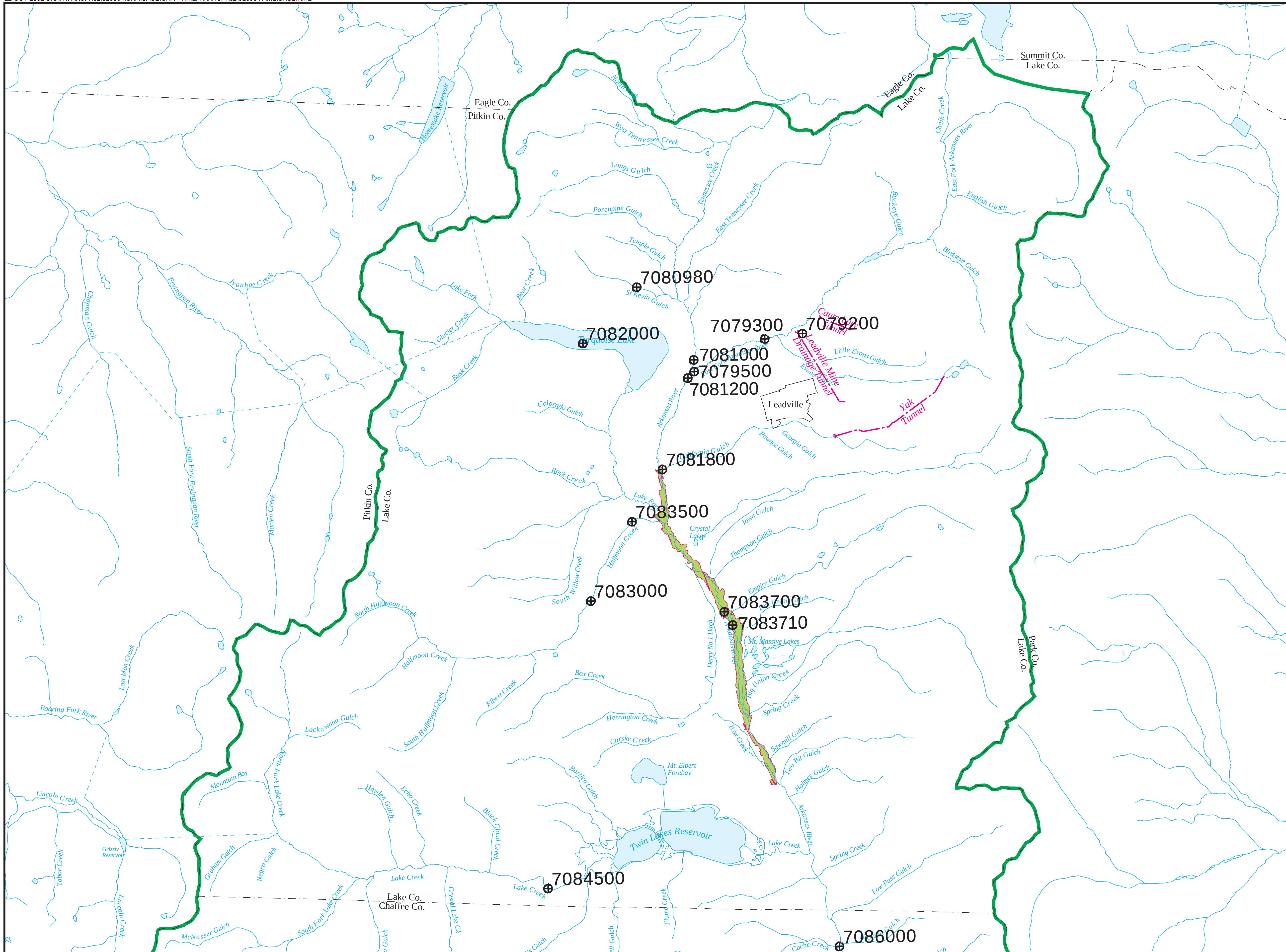
Average Metals Concentration in Stomach Contents of Tree Swallows from Reach 3 (ppm wet weight)[1]

	n	Cadmium	Copper	Lead	Zinc
Reach 3	2	0.68	6.77	1.22	40.14
Reach 2	3	1.52	9.57	3.87	66.87
Reach 0	4	1.15	11.60	1.75	73.86
Benchmark	--	2.00	NR[2]	2.00	50.00

[1]From: Custer et al. 2003 In Press
[2]NR=Benchmark not reported

FIGURES

22-OCT-2002 GRA: N:\ARCPRJ2\010004\GRA\GAGE.GRA * AML: N:\ARCPRJ2\010004\AML\GAGE.AML



UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

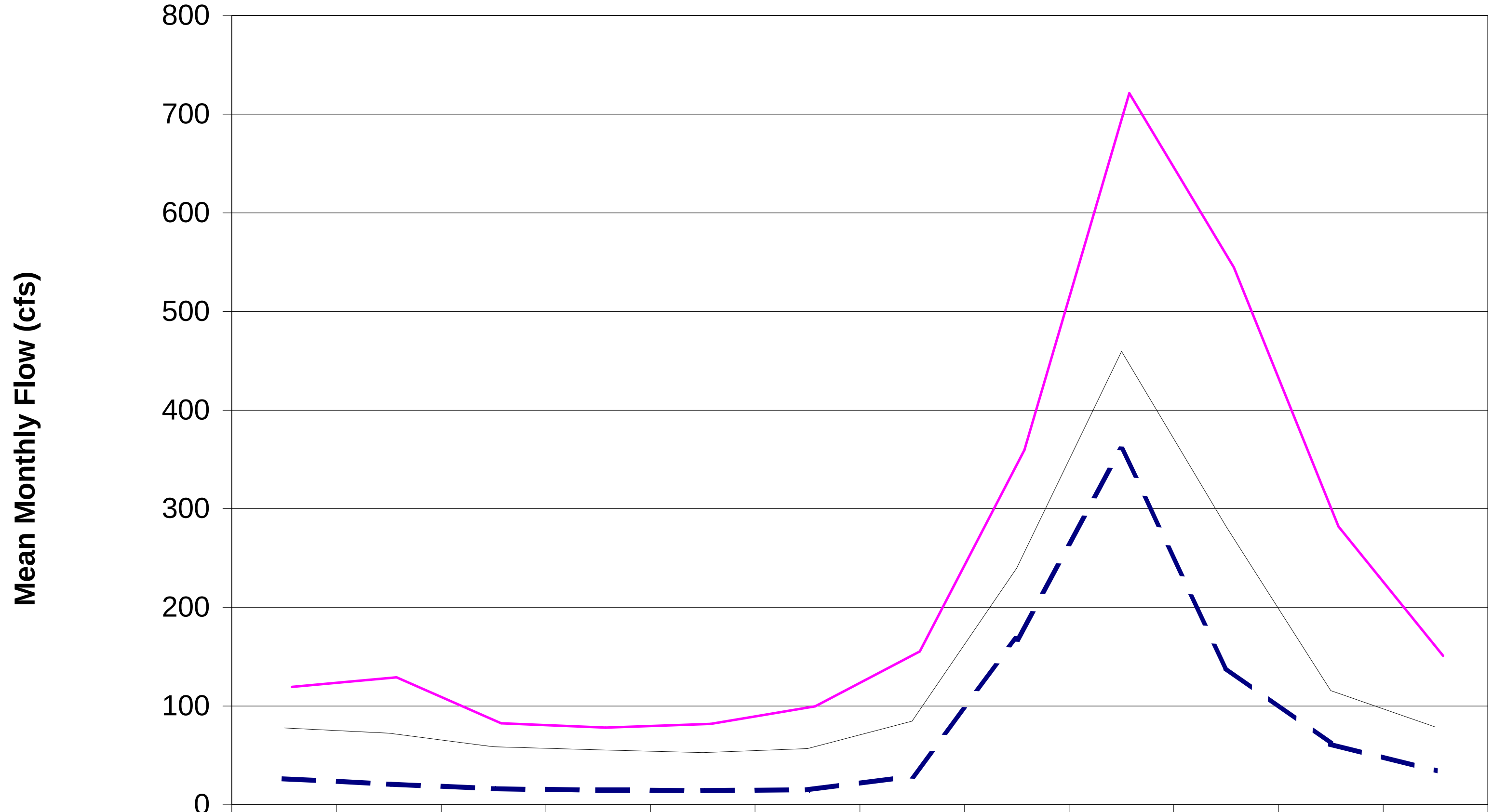
FIGURE 2-1

GAGING STATIONS

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

MFG, Inc.

consulting scientists and engineers



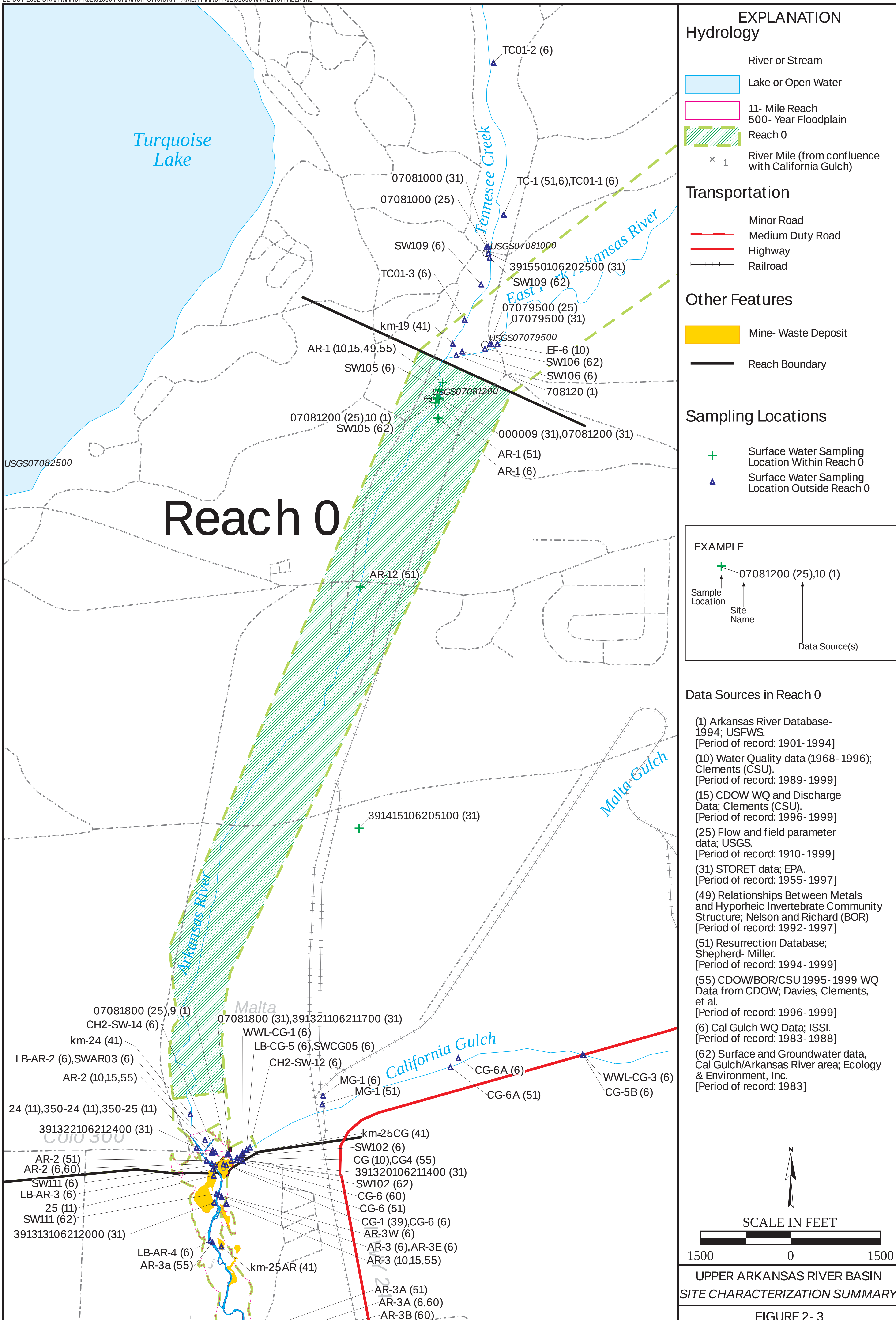
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Leadville Junction	26.4	21	16.4	14.6	14.3	14.9	29.1	168	360	139	61.5	34.5
Malta	119.31	129.24	82.556	78.079	82.06	99.655	155.27	359.4	721.23	544.67	281.88	150.98
Empire Gulch	77.935	72.4	58.871	55.613	52.788	56.796	84.767	239.74	459.46	282.06	115.61	78.717

Time

POR for the Leadville Junction Gage is 1967 to 1998, POR for the Malta Gage is 1964 to 1984, and POR for the Empire Gudlch gage is 1990 to 1993

Figure 2-2

Mean Monthly Flows at USGS Gages Located at Leadville Junction (7081200), Malta (7083700), and near Empire Gulch (7083710)



UPPER ARKANSAS RIVER BASIN
SITE CHARACTERIZATION SUMMARY

FIGURE 2- 3
SURFACE WATER SAMPLE LOCATIONS
EAST FORK CONFLUENCE TO CALIFORNIA GULCH
(REACH 0)

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

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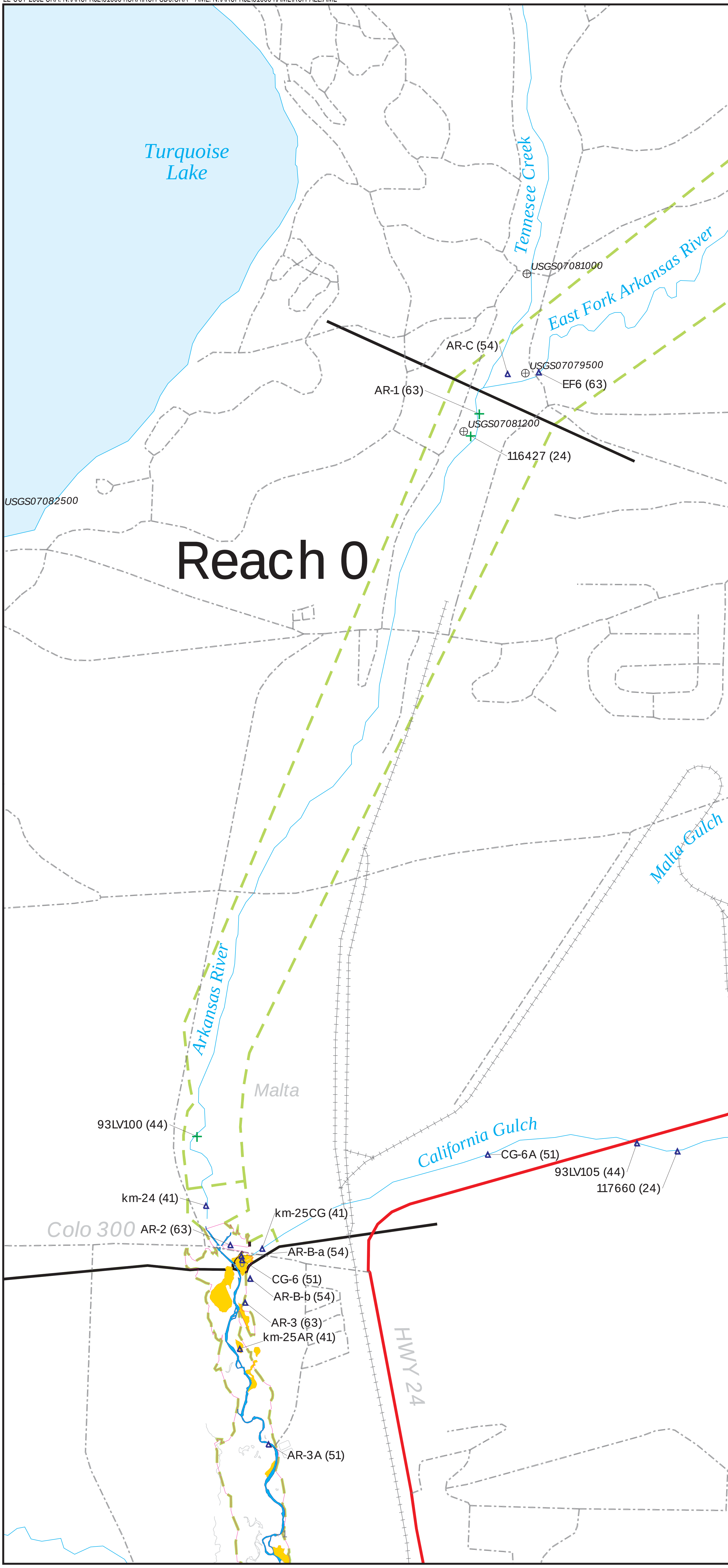
consulting scientists and engineers

22-OCT-2002 GRA: N:\ARCPRJ2\010004\GRA\RCH-SD0.GRA * AML: N:\ARCPRJ2\010004\AML\RCH-ALL.AML



EXPLANATION

Hydrology

River or Stream

Lake or Open Water

11- Mile Reach
500- Year Floodplain

Reach 0

× 1 River Mile (from confluence with California Gulch)

Transportation

Minor Road

Medium Duty Road

Highway

Railroad

Other Features

Mine- Waste Deposit

Reach Boundary

Sampling Locations

Stream Sediment Sampling Location Within Reach 0

Stream Sediment Sampling Location Outside Reach 0

EXAMPLE

116427 (24)

Sample Location

Site Name

Data Source(s)

Data Sources in Reach 0

(24) NURE Stream Sediment Data; USGS.
[Period of record: 1976-1979]

(44) Geochemical and Lead Isotope data for stream and lake sediments; S.E. Church (USGS).
[Period of record: 1993-1994]

(63) 1995-1996 Sediment data from CSU
[Period of record: 1995-1996]

N

SCALE IN FEET

1500 0 1500

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2-4
STREAM SEDIMENT
SAMPLE LOCATIONS
EAST FORK CONFLUENCE
TO CALIFORNIA GULCH
(REACH 0)

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

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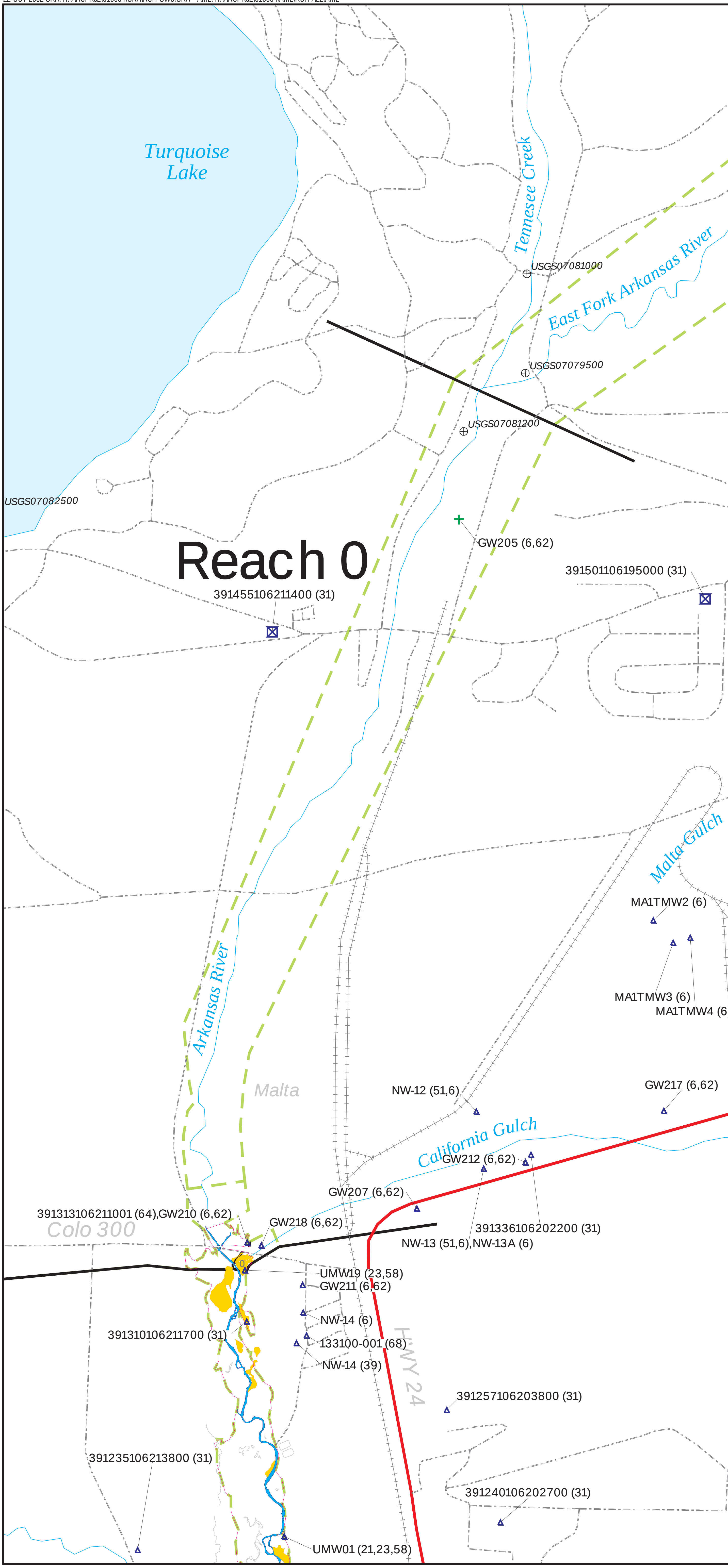

EXPLANATION

Hydrology

- River or Stream
- Lake or Open Water
- 11- Mile Reach 500- Year Floodplain
- Reach 0
- River Mile (from confluence with California Gulch)

Transportation

- Minor Road
- Medium Duty Road
- Highway
- Railroad

Other Features

- Mine- Waste Deposit
- Reach Boundary

Sampling Locations

- Potential Domestic Water Supply (or other deeper well) Within Reach 0
- Shallow Monitoring Well Within Reach 0
- Groundwater Sampling Location, Depth Unknown, Within Reach 0
- Groundwater Sampling Location Outside Reach 0

EXAMPLE

391501106195000 (31)

Sample Location — Site Name — Data Source(s)

Data Sources in Reach 0

(31) STORET data; EPA.
[Period of record: 1955-1997]

(6) Cal Gulch WQ Data; ISSI.
[Period of record: 1983-1988]

(62) Surface and Groundwater data, Cal Gulch/Arkansas River area; Ecology & Environment, Inc.
[Period of record: 1983]

N

SCALE IN FEET

1500 0 1500

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2-5
GROUNDWATER SAMPLE LOCATIONS
EAST FORK CONFLUENCE TO CALIFORNIA GULCH
(REACH 0)

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

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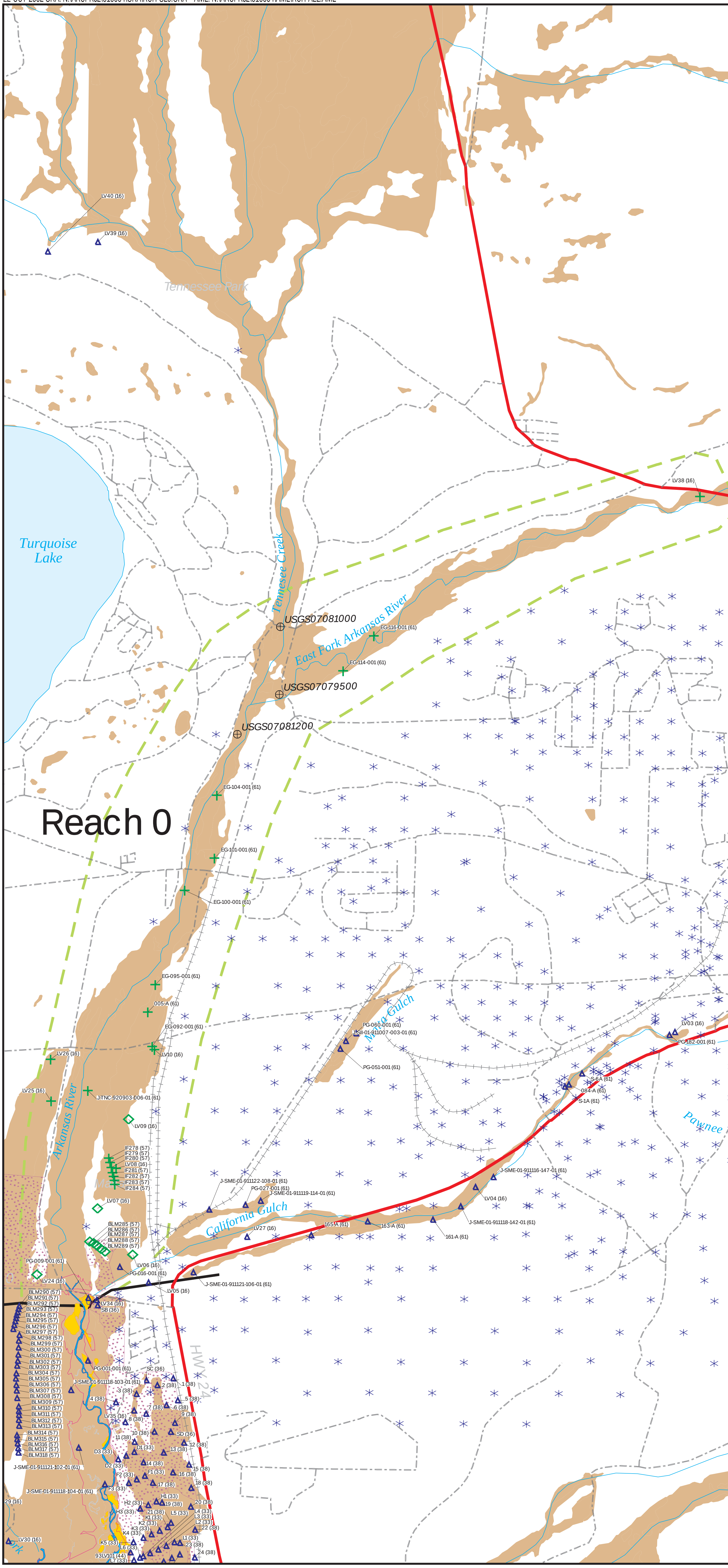

EXPLANATION

Hydrology

- River or Stream
- Lake or Open Water
- 11- Mile Reach 500- Year Floodplain
- Reach 0 (Vegetation/Soil)
- Lowland Zone - Based on presence of riparian species (CDOW Vegetation Mapping, 2001)
- Irrigated Area (SAIC, 2001)
- × 1 River Mile (from confluence with California Gulch)

Transportation

- Minor Road
- Medium Duty Road
- Highway
- Railroad

Other Features

- Mine- Waste Deposit
- Reach Boundary

Sampling Locations

- Lowland Soil Sampling Location Within Reach 0
- Upland Soil Sampling Location Within Reach 0
- Soil Sampling Location Outside Reach 0
- AIRSHED Sample Location

EXAMPLE

LV38 (16)

Sample Location

Site Name

Data Source(s)

Data Sources in Reach 0

(16) 1986/1987 Soil and Vegetation Metals Data; Keammerer. [Period of record: 1987]

(57) BLM July 2000 Soil/Sediment Data; BLM. [Period of record: 2000]

(61) Surface soils data - 0 to 2 inches; Walsh. [Period of record: 1986- 1997]

N

SCALE IN FEET

2200 0 2200

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2- 6

SOIL SAMPLE LOCATIONS EAST FORK CONFLUENCE TO CALIFORNIA GULCH (REACH 0)

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

MFG, Inc.

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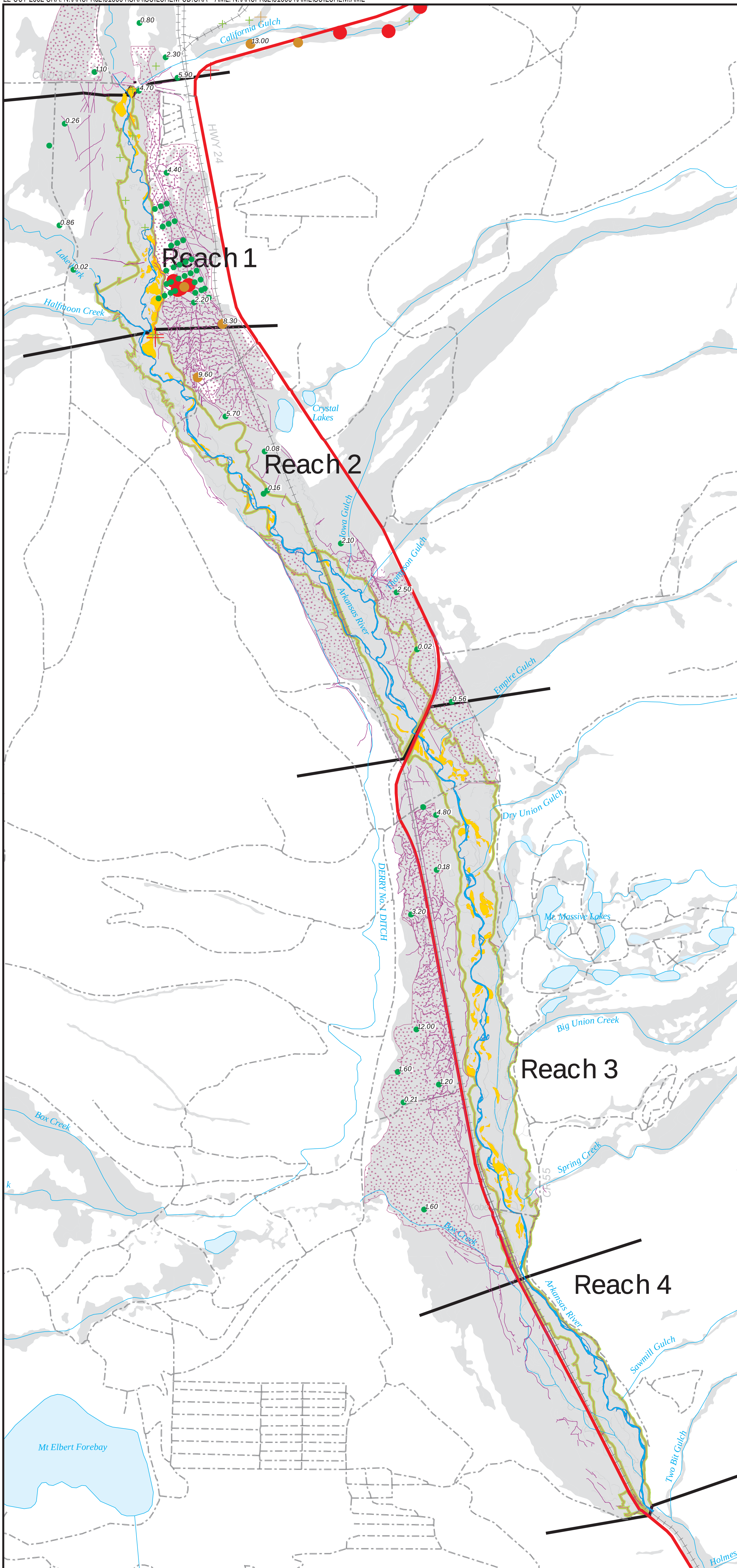

EXPLANATION

CADMIUM- TOTAL CONCENTRATION (ppm)
METHOD: Dry weight (total)

- Cd- Non Toxic: 0 ppm to < = 30 ppm
- Cd- Possibly Toxic: > 30 ppm to < = 50 ppm
- Cd- Toxic: > 50 ppm

METHOD: XRF

- Cd- Non Toxic: 0 ppm to < = 30 ppm
- Cd- Possibly Toxic: > 30 ppm to < = 50 ppm
- Cd- Toxic: > 50 ppm

Plant Available (AB- DTPA) Concentration (ppm)
(Shown as text near sample location)
(From Keammerer, 1987)

- Cd- Non Toxic: 0 ppm to < = 15 ppm
- Cd- Possibly Toxic: > 15 to < = 30 ppm
- Cd- Toxic: > 30 ppm

Toxicity values from:
Kabata- Pendias, 2001

There are also limited soil data at depths greater than 6" at some sampling locations. These data are not shown on this plot.

Hydrology

- River or Stream
- Lake or Open Water
- 11- Mile Reach 500- Year Floodplain
- Lowland Zone - Based on presence of riparian species (CDOW Vegetation Mapping, 2001)
- Irrigated Area (SAIC, 2001)
- Drainage/Irrigation Network

Transportation

- Minor Road
- Medium Duty Road
- Highway
- Railroad

Other Features

- Mine- Waste Deposit
- Reach Boundary

EXAMPLE
8.6
Plant Available Concentration
Sample Location

N

SCALE IN FEET
3000 0 3000

UPPER ARKANSAS RIVER BASIN
SITE CHARACTERIZATION SUMMARY

FIGURE 2- 7
CADMIUM CONCENTRATIONS (PPM)
0- 6" DEPTH SOIL
IN THE
11- MILE REACH

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

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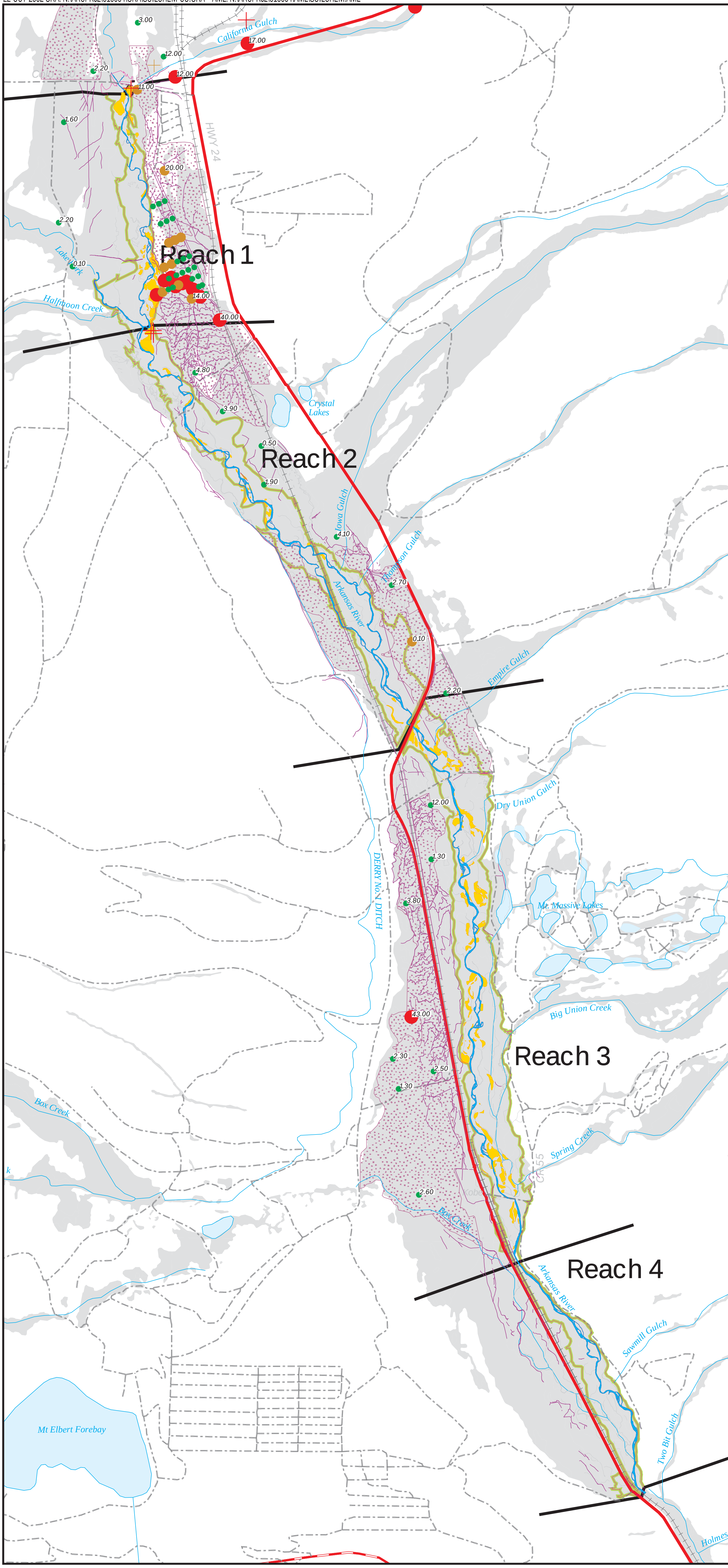

EXPLANATION

COPPER- TOTAL CONCENTRATION (ppm)
METHOD: Dry weight (total)

- Cu- Non Toxic: 0 ppm to < = 100 ppm
- Cu- Possibly Toxic: > 100 ppm to < = 150 ppm
- Cu- Toxic: > 150 ppm

METHOD: XRF

- Cu- Non Toxic: 0 ppm to < = 100 ppm
- Cu- Possibly Toxic: > 100 ppm to < = 150 ppm
- Cu- Toxic: > 150 ppm

Plant Available (AB- DTPA) Concentration (ppm)
(Shown as text near sample location)
(From Keammerer, 1987)

- Cu- Non Toxic: 0 ppm to < = 50 ppm
- Cu- Possibly Toxic: > 50 to < = 100 ppm
- Cu- Toxic: > 100 ppm

Toxicity values from: Kabata- Pendias, 2001

There are also limited soil data at depths greater than 6" at some sampling locations. These data are not shown on this plot.

Hydrology

- River or Stream
- Lake or Open Water
- 11- Mile Reach 500- Year Floodplain
- Lowland Zone - Based on presence of riparian species (CDOW Vegetation Mapping, 2001)
- Irrigated Area (SAIC, 2001)
- Drainage/Irrigation Network

Transportation

- Minor Road
- Medium Duty Road
- Highway
- Railroad

Other Features

- Mine- Waste Deposit
- Reach Boundary

EXAMPLE
8.6
Plant Available Concentration
Sample Location

N

SCALE IN FEET
3000 0 3000

UPPER ARKANSAS RIVER BASIN
SITE CHARACTERIZATION SUMMARY

FIGURE 2- 8
COPPER CONCENTRATIONS (PPM)
0- 6" DEPTH SOIL
IN THE
11- MILE REACH

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

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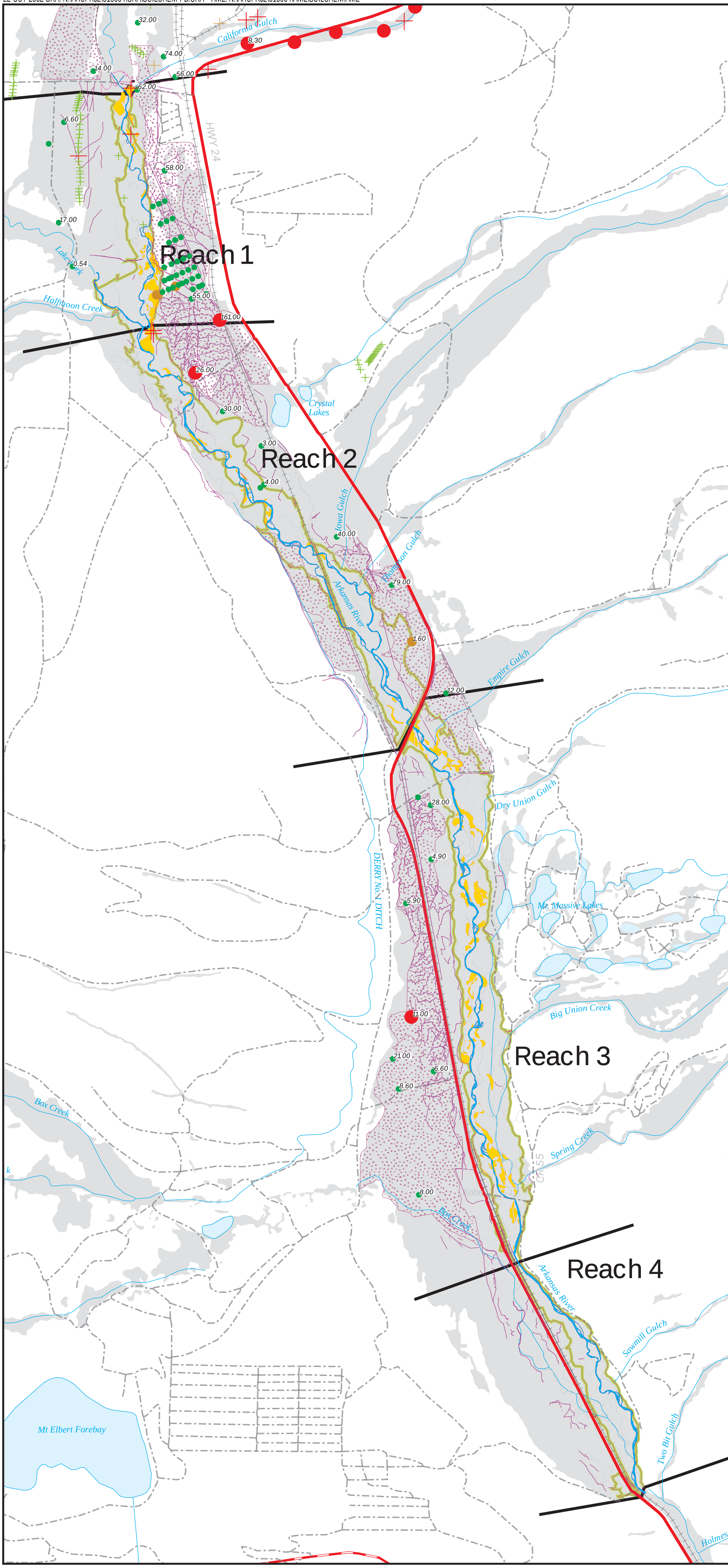


EXPLANATION

LEAD- TOTAL CONCENTRATION (ppm)
METHOD: Dry weight (total)

- Pb- Non Toxic: 0 ppm to < = 1000 ppm
- Pb- Possibly Toxic: > 1000 ppm to < = 1500 ppm
- Pb- Toxic: > 1500 ppm

METHOD: XRF

- Pb- Non Toxic: 0 ppm to < = 1000 ppm
- Pb- Possibly Toxic: > 1000 ppm to < = 1500 ppm
- Pb- Toxic: > 1500 ppm

Plant Available (AB- DTPA) Concentration (ppm)
(Shown as text near sample location)
(From Keammerer, 1987)

- Pb- Non Toxic: 0 ppm to < = 300 ppm
- Pb- Possibly Toxic: > 300 to < = 400 ppm
- Pb- Toxic: > 400 ppm

Toxicity values from: Kabata- Pendias, 2001

There are also limited soil data at depths greater than 6" at some sampling locations. These data are not shown on this plot.

Hydrology

- River or Stream
- Lake or Open Water
- 11- Mile Reach 500- Year Floodplain
- Lowland Zone - Based on presence of riparian species (CDOW Vegetation Mapping, 2001)
- Irrigated Area (SAIC, 2001)
- Drainage/Irrigation Network

Transportation

- Minor Road
- Medium Duty Road
- Highway
- Railroad

Other Features

- Mine- Waste Deposit
- Reach Boundary

EXAMPLE
8.6
Plant Available Concentration
Sample Location

N

SCALE IN FEET
3000 0 3000

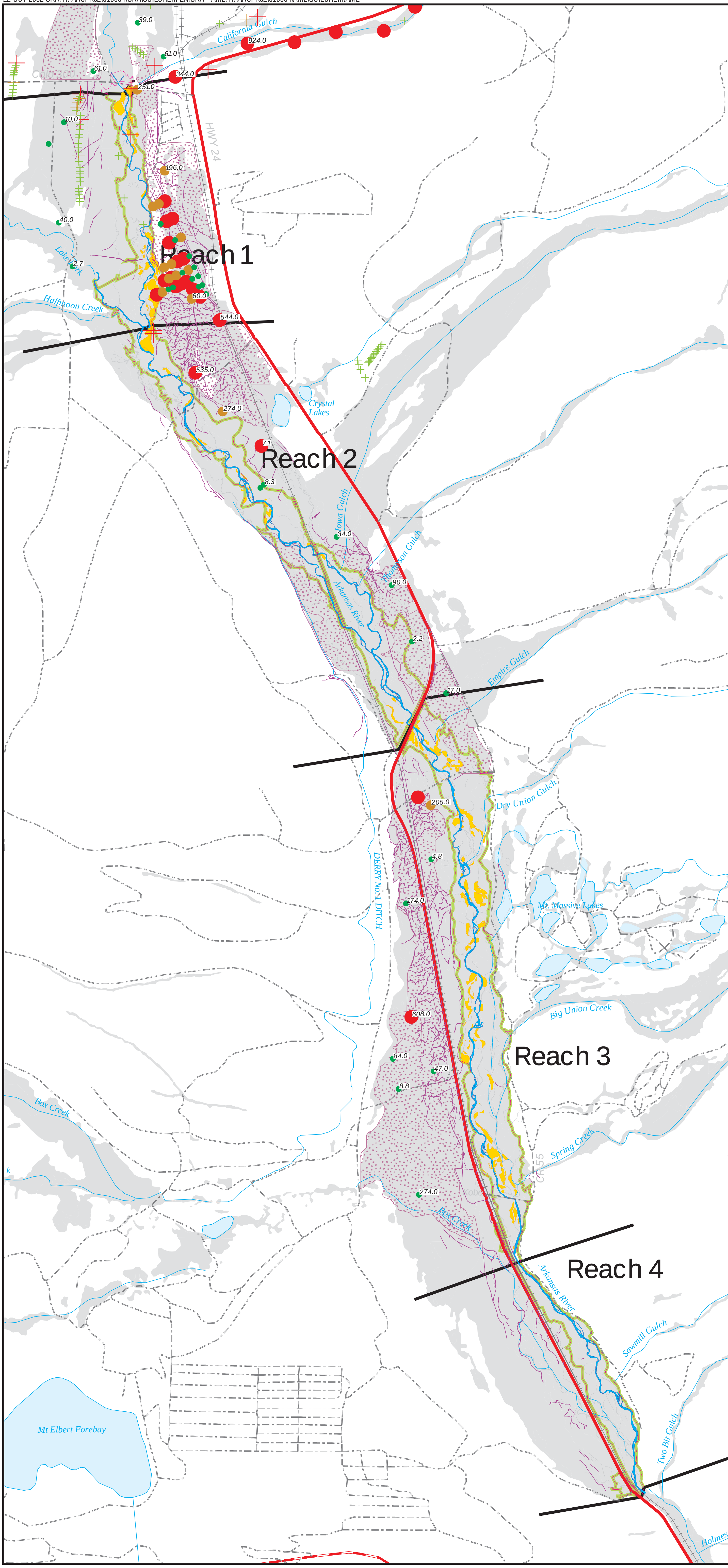
UPPER ARKANSAS RIVER BASIN
SITE CHARACTERIZATION SUMMARY

FIGURE 2- 9
LEAD CONCENTRATIONS (PPM)
0- 6" DEPTH SOIL
IN THE
11- MILE REACH

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

MFG, Inc.
consulting scientists and engineers

22-OCT-2002 GRA: N:\ARCPRJ2\010004\GRA\SOILCHEM-ZN.GRA * AML: N:\ARCPRJ2\010004\AML\SOILCHEM.AML



EXPLANATION

ZINC- TOTAL CONCENTRATION (ppm)
METHOD: Dry weight (total)

- Zn- Non Toxic: 0 ppm to < = 1000 ppm
- Zn- Possibly Toxic: > 1000 ppm to < = 1500 ppm
- Zn- Toxic: > 1500 ppm

METHOD: XRF

- Zn- Non Toxic: 0 ppm to < = 1000 ppm
- Zn- Possibly Toxic: > 1000 ppm to < = 1500 ppm
- Zn- Toxic: > 1500 ppm

Plant Available (AB- DTPA) Concentration (ppm) (Shown as text near sample location) (From Keammerer, 1987)

- Zn- Non Toxic: 0 ppm to < = 300 ppm
- Zn- Possibly Toxic: > 300 to < = 400 ppm
- Zn- Toxic: > 400 ppm

Toxicity values from:
Kabata- Pendias, 2001
Paschke, et al., 2000

There are also limited soil data at depths greater than 6" at some sampling locations. These data are not shown on this plot.

Hydrology

- River or Stream
- Lake or Open Water
- 11- Mile Reach 500- Year Floodplain
- Lowland Zone - Based on presence of riparian species (CDOW Vegetation Mapping, 2001)
- Irrigated Area (SAIC, 2001)
- Drainage/Irrigation Network

Transportation

- Minor Road
- Medium Duty Road
- Highway
- Railroad

Other Features

- Mine- Waste Deposit
- Reach Boundary

EXAMPLE
8.6
Plant Available Concentration
Sample Location

N

SCALE IN FEET
3000 0 3000

UPPER ARKANSAS RIVER BASIN
SITE CHARACTERIZATION SUMMARY

FIGURE 2- 10
ZINC CONCENTRATIONS (PPM)
0- 6" DEPTH SOIL
IN THE
11- MILE REACH

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

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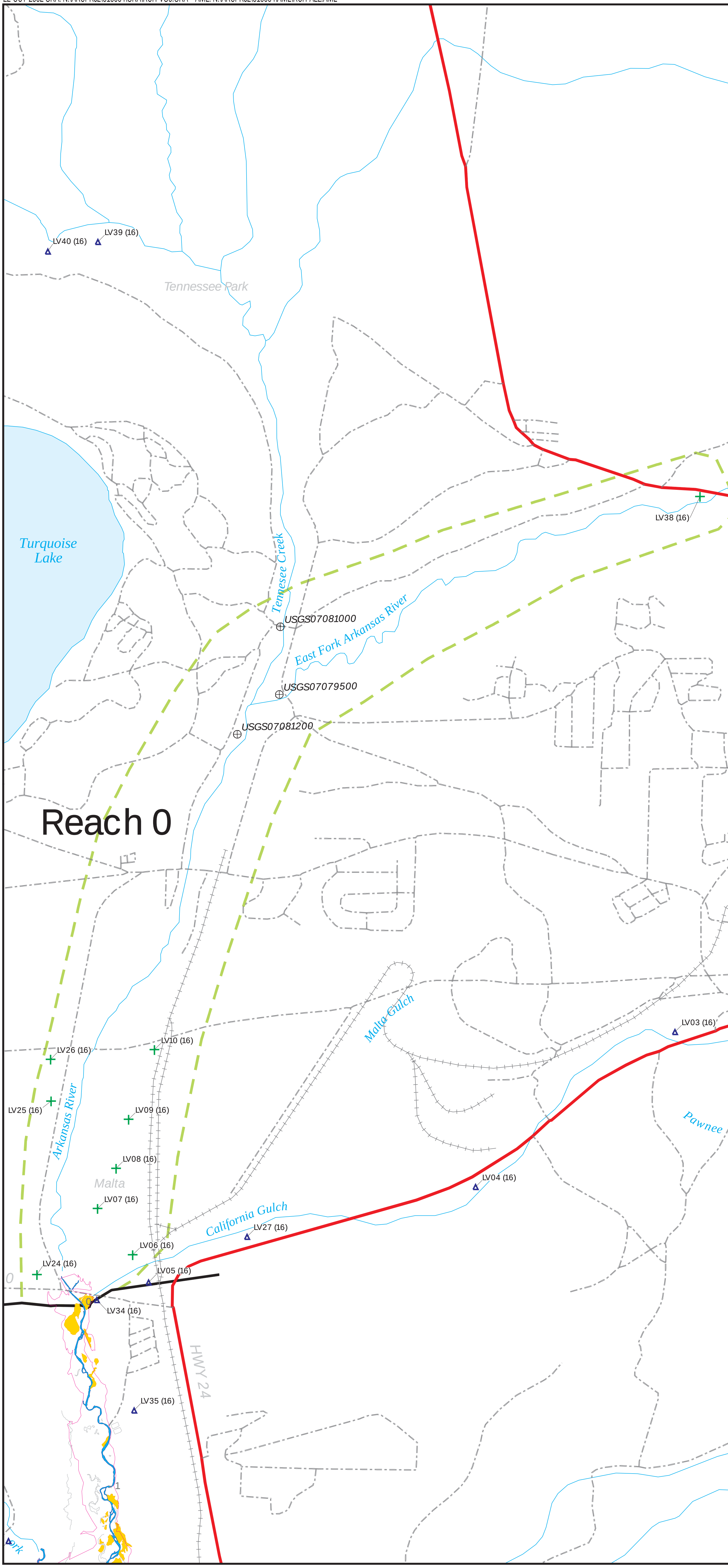

EXPLANATION

Hydrology

River or Stream

Lake or Open Water

11- Mile Reach
500- Year Floodplain

Reach 0 (Vegetation/Soil)

River Mile (from confluence with California Gulch)

Transportation

Minor Road

Medium Duty Road

Highway

Railroad

Other Features

Mine- Waste Deposit

Reach Boundary

Sampling Locations

Vegetation Sampling Location Within Reach 0

Vegetation Sampling Location Outside Reach 0

EXAMPLE

LV38 (16)

Sample Location

Site Name

Data Source(s)

Data Sources in Reach 0

(16) 1986/1987 Soil and Vegetation Metals Data; Keammerer.
[Period of record: 1987]

SCALE IN FEET

2200 0 2200

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2-11

VEGETATION SAMPLE LOCATIONS
EAST FORK CONFLUENCE
TO CALIFORNIA GULCH
(REACH 0)

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

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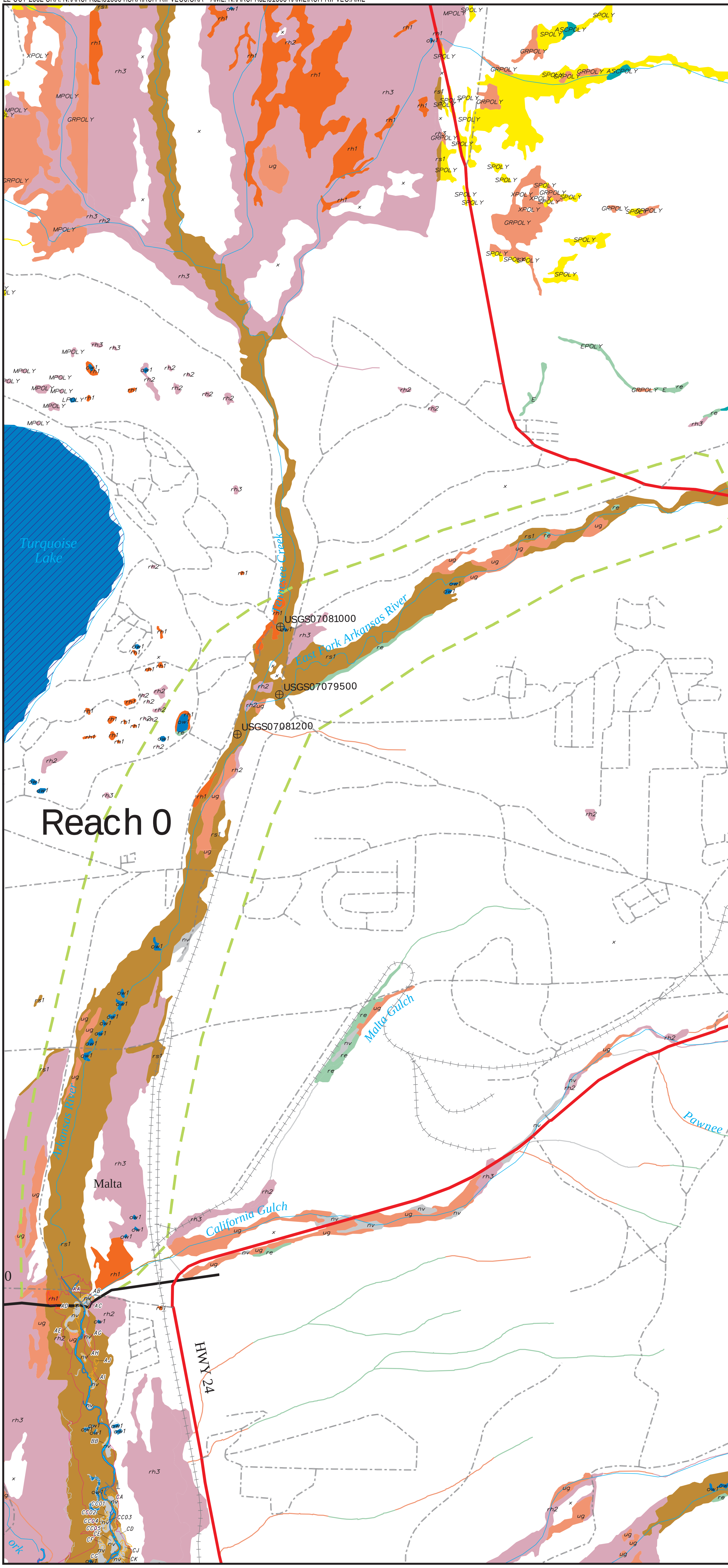

EXPLANATION

Hydrology

- River or Stream
- Lake or Open Water
- 11- Mile Reach 500- Year Floodplain
- Reach 0 (Vegetation/Soil)
- River Mile (from confluence with California Gulch)

Transportation

- Minor Road
- Medium Duty Road
- Highway
- Railroad

Other Features

- Mine- Waste Deposit
- Reach Boundary

Vegetation (CDOW, 2001)

- General Tree
- Aspen
- Cotton Wood
- Russian Olive
- Riparian Evergreen
- Riparian Shrub (general)
- Willow
- Tamarisk
- Alpine Willow
- Gambel's Oak
- Riparian Herbaceous (general)
- Riparian Herbaceous (Standing Water)
- Riparian Herbaceous (Waterlogged Soils)
- Open Water-Lentic
- Open Water-Riverine
- Open Water-Canal
- Non-Vegetated
- Sandbar
- Upland Tree
- Upland Shrub
- Upland Grass

- General Tree (rt)
- Aspen (ASA, ASB, ASC, ASAPOLY, ASBPOLY, ASCPOLY, rt1)
- Cotton Wood (COA, COAPOLY, COB, COBPOLY, COC, COCPOLY, rt2)
- Russian Olive (rt3)
- Riparian Evergreen (E, EA, EAPOLY, EB, EBPOLY, EC, ECPOLY, EPOLY, re)
- Riparian Shrub (general) (S, SPOLY, rs)
- Willow (rs1)
- Tamarisk (rs2)
- Alpine Willow (AW, AWPOLY, rs3)
- Gambel's Oak (rs4)
- Riparian Herbaceous (general) (rh)
- Riparian Herbaceous (Standing Water) (rh1)
- Riparian Herbaceous (Waterlogged Soils) (M, MPOLY, rh3, rh2)
- Open Water-Lentic (LPOLY, ow1, shw)
- Open Water-Riverine (RIVER, RIVERPOLY, STPOLY, ow2)
- Open Water-Canal (ow3)
- Non-Vegetated (NVPOLY, nv)
- Sandbar (SB, SBPOLY, sb)
- Upland Tree (ut)
- Upland Shrub (us)
- Upland Grass (GR, GRPOLY, ug)
- Urban (ct)

N

SCALE IN FEET

2200 0 2200

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2-12

RIPARIAN VEGETATION (REACH 0)

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

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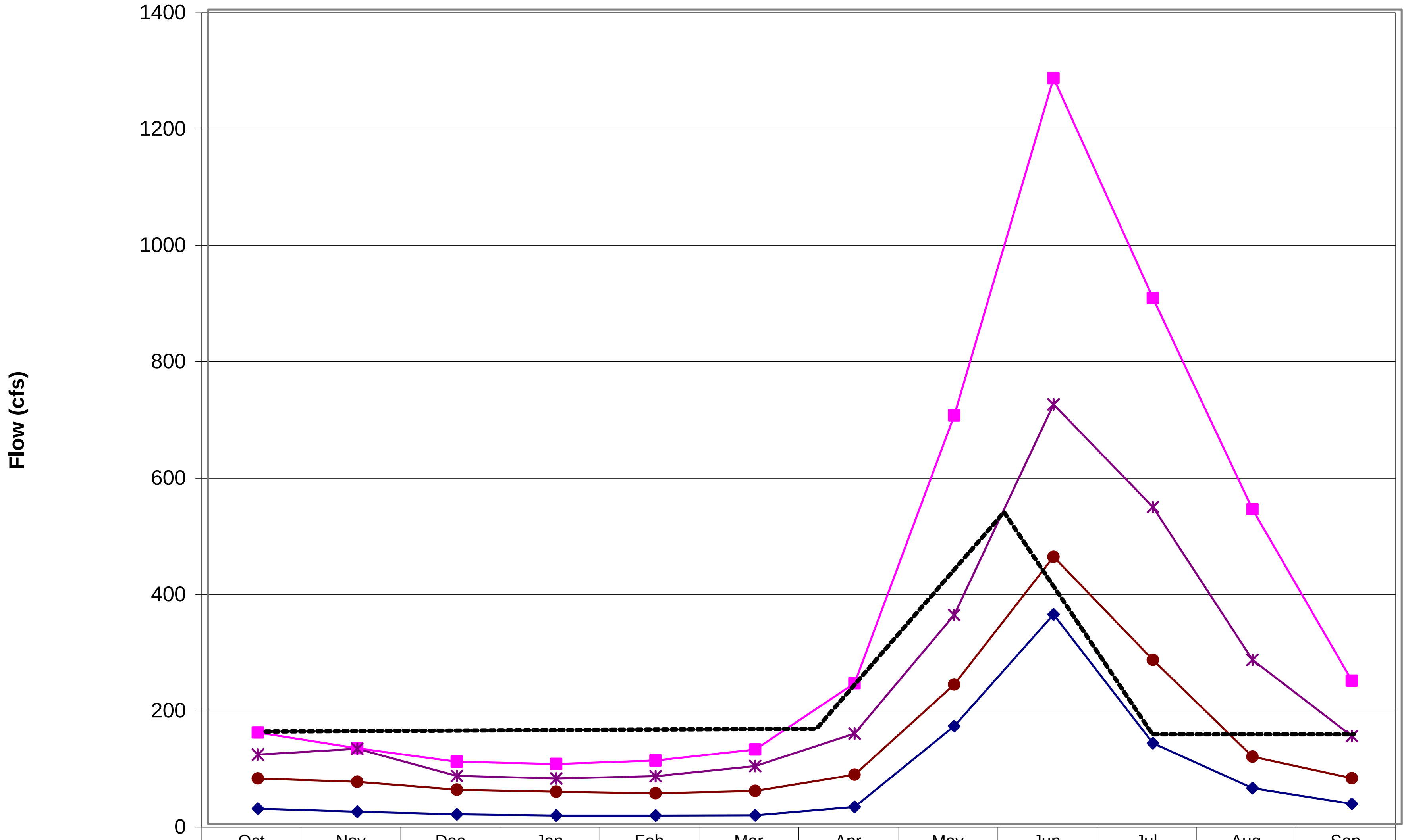


	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Leadville	26.4	21	16.4	14.6	14.3	14.9	29.1	168	360	139	61.5	34.5
Granite	157	130	107	103	109	128	242	702	1282	904	541	246
HWY 24	119.310174	129.238462	82.5558313	78.0794045	82.0599455	99.6550868	155.269231	359.399504	721.233333	544.669975	281.880893	150.976923
Below Empire	77.9354839	72.4	58.8709677	55.6129032	52.7882353	56.7956989	84.7666667	239.735537	459.458333	282.056452	115.612903	78.7166667

Time

Figure 2-13

Mean Monthly Flows in the Arkansas River and Optimal Flows for Brown Trout Based on Predicted Flows from PHABSIM

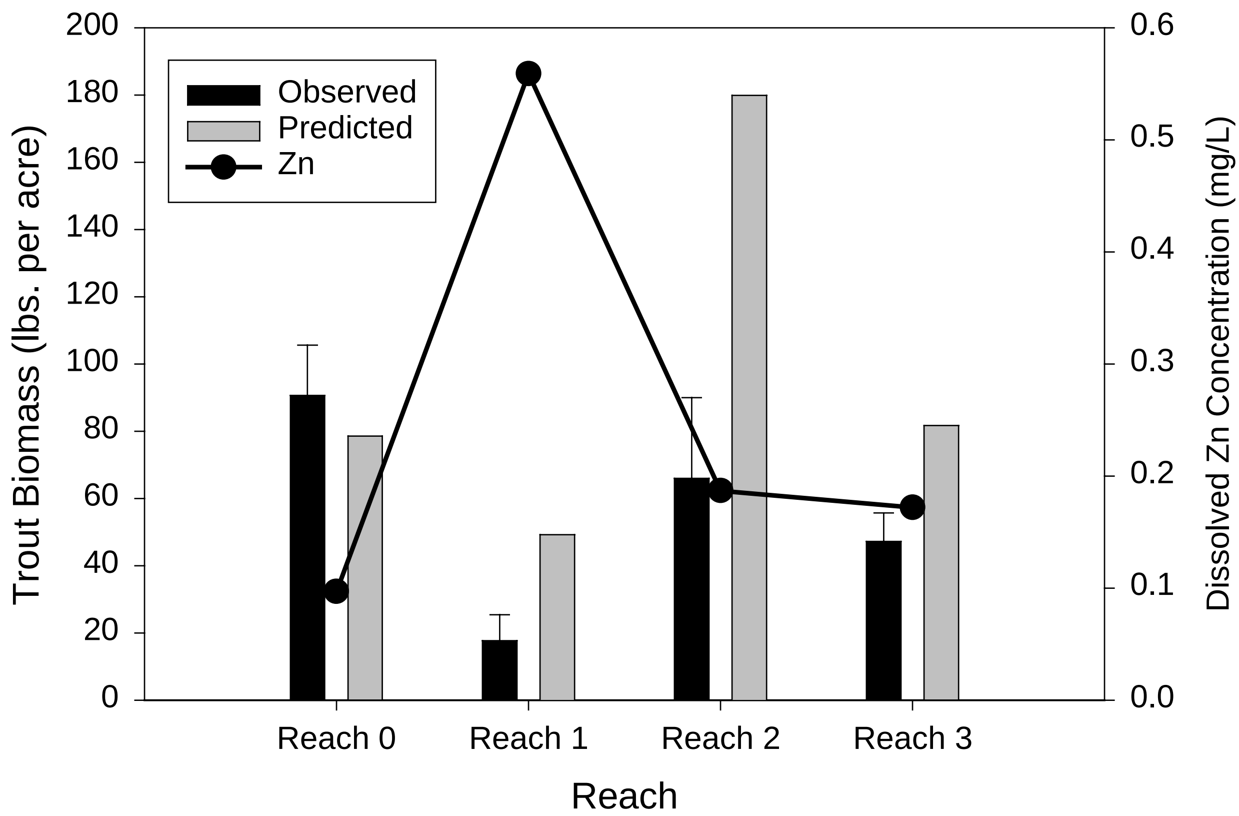


Figure 2-14

Relationship between Zn Concentrations and Observed and Predicted Brown Trout Biomass in the Upper Arkansas River Basin. Estimates of Predicted Brown Trout Biomass was Based on the HQI.

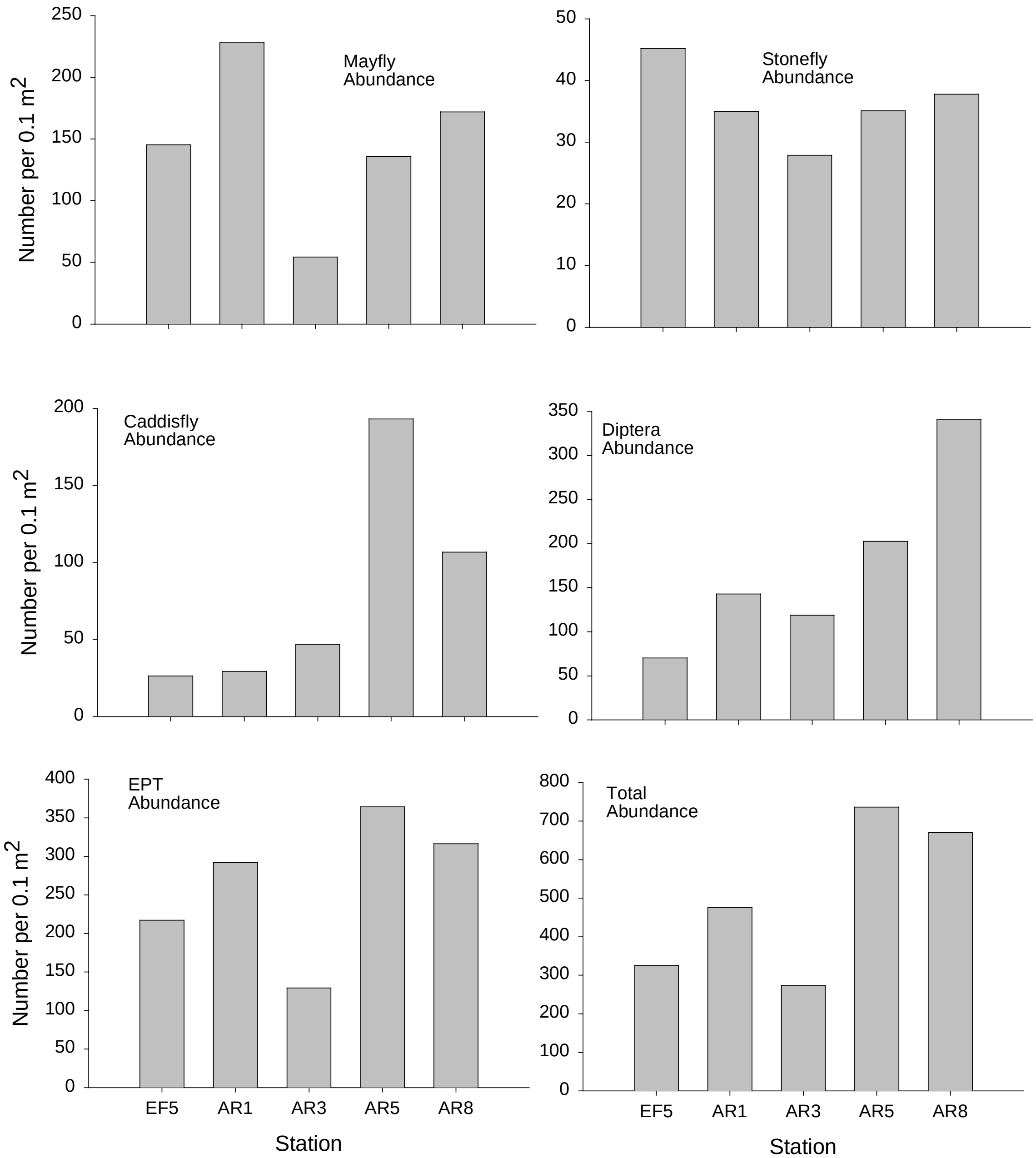


Figure 2-15

Abundance of Major Macroinvertebrate Groups Collected from Arkansas River Stations between 1989 and 1999 (All Dates Combined).

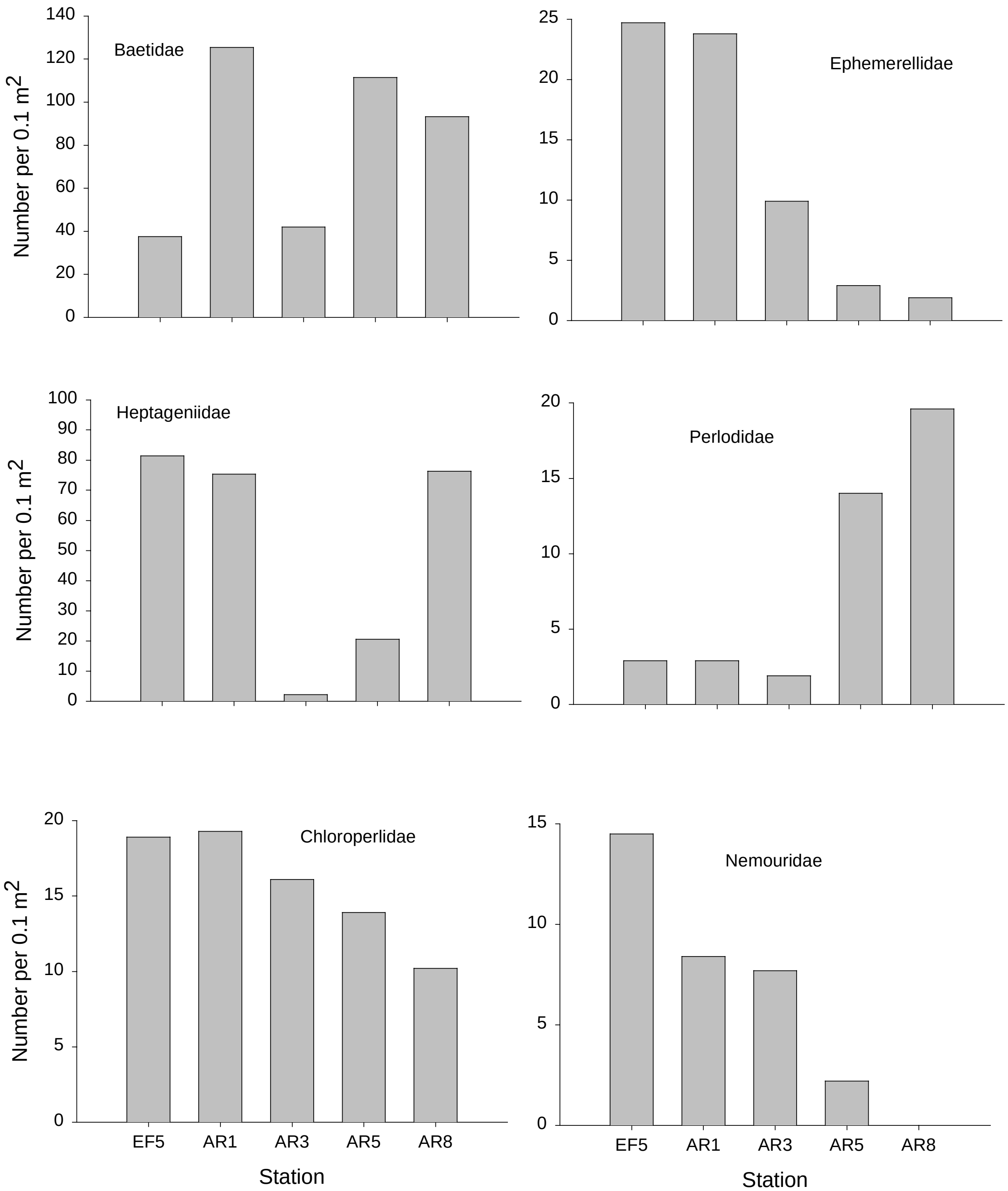


Figure 2-16

Abundance of Dominant Mayflies and Stoneflies Collected from Arkansas River Stations between 1989 and 1999 (All Dates Combined).

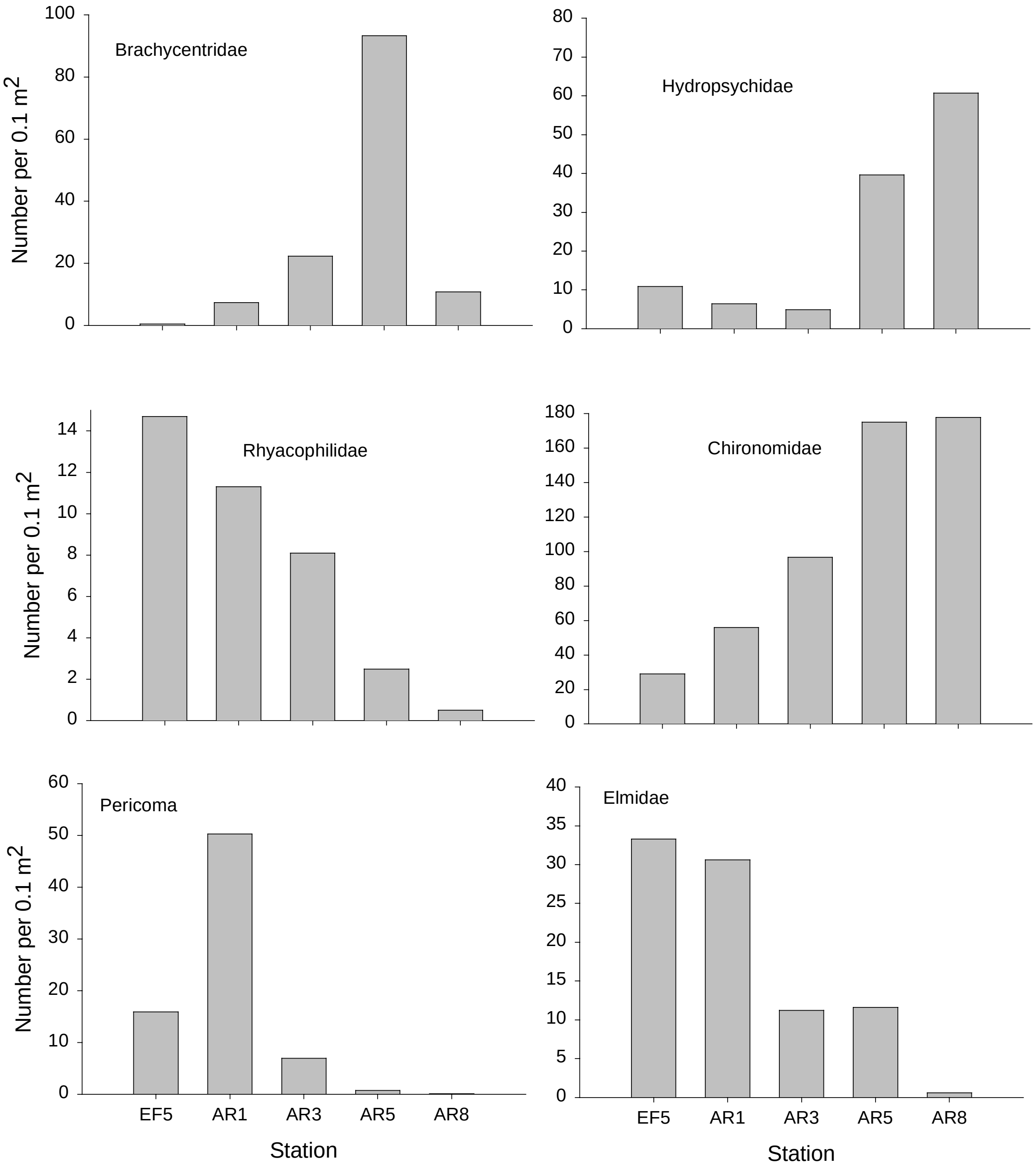


Figure 2-17

Abundance of Dominant Caddisflies, Dipterans, and Beetles Collected from Arkansas River Stations between 1989 and 1999 (All Dates Combined).

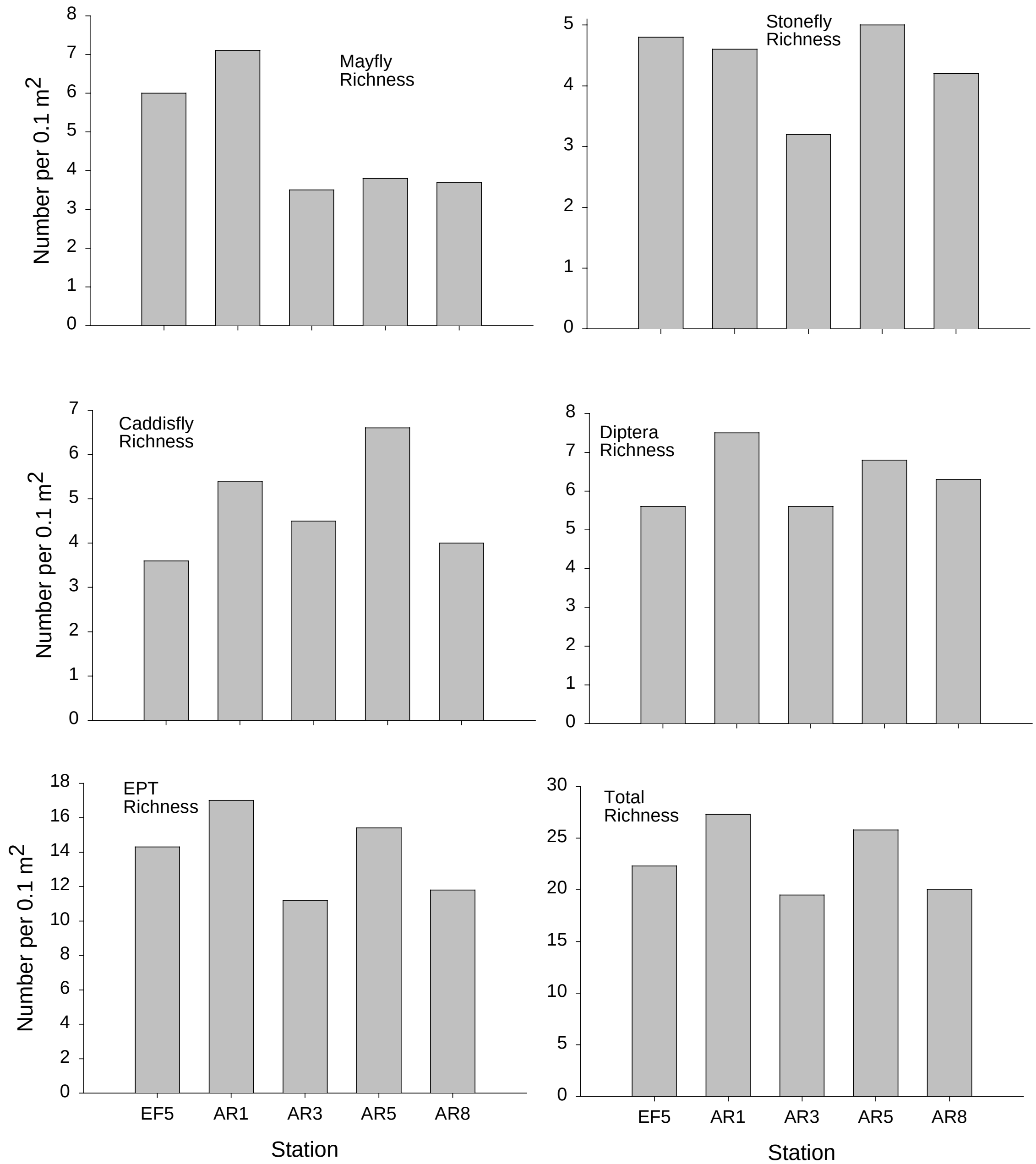


Figure 2-18

Species Richness of Benthic Macroinvertbrates Collected from Arkansas River Stations between 1989 and 1999 (All Dates Combined).

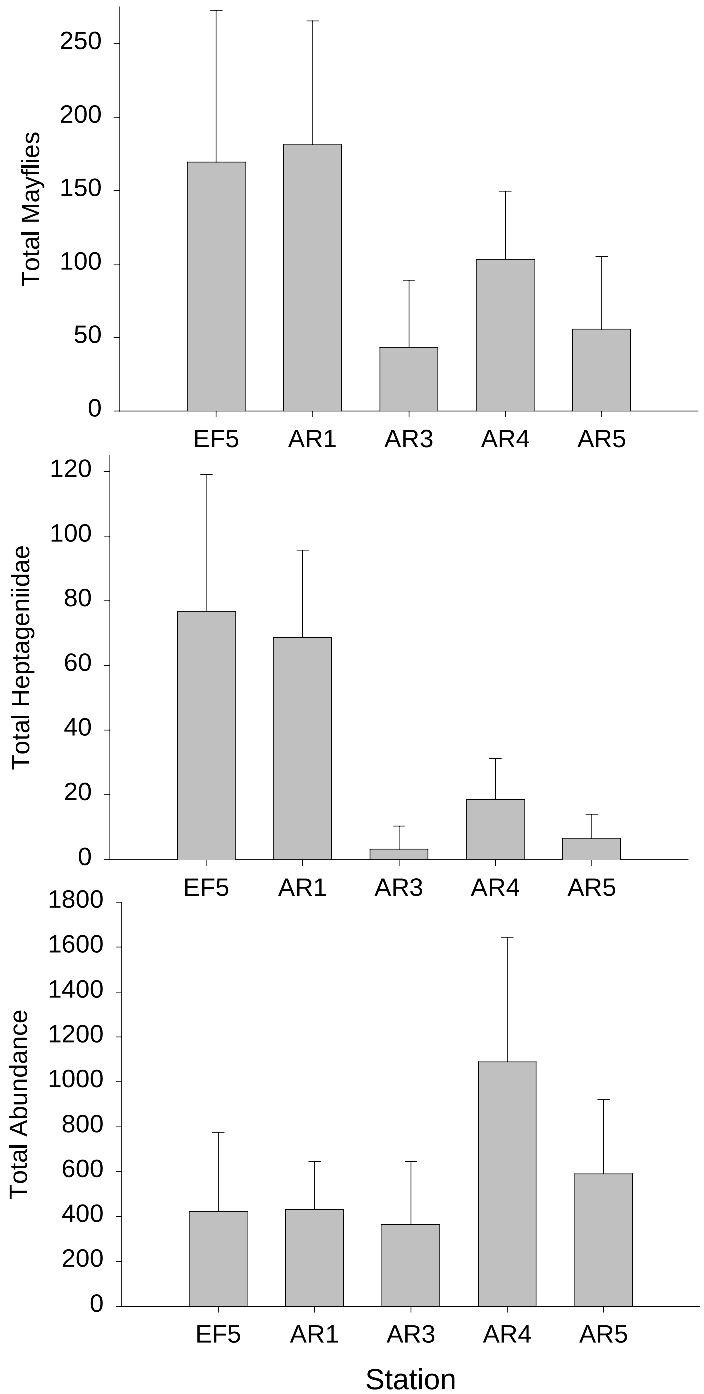


Figure 2-19

Total Number of Mayflies, Number of Heptageniidae, and Total Macroinvertebrate Abundance in the Arkansas River, 1994-1999 (All Dates Combined). Data Collected by Chadwick and Associates.

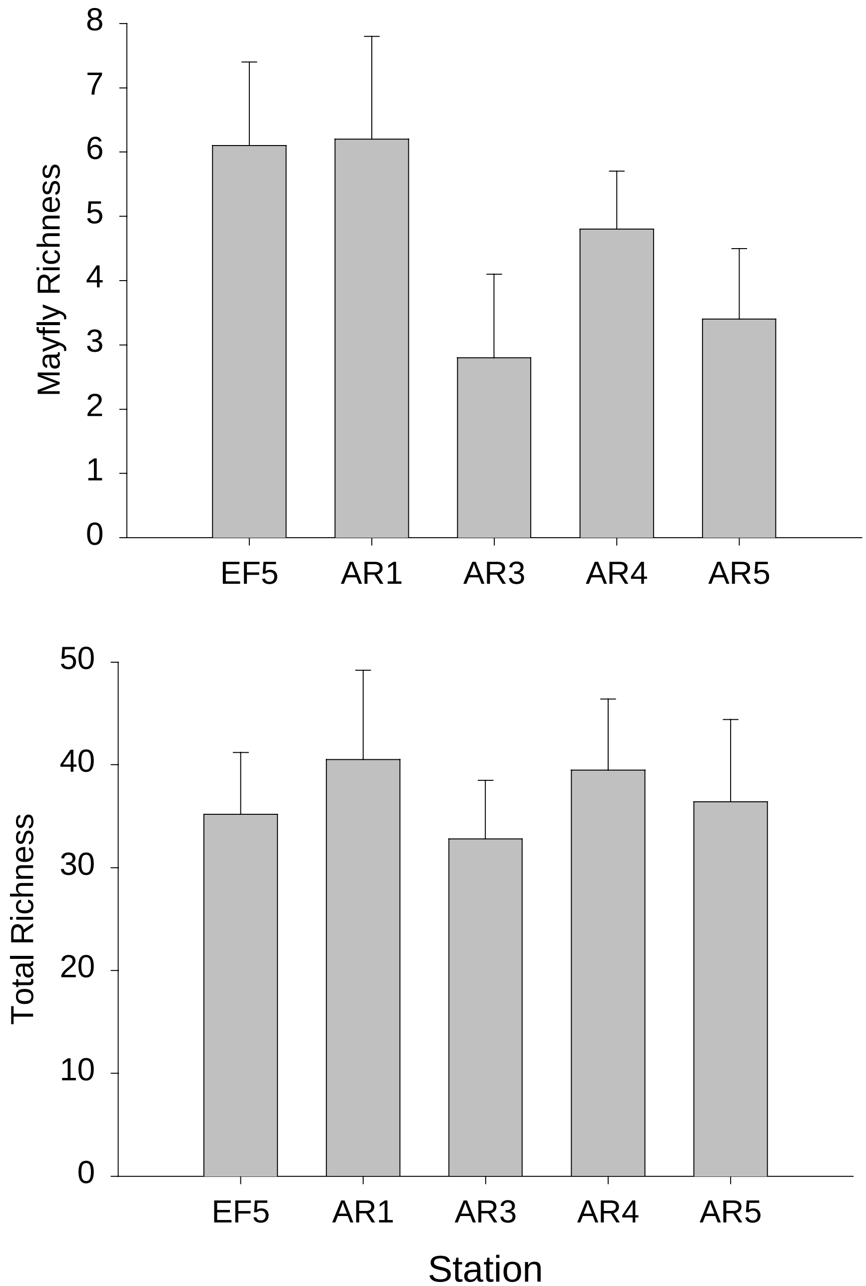


Figure 2-20

Total Species Richness and Species Richness of Mayflies in the Arkansas River, 1994-1999 (All Dates Combined). Data Collected by Chadwick and Associates.

Reach 0 (Station EF5)

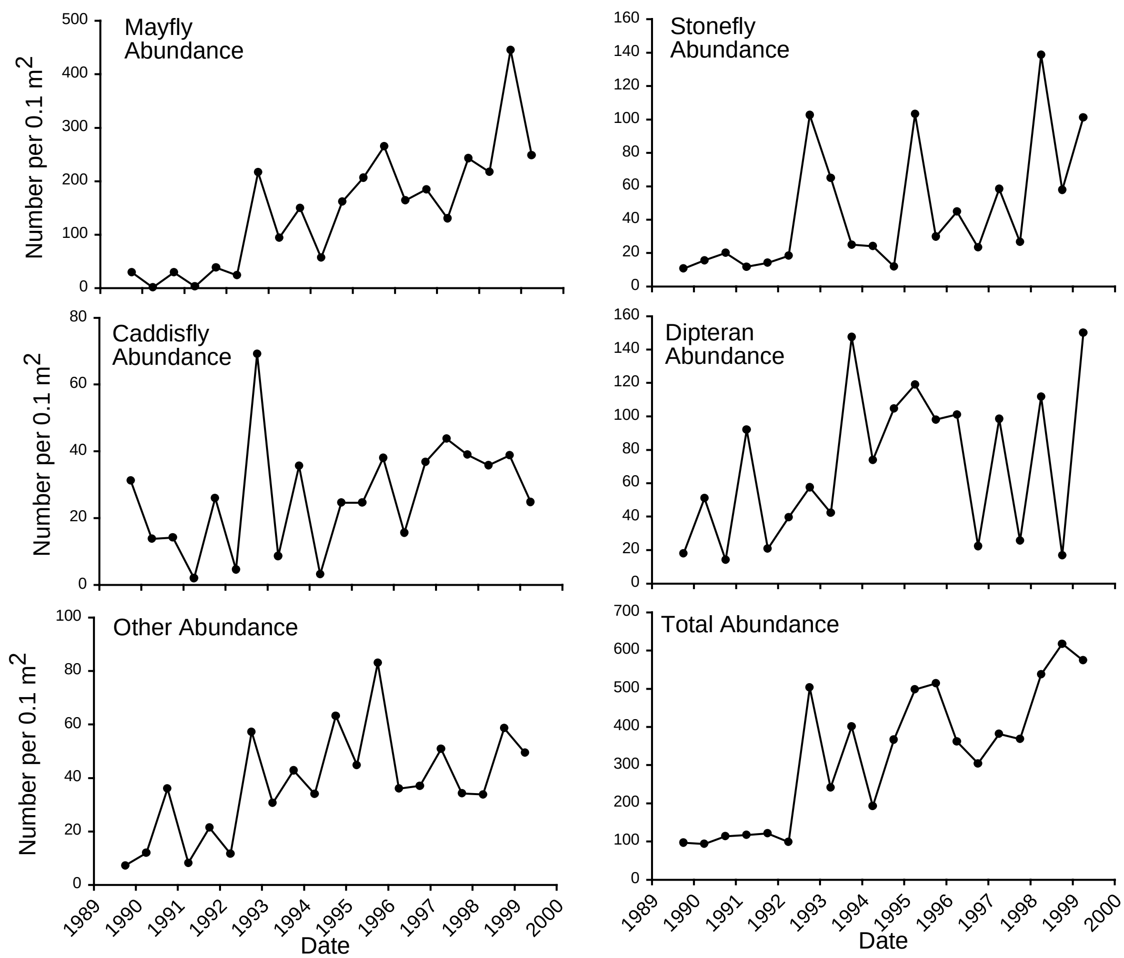


Figure 2-21

Abundance of Major Macroinvertebrate Groups in the Arkansas River (Reach 0, Station EF-5).

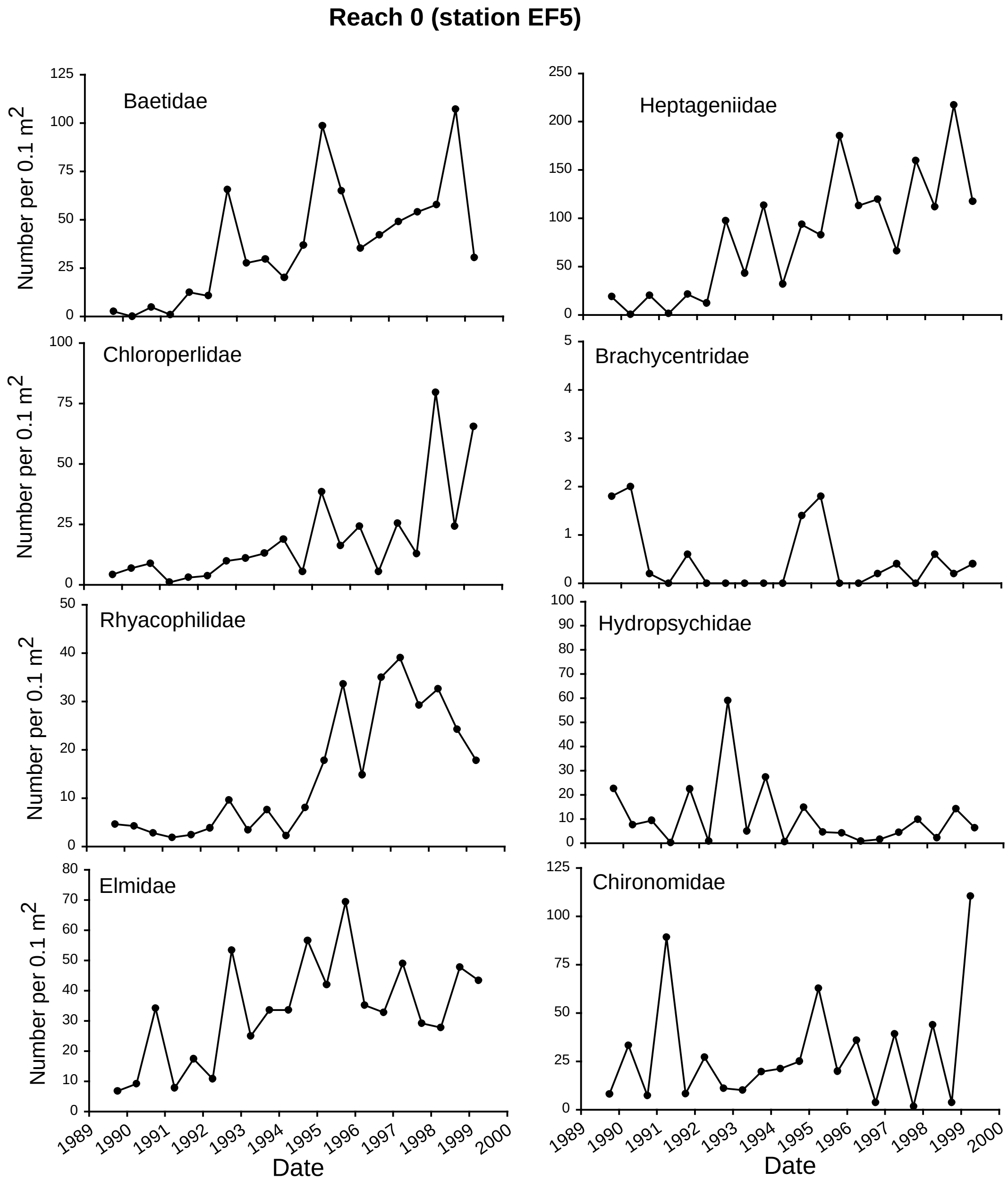


Figure 2-22

Abundance of Dominant Macroinvertebrate Taxa in the Arkansas River (Reach 0, Station EF-5).

Reach 0 (Station EF5)

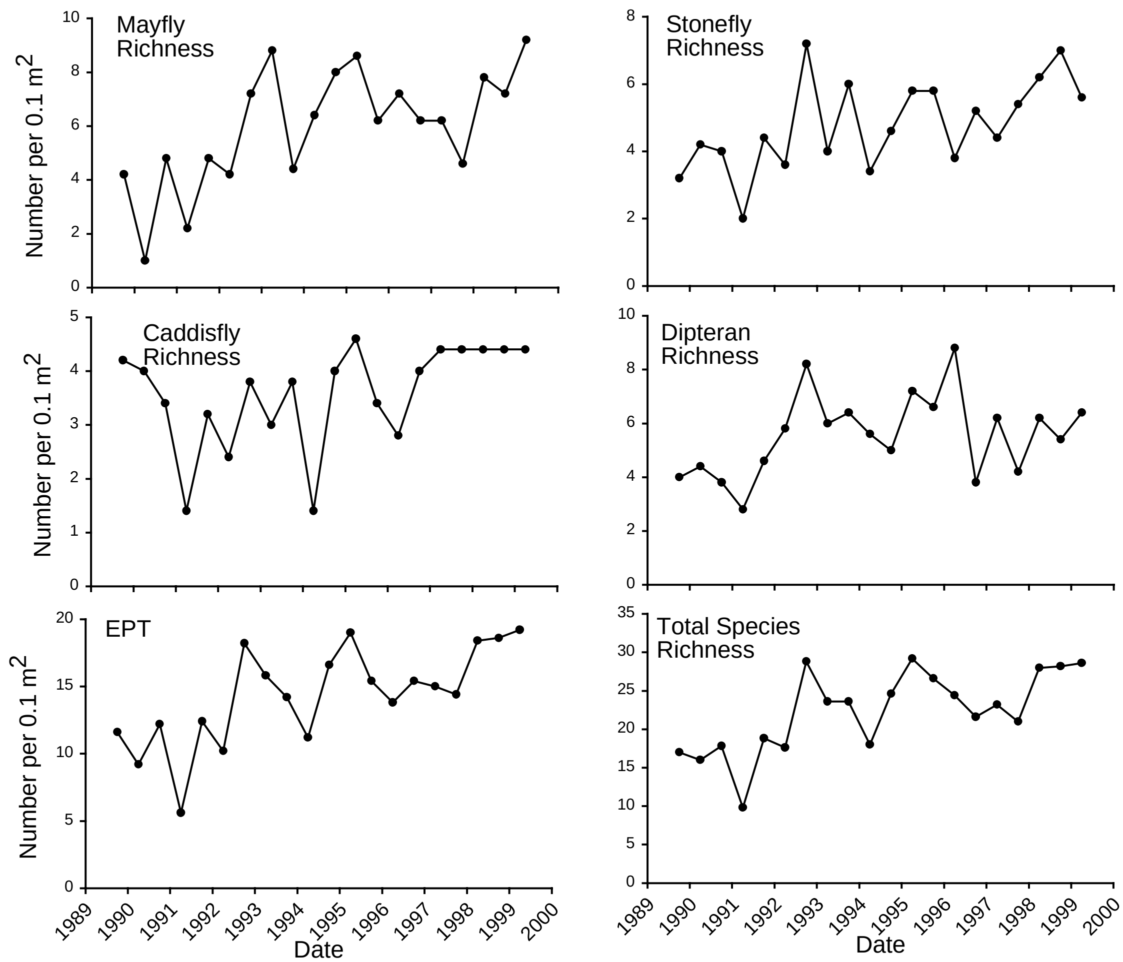


Figure 2-23

Species Richness of Major Macroinvertebrate Groups in the Arkansas River (Reach 0, Station EF-5).

Reach 0 (Station AR1)

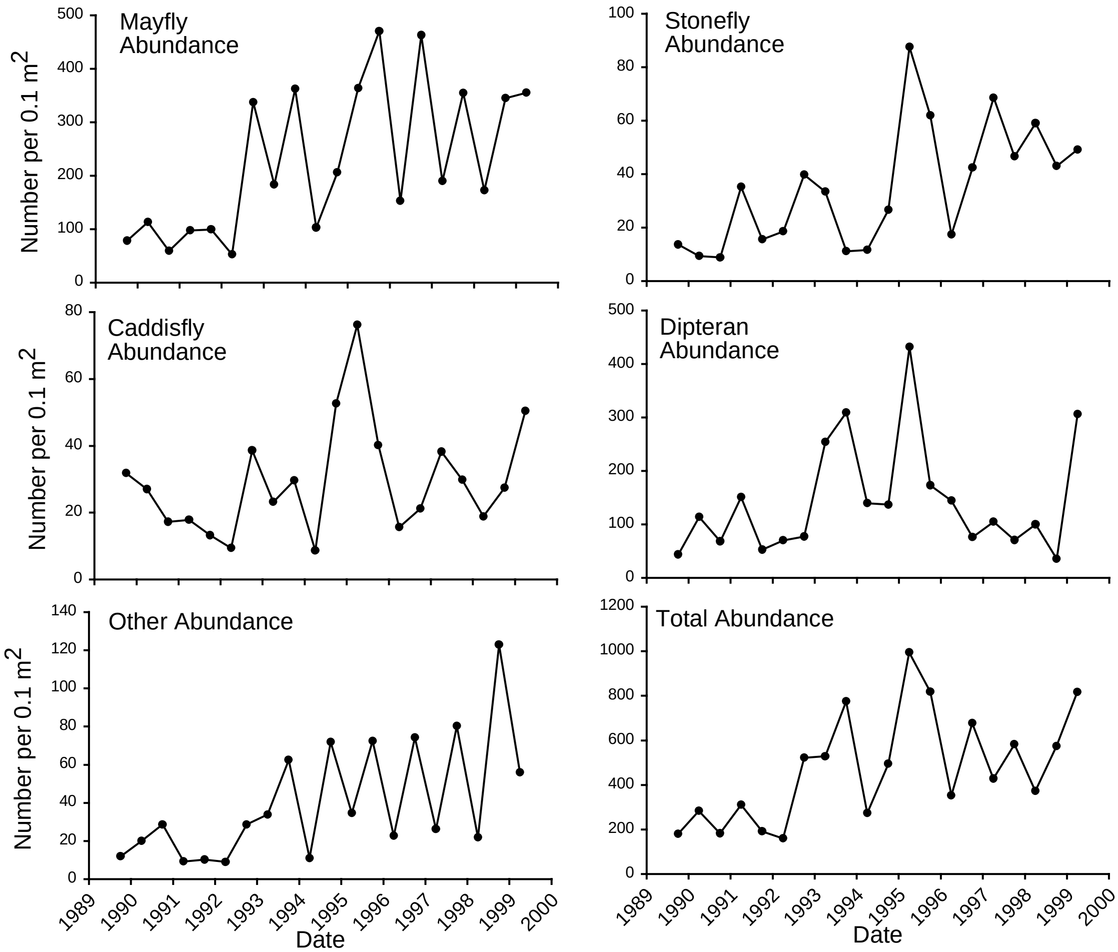


Figure 2-24

Abundance of Major Macroinvertebrate Groups in the Arkansas River (Reach 0, Station AR-1).

Reach 0 (station AR1)

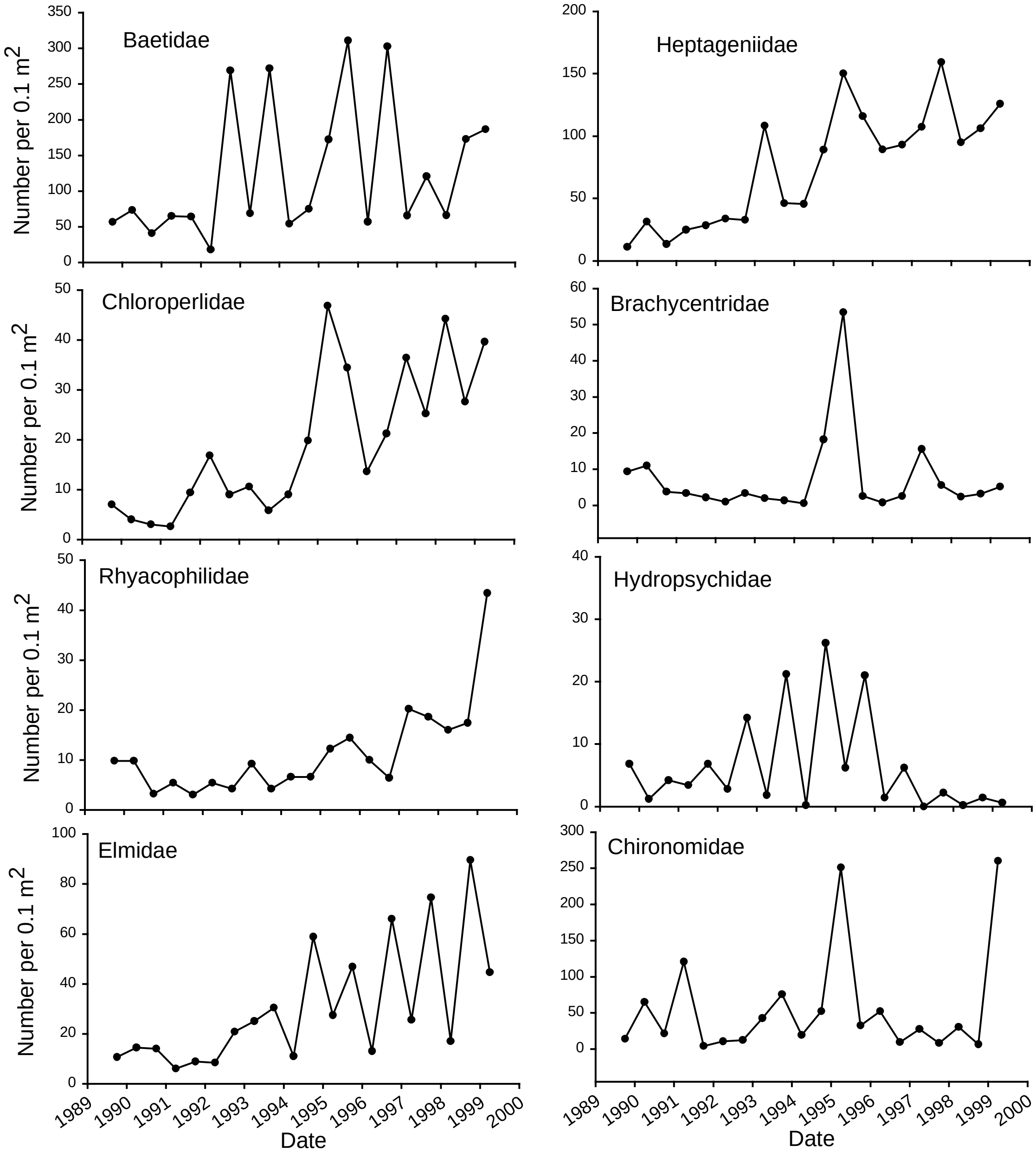


Figure 2-25

Abundance of Dominant Macroinvertebrate Taxa in the Arkansas River (Reach 0, Station AR-1).

Reach 0 (Station AR1)

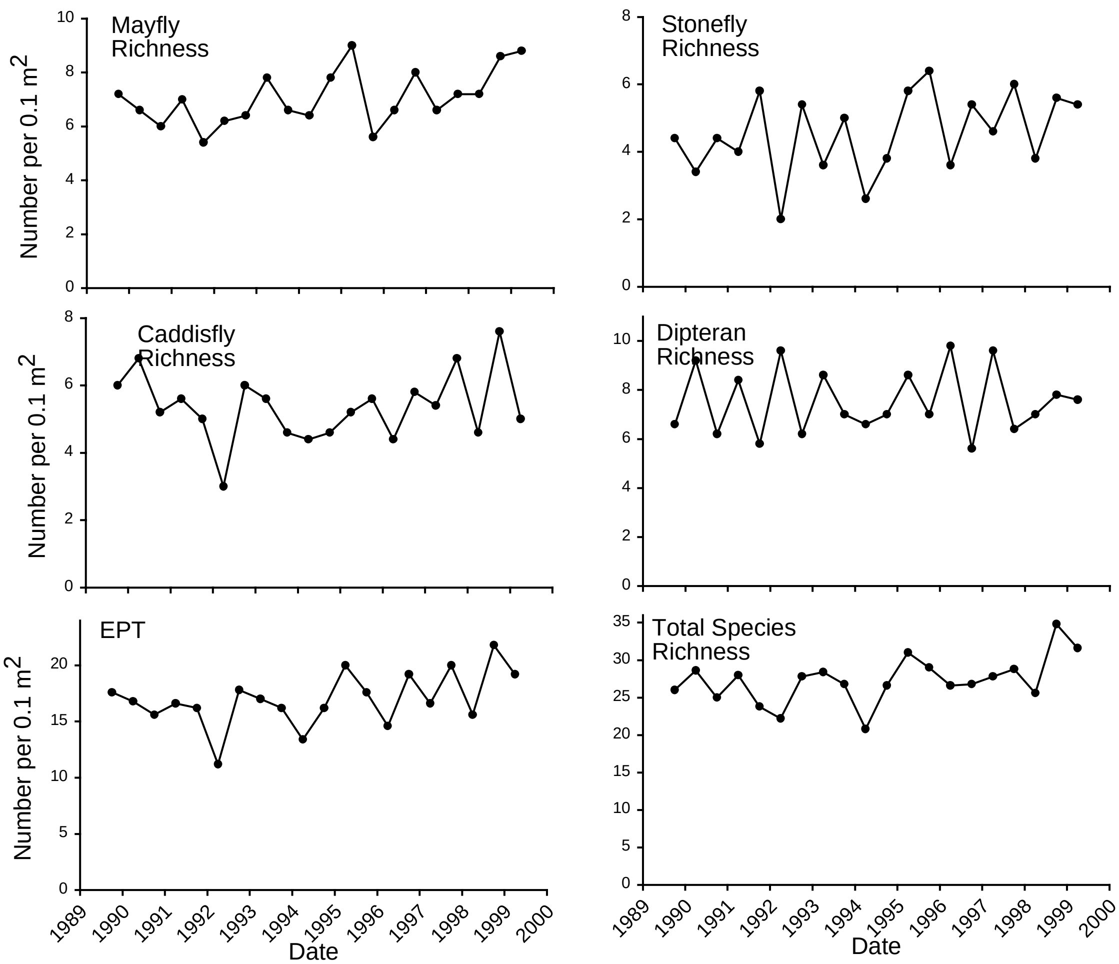


Figure 2-26

Species Richness of Major Macroinvertebrate Groups in the Arkansas River (Reach 0, Station AR-1).

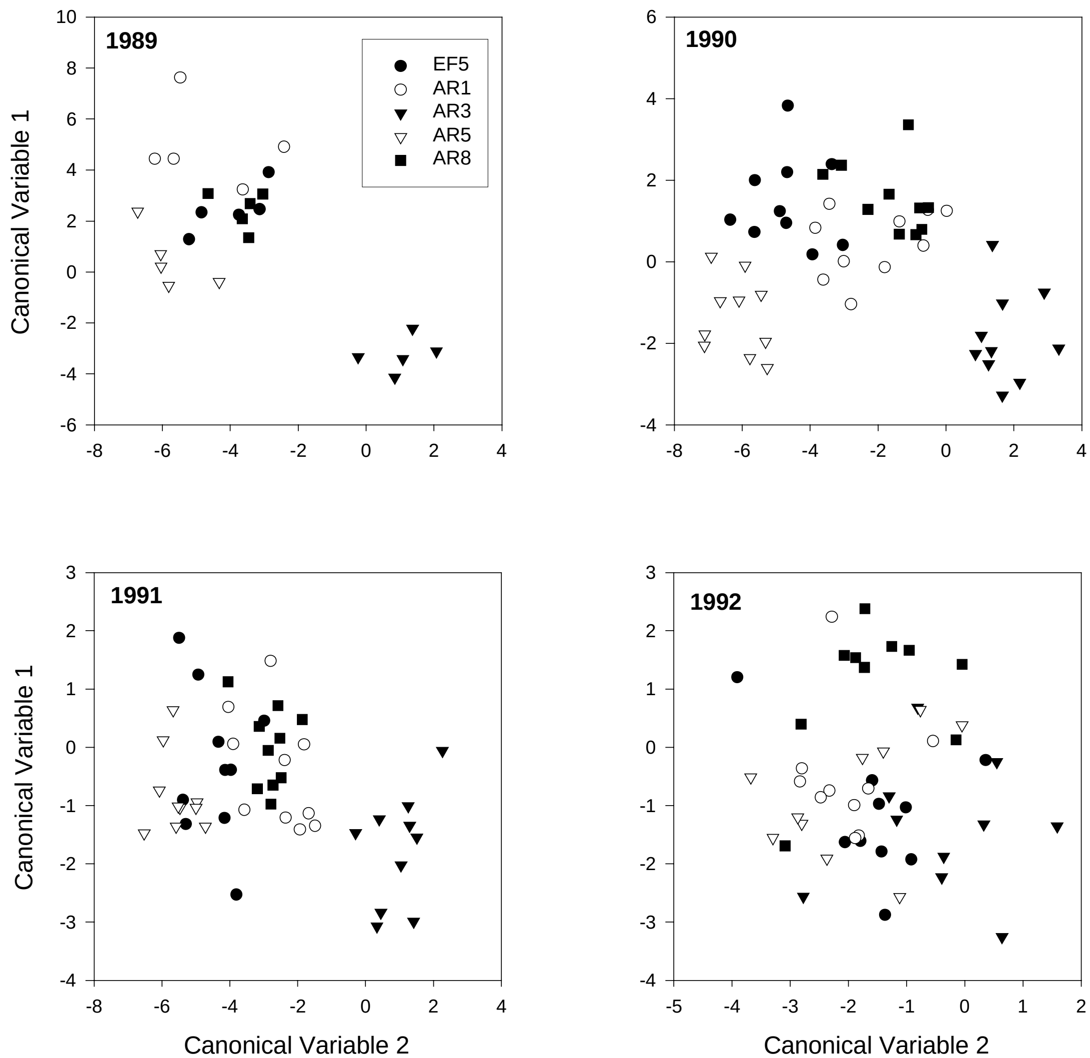


Figure 2-27

Multivariate Analysis of Benthic Community Responses to Metals in the Arkansas River before Treatment of the Leadville Mine Drainage Tunnel and California Gulch (1989 to 1992) [1]

[1] The analysis is based on the abundance of the 12 dominant taxa collected.

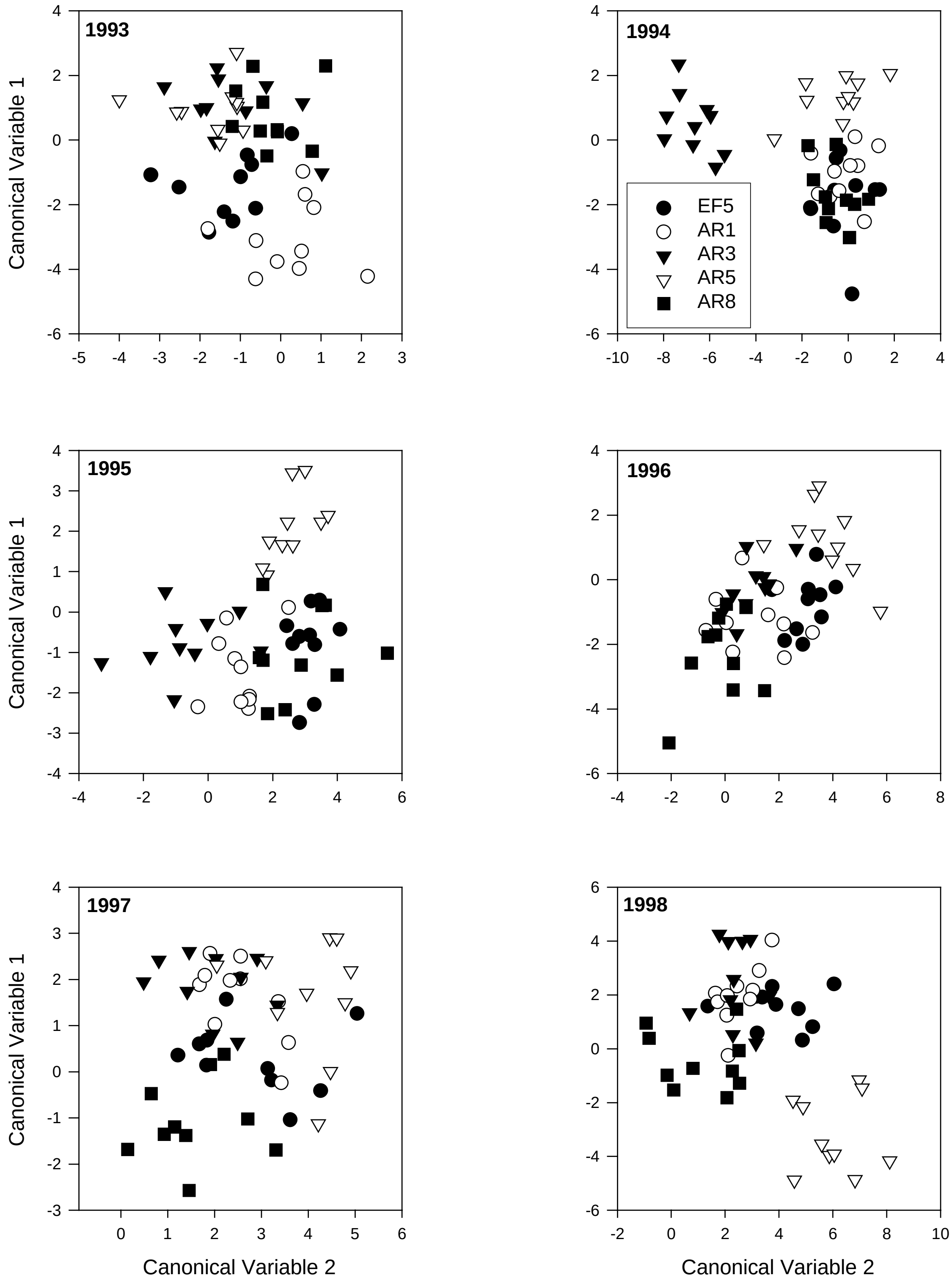


Figure 2-28

Multivariate Analysis of Benthic Community Responses to Metals in the Arkansas River after Treatment of Leadville Mine Drainage Tunnel and California Gulch (1993 to 1998) [1]

---

[1] The analysis is based on the abundance of the 12 dominant taxa collected.

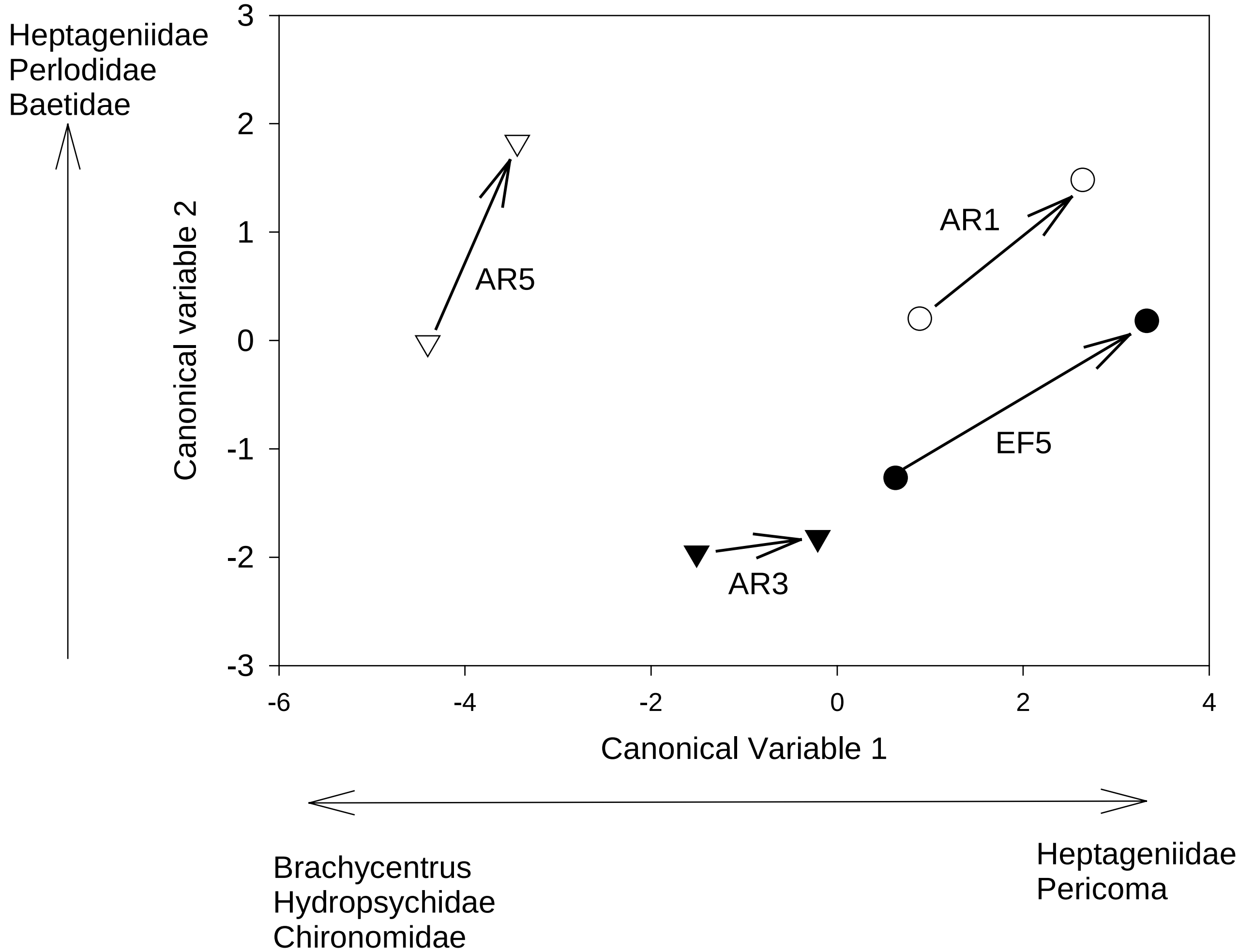


Figure 2-29

Multivariate Analysis of Benthic Community Responses to Improvements in Water Quality [1]

---

[1] The arrows in the box show directional changes in canonical space before (1989-1992) and after (1993-1998) remediation. The dominant taxa responsible for these changes along each canonical axis are also shown.

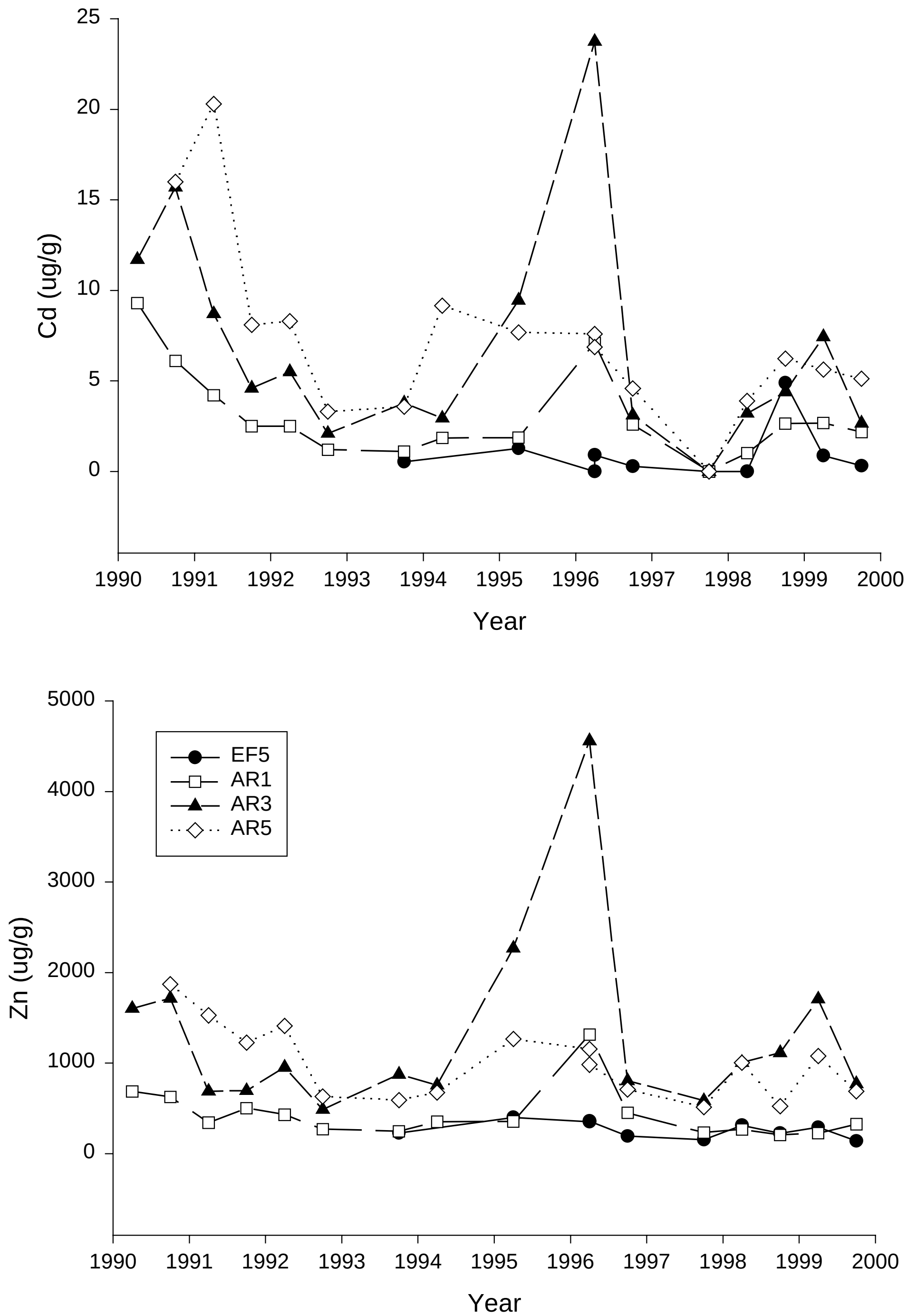


Figure 2-30

Metal Concentrations in the Caddisfly *Arctopsyche grandis* Collected from Reach 0 (EF-5, AR-1), Reach 1 (AR-3), and Reach 3 (AR-5) between 1990 and 1999.

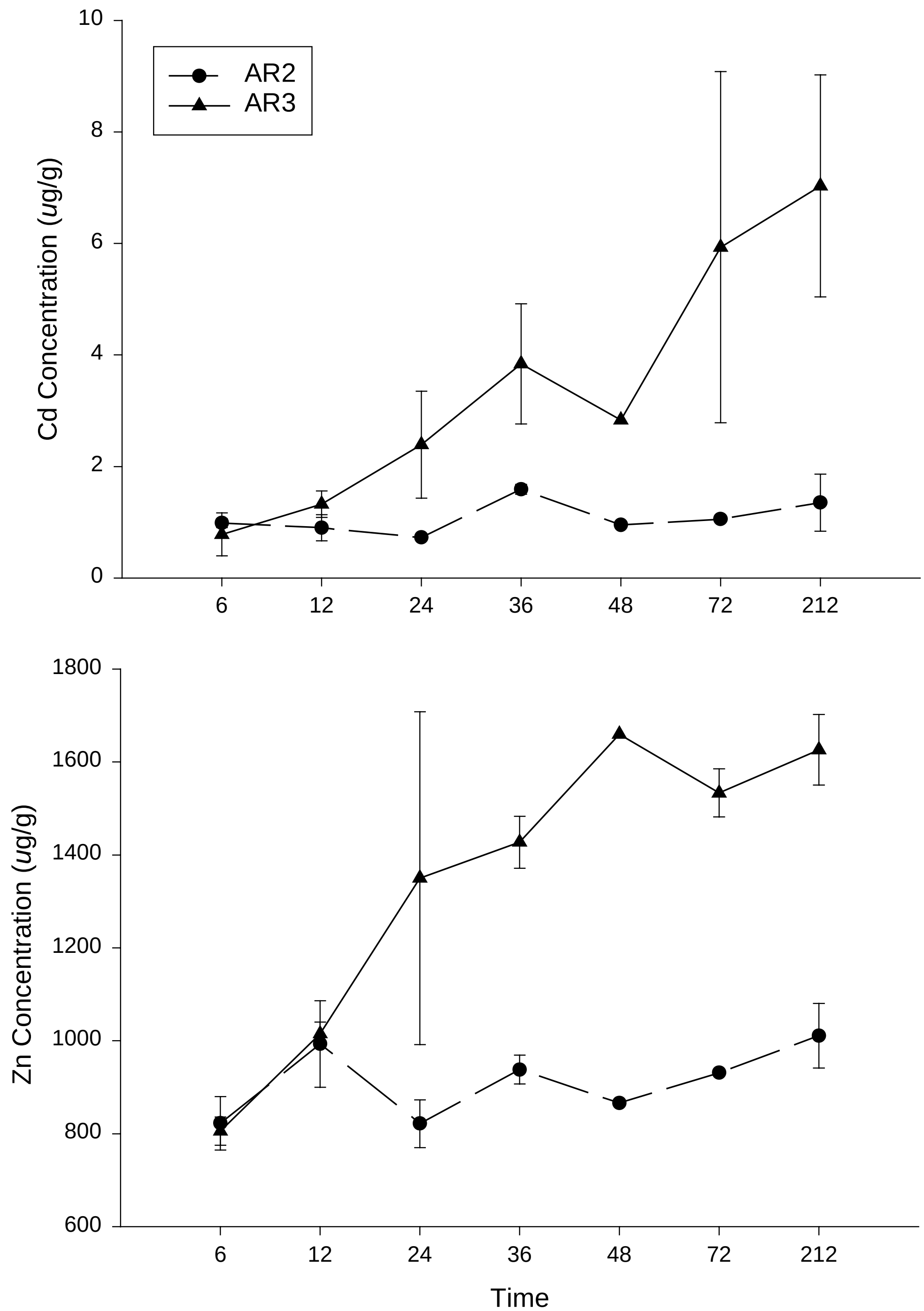


Figure 2-31

Uptake of Heavy Metals by the Caddisfly *Brachycentrus americanus* Exposed to Metals in Reach 0 (AR-2) and Reach 1 (AR-3).

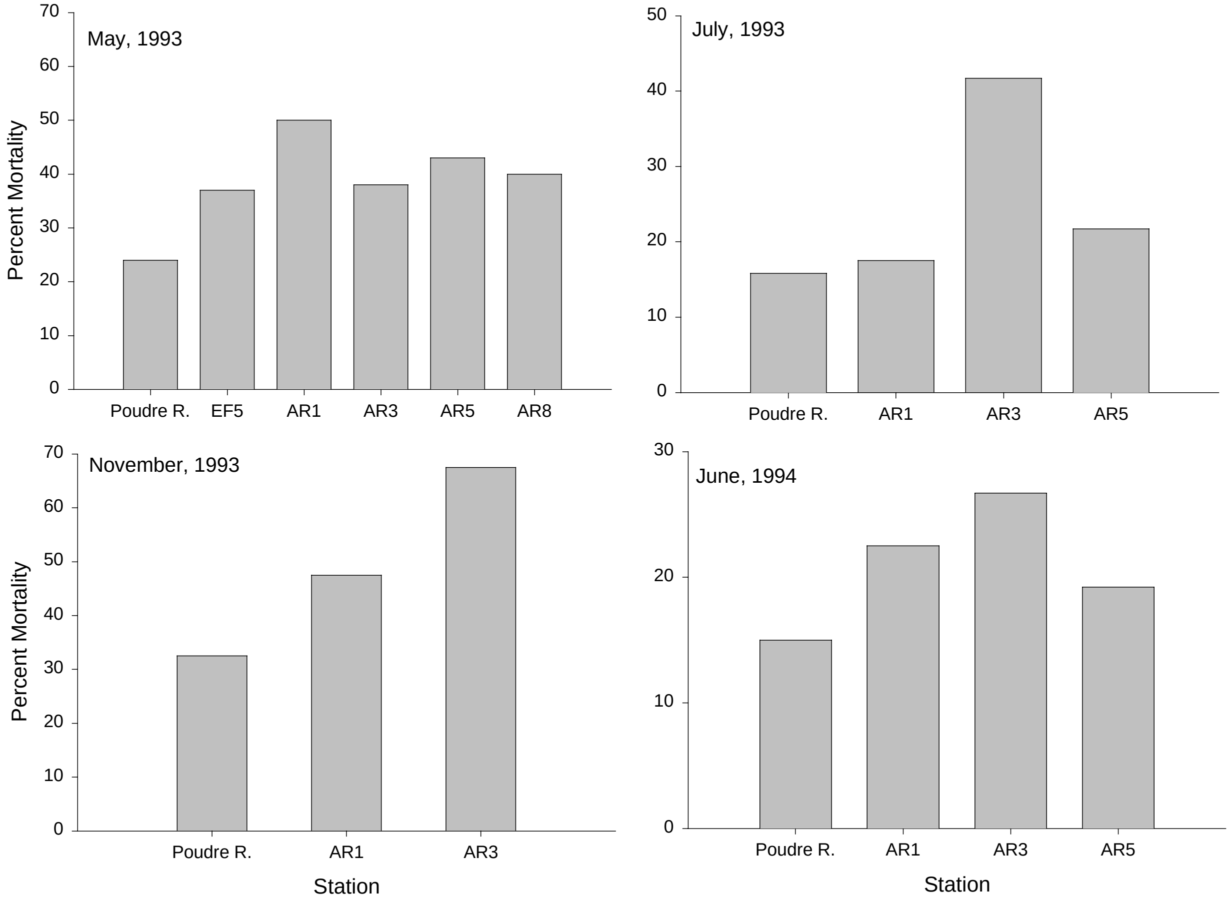


Figure 2-32

Mortality of *Chironomus riparius* Exposed to Sediments from Reach 0 (EF-5, AR-1), Reach 1 (AR-3), and Reach 3 (AR-5). Data from a Reference Site (Cache la Poudre River) and a Site below the 11-Mile Reach are Shown for Comparison.

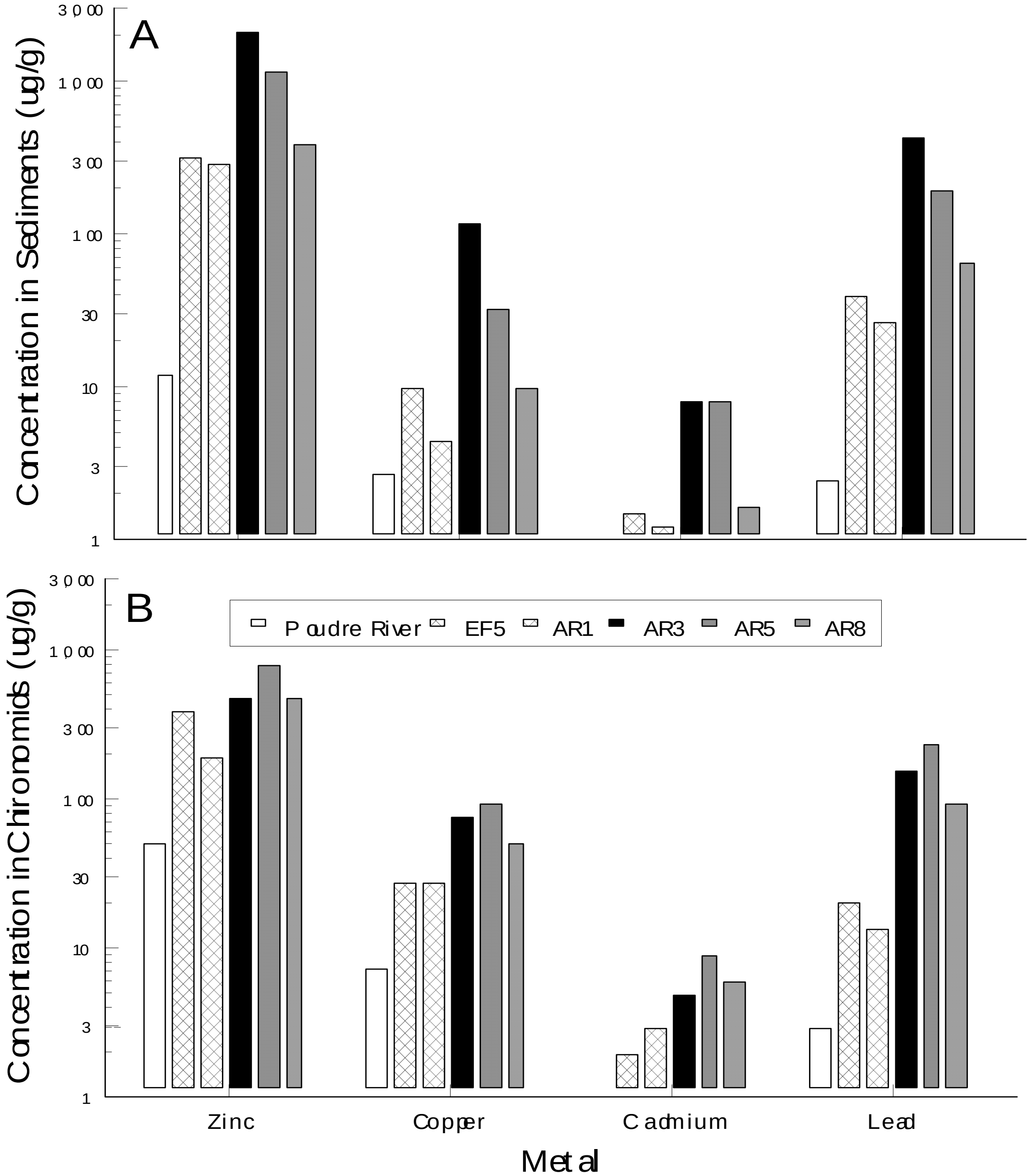


Figure 2-33

A. Concentrations of Heavy Metals in Sediments Collected from the Arkansas River.
B. Concentrations of Heavy Metals in Chironomids Exposed to Sediments Collected from the Arkansas River.

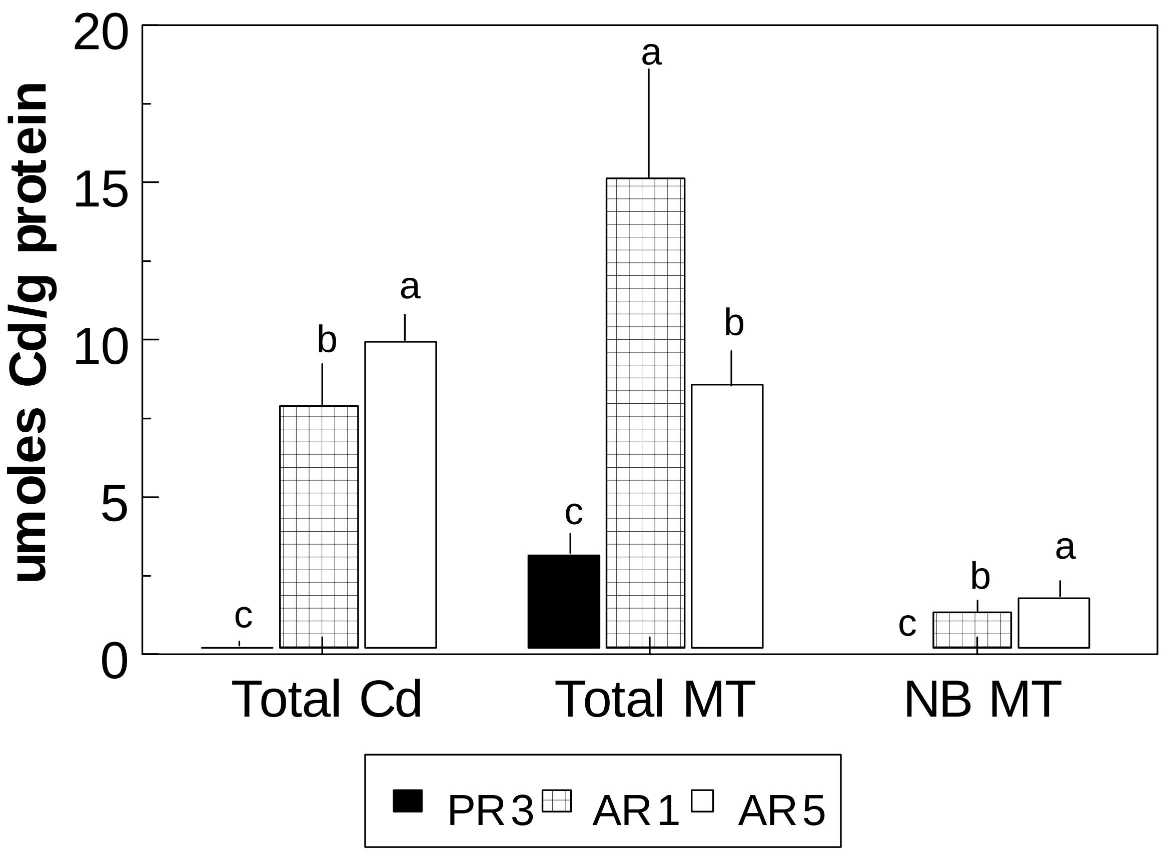


Figure 2-34

Levels of Metallothionein in Mayflies Collected from the Arkansas River.

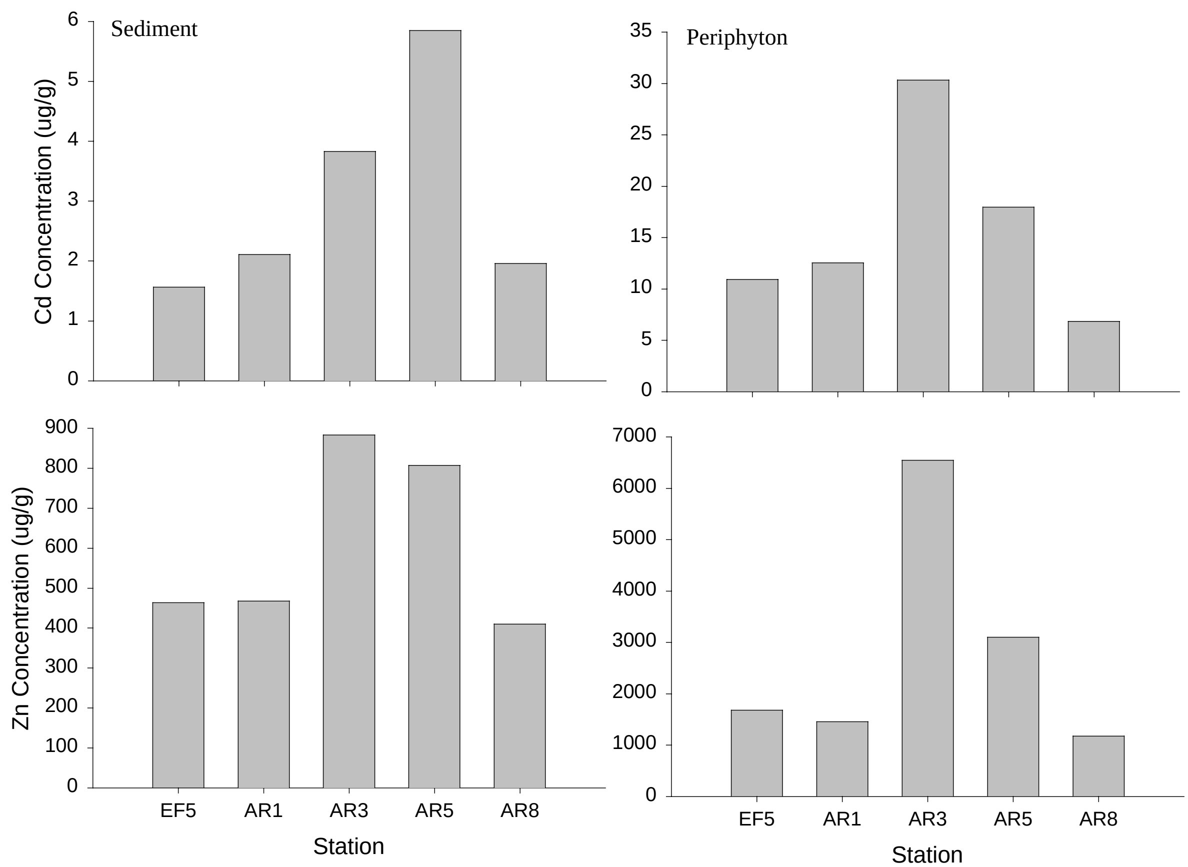


Figure 2-35

Cd and Zn Concentrations Measured in Sediment and Periphyton from Reach 0 (EF-5, AR-1), Reach 1 (AR-3), and Reach 3 (AR-5). These Values are Compared to Data Collected below the 11-Mile Reach (AR-8).

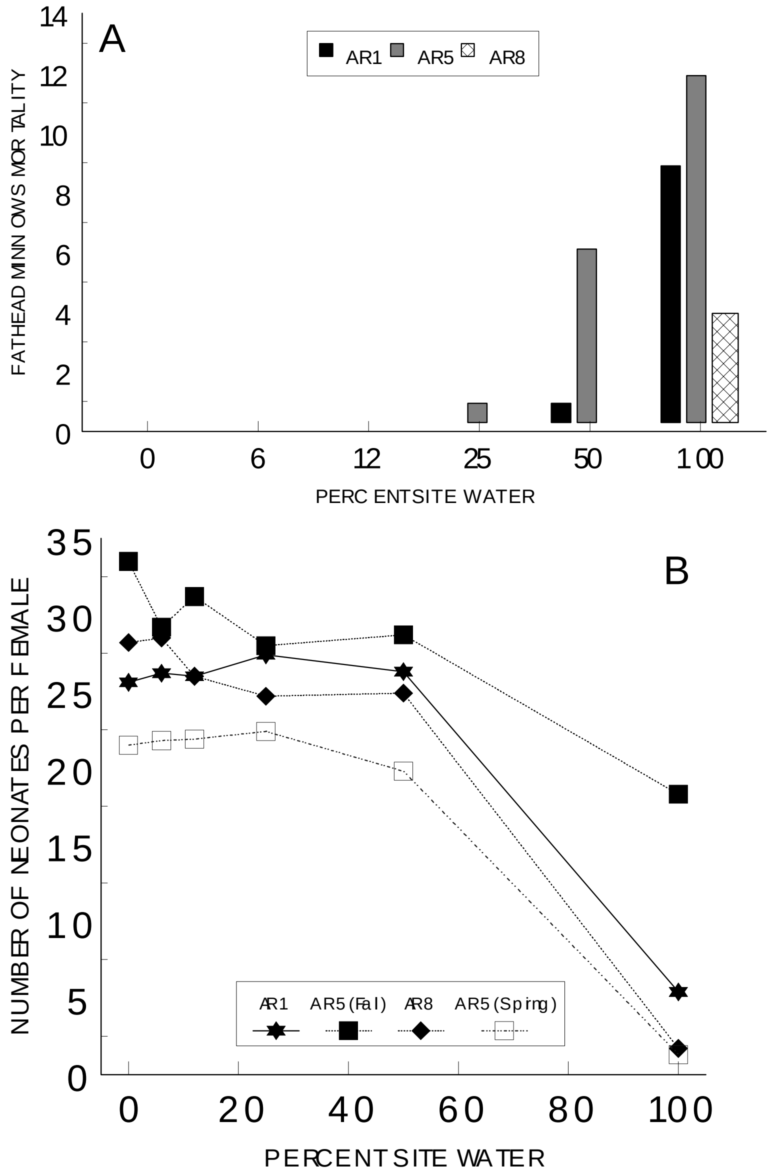


Figure 2-36

A. Mortality of Fathead Minnows Exposed to Water from the Arkansas River.
B. Effects of Arkansas River Water on Reproduction of *Ceriodaphnia dubia.*

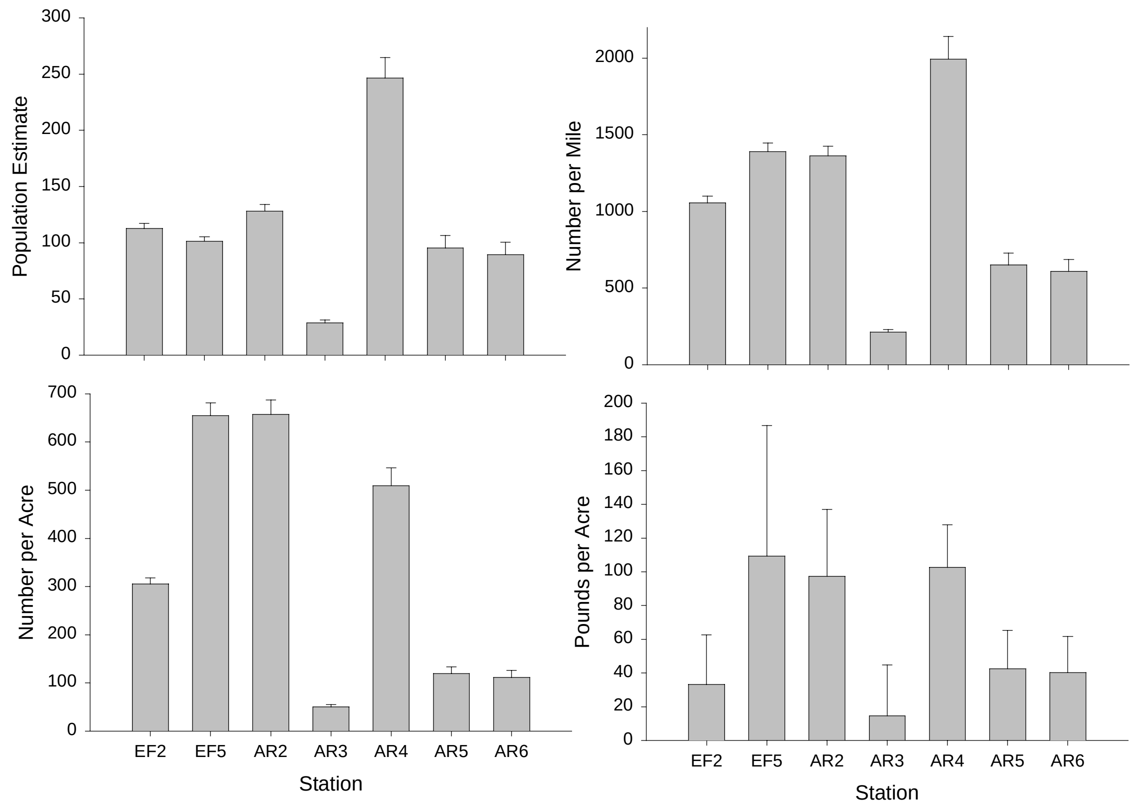


Figure 2-37

Abundance and Biomass of Brown Trout Collected from Reach 0 (EF-2, EF-5, AR-2), Reach 1 (AR-3), Reach 2 (AR-4), and Reach 3 (AR-5, AR-6) in September 1994.

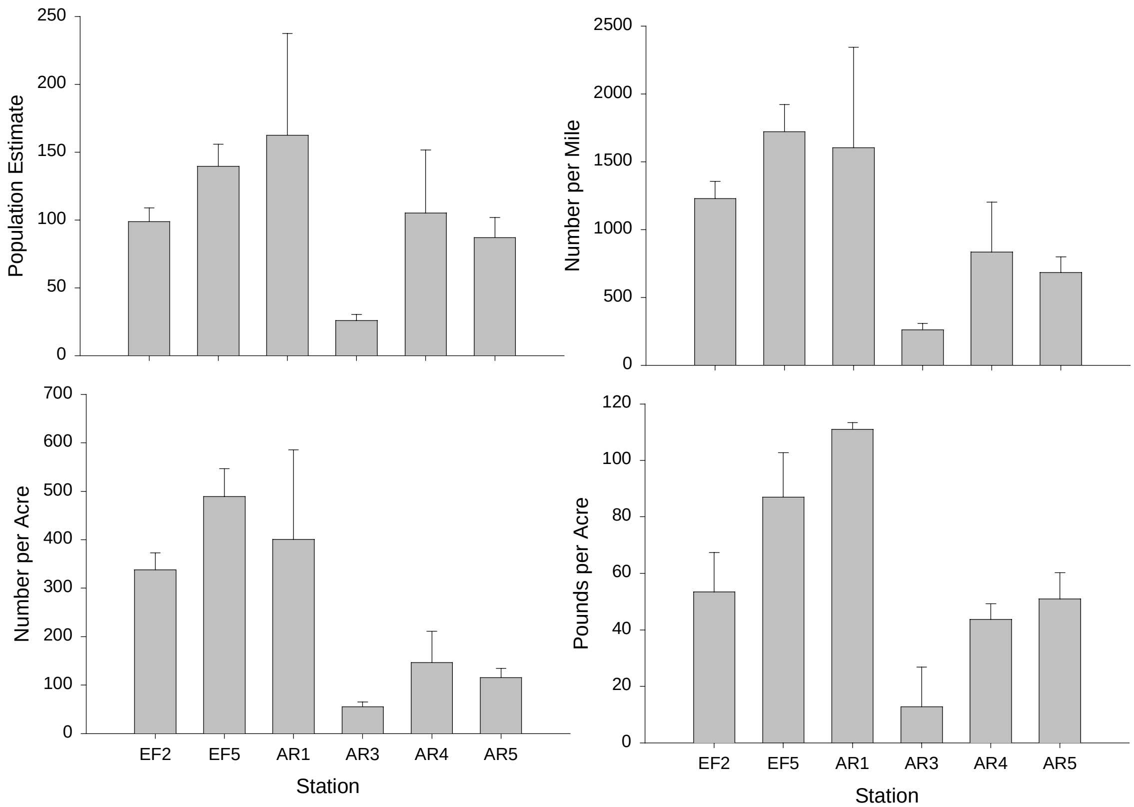


Figure 2-38

Abundance and Biomass of Brown Trout Collected from Reach 0 (EF-2, EF-5, AR-1), Reach 1 (AR-3), Reach 2 (AR-4), and Reach 3 (AR-5) in August 1997.

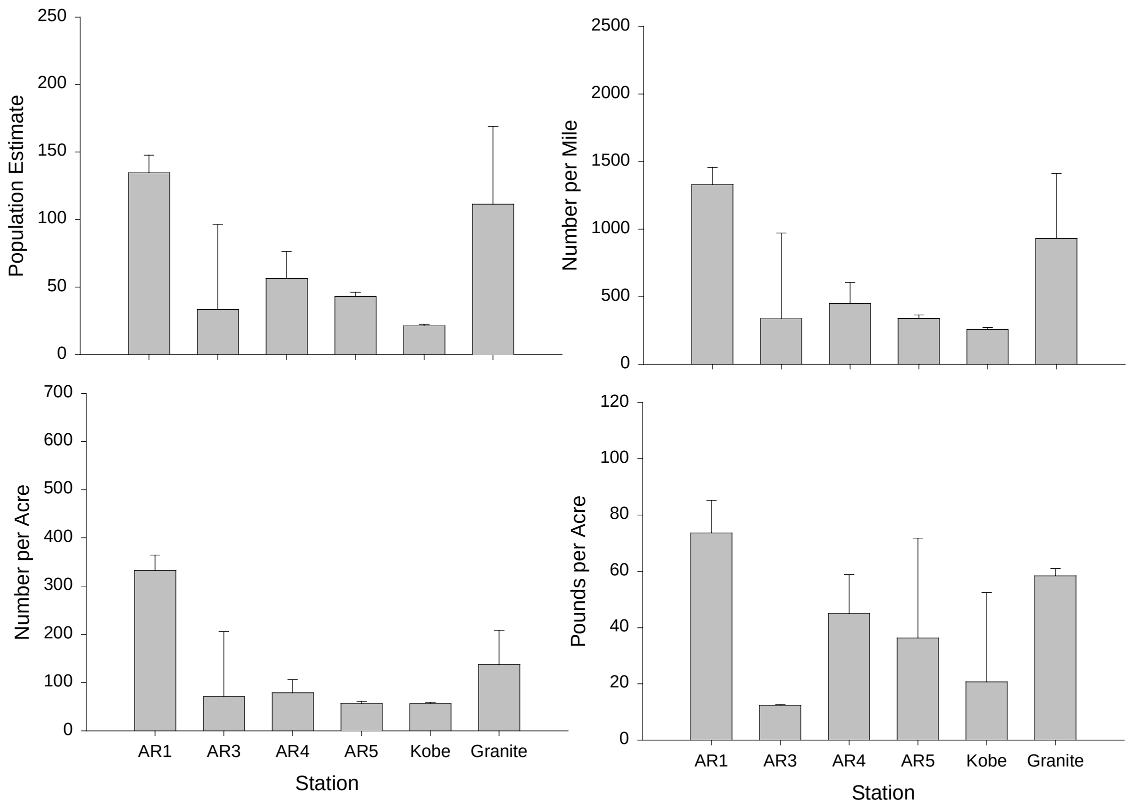


Figure 2-39

Abundance and Biomass of Brown Trout Collected from Reach 0 (AR-1), Reach 1 (AR-3), Reach 2 (AR-4), and Reach 3 (AR-5, Kobe) in April 1998. Data from below the 11-Mile Reach (Granite) are Included for Comparison.

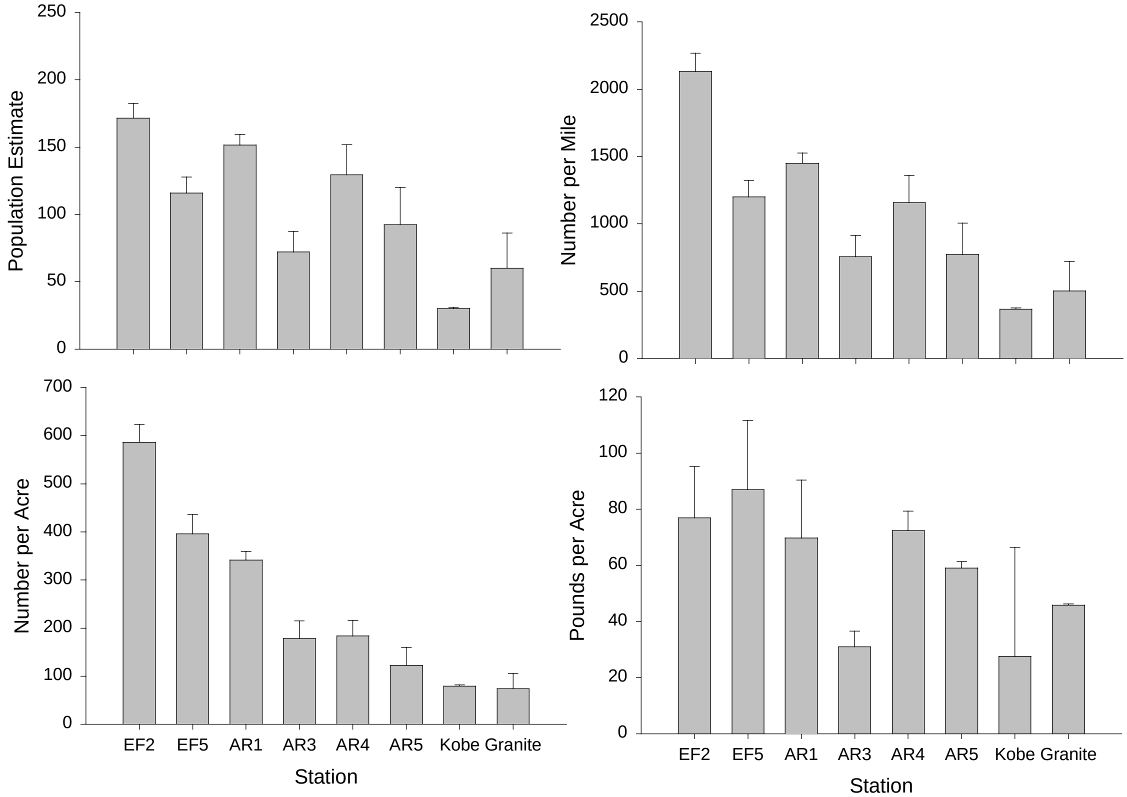


Figure 2-40

Abundance and Biomass of Brown Trout Collected from Reach 0 (EF-2, EF-5, AR-1), Reach 1 (AR-3), Reach 2 (AR-4), and Reach 3 (AR-5, Kobe) in September 1999. Data from Below the 11-Mile Reach (Granite) are Included for Comparison.

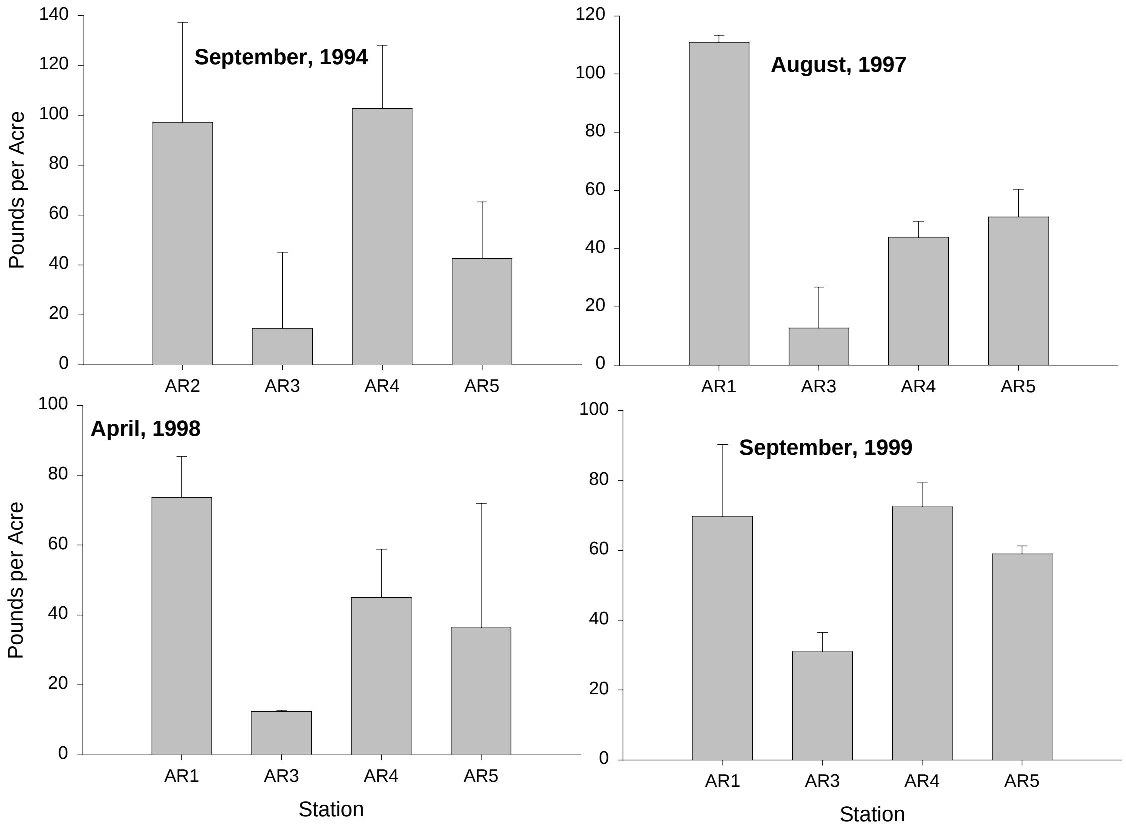


Figure 2-41

Comparison of Biomass of Brown Trout Collected from Reach 0 (AR-1, AR-2), Reach 1 (AR-3), Reach 2 (AR-4), and Reach 3 (AR-5) on All Sampling Occasions.

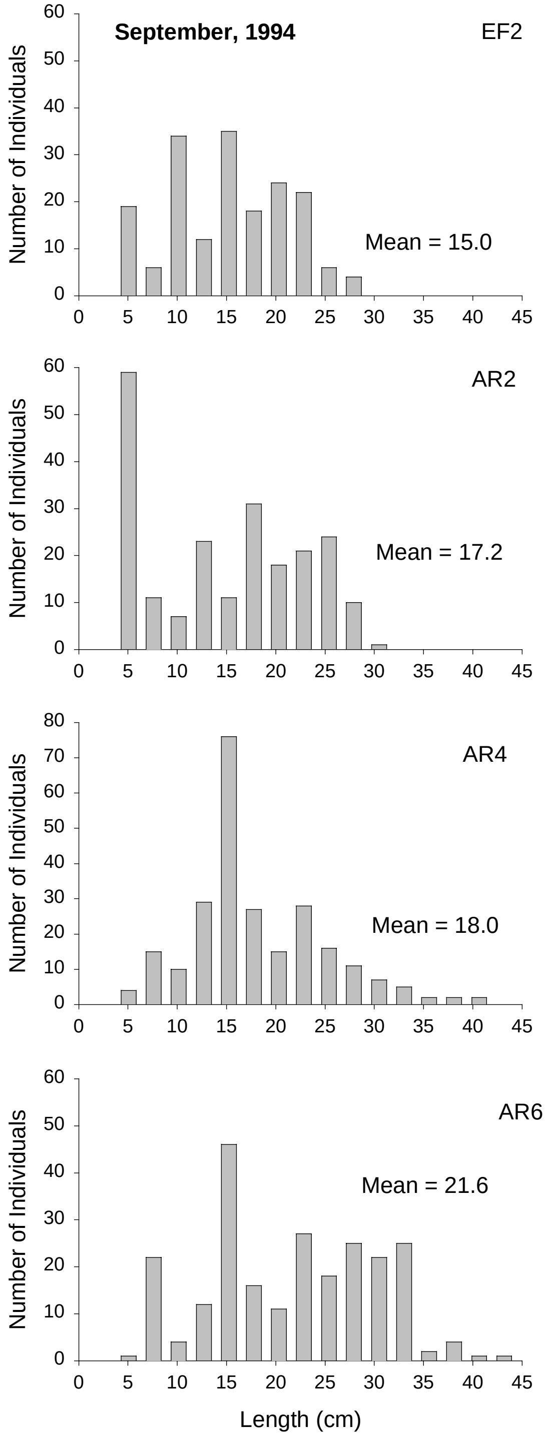


Figure 2-42

Length-Frequency Distributions of Brown Trout at Reach 0 (EF-2, EF-5, AR-2), Reach 1 (AR-3), Reach 2 (AR-4), and Reach 3 (AR-5, AR-6) in September 1994.

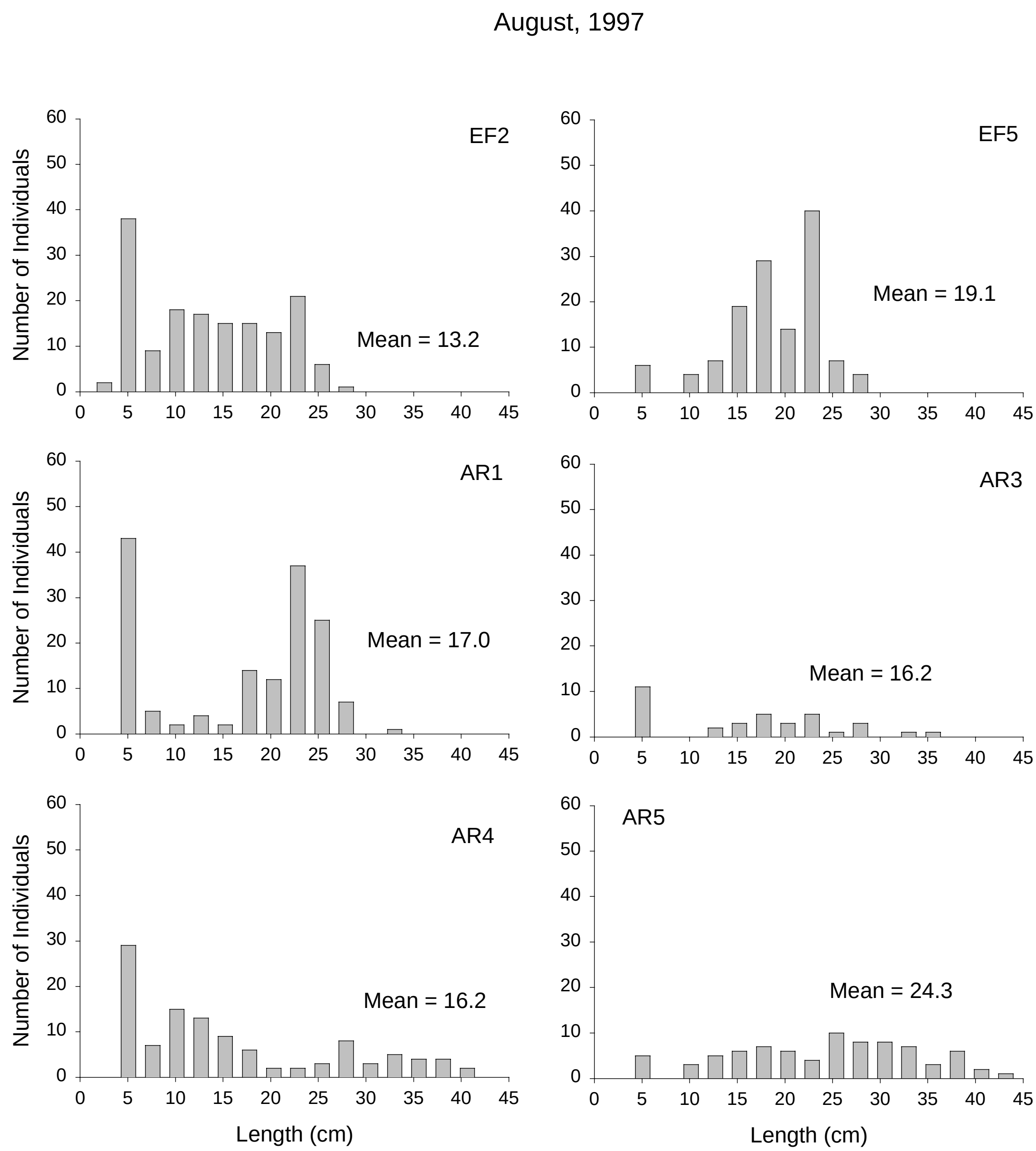


Figure 2-43

Length-Frequency Distributions of Brown Trout at Reach 0 (EF-2, EF-5, AR-1), Reach 1 (AR-3), Reach 2 (AR-4), and Reach 3 (AR-5) in August 1997.

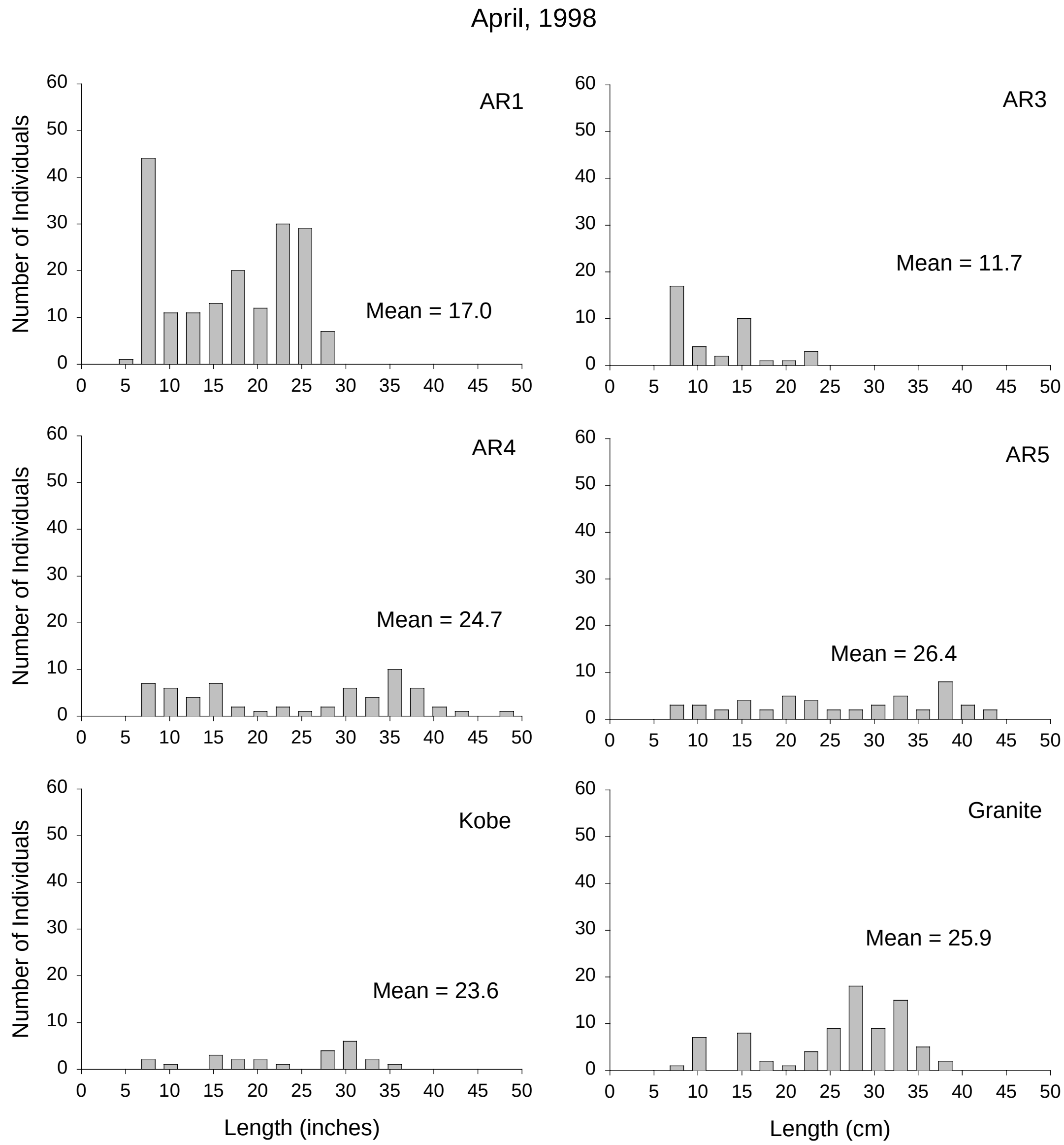


Figure 2-44

Length-Frequency Distributions of Brown Trout at Reach 0 (AR-1), Reach 1 (AR-3), Reach 2 (AR-4), and Reach 3 (AR-5, Kobe) in April 1998. Data from below the 11-Mile Reach (Granite) are Included for Comparison.

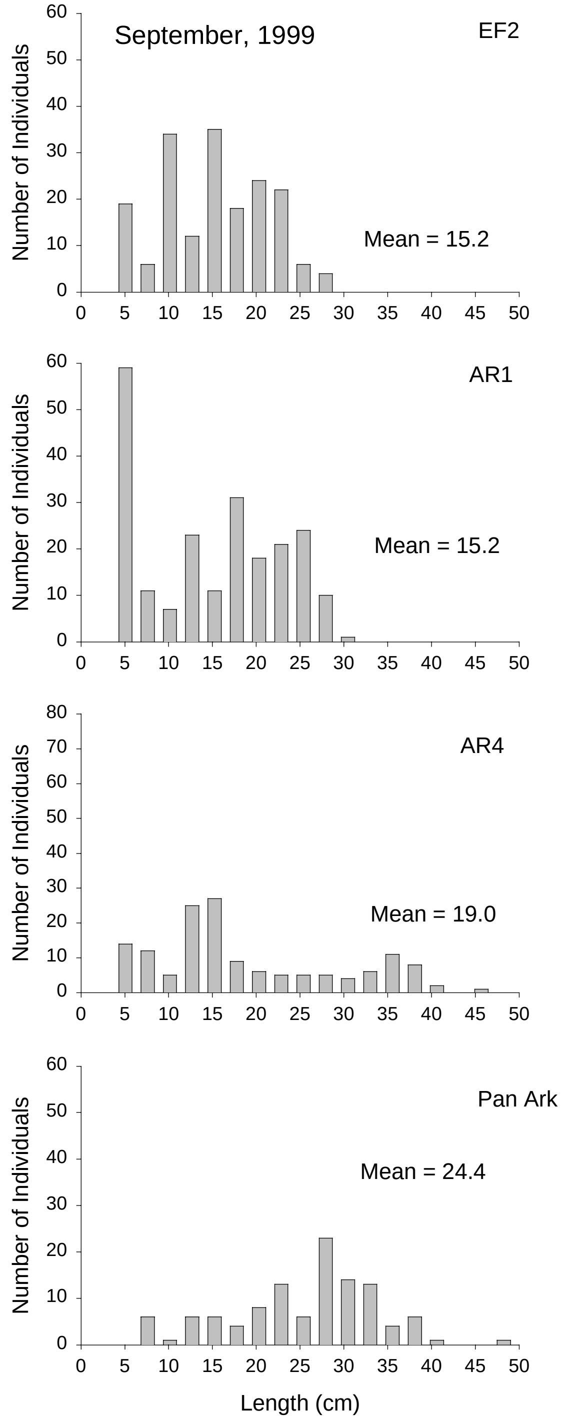


Figure 2-45

Length-Frequency Distributions of Brown Trout at Reach 0 (EF-2, EF-5, AR-1), Reach 1 (AR-3), Reach 2 (AR-4), and Reach 3 (AR-5, Pan Ark) in September 1999.

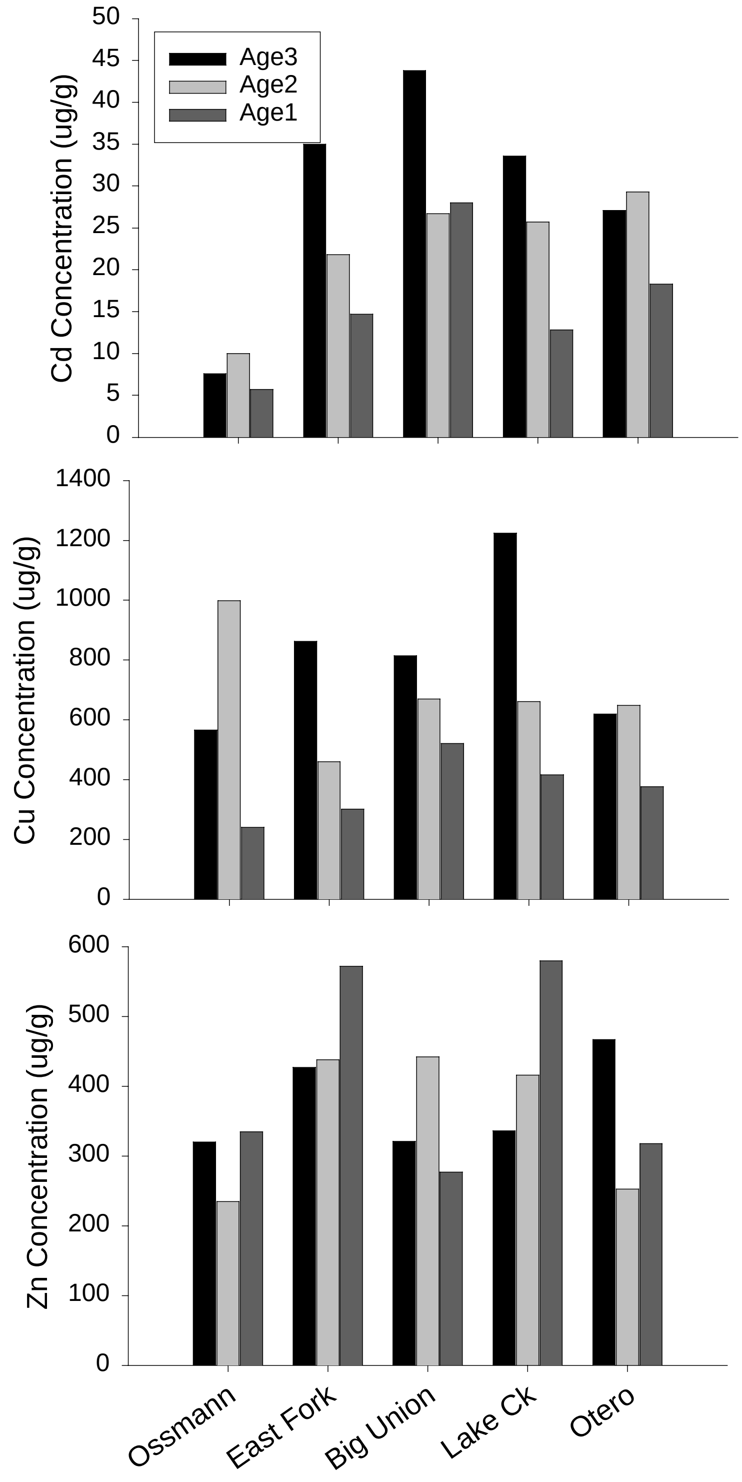


Figure 2-46

Concentrations of Metals in Brown Trout Liver Tissue Collected from Reach 0 (East Fork), Reach 3 (Big Union), and Reach 4 (Lake Creek). Data from a Reference Site (Ossmann) and from below the 11-Mile Reach (Otero) are Included for Comparison.

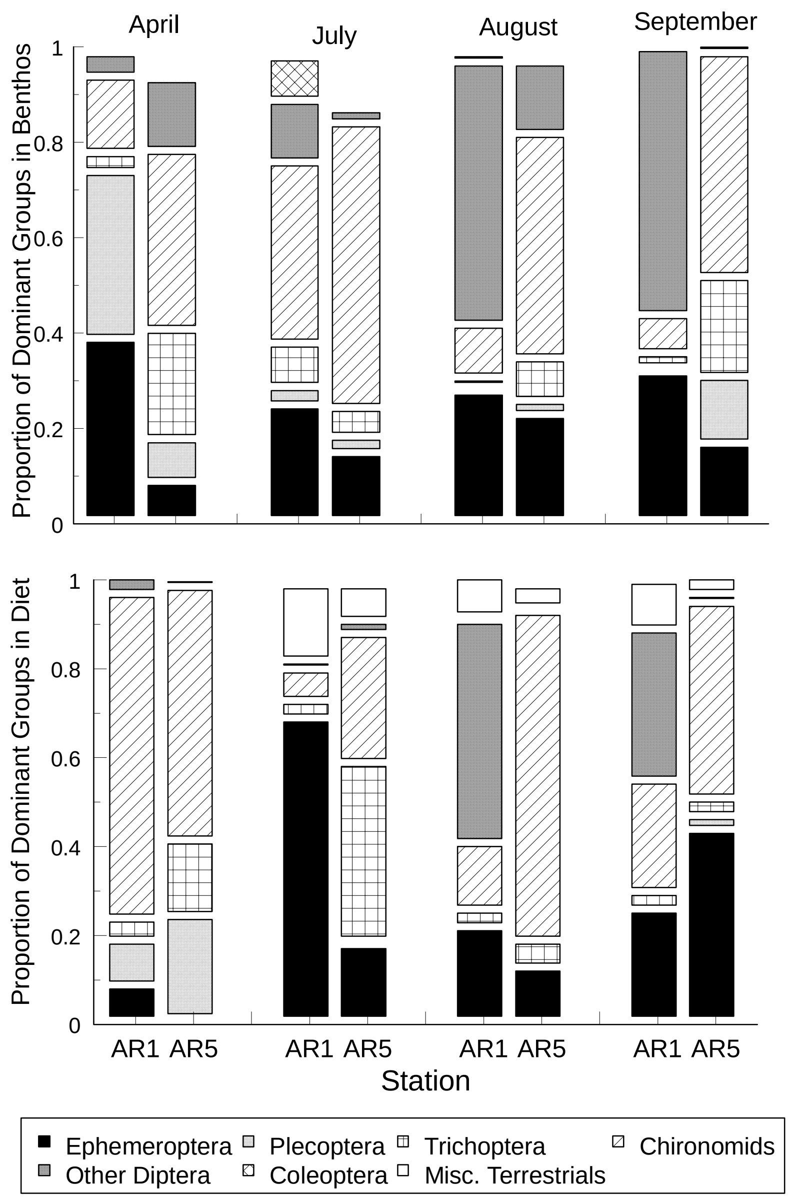
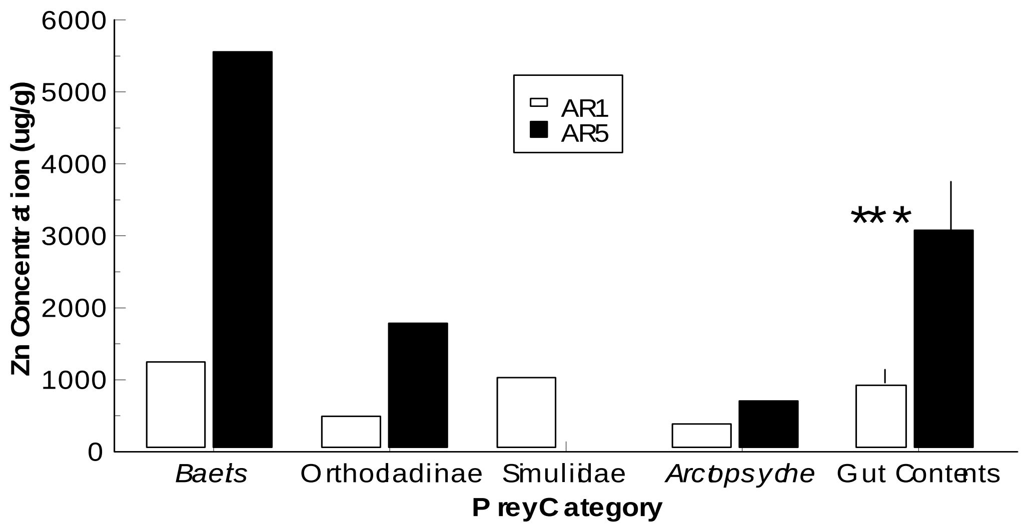


Figure 2-47

Abundance of Dominant Macroinvertebrate Groups in the Benthos and in the Diet of Brown Trout Collected from Reach 0 (AR-1) and Reach 3 (AR-5)



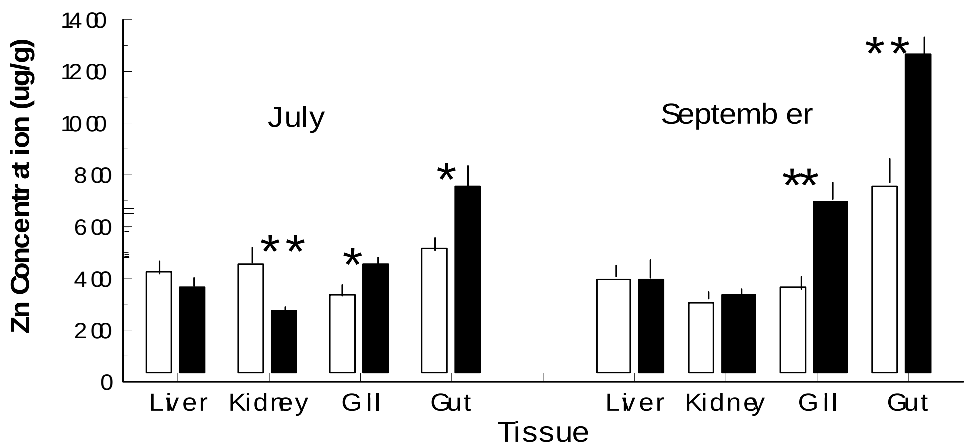
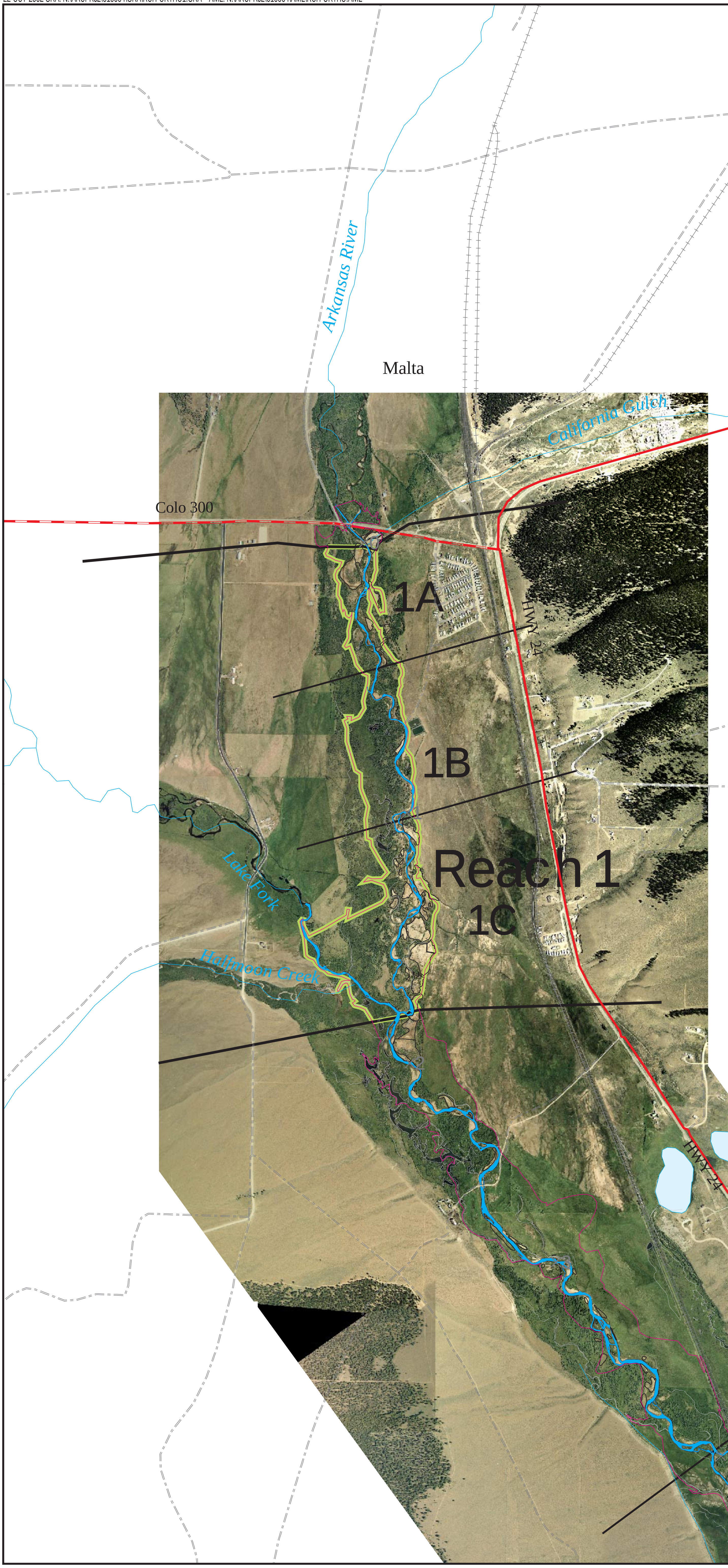


Figure 2-48

Metal Concentrations in Dominant Prey Taxa, Stomach Contents, and Brown Trout Tissue from Reach 0 (AR-1) and Reach 3 (AR-5).

22-OCT-2002 GRA: N:\ARCPRJ2\010004\GRA\RCH-ORTHO1.GRA * AML: N:\ARCPRJ2\010004\AML\RCH-ORTHO.AML



EXPLANATION

Hydrology

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

Transportation

- Minor Road
- Medium Duty Road
- Highway
- Railroad

Other Features

- Mine- Waste Deposit
- Reach Boundary

N

SCALE IN FEET

1500 0 1500

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2- 49

1996 ORTHOPHOTOGRAPHY
CALIFORNIA GULCH
TO LAKE FORK
(REACH 1)

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

MFG, Inc.

consulting scientists and engineers

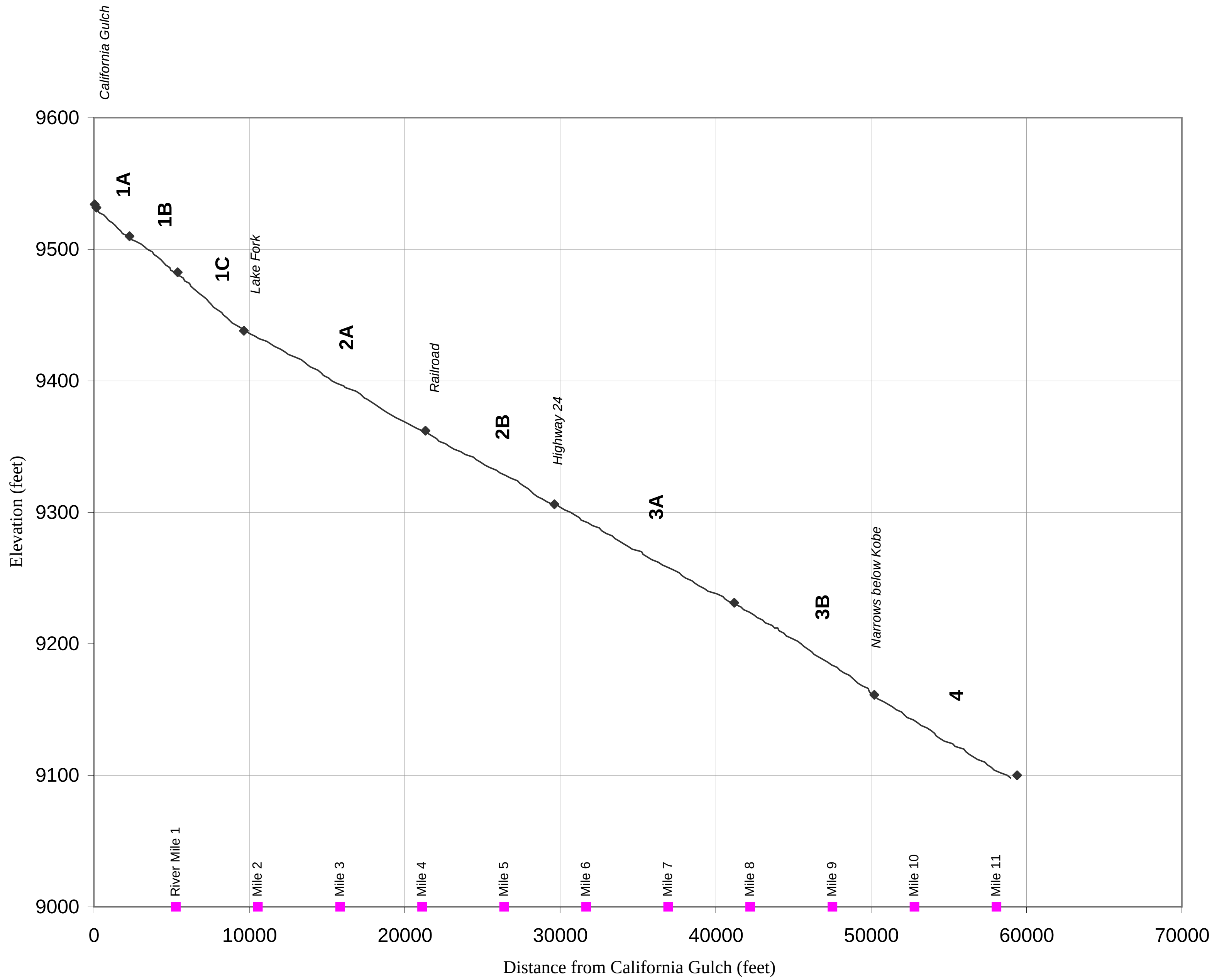
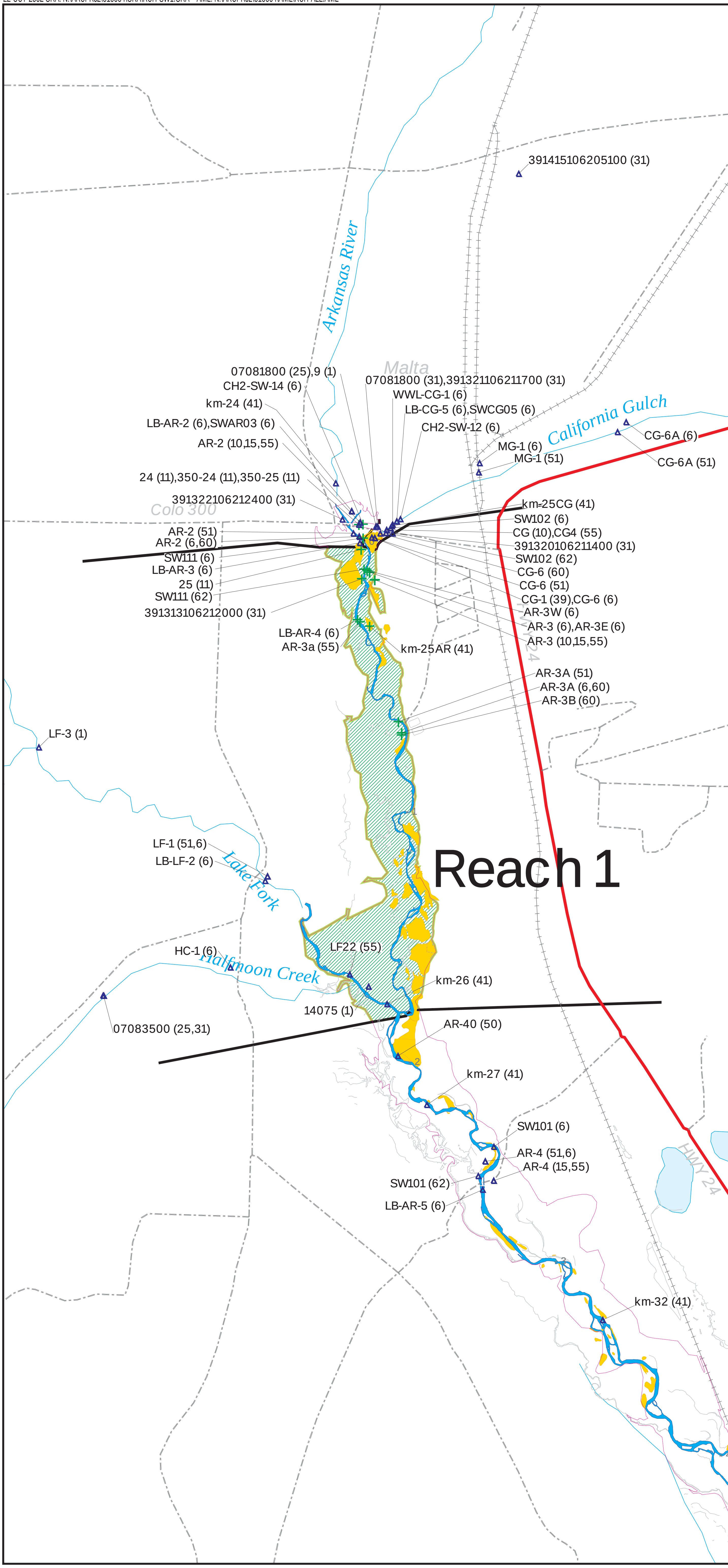


Figure 2-50

Arkansas River Elevation Profile

22-OCT-2002 GRA: N:\ARCPRJ2\010004\GRA\RCH-SW1.GRA * AML: N:\ARCPRJ2\010004\AML\RCH-ALL.AML



EXPLANATION

Hydrology

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

Transportation

- Minor Road
- Medium Duty Road
- Highway
- Railroad

Other Features

- Mine- Waste Deposit
- Reach Boundary

Sampling Locations

- \+ Surface Water Sampling Location Within Reach 1
- Δ Surface Water Sampling Location Outside Reach 1

EXAMPLE

+ AR-3 (10,15,55)

Sample Location — Site Name — Data Source(s)

Data Sources in Reach 1

(10) Water Quality data (1968- 1996); Clements (CSU). [Period of record: 1989- 1999]

(11) CDOW- RiverWatch data; CDOW. [Period of record: 1922- 1999]

(15) CDOW WQ and Discharge Data; Clements (CSU). [Period of record: 1996- 1999]

(31) STORET data; EPA. [Period of record: 1955- 1997]

(41) Selected hydrologic data for the upper Arkansas River basin, Colorado, 1986- 89; Kimball, Callender and Axtmann (USGS). [Period of record: 1988- 1989]

(51) Resurrection Database; Shepherd- Miller. [Period of record: 1994- 1999]

(55) CDOW/BOR/CSU 1995- 1999 WQ Data from CDOW; Davies, Clements, et al. [Period of record: 1996- 1999]

(6) Cal Gulch WQ Data; ISSI. [Period of record: 1983- 1988]

(60) 2000 Spring/Storm Surface Water Data - OU6/Cal Gulch; CDM Federal. [Period of record: 2000]

(62) Surface and Groundwater data, Cal Gulch/Arkansas River area; Ecology & Environment, Inc. [Period of record: 1983]

N

SCALE IN FEET

1500 0 1500

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2- 51
SURFACE WATER SAMPLE LOCATIONS
CALIFORNIA GULCH TO LAKE FORK
(REACH 1)

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

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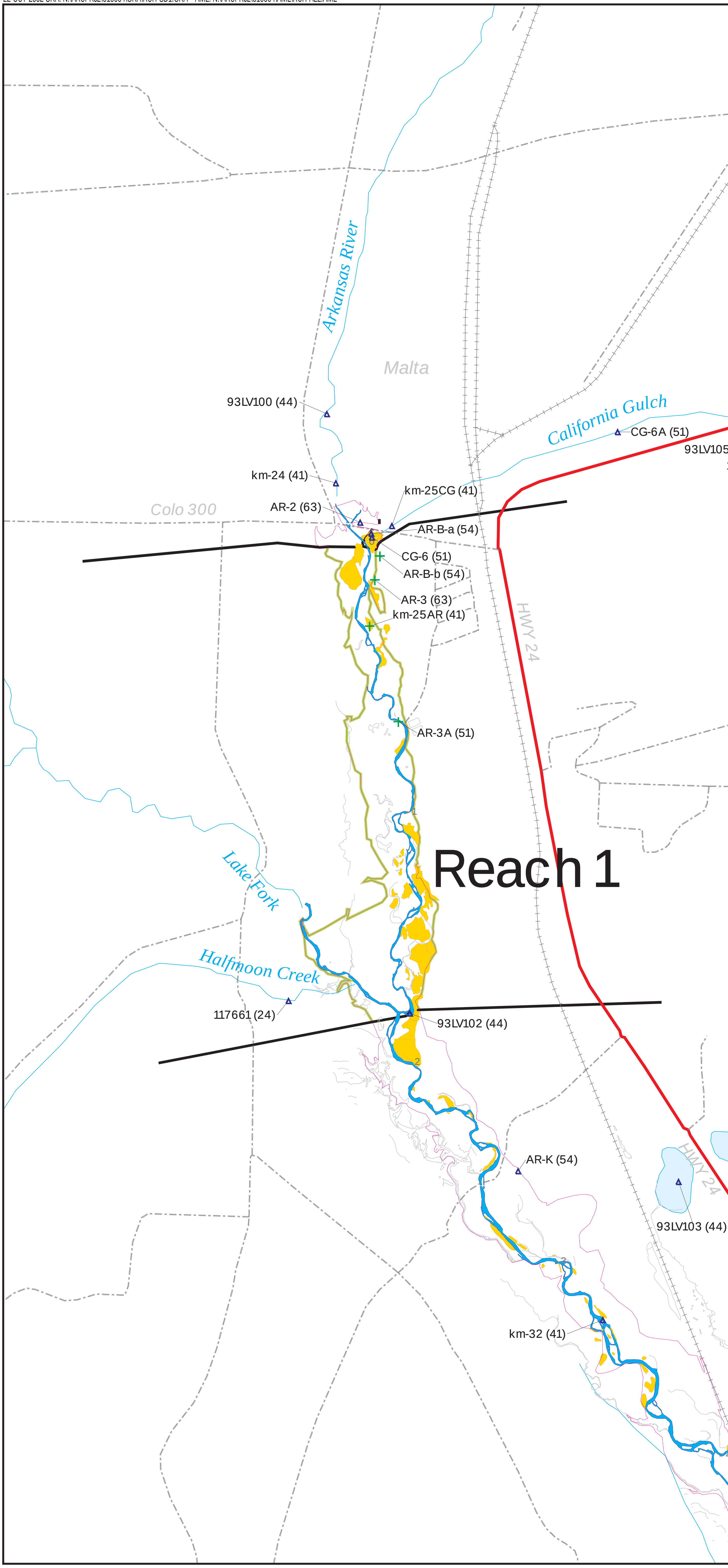

EXPLANATION

Hydrology

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

Transportation

- Minor Road
- Medium Duty Road
- Highway
- Railroad

Other Features

- Mine- Waste Deposit
- Reach Boundary

Sampling Locations

- Stream Sediment Sampling Location Within Reach 1
- Stream Sediment Sampling Location Outside Reach 1

EXAMPLE

km-25AR (41)

Sample Location

Site Name

Data Source(s)

Data Sources in Reach 1

(41) Selected hydrologic data for the upper Arkansas River basin, Colorado, 1986- 89; Kimball, Callender and Axtmann (USGS).
[Period of record: 1988- 1989]

(51) Resurrection Database; Shepherd- Miller.
[Period of record: 1994- 1999]

(54) USFWS Sediment Samples; USFWS.
[Period of record: 1998]

(63) 1995- 1996 Sediment data from CSU
[Period of record: 1995- 1996]

N

SCALE IN FEET

1500 0 1500

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2- 52
STREAM SEDIMENT
SAMPLE LOCATIONS
CALIFORNIA GULCH
TO LAKE FORK
(REACH 1)

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

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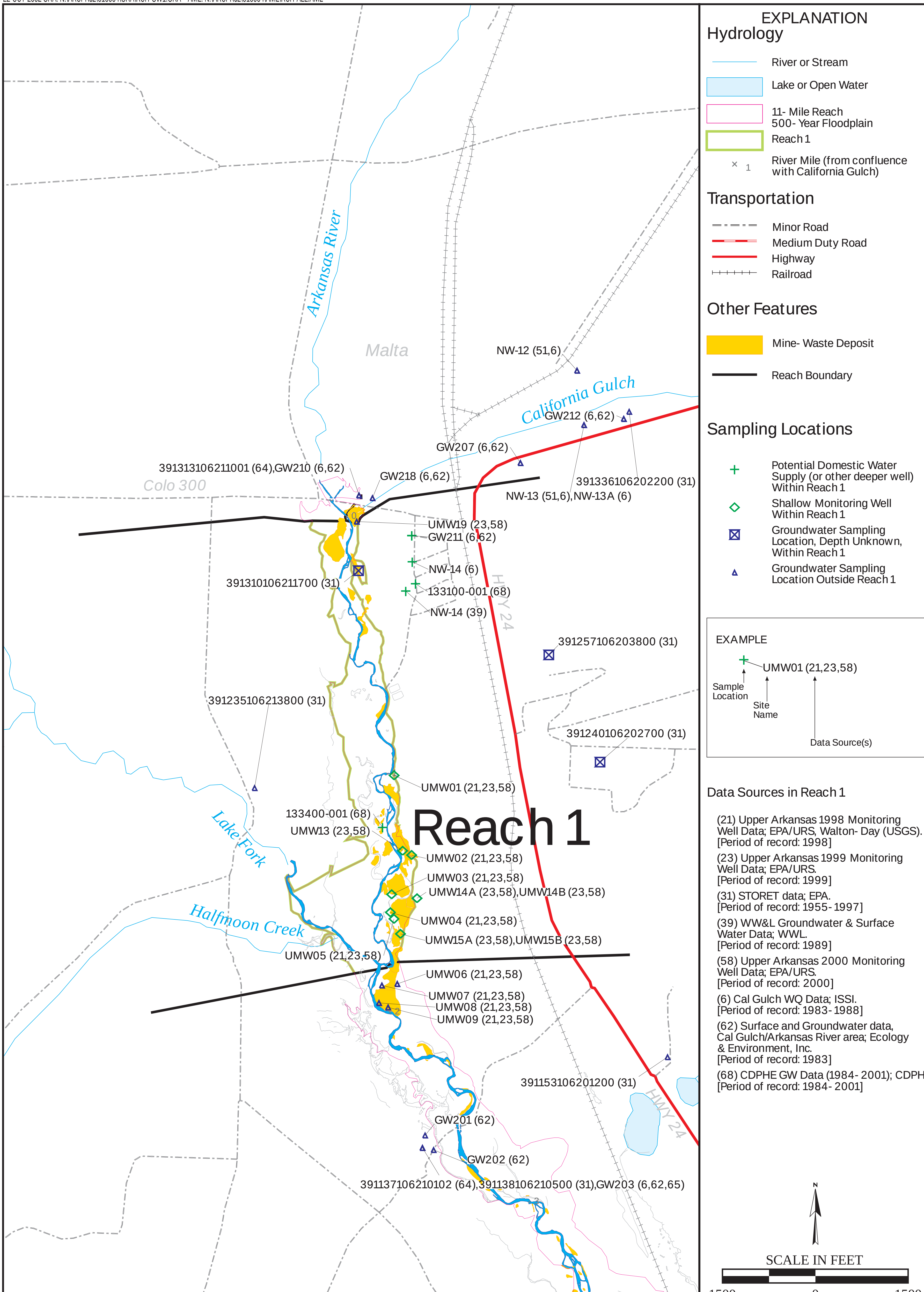
22-OCT-2002 GRA: N:\ARCPRJ2\010004\GRA\RCH-GW1.GRA * AML: N:\ARCPRJ2\010004\AML\RCH-ALL.AML



UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2- 53
GROUNDWATER SAMPLE LOCATIONS
CALIFORNIA GULCH TO LAKE FORK
(REACH 1)

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

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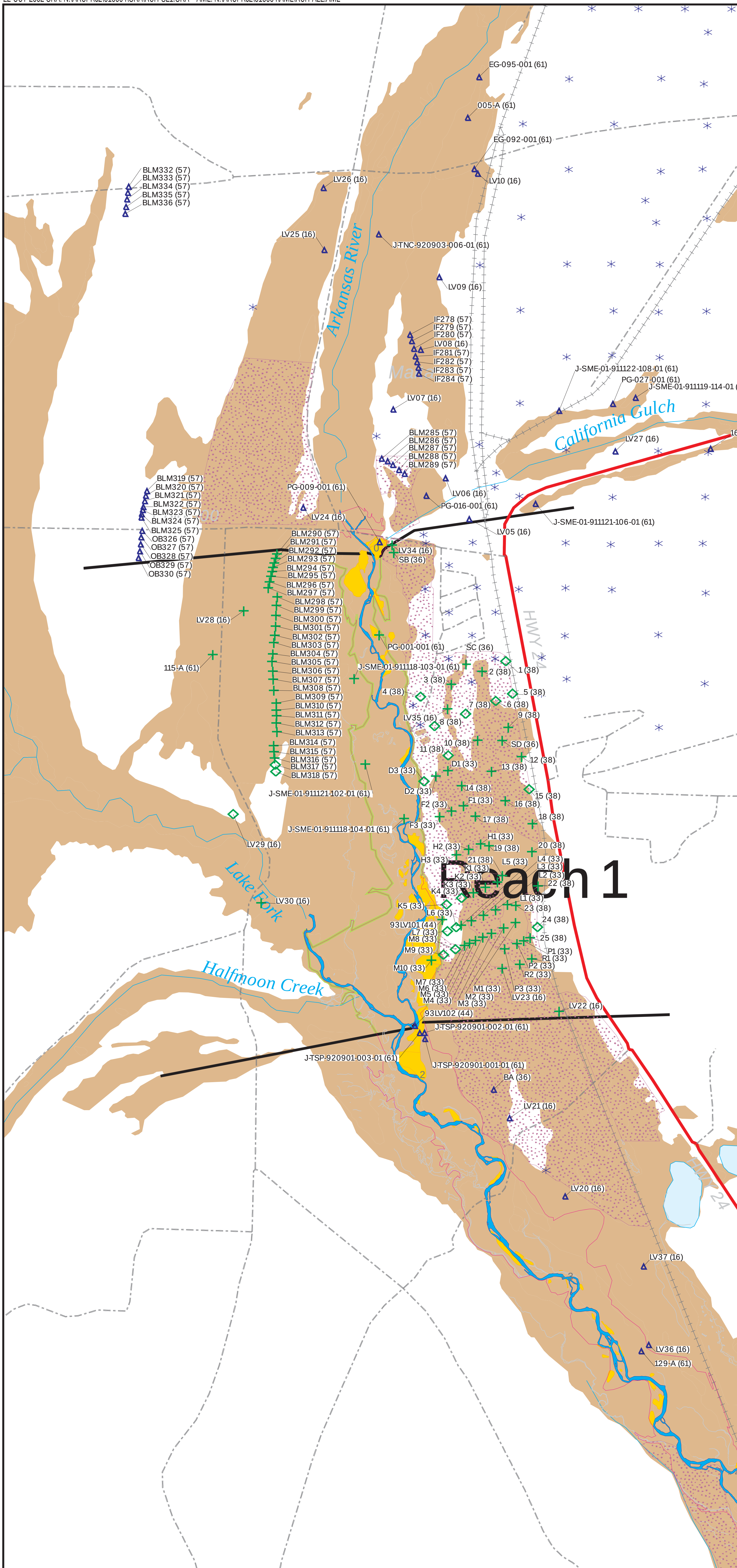
consulting scientists and engineers

22-OCT-2002 GRA: N:\ARCPRJ2\010004\GRA\RCH-SL1.GRA * AML: N:\ARCPRJ2\010004\AML\RCH-ALL.AML



EXPLANATION

Hydrology

- River or Stream
- Lake or Open Water
- 11- Mile Reach 500- Year Floodplain
- Reach 1
- Lowland Zone - Based on presence of riparian species (CDOW Vegetation Mapping, 2001)
- Irrigated Area (SAIC, 2001)
- River Mile (from confluence with California Gulch)

Transportation

- Minor Road
- Medium Duty Road
- Highway
- Railroad

Other Features

- Mine- Waste Deposit
- Reach Boundary

Sampling Locations

- Lowland Soil Sampling Location Within Reach 1
- Upland Soil Sampling Location Within Reach 1
- Soil Sampling Location Outside Reach 1
- AIRSHED Sample Location

EXAMPLE

LV34 (16)

Sample Location

Site Name

Data Source(s)

Data Sources in Reach 1

(16) 1986/1987 Soil and Vegetation Metals Data; Keammerer. [Period of record: 1987]

(33) Seppi Ranch Soils- Swyers Data; Swyer (CMC). [Period of record: 1989]

(36) Metal Contamination in Soils and Plants Near Leadville; David Levy (CSU). [Period of record: 1988]

(38) Seppi Ranch Soils - Colby Data; Colby (CMC). [Period of record: 1998]

(44) Geochemical and Lead Isotope data for stream and lake sediments; S.E. Church (USGS). [Period of record: 1993- 1994]

(57) BLM July 2000 Soil/Sediment Data; BLM. [Period of record: 2000]

(61) Surface soils data - 0 to 2 inches; Walsh. [Period of record: 1986- 1997]

N

SCALE IN FEET

1500 0 1500

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2- 54

SOIL SAMPLE LOCATIONS CALIFORNIA GULCH TO LAKE FORK (REACH 1)

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

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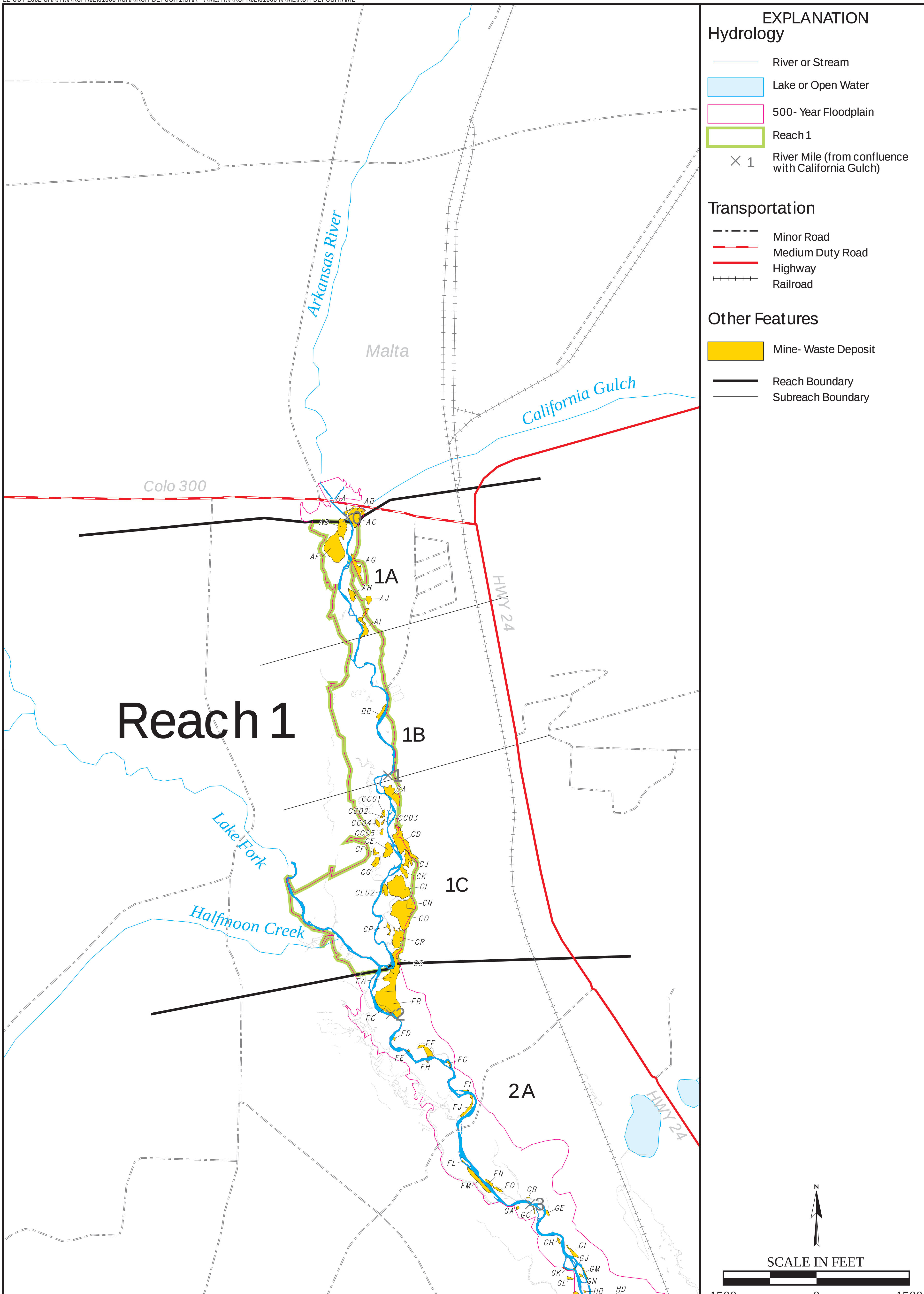
22-OCT-2002 GRA: N:\ARCPRJ2\010004\GRA\RCH-DEPOSIT1.GRA * AML: N:\ARCPRJ2\010004\AML\RCH-DEPOSIT.AML



UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2- 55
MINE- WASTE DEPOSIT LOCATIONS
CALIFORNIA GULCH TO LAKE FORK
(REACH 1)

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

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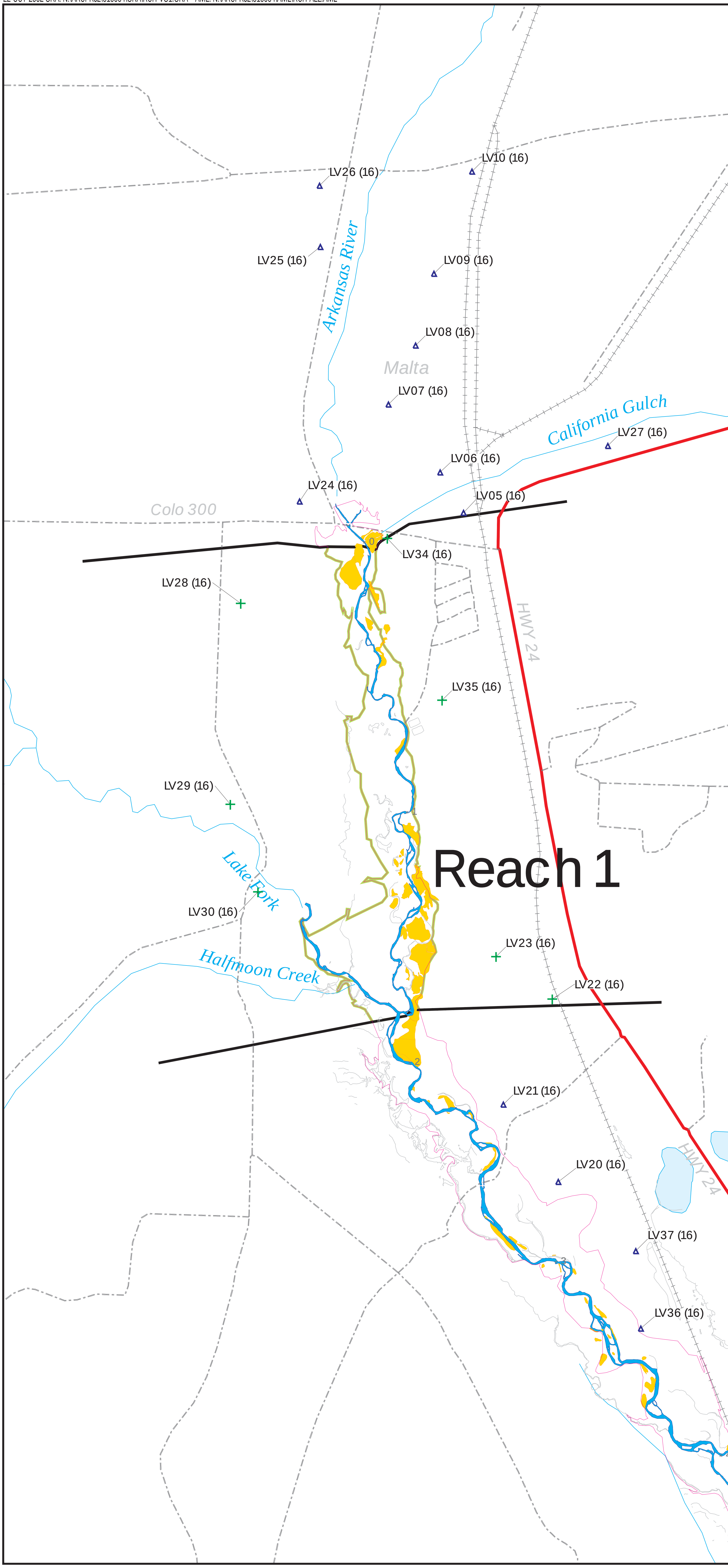
22-OCT-2002 GRA: N:\ARCPRJ2\010004\GRA\RCH-VG1.GRA * AML: N:\ARCPRJ2\010004\AML\RCH-ALL.AML



EXPLANATION

Hydrology

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

Transportation

- Minor Road
- Medium Duty Road
- Highway
- Railroad

Other Features

- Mine- Waste Deposit
- Reach Boundary

Sampling Locations

- Vegetation Sampling Location Within Reach 1
- Vegetation Sampling Location Outside Reach 1

EXAMPLE

LV34 (16) — Sample Location; Site Name; Data Source(s)

Data Sources in Reach 1

(16) 1986/1987 Soil and Vegetation Metals Data; Keammerer. [Period of record: 1987]

SCALE IN FEET

1500 0 1500

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2- 56

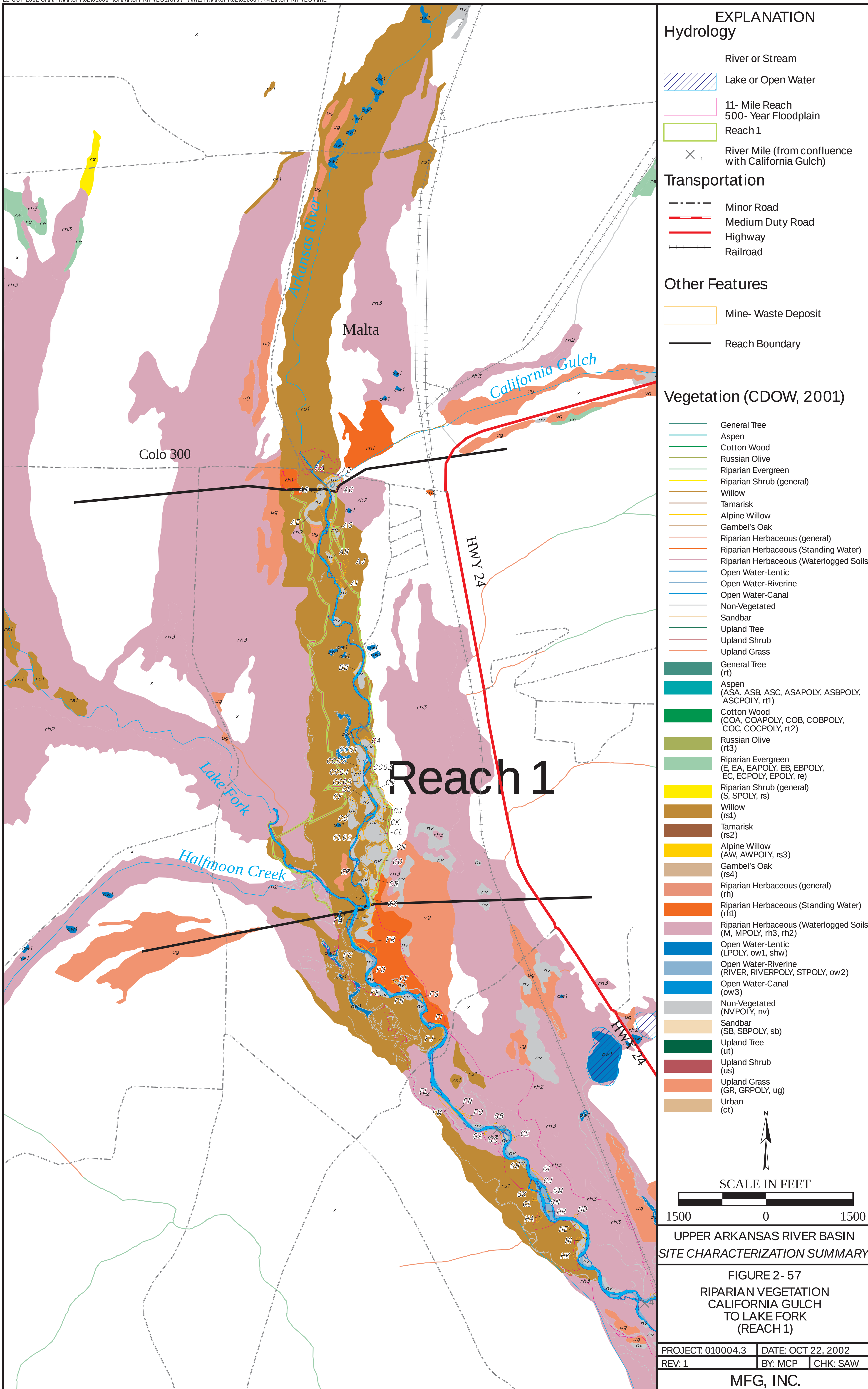
VEGETATION SAMPLE LOCATIONS CALIFORNIA GULCH TO LAKE FORK (REACH 1)

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

MFG, Inc.

consulting scientists and engineers

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



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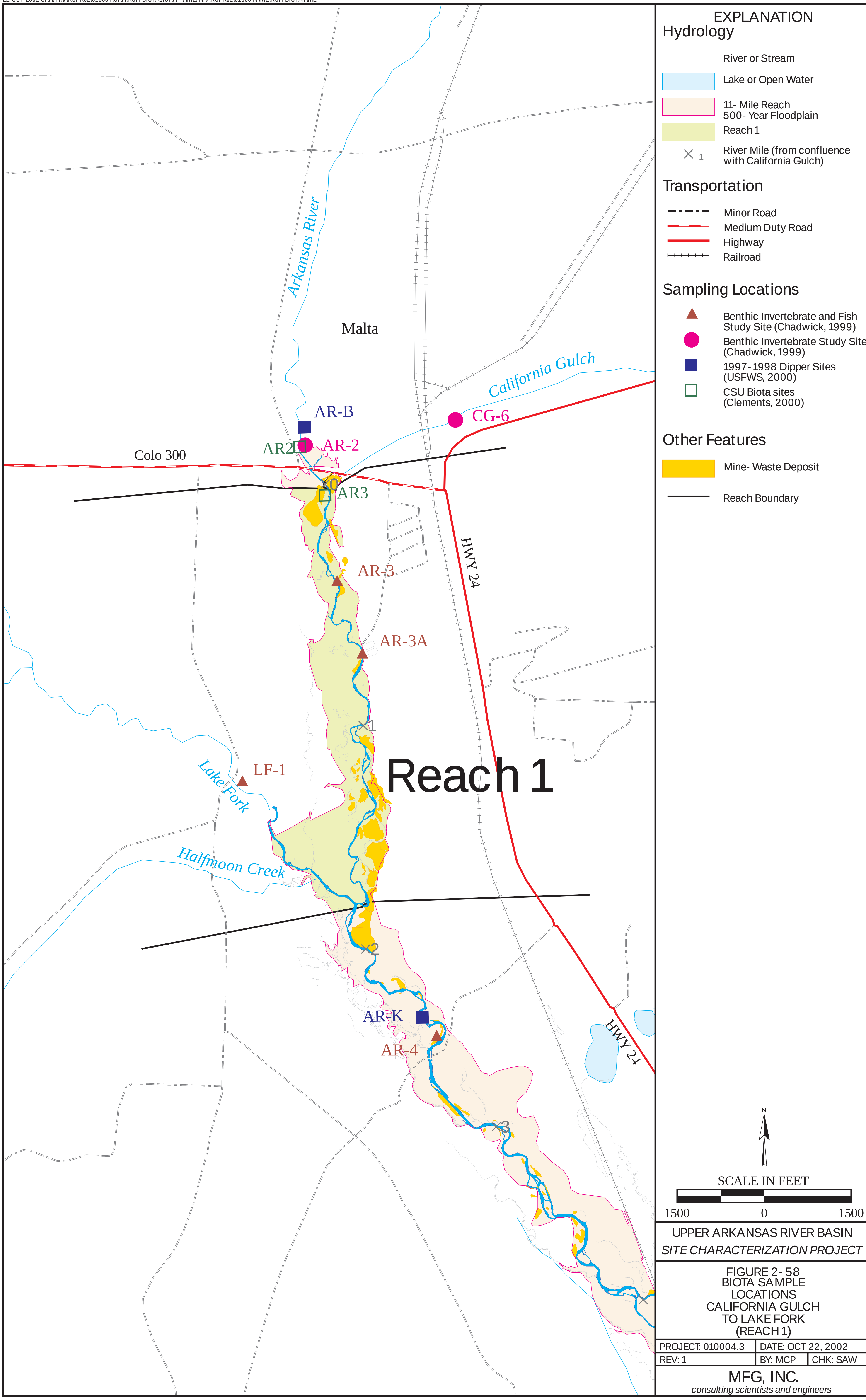


Reach 1 (Station AR3)

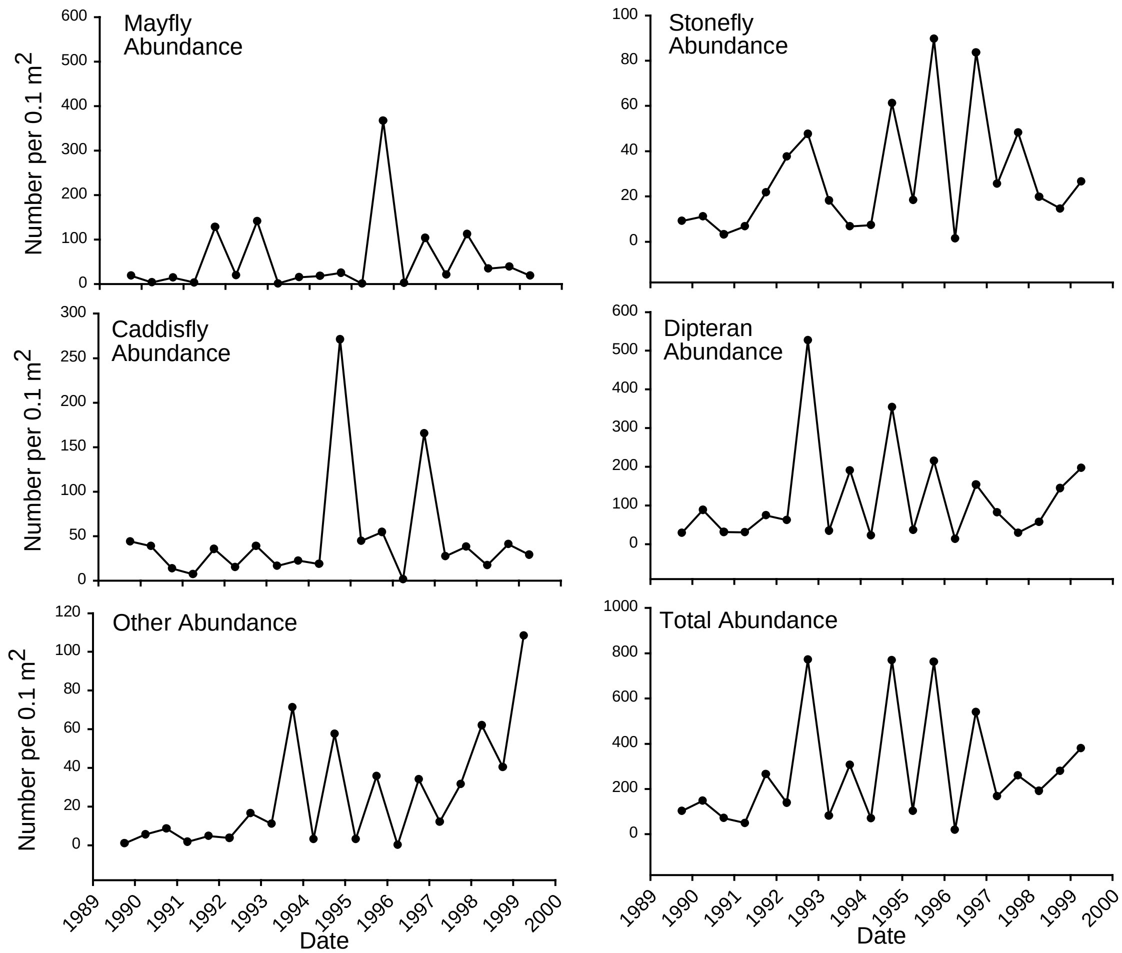


Figure 2-59

Abundance of Major Macroinvertebrate Groups in the Arkansas River (Reach 1).

Reach 1 (station AR3)

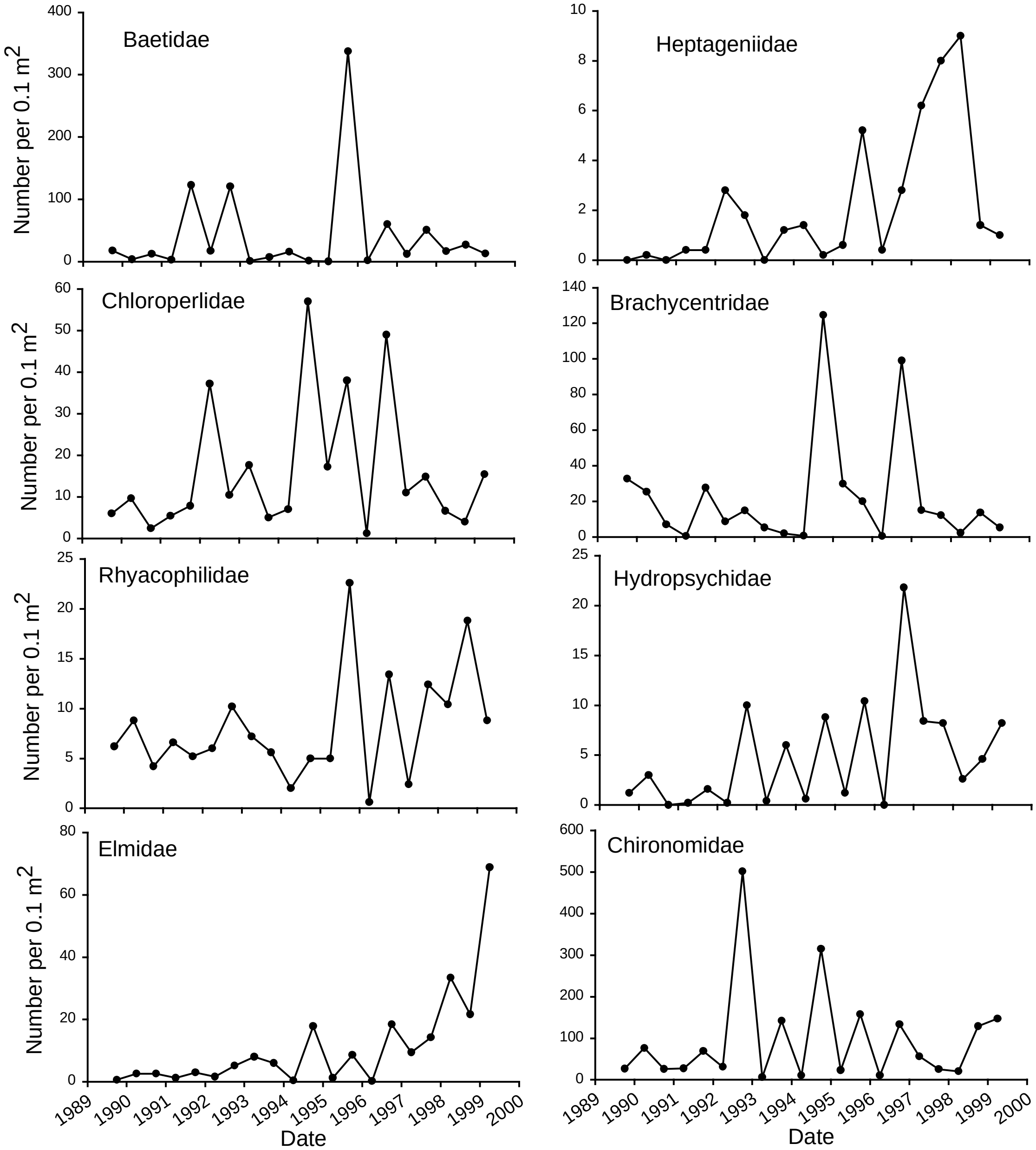


Figure 2-60

Abundance of Dominant Macroinvertebrate Taxa in the Arkansas River (Reach 1).

Reach 1 (Station AR3)

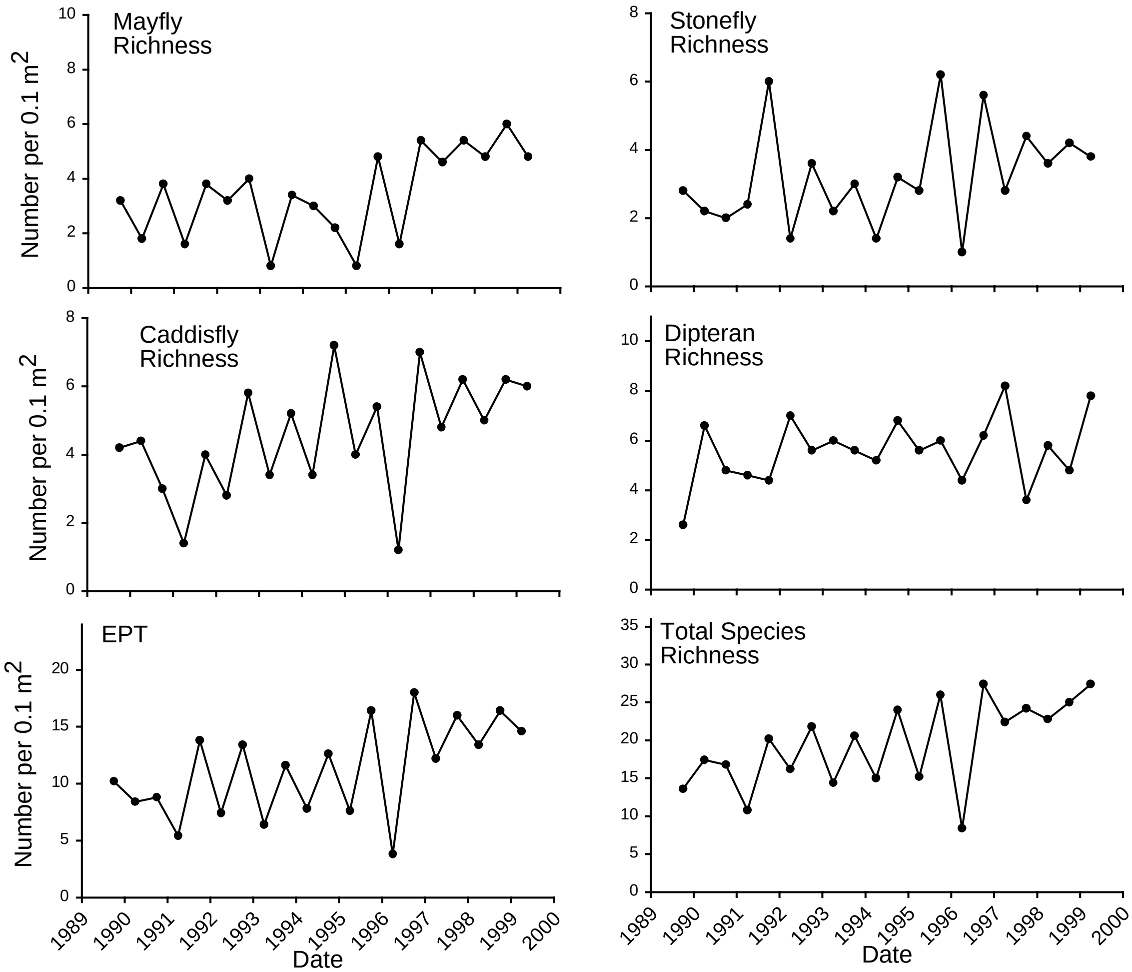
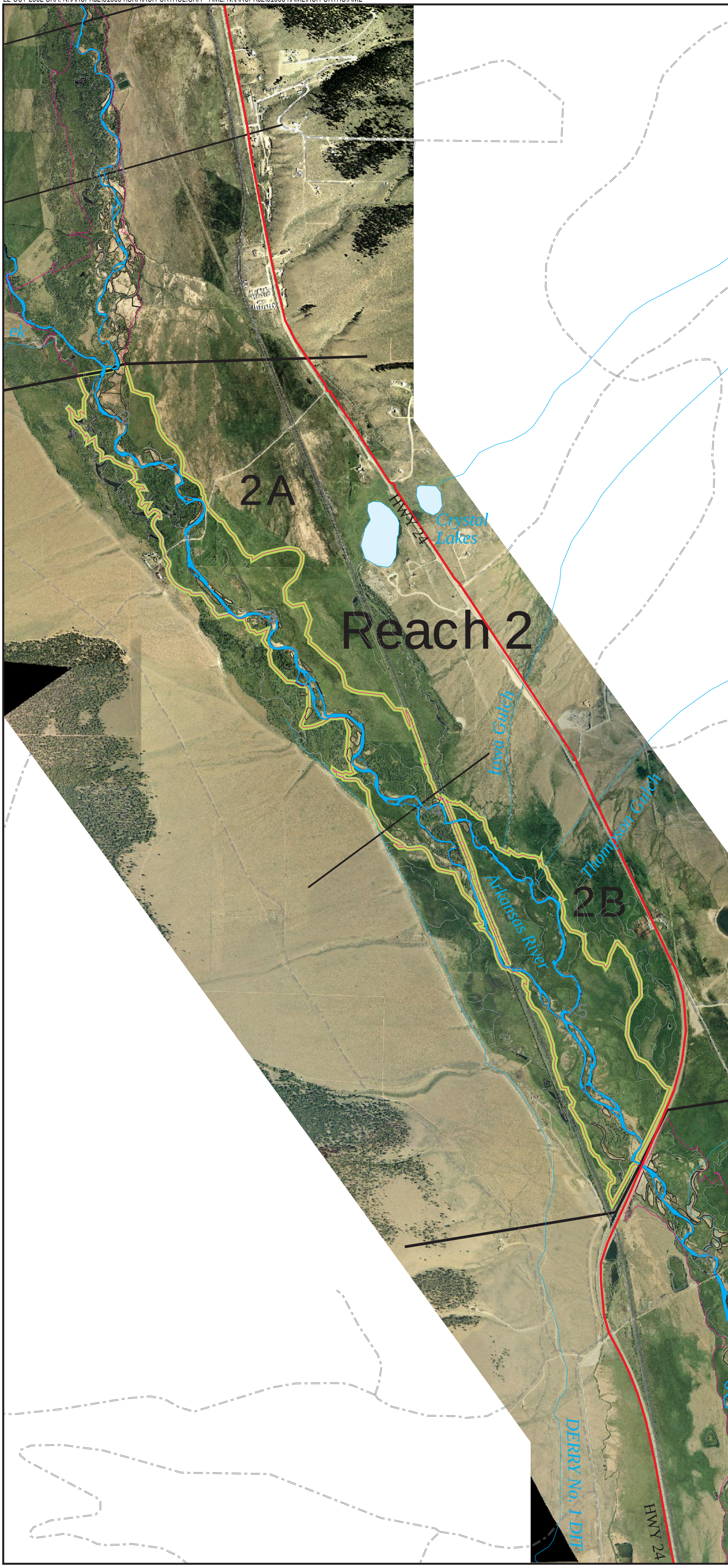


Figure 2-61

Species Richness of Major Macroinvertebrate Groups in the Arkansas River (Reach 1).

22-OCT-2002 GRA: N:\ARCPRJ2\010004\GRA\RCH-ORTHO2.GRA * AML: N:\ARCPRJ2\010004\AML\RCH-ORTHO.AML



EXPLANATION

Hydrology

- River or Stream
- Lake or Open Water
- 500- Year Floodplain
- Reach 2
- River Mile (from confluence with California Gulch)

Transportation

- Minor Road
- Medium Duty Road
- Highway
- Railroad

Other Features

- Mine- Waste Deposit
- Reach Boundary

N

SCALE IN FEET

1500 0 1500

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2- 62
1996 ORTHOPHOTOGRAPHY
LAKE FORK
TO HWY 24 BRIDGE
(REACH 2)

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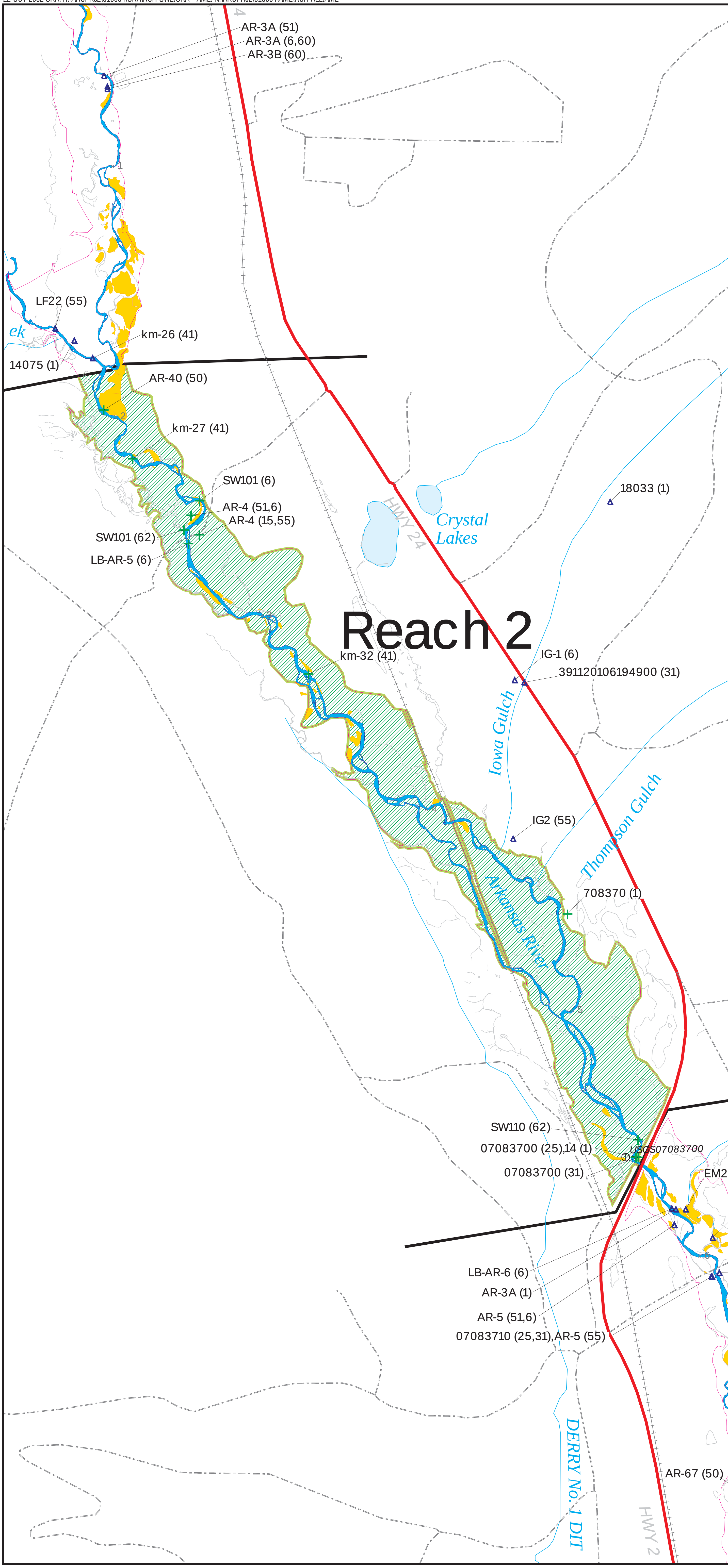

EXPLANATION

Hydrology

River or Stream

Lake or Open Water

11- Mile Reach
500- Year Floodplain

Reach 2

× 1 River Mile (from confluence with California Gulch)

Transportation

Minor Road

Medium Duty Road

Highway

Railroad

Other Features

Mine- Waste Deposit

Reach Boundary

Sampling Locations

Surface Water Sampling Location Within Reach 2

Surface Water Sampling Location Outside Reach 2

EXAMPLE

708370 (1)

Sample Location

Site Name

Data Source(s)

Data Sources in Reach 2

(1) Arkansas River Database- 1994; USFWS.
[Period of record: 1901- 1994]

(15) CDOW WQ and Discharge Data; Clements (CSU).
[Period of record: 1996- 1999]

(25) Flow and field parameter data; USGS.
[Period of record: 1910- 1999]

(31) STORET data; EPA.
[Period of record: 1955- 1997]

(41) Selected hydrologic data for the upper Arkansas River basin, Colorado, 1986- 89; Kimball, Callender and Axtmann (USGS).
[Period of record: 1988- 1989]

(50) Effects of Fluvial Tailings Deposits on Soils and Surface and Groundwater- Upper Arkansas River, Colorado, 1992- 96; Walton-Day et al. (USGS).
[Period of record: 1992- 1996]

(51) Resurrection Database; Shepherd- Miller.
[Period of record: 1994- 1999]

(55) CDOW/BOR/CSU 1995- 1999 WQ Data from CDOW; Davies, Clements, et al.
[Period of record: 1996- 1999]

(6) Cal Gulch WQ Data; ISSI.
[Period of record: 1983- 1988]

(62) Surface and Groundwater data, Cal Gulch/Arkansas River area; Ecology & Environment, Inc.
[Period of record: 1983]

N

SCALE IN FEET

1500 0 1500

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2- 63
SURFACE WATER SAMPLE LOCATIONS
LAKE FORK
TO HWY 24 BRIDGE
(REACH 2)

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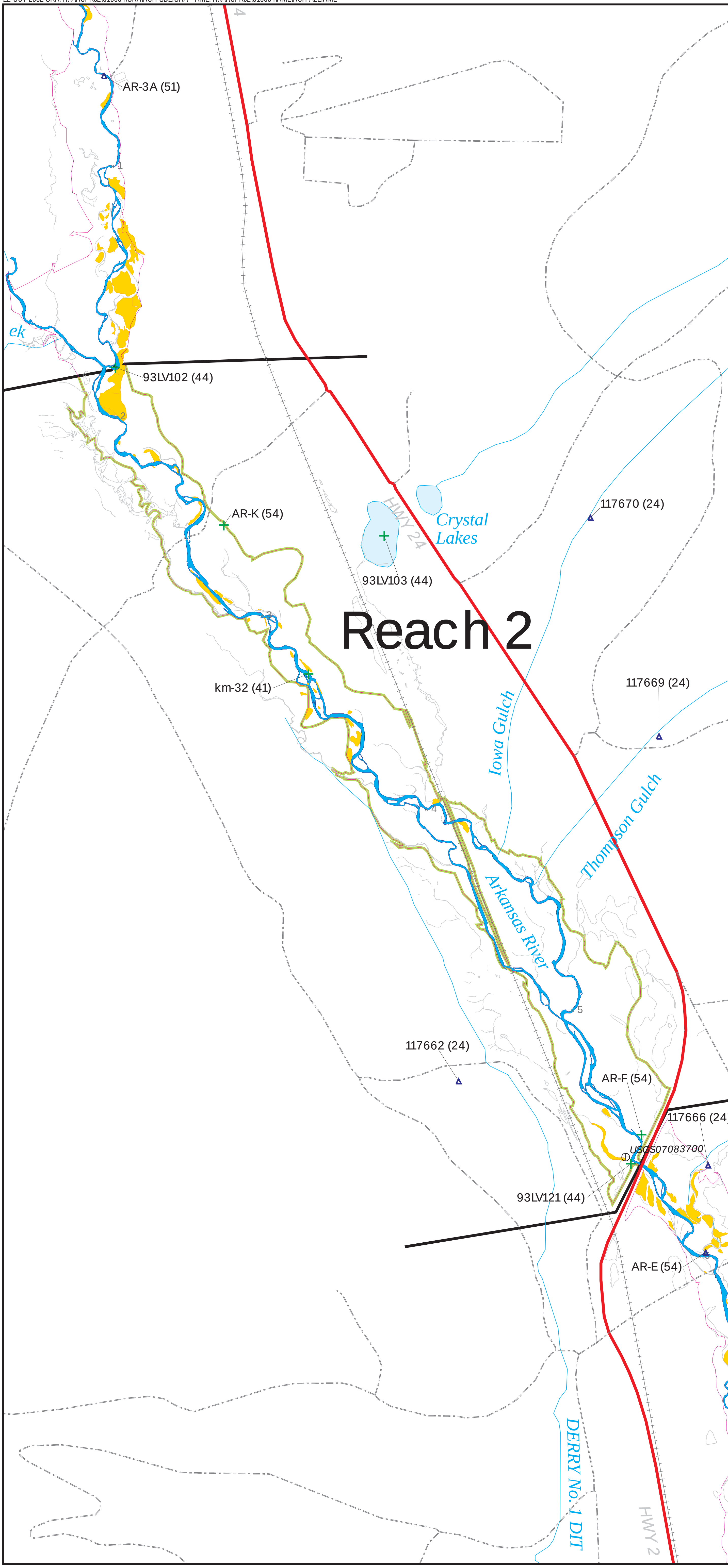

EXPLANATION

Hydrology

River or Stream
Lake or Open Water
11- Mile Reach 500- Year Floodplain
Reach 2
River Mile (from confluence with California Gulch)

Transportation

Minor Road
Medium Duty Road
Highway
Railroad

Other Features

Mine- Waste Deposit
Reach Boundary

Sampling Locations

Stream Sediment Sampling Location Within Reach 2
Stream Sediment Sampling Location Outside Reach 2

EXAMPLE

km-24 (41)
Sample Location
Site Name
Data Source(s)

Data Sources in Reach 2

(41) Selected hydrologic data for the upper Arkansas River basin, Colorado, 1986- 89; Kimball, Callender and Axtmann (USGS).
[Period of record: 1988- 1989]

(44) Geochemical and Lead Isotope data for stream and lake sediments; S.E. Church (USGS).
[Period of record: 1993- 1994]

(54) USFWS Sediment Samples; USFWS.
[Period of record: 1998]

SCALE IN FEET
1500 0 1500

UPPER ARKANSAS RIVER BASIN
SITE CHARACTERIZATION SUMMARY

FIGURE 2- 64
STREAM SEDIMENT SAMPLE LOCATIONS
LAKE FORK TO HWY 24 BRIDGE
(REACH 2)

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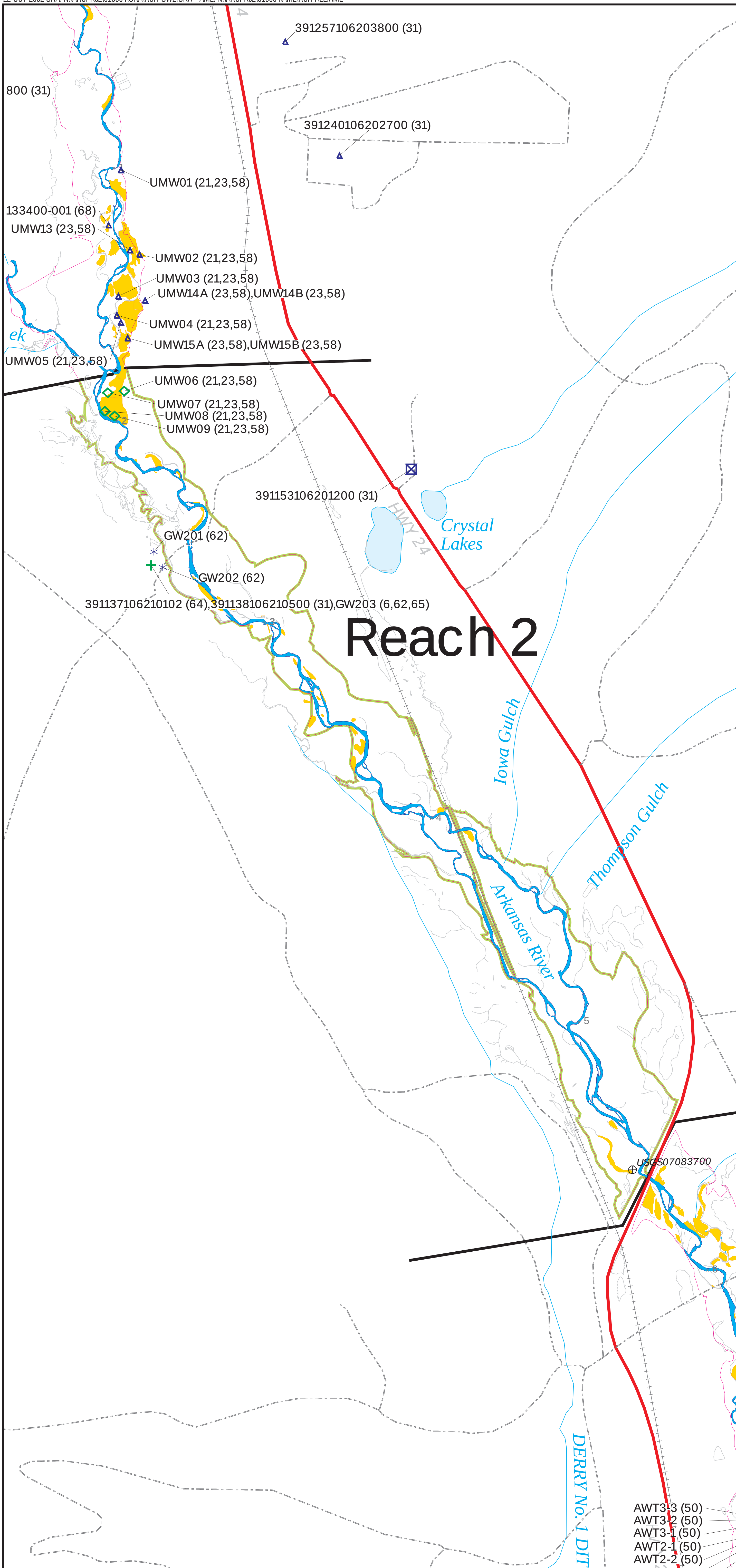

EXPLANATION

Hydrology

River or Stream

Lake or Open Water

11- Mile Reach
500- Year Floodplain

Reach 2

River Mile (from confluence with California Gulch)

Transportation

Minor Road

Medium Duty Road

Highway

Railroad

Other Features

Mine- Waste Deposit

Reach Boundary

Sampling Locations

Potential Domestic Water Supply (or other deeper well) Within Reach 2

Shallow Monitoring Well Within Reach 2

Spring or Seep Sampling Location

Groundwater Sampling Location, Depth Unknown, Within Reach 2

Groundwater Sampling Location Outside Reach 2

EXAMPLE

UMW06 (21,23,58)

Sample Location

Site Name

Data Source(s)

Data Sources in Reach 2

(21) Upper Arkansas 1998 Monitoring Well Data; EPA/URS, Walton- Day (USGS). [Period of record: 1998]

(23) Upper Arkansas 1999 Monitoring Well Data; EPA/URS. [Period of record: 1999]

(31) STORET data; EPA. [Period of record: 1955- 1997]

(58) Upper Arkansas 2000 Monitoring Well Data; EPA/URS. [Period of record: 2000]

(6) Cal Gulch WQ Data; ISSI. [Period of record: 1983- 1988]

(62) Surface and Groundwater data, Cal Gulch/Arkansas River area; Ecology & Environment, Inc. [Period of record: 1983]

(64) USGS Upper Arkansas Basin - Semi- Annual Well Network (Water Levels 1963- 2000); Haley (USGS) [Period of record: 1963- 2000]

(65) Preliminary EPA GW data for well at Dr. Smiths residence; EPA/URS. [Period of record: 2001]

N

SCALE IN FEET

1500 0 1500

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2- 65
GROUNDWATER SAMPLE LOCATIONS
LAKE FORK
TO HWY 24 BRIDGE
(REACH 2)

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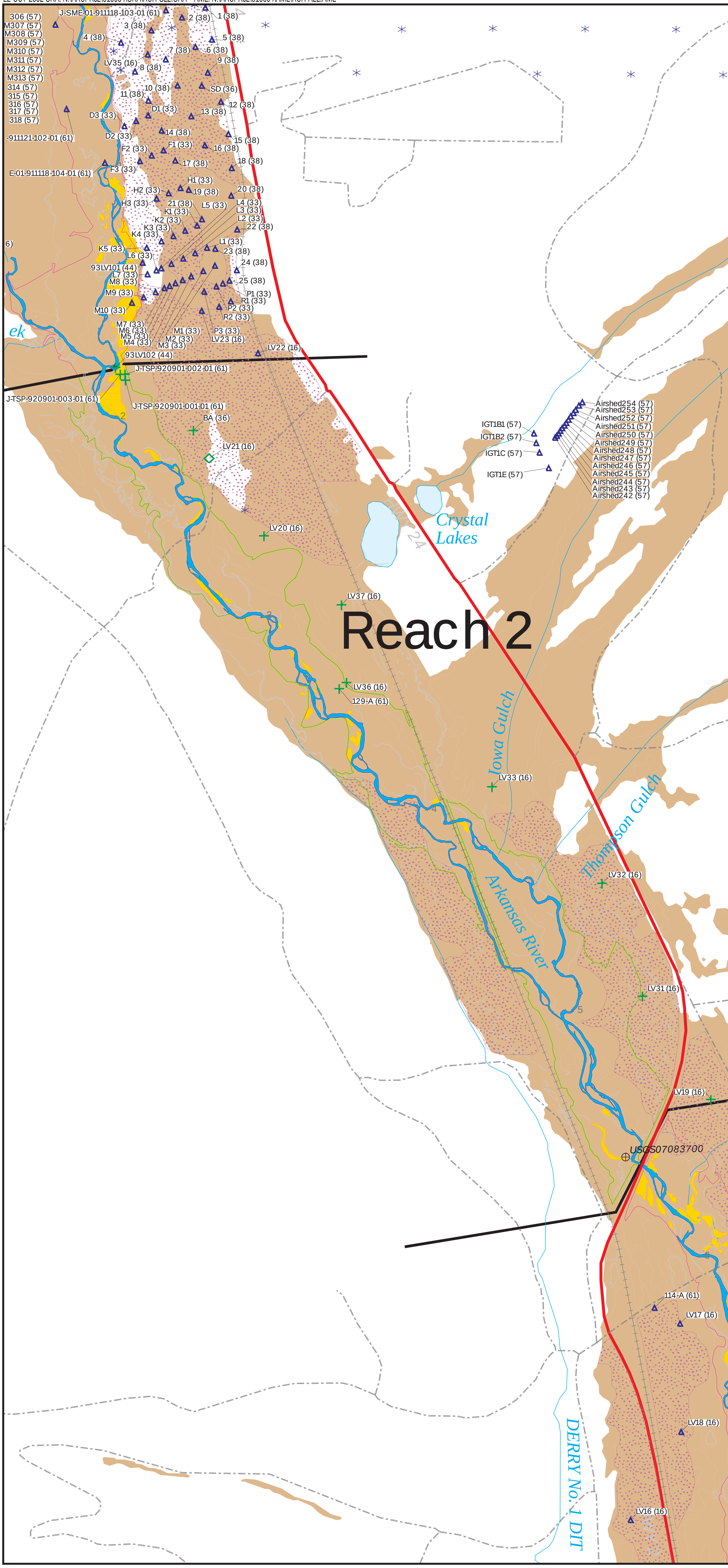

EXPLANATION

Hydrology

- River or Stream
- Lake or Open Water
- 11- Mile Reach 500- Year Floodplain
- Reach 2
- Lowland Zone - Based on presence of riparian species (CDOW Vegetation Mapping, 2001)
- Irrigated Area (SAIC, 2001)
- River Mile (from confluence with California Gulch)

Transportation

- Minor Road
- Medium Duty Road
- Highway
- Railroad

Other Features

- Mine- Waste Deposit
- Reach Boundary

Sampling Locations

- Lowland Soil Sampling Location Within Reach 2
- Upland Soil Sampling Location Within Reach 2
- Soil Sampling Location Outside Reach 2
- AIRSHED Sample Location

EXAMPLE

LV20 (16)

Sample Location

Site Name

Data Source(s)

Data Sources in Reach 2

(16) 1986/1987 Soil and Vegetation Metals Data; Keammerer. [Period of record: 1987]

(36) Metal Contamination in Soils and Plants Near Leadville; David Levy (CSU). [Period of record: 1988]

(44) Geochemical and Lead Isotope data for stream and lake sediments; S.E. Church (USGS). [Period of record: 1993- 1994]

(61) Surface soils data - 0 to 2 inches; Walsh. [Period of record: 1986- 1997]

SCALE IN FEET

1500 0 1500

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2- 66

SOIL SAMPLE LOCATIONS
LAKE FORK
TO HWY 24 BRIDGE
(REACH 2)

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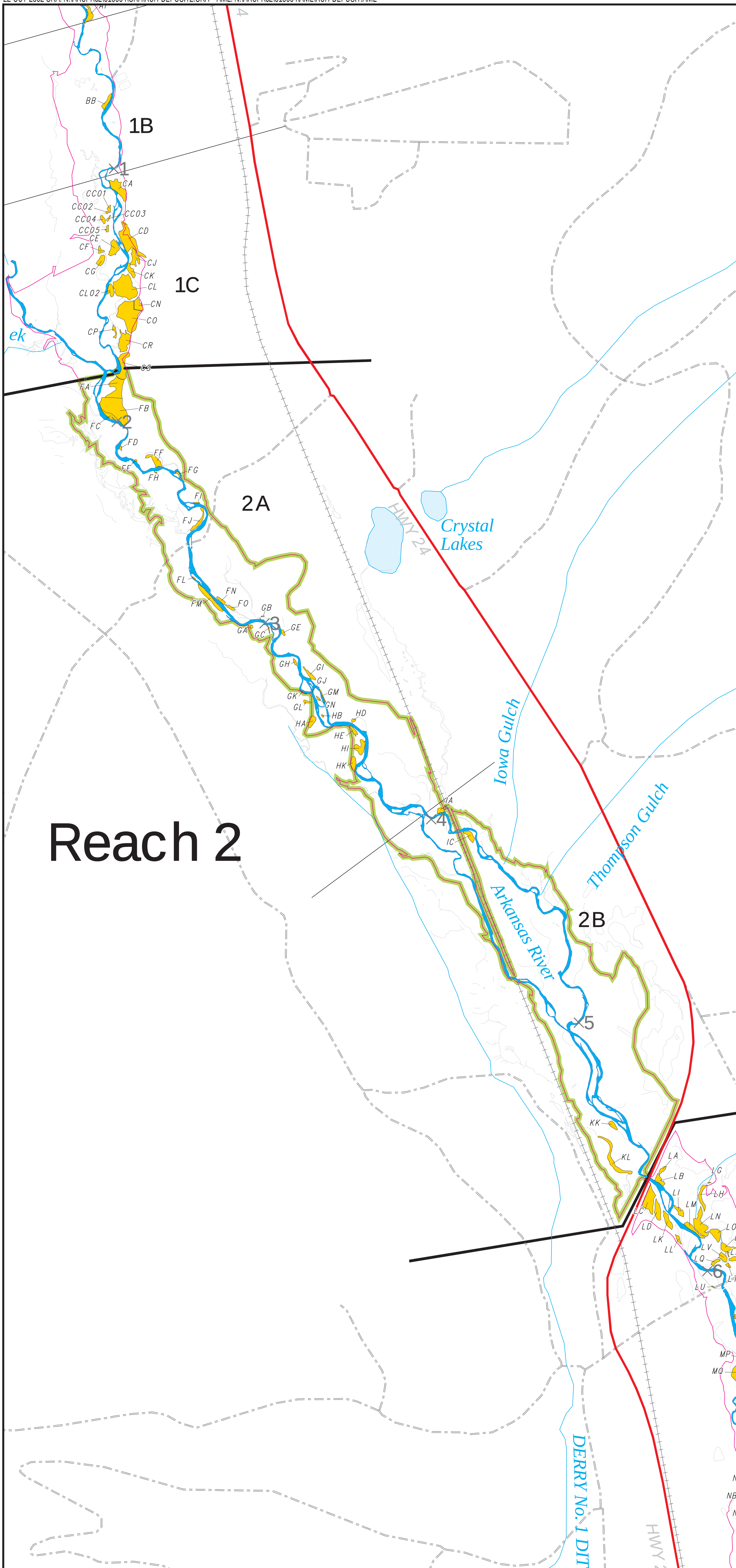

EXPLANATION

Hydrology

- River or Stream
- Lake or Open Water
- 500- Year Floodplain
- Reach 2
- × 1 River Mile (from confluence with California Gulch)

Transportation

- Minor Road
- Medium Duty Road
- Highway
- Railroad

Other Features

- Mine- Waste Deposit
- Reach Boundary
- Subreach Boundary

N

SCALE IN FEET

1500 0 1500

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2- 67
MINE- WASTE DEPOSIT
LOCATIONS
LAKE FORK
TO HWY 24 BRIDGE
(REACH 2)

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REV: 1	BY: MCP	CHK: SAW

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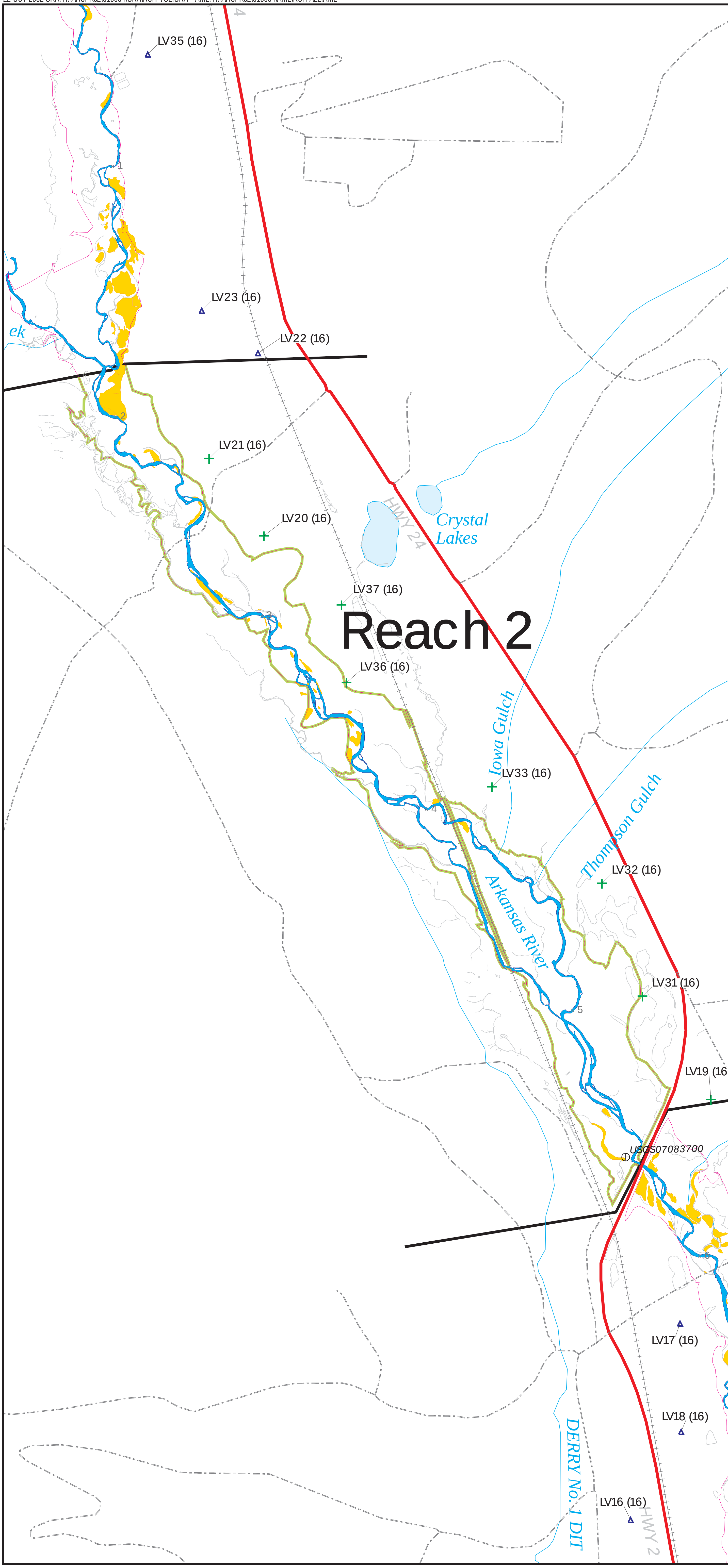

EXPLANATION

Hydrology

- River or Stream
- Lake or Open Water
- 11- Mile Reach 500- Year Floodplain
- Reach 2
- × 1 River Mile (from confluence with California Gulch)

Transportation

- Minor Road
- Medium Duty Road
- Highway
- Railroad

Other Features

- Mine- Waste Deposit
- Reach Boundary

Sampling Locations

- \+ Vegetation Sampling Location Within Reach 2
- Δ Vegetation Sampling Location Outside Reach 2

EXAMPLE

LV21 (16)

Sample Location

Site Name

Data Source(s)

Data Sources in Reach 2

(16) 1986/1987 Soil and Vegetation Metals Data; Keammerer. [Period of record: 1987]

N

SCALE IN FEET

1500 0 1500

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2- 68
VEGETATION SAMPLE LOCATIONS
LAKE FORK
TO HWY 24 BRIDGE
(REACH 2)

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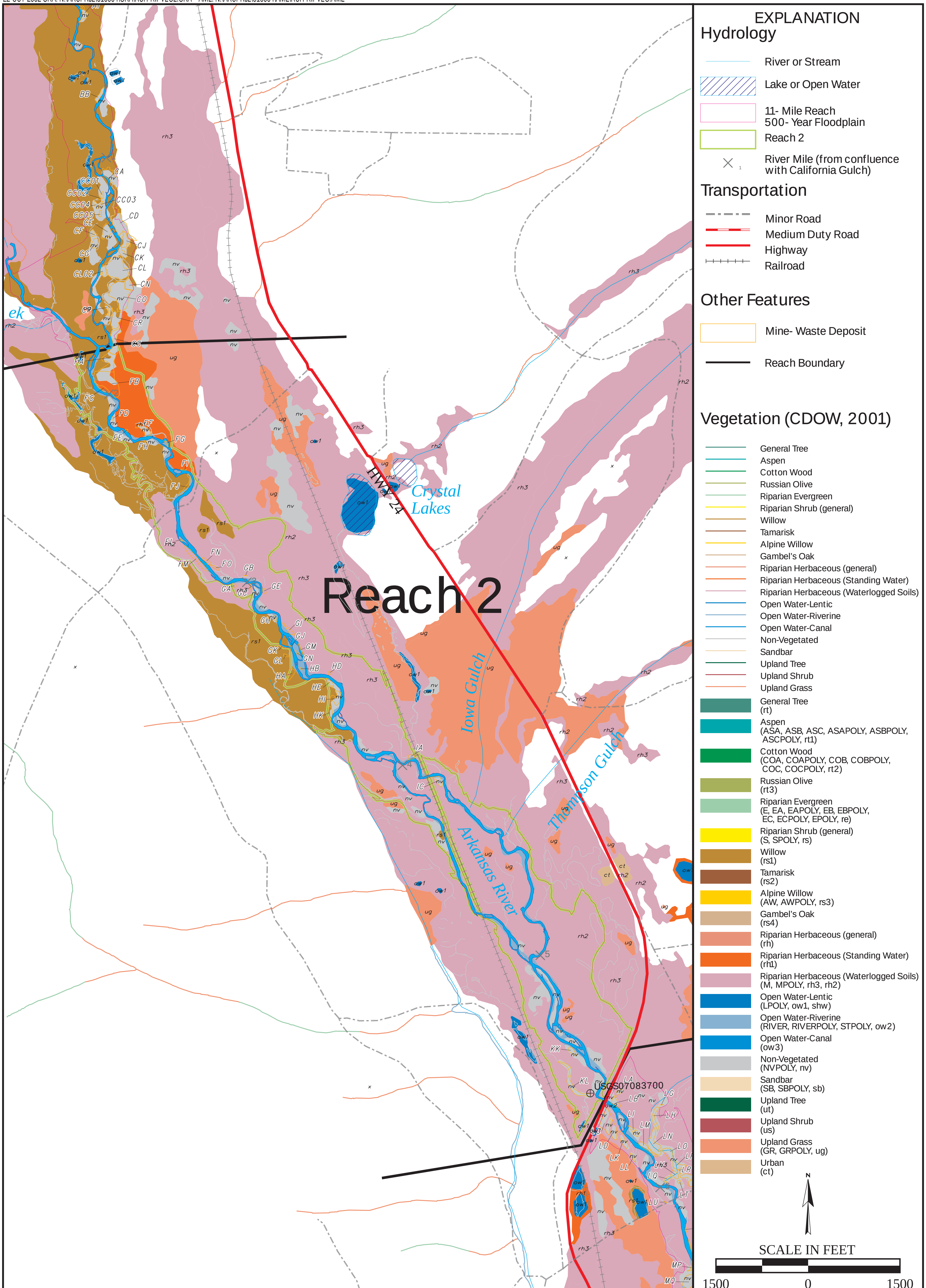

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2- 69

RIPARIAN VEGETATION
LAKE FORK
TO HWY 24 BRIDGE
(REACH 2)

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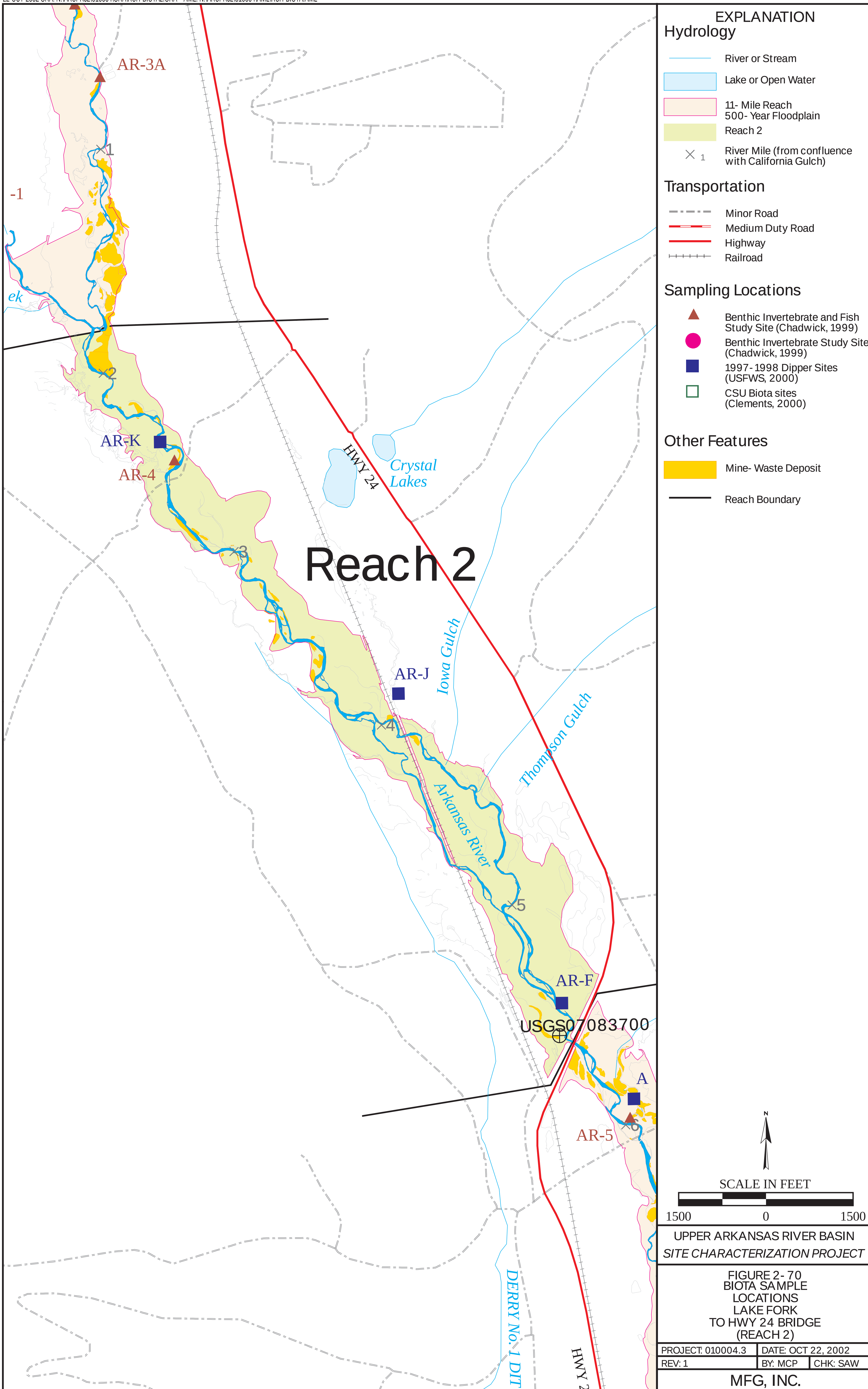

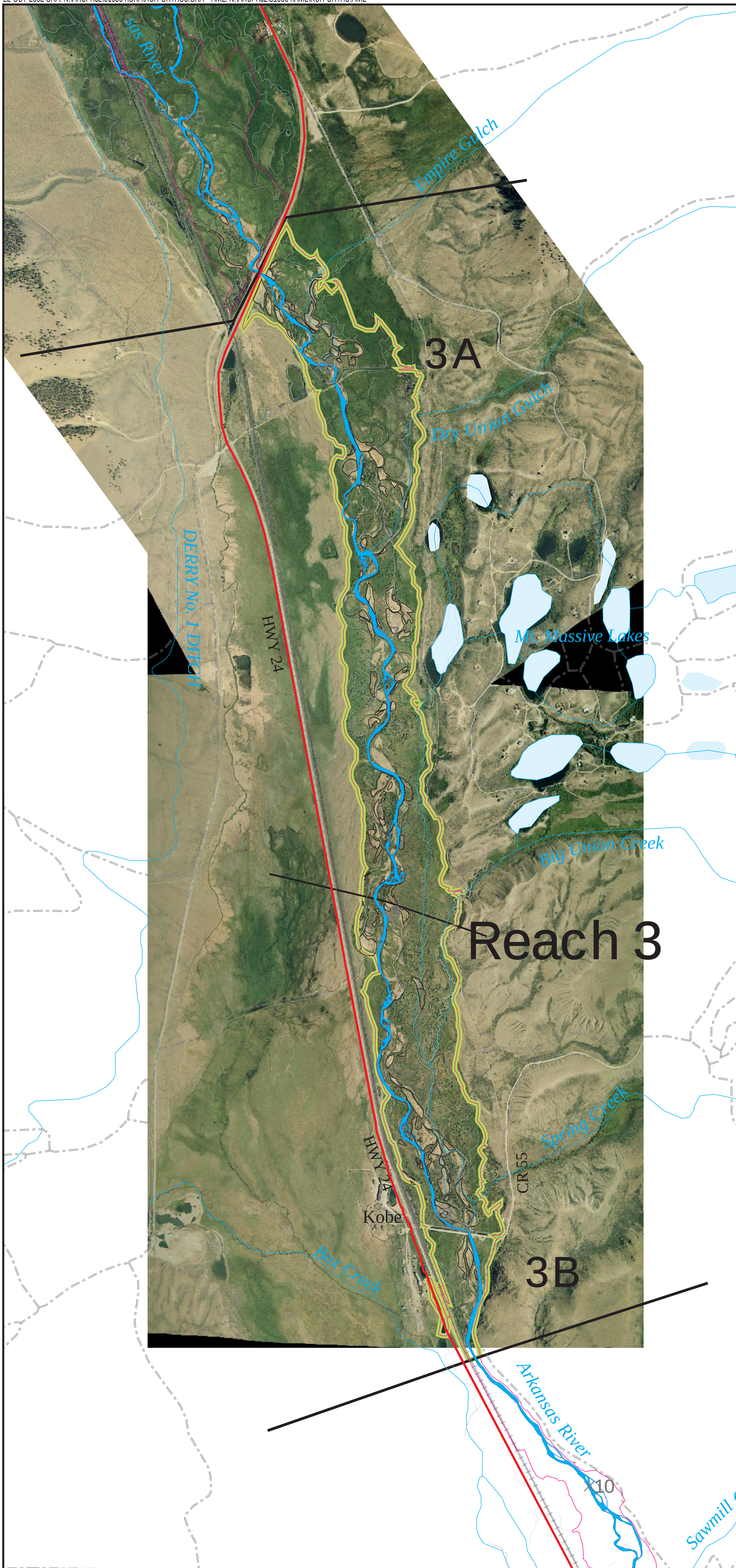

EXPLANATION

Hydrology

- River or Stream
- Lake or Open Water
- 500- Year Floodplain
- Reach 3
- River Mile (from confluence with California Gulch)

Transportation

- Minor Road
- Medium Duty Road
- Highway
- Railroad

Other Features

- Mine- Waste Deposit
- Reach Boundary

N

SCALE IN FEET

1500 0 1500

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2- 71
1996 ORTHOPHOTOGRAPHY
HWY 24 BRIDGE
TO NARROWS BELOW KOBE
(REACH 3)

PROJECT: 010004.3	DATE: OCT 22, 2002	
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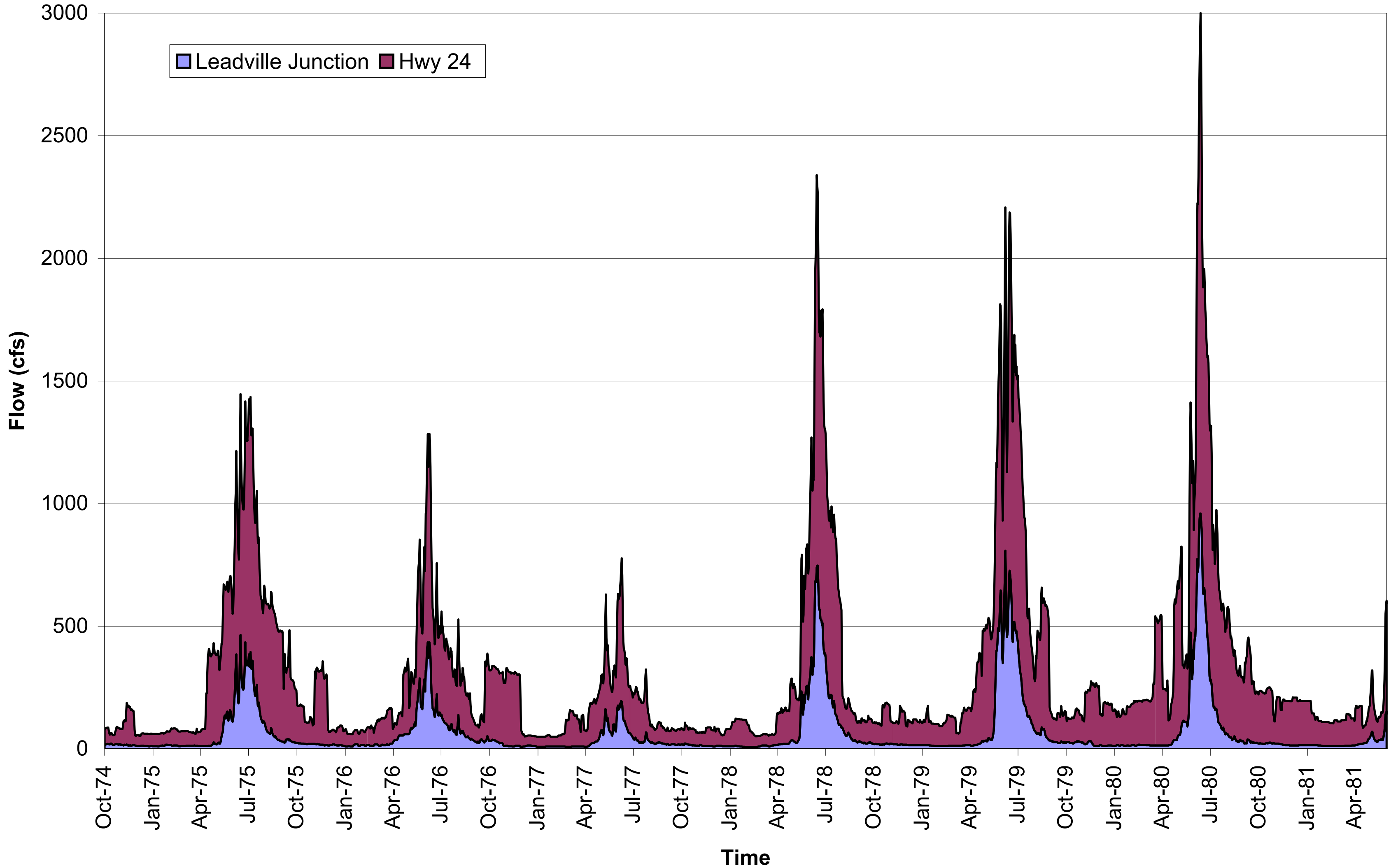


Figure 2-72

Mean Daily Flows in the Arkansas River from 1974 to 1981 (Pre-Mt. Elbert Conduit) at Leadville Junction (7081200) and the Station downstream of the Highway 24 Bridge Crossing (7083700)

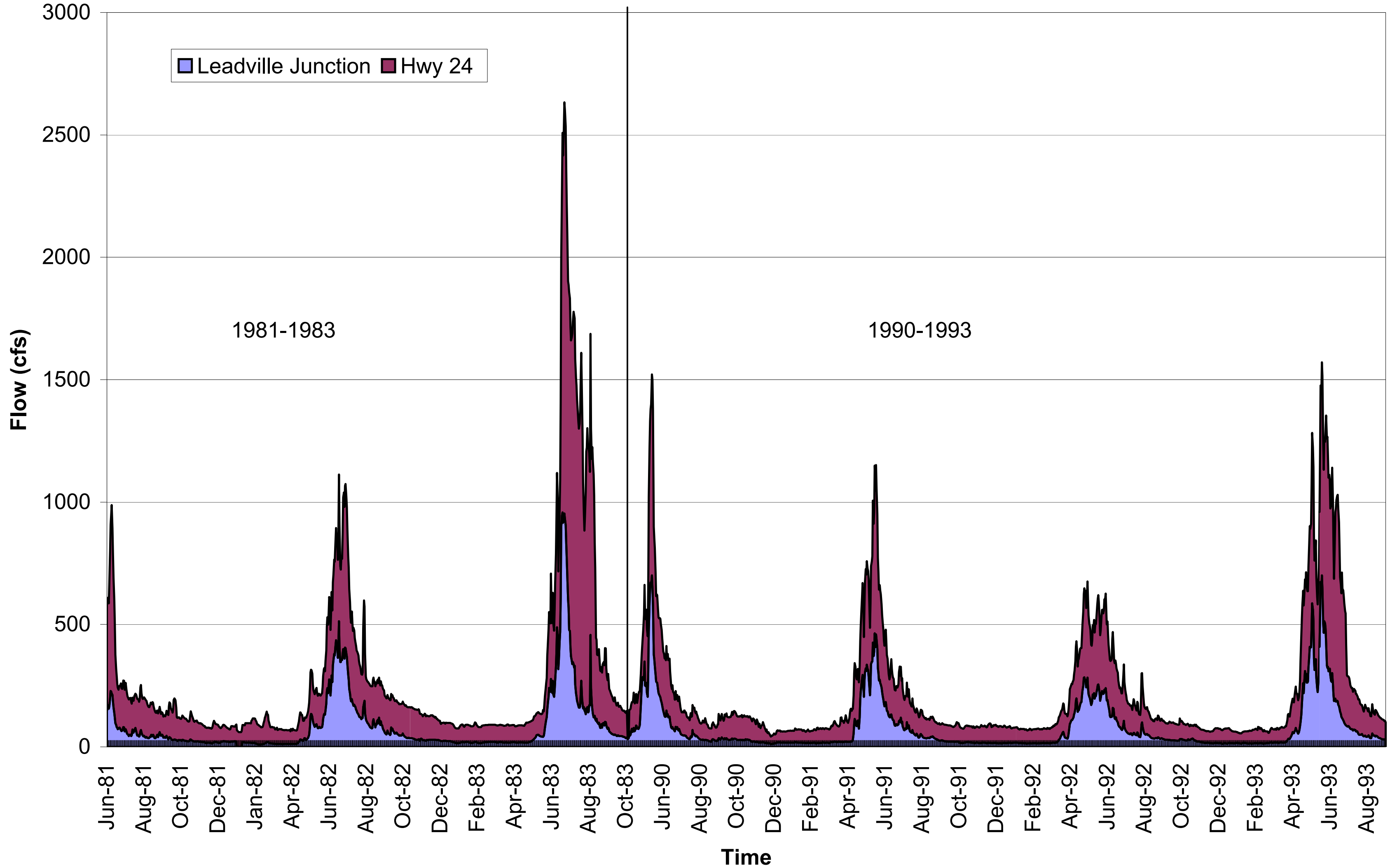
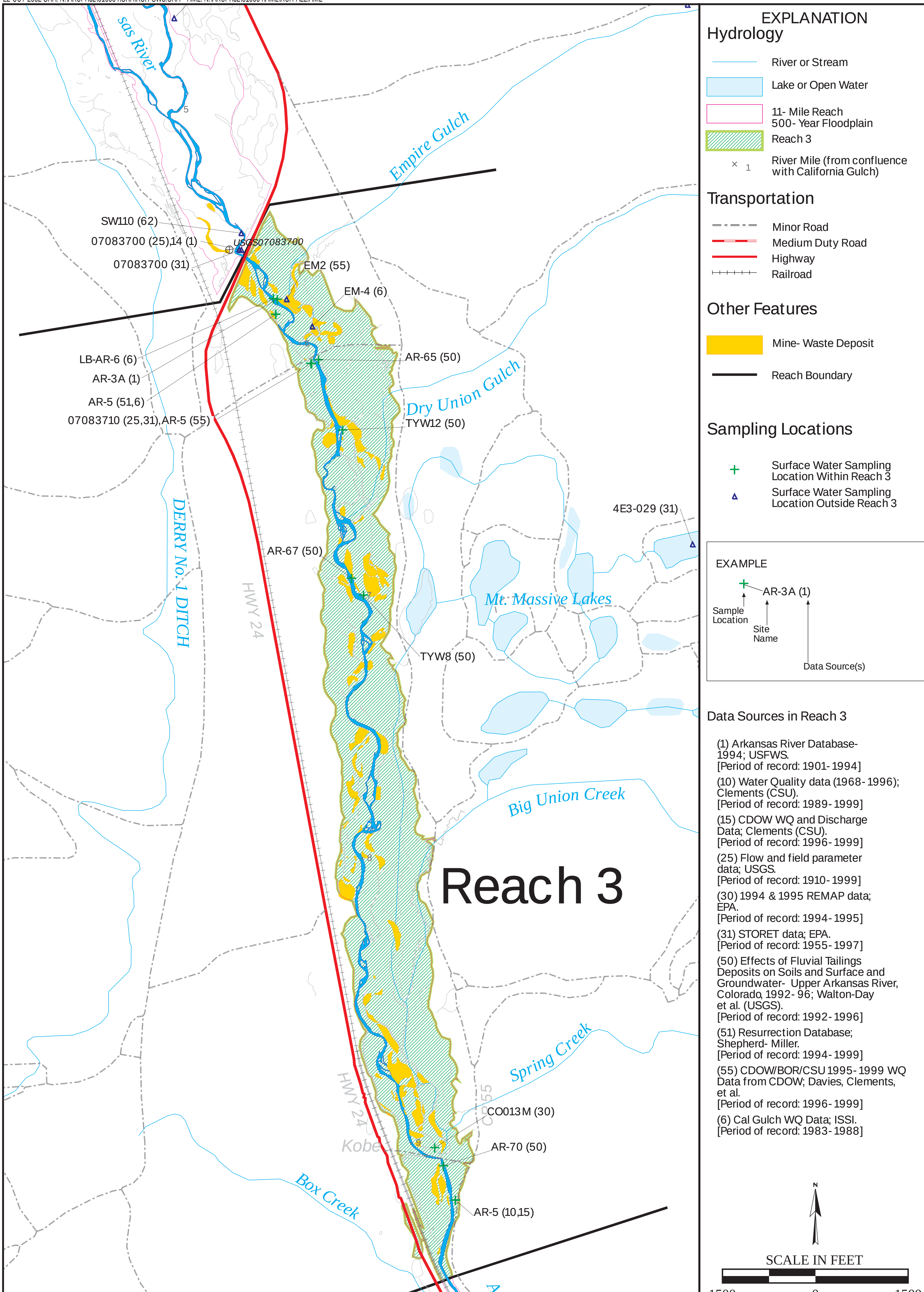


Figure 2-73

Mean Daily Flows in the Arkansas River from 1981 to 1983 and 1990 to 1993 at Leadville Junction (7081200) and the Station downstream of the Highway 24 Bridge Crossing (7083710)

22-OCT-2002 GRA: N:\ARCPRJ2\010004\GRA\RCH-SW3.GRA * AML: N:\ARCPRJ2\010004\AML\RCH-ALL.AML



UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2- 74
SURFACE WATER SAMPLE LOCATIONS
HWY 24 BRIDGE TO NARROWS BELOW KOBE
(REACH 3)

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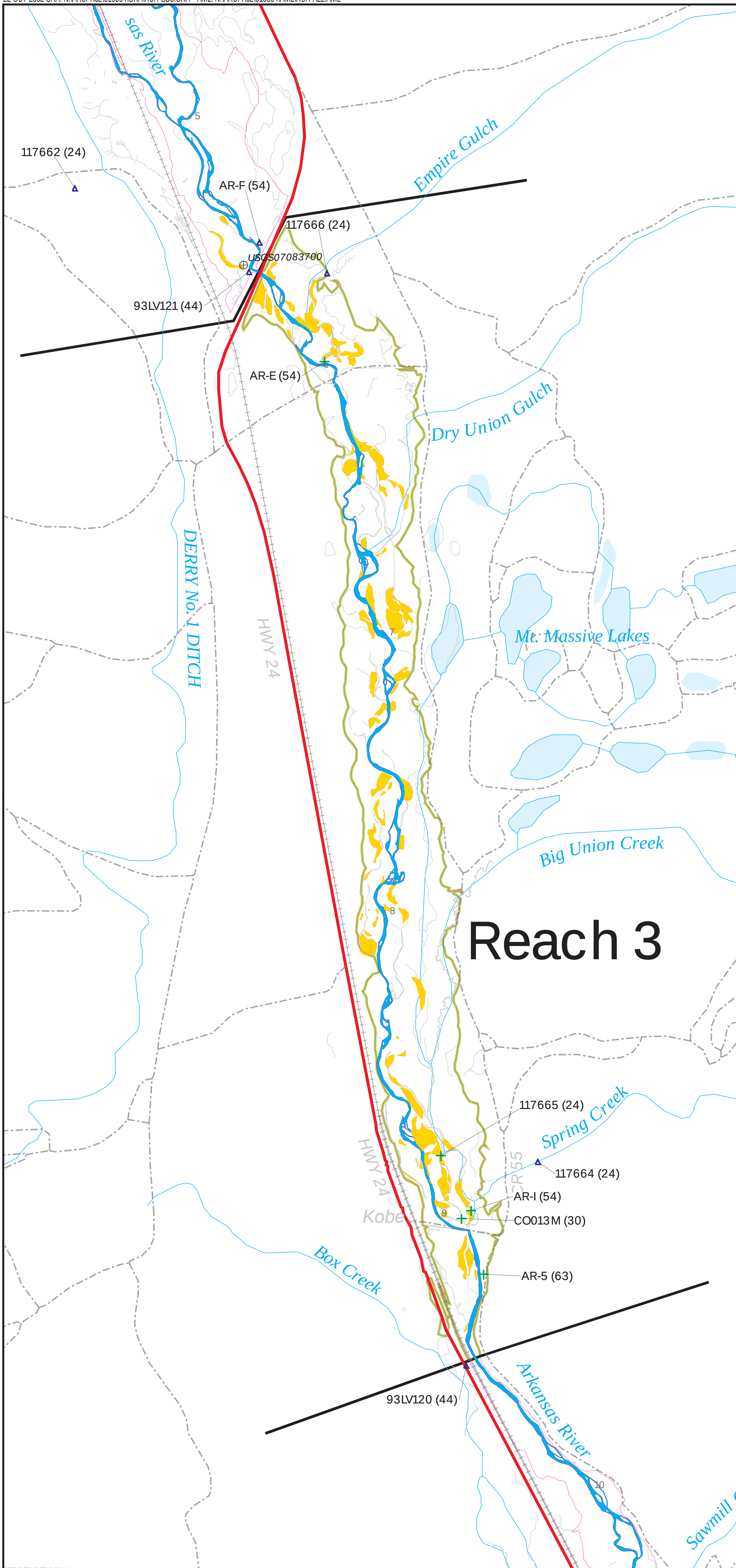

EXPLANATION

Hydrology

River or Stream

Lake or Open Water

11- Mile Reach
500- Year Floodplain

Reach 3

River Mile (from confluence with California Gulch)

Transportation

Minor Road

Medium Duty Road

Highway

Railroad

Other Features

Mine- Waste Deposit

Reach Boundary

Sampling Locations

Stream Sediment Sampling Location Within Reach 3

Stream Sediment Sampling Location Outside Reach 3

EXAMPLE

117665 (24)

Sample Location — Site Name — Data Source(s)

Data Sources in Reach 3

(24) NURE Stream Sediment Data; USGS.
[Period of record: 1976-1979]

(30) 1994 & 1995 REMAP data; EPA.
[Period of record: 1994-1995]

(54) USFWS Sediment Samples; USFWS.
[Period of record: 1998]

(63) 1995-1996 Sediment data from CSU
[Period of record: 1995-1996]

N

SCALE IN FEET

1500 0 1500

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2-75
STREAM SEDIMENT
SAMPLE LOCATIONS
HWY 24 BRIDGE
TO NARROWS BELOW KOBE
(REACH 3)

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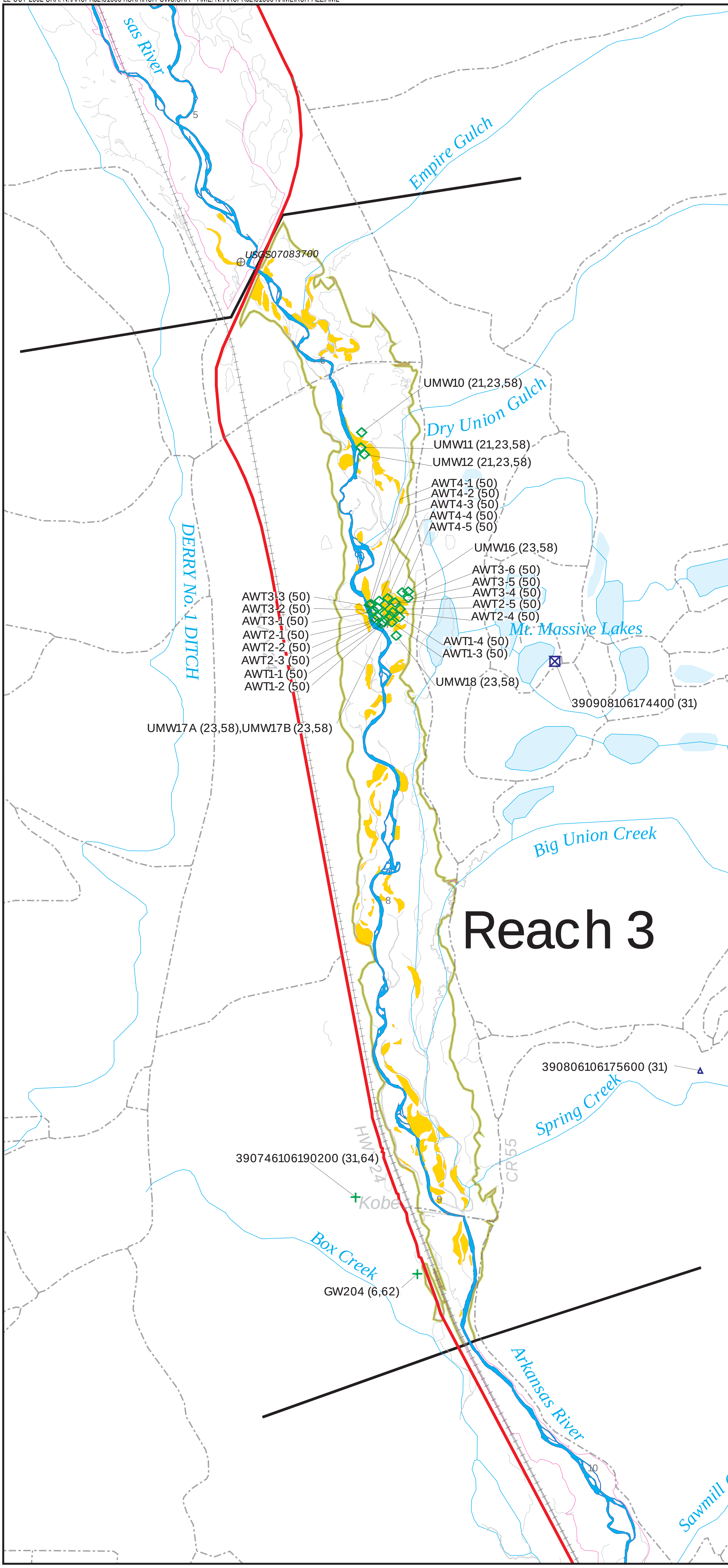

EXPLANATION

Hydrology

- River or Stream
- Lake or Open Water
- 11- Mile Reach 500- Year Floodplain
- Reach 3
- River Mile (from confluence with California Gulch)

Transportation

- Minor Road
- Medium Duty Road
- Highway
- Railroad

Other Features

- Mine- Waste Deposit
- Reach Boundary

Sampling Locations

- Potential Domestic Water Supply (or other deeper well) Within Reach 3
- Shallow Monitoring Well Within Reach 3
- Groundwater Sampling Location, Depth Unknown, Within Reach 3
- Groundwater Sampling Location Outside Reach 3

EXAMPLE

UMW10 (21,23,58)

Sample Location — Site Name — Data Source(s)

Data Sources in Reach 3

(21) Upper Arkansas 1998 Monitoring Well Data; EPA/URS, Walton- Day (USGS). [Period of record: 1998]

(23) Upper Arkansas 1999 Monitoring Well Data; EPA/URS. [Period of record: 1999]

(31) STORET data; EPA. [Period of record: 1955- 1997]

(50) Effects of Fluvial Tailings Deposits on Soils and Surface and Groundwater- Upper Arkansas River, Colorado, 1992- 96; Walton-Day et al. (USGS). [Period of record: 1992- 1996]

(58) Upper Arkansas 2000 Monitoring Well Data; EPA/URS. [Period of record: 2000]

(6) Cal Gulch WQ Data; ISSI. [Period of record: 1983- 1988]

(62) Surface and Groundwater data, Cal Gulch/Arkansas River area; Ecology & Environment, Inc. [Period of record: 1983]

(64) USGS Upper Arkansas Basin - Semi- Annual Well Network (Water Levels 1963- 2000); Haley (USGS) [Period of record: 1963- 2000]

N

SCALE IN FEET

1500 0 1500

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2- 76
GROUNDWATER SAMPLE LOCATIONS
HWY 24 BRIDGE TO NARROWS BELOW KOBE (REACH 3)

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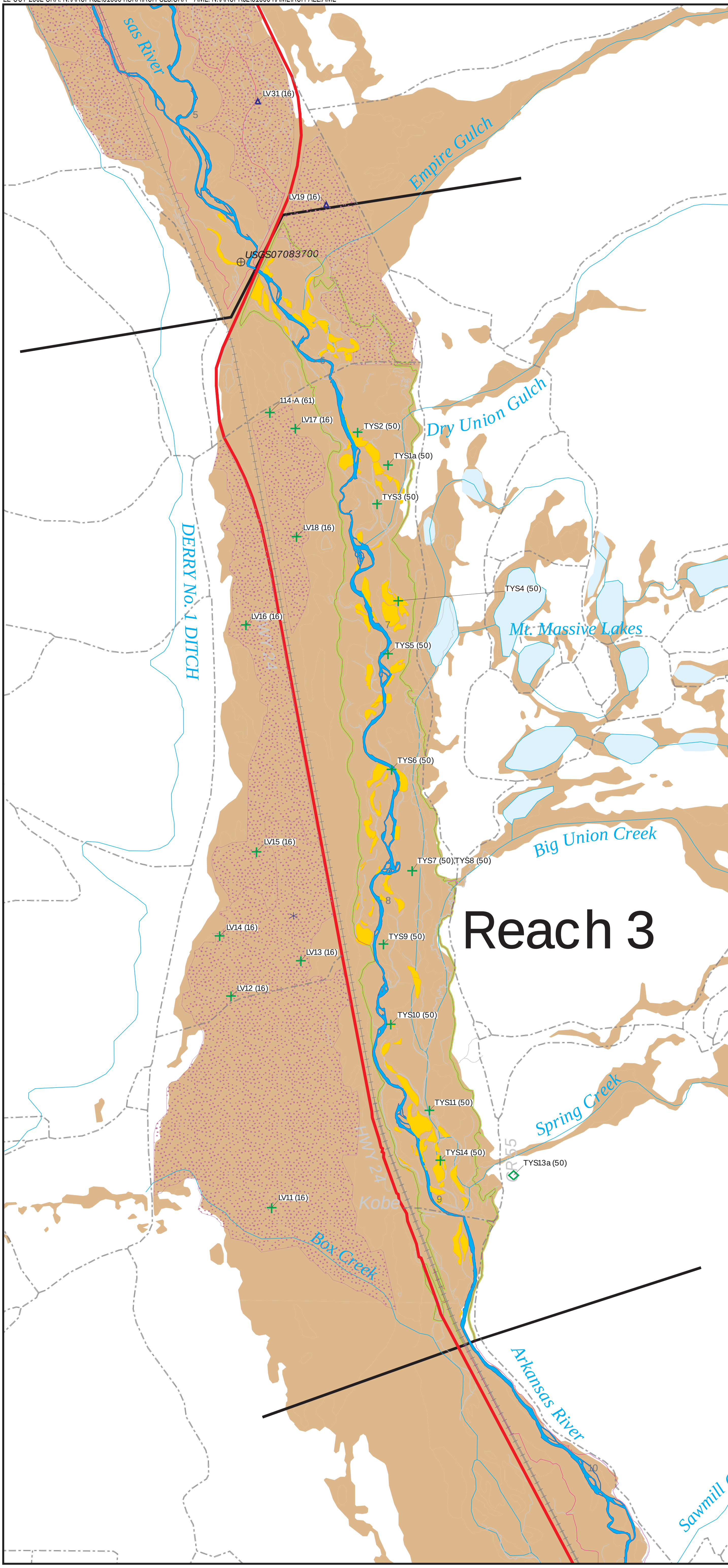

EXPLANATION

Hydrology

- River or Stream
- Lake or Open Water
- 11- Mile Reach 500- Year Floodplain
- Reach 3
- Lowland Zone - Based on presence of riparian species (CDOW Vegetation Mapping, 2001)
- Irrigated Area (SAIC, 2001)
- River Mile (from confluence with California Gulch)

Transportation

- Minor Road
- Medium Duty Road
- Highway
- Railroad

Other Features

- Mine- Waste Deposit
- Reach Boundary

Sampling Locations

- Lowland Soil Sampling Location Within Reach 3
- Upland Soil Sampling Location Within Reach 3
- Soil Sampling Location Outside Reach 3
- AIRSHED Sample Location

EXAMPLE

LV17 (16)

Sample Location — Site Name — Data Source(s)

Data Sources in Reach 3

(16) 1986/1987 Soil and Vegetation Metals Data; Keammerer. [Period of record: 1987]

(50) Effects of Fluvial Tailings Deposits on Soils and Surface and Groundwater- Upper Arkansas River, Colorado, 1992- 96; Walton-Day et al. (USGS). [Period of record: 1992- 1996]

(61) Surface soils data - 0 to 2 inches; Walsh. [Period of record: 1986- 1997]

SCALE IN FEET

1500 0 1500

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2- 77
SOIL SAMPLE LOCATIONS
HWY 24 BRIDGE
TO NARROWS BELOW KOBE
(REACH 3)

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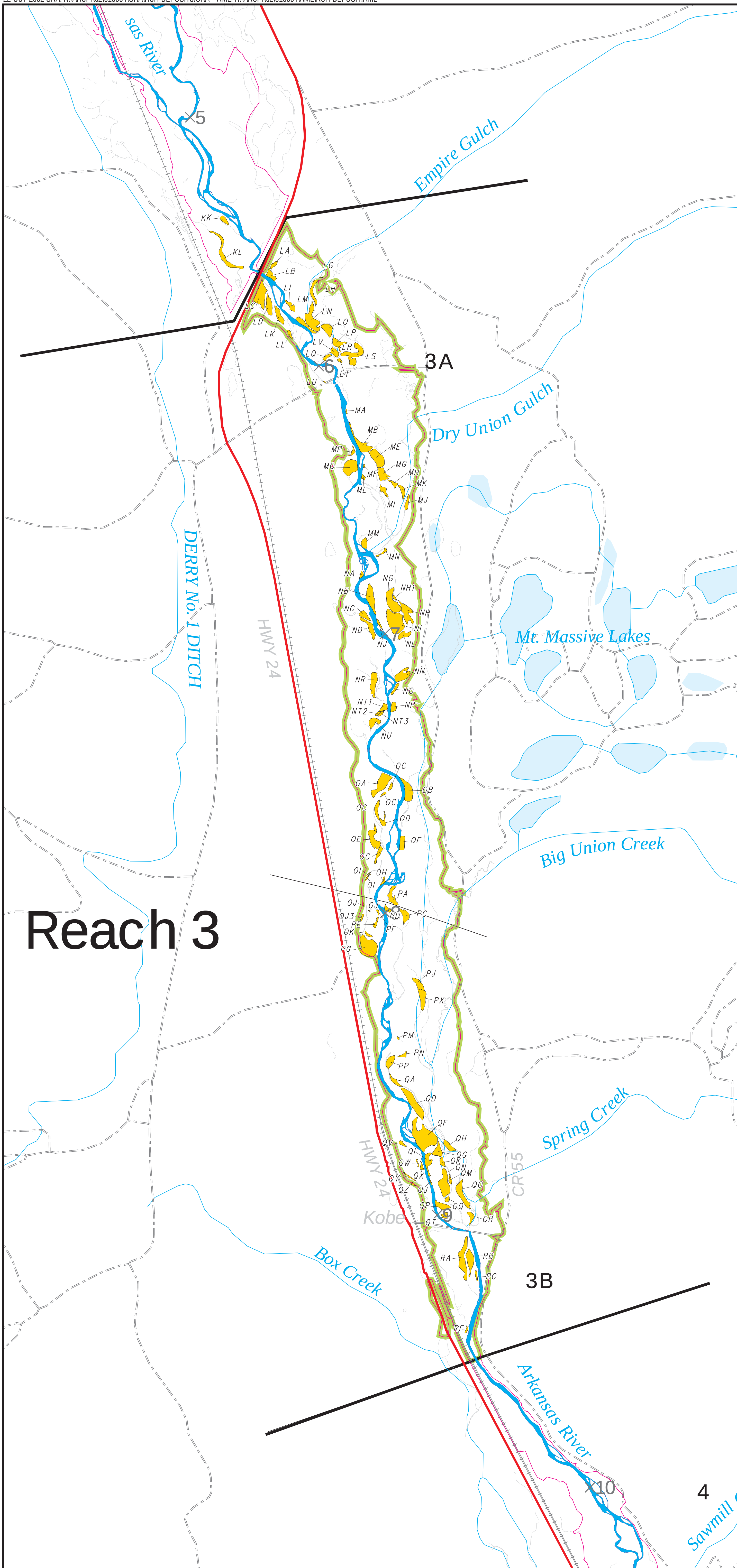

EXPLANATION

Hydrology

- River or Stream
- Lake or Open Water
- 500- Year Floodplain
- Reach 3
- × 1 River Mile (from confluence with California Gulch)

Transportation

- Minor Road
- Medium Duty Road
- Highway
- Railroad

Other Features

- Mine- Waste Deposit
- Reach Boundary
- Subreach Boundary

N

SCALE IN FEET

1500 0 1500

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2- 78
MINE- WASTE DEPOSIT
LOCATIONS
HWY 24 BRIDGE
TO NARROWS BELOW KOBE
(REACH 3)

PROJECT: 010004.3	DATE: OCT 22, 2002	
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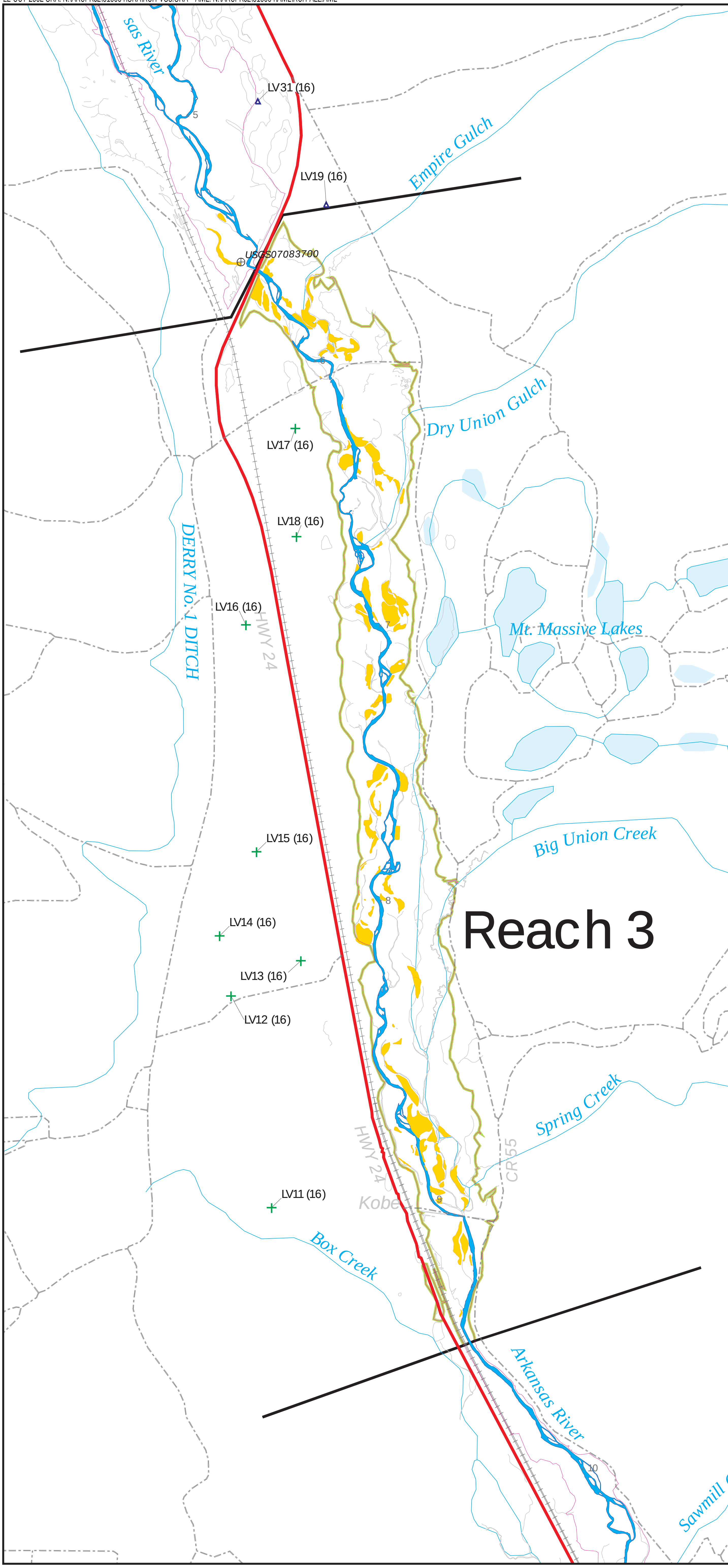

EXPLANATION

Hydrology

- River or Stream
- Lake or Open Water
- 11- Mile Reach 500- Year Floodplain
- Reach 3
- × 1 River Mile (from confluence with California Gulch)

Transportation

- Minor Road
- Medium Duty Road
- Highway
- Railroad

Other Features

- Mine- Waste Deposit
- Reach Boundary

Sampling Locations

- Vegetation Sampling Location Within Reach 3
- Vegetation Sampling Location Outside Reach 3

EXAMPLE

LV17 (16)

Sample Location

Site Name

Data Source(s)

Data Sources in Reach 3

(16) 1986/1987 Soil and Vegetation Metals Data; Keammerer. [Period of record: 1987]

N

SCALE IN FEET

1500 0 1500

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2- 79

VEGETATION SAMPLE LOCATIONS
HWY 24 BRIDGE
TO NARROWS BELOW KOBE
(REACH 3)

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

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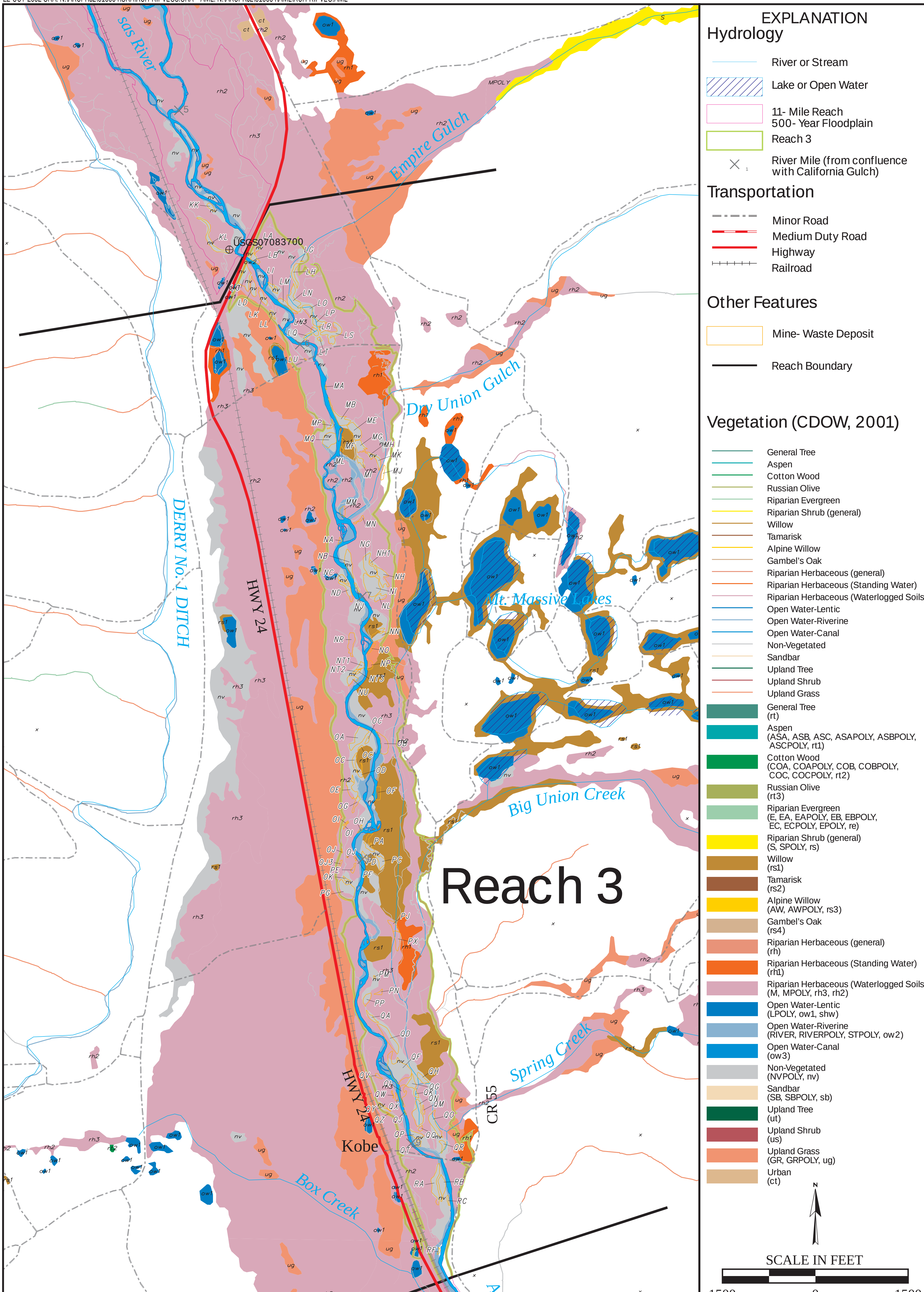

UPPER ARKANSAS RIVER BASIN

SITE CHARACTERIZATION SUMMARY

FIGURE 2- 80

RIPARIAN VEGETATION
HWY 24 BRIDGE
TO NARROWS BELOW KOBE
(REACH 3)

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

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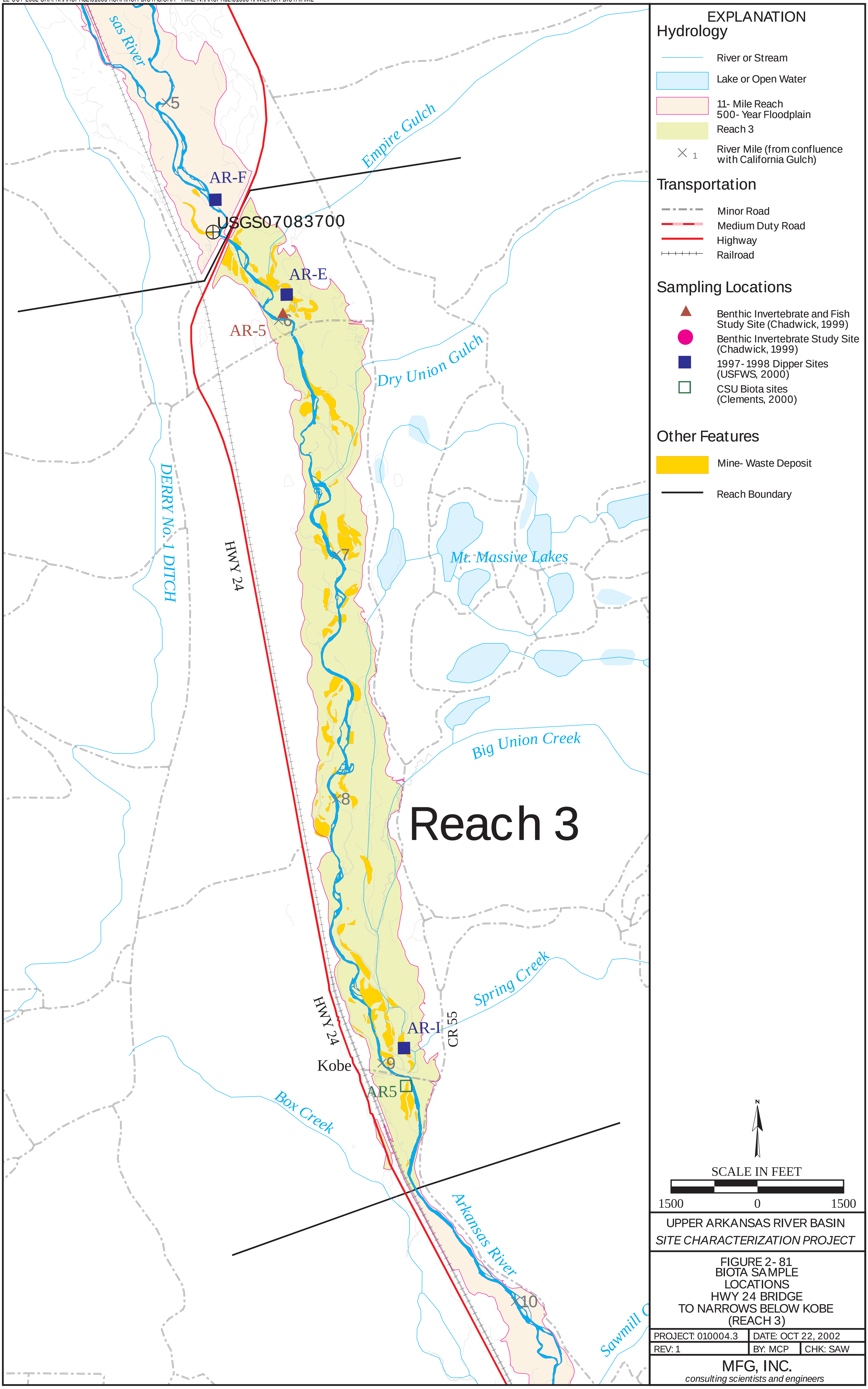
EXPLANATION
Hydrology
River or Stream
Lake or Open Water
11- Mile Reach 500- Year Floodplain
Reach 3
River Mile (from confluence with California Gulch)
Transportation
Minor Road
Medium Duty Road
Highway
Railroad
Sampling Locations
Benthic Invertebrate and Fish Study Site (Chadwick, 1999)
Benthic Invertebrate Study Site (Chadwick, 1999)
1997-1998 Dipper Sites (USFWS, 2000)
CSU Biota sites (Clements, 2000)
Other Features
Mine- Waste Deposit
Reach Boundary
Reach 3
sas River
Empire Gulch
AR-F
USGS07083700
AR-E
AR-5
Dry Union Gulch
Mt. Massive Lakes
DERRY No. 1 DITCH
HWY 24
Big Union Creek
Spring Creek
CR 55
AR-I
Kobe
AR5
Box Creek
Arkansas River
Sawmill C
5
6
7
8
9
10
N
SCALE IN FEET
1500 0 1500
UPPER ARKANSAS RIVER BASIN
SITE CHARACTERIZATION PROJECT
FIGURE 2-81
BIOTA SAMPLE LOCATIONS
HWY 24 BRIDGE
TO NARROWS BELOW KOBE
(REACH 3)
PROJECT: 010004.3
DATE: OCT 22, 2002
REV: 1
BY: MCP
CHK: SAW
MFG, INC.
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Reach 3 (Station AR5)

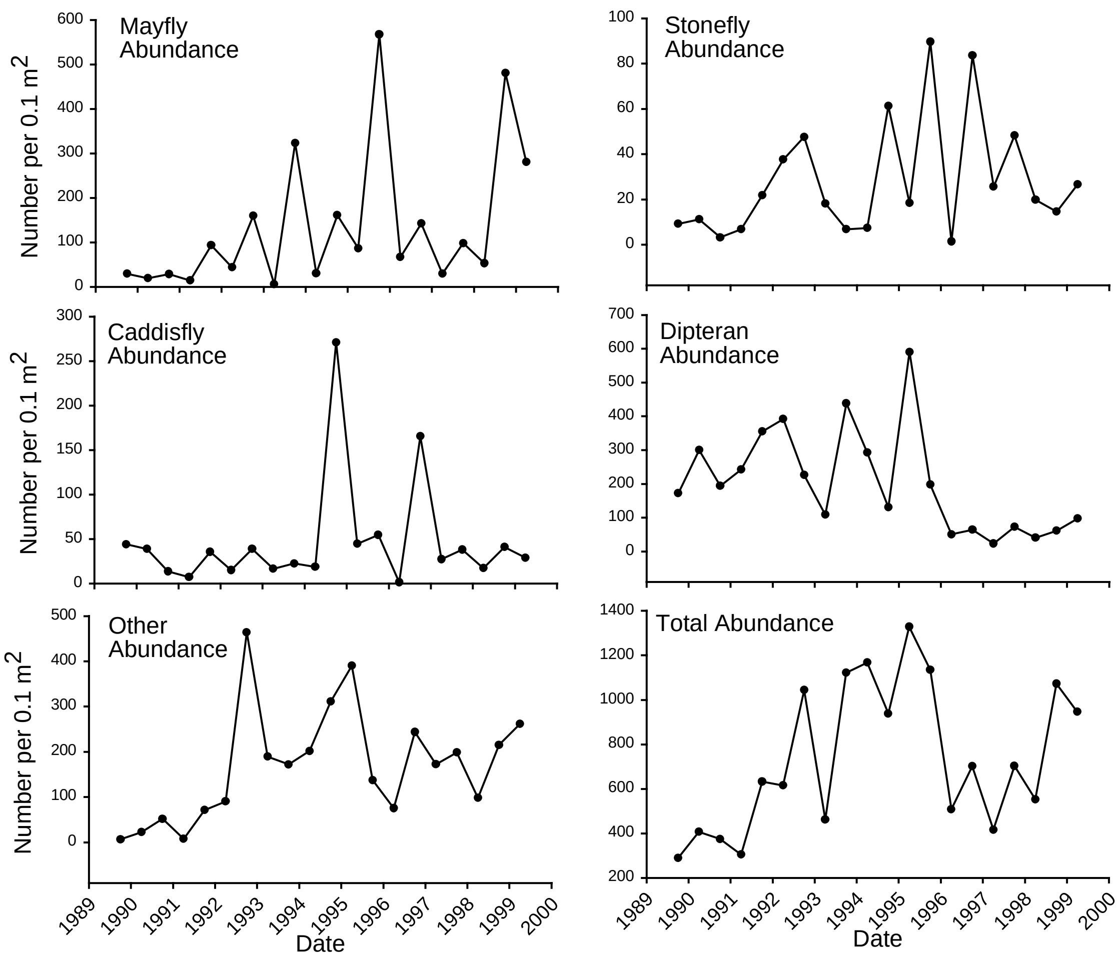


Figure 2-82

Abundance of Major Macroinvertebrate Groups in the Arkansas River (Reach 3).

Reach 3 (station AR5)

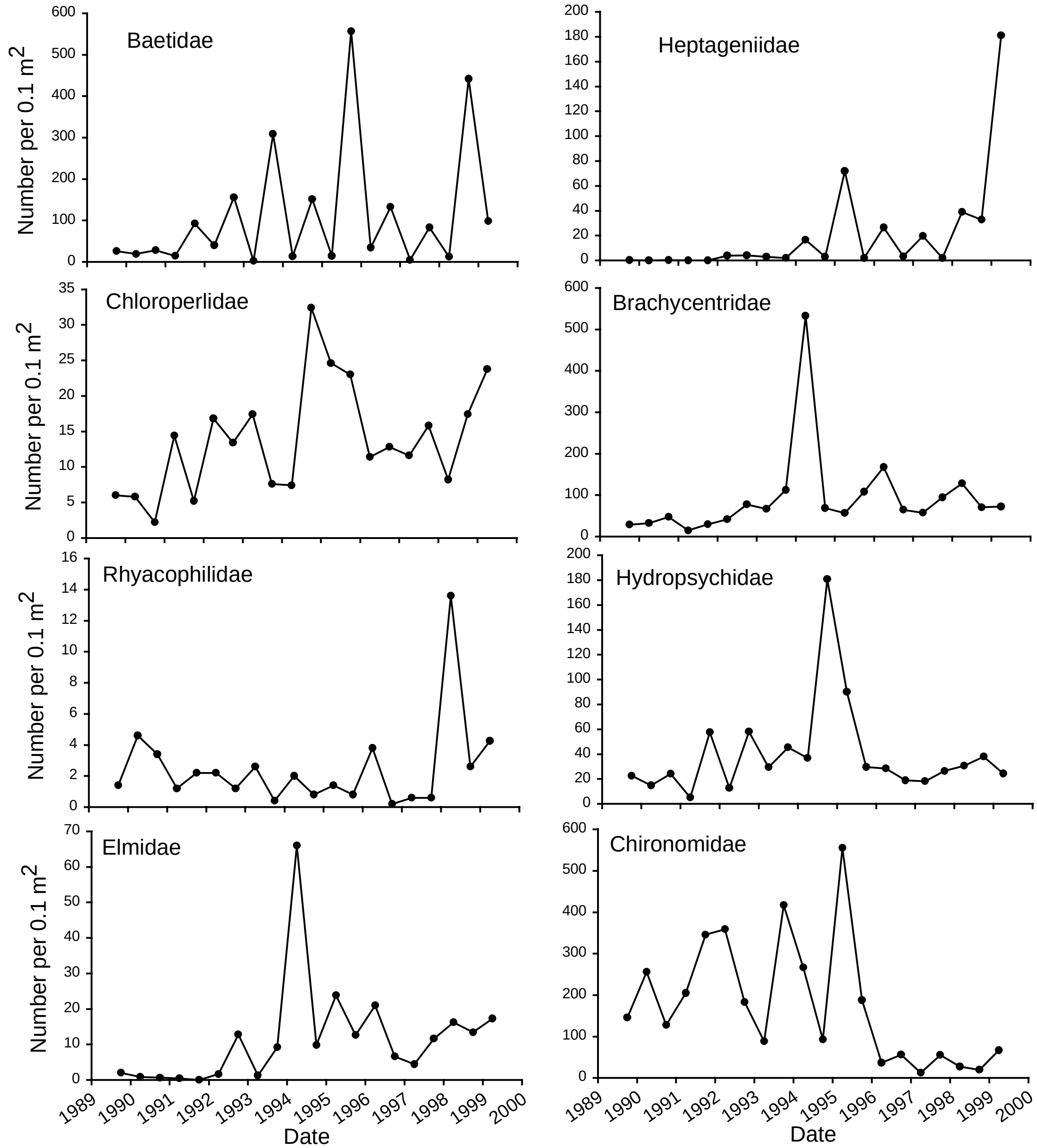


Figure 2-83

Abundance of Dominant Macroinvertebrate Taxa in the Arkansas River (Reach 3).

Reach 3 (Station AR5)

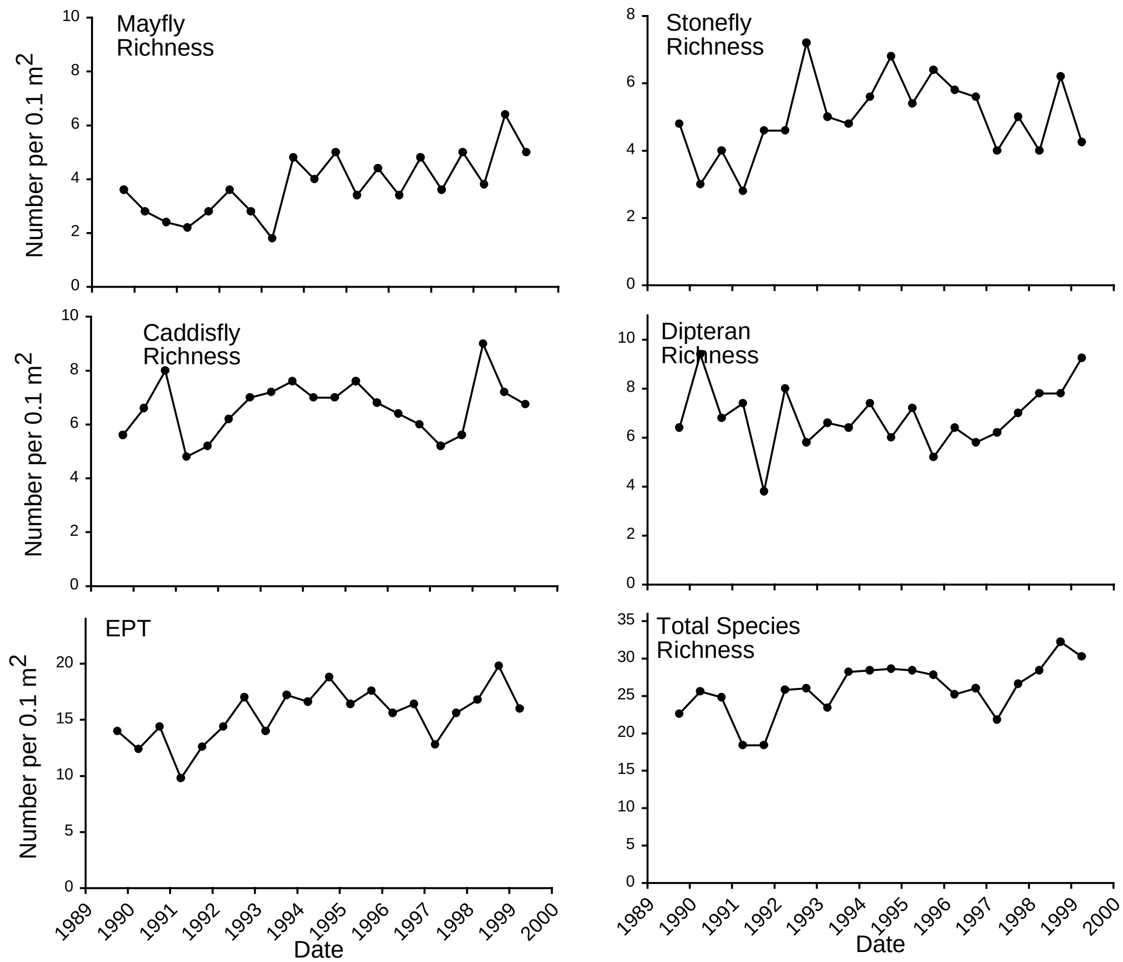


Figure 2-84

Species Richness of Major Macroinvertebrate Groups in the Arkansas River (Reach 3).

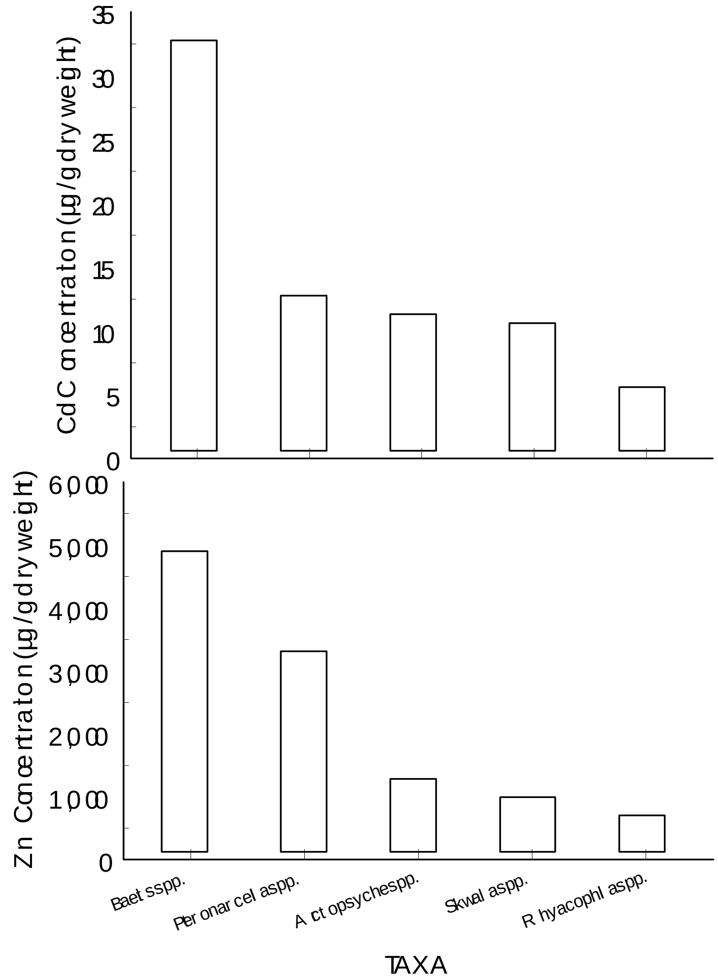


Figure 2-85

Differences in Heavy Metal Concentrations among Different Species of Benthic Macroinvertebrates Collected from Station AR-5 in Reach 3 of the Arkansas River.

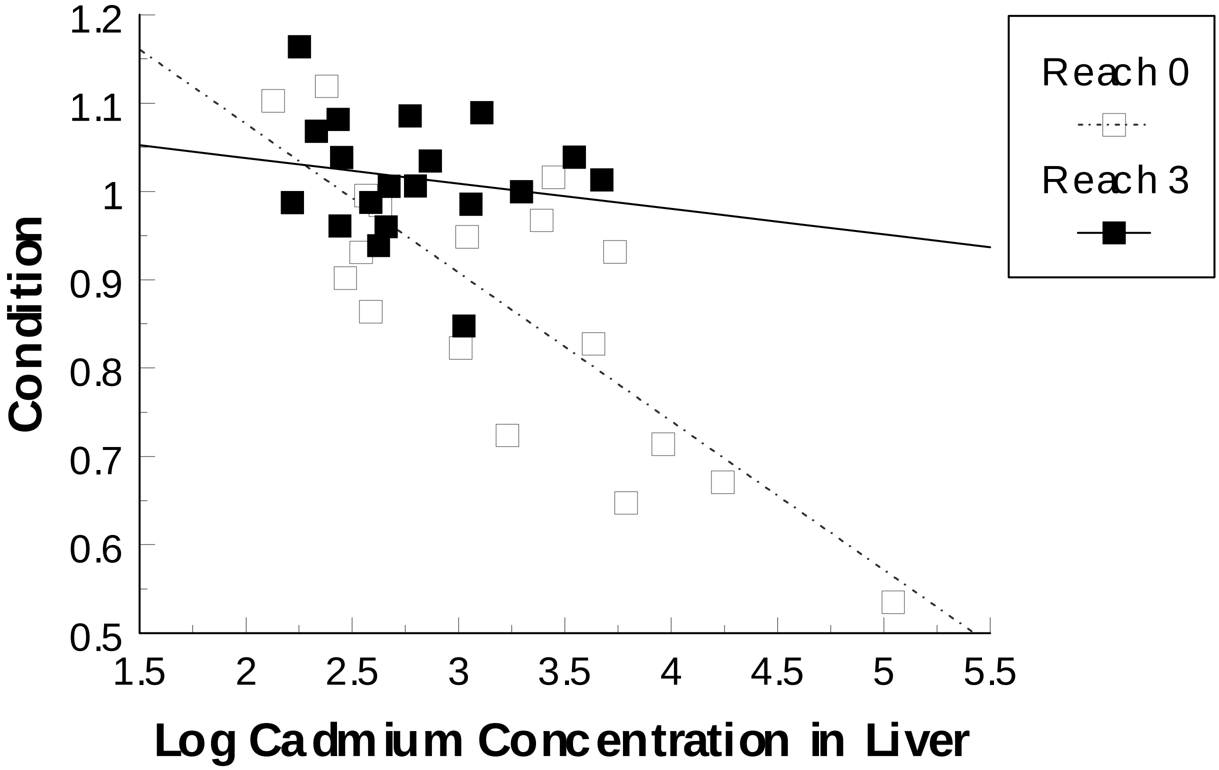


Figure 2-86

Relationship between Fish Condition and Cd Levels in Liver Tissue of Brown Trout Collected from Reach 0 (AR-1) and Reach 3 (AR-5).

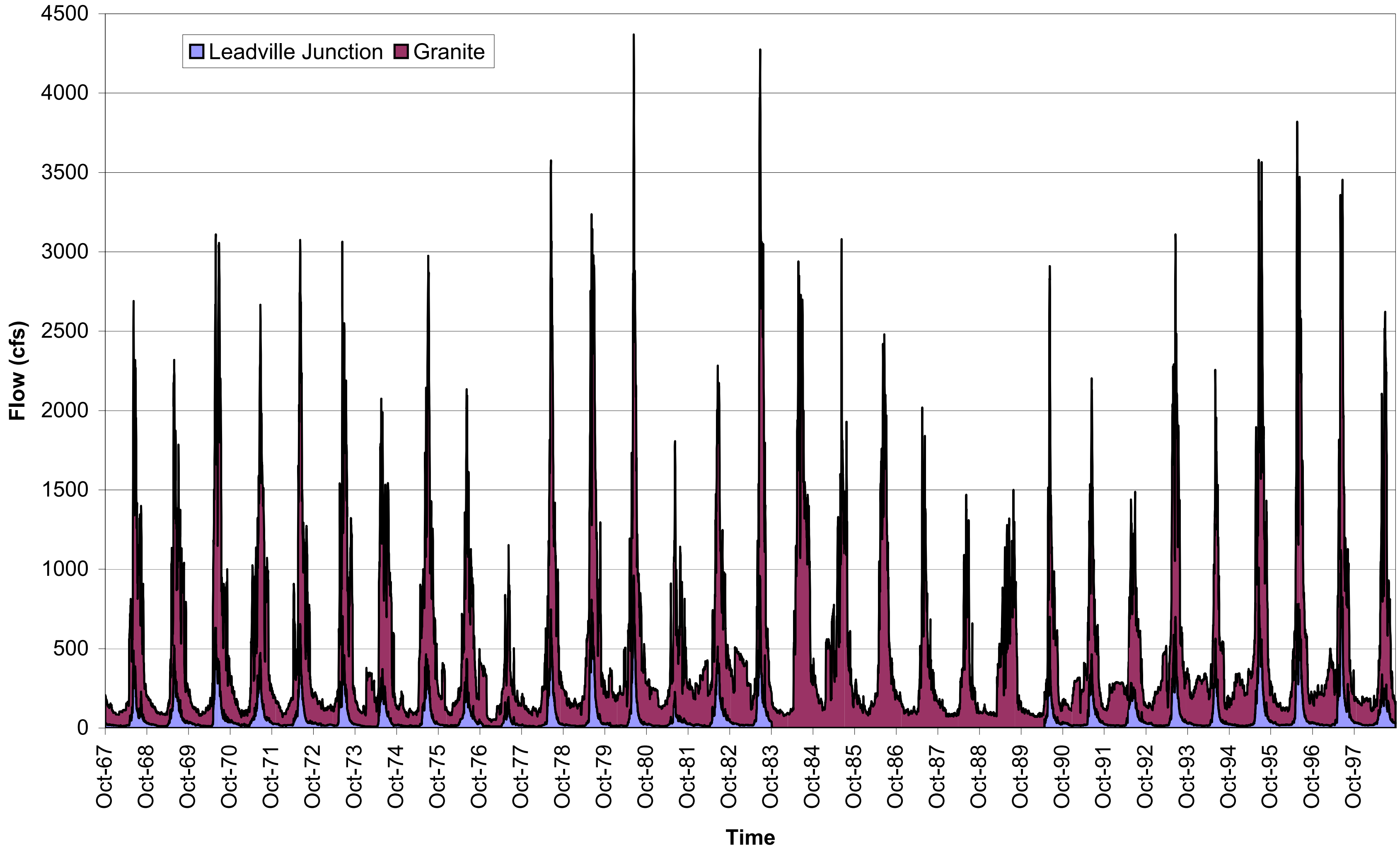
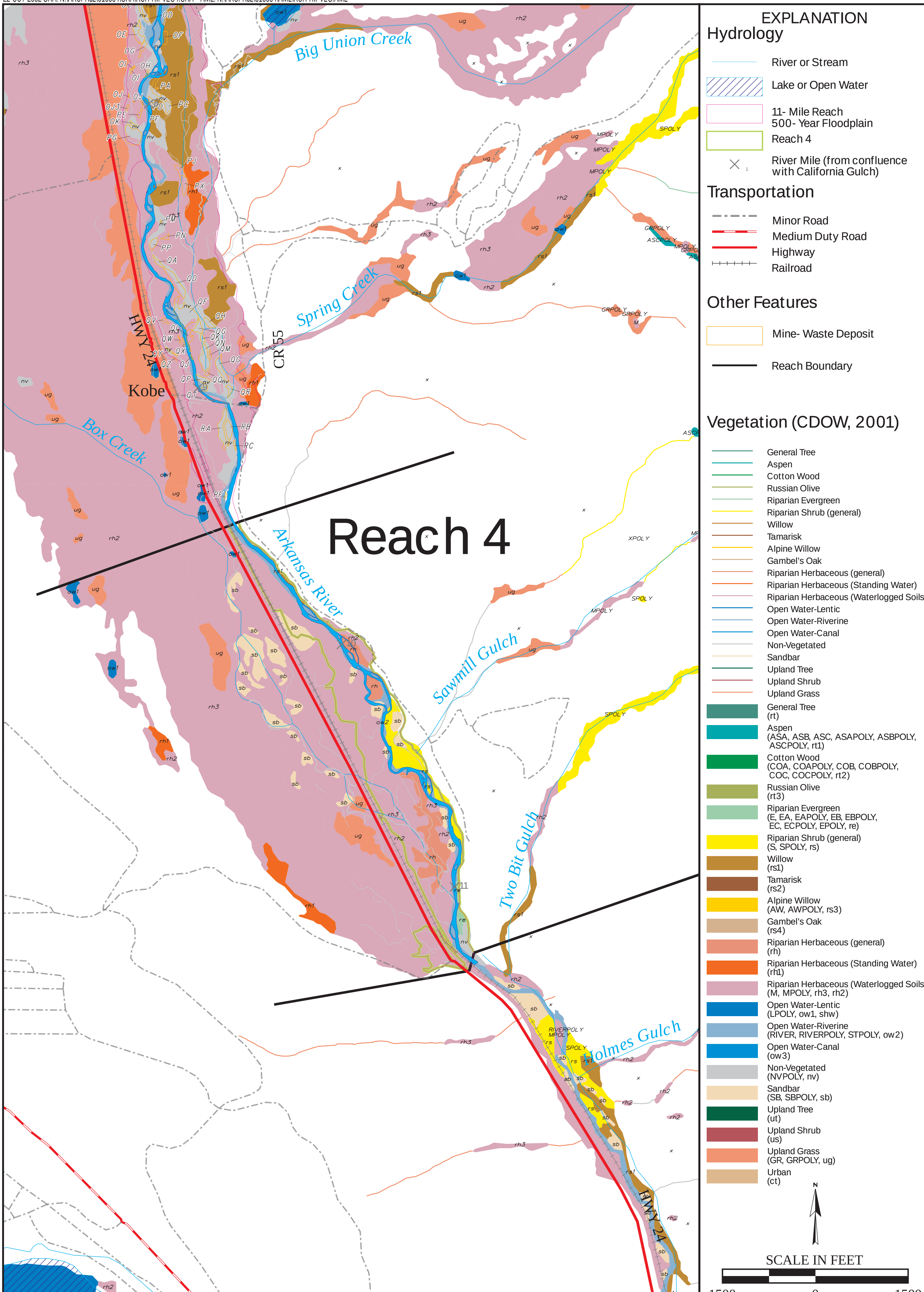


Figure 2-87

Mean Daily Flows in the Arkansas River from 1967 to 1998 at the Leadville Junction Station (7081200) and the Granite Station (7086000)

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



UPPER ARKANSAS RIVER BASIN
SITE CHARACTERIZATION SUMMARY

FIGURE 2- 88
RIPARIAN VEGETATION NARROWS BELOW KOBE TO ABOVE TWO- BIT GULCH (REACH 4)

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