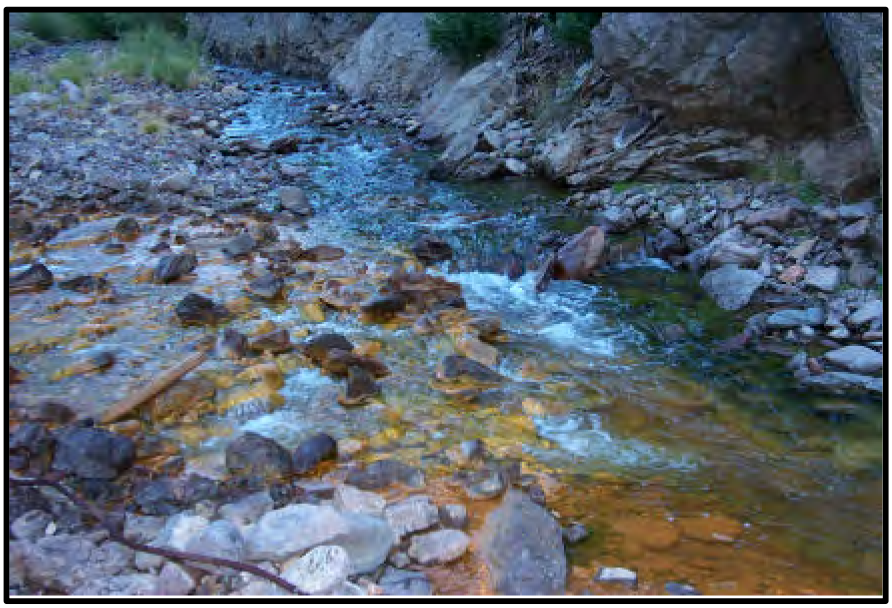
Report on Surface and Mine Water Sampling and Monitoring in Willow Creek Watershed, Mineral County, CO (1999-2002)



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Introduction

Willow Creek, formed by the confluence of East and West Willow Creeks, is a tributary of the Rio Grande River near its headwaters in the San Juan Mountains in Mineral County, Colorado**.** Historic mining activities related to underground mining of silver and selected base metals resulted in significant water quality impairment in the 35 square mile Willow Creek watershed (zinc, cadmium and lead exceed the Colorado Table Value Standards). The Willow Creek Watershed contains Stream Segments 6 and 7 in the Rio Grande Basin, and Classifications include Recreation 1a, Aquatic Life Cold 1, and Agriculture. Surface water quality is affected for more than 7 miles of Willow Creek and its tributaries, with nearly 5 miles above state water quality standards for heavy metals and pH. For Segment 7, which constitutes the lower, heavily mined areas of the creek, there is a temporary modification (expires 2007) to recognize existing water quality instead of state standards for organic and inorganic parameters. Willow Creek from the confluence of East and West branches to the Rio Grande is recommended for the 2004 Colorado impaired waters list (303d) for pH. The Rio Grande River below the confluence with Willow Creek (Segment 4) has also been recommended for the 2004 303d list for high levels of zinc (38 mile reach) and cadmium (7 mile reach). Classifications for Segment 4 include Recreation 1a, Aquatic Life Cold 1, Water Supply, and Agriculture. The residents of the town of Creede and the surrounding portion of Mineral County have developed a community-based effort to identify and address the most pressing environmental concerns in the Willow Creek watershed. The Willow Creek Reclamation Committee (WCRC), convened in 1999, is directing a stakeholder effort aimed at improving water quality and physical habitat in the Willow Creek watershed as part of a long-term watershed management program which will focus on restoring aquatic resources and protecting the Rio Grande from future fish kills.

From 1999 through 2003, the WCRC, with technical and financial assistance from the US Environmental Protection Agency, the United States Forest Service, the Natural Resources Conservation Service, the Colorado Division of Minerals and Geology and the Colorado Department of Public Health and Environment, has directed a variety of watershed characterization efforts. These efforts have been aimed at:

(1) Identifying sources of heavy metals
(2) Characterizing transport of heavy metals to surface waters
(3) Quantifying heavy metals loading to Willow Creek and the Rio Grande River
(4) Characterizing mine waste materials
(5) Biological assessment of aquatic resources
(6) Characterizing hydrological conditions in underground mine workings

The findings and conclusions from these characterization efforts are summarized in a series of five reports prepared by the Technical Advisory Committee of the WCRC. These reports include:

(1) Report on Surface and Groundwater Sampling and Monitoring in Willow Creek Watershed, Mineral County, CO (1999-2002)
(2) Report on Characterization of Groundwater in the Alluvial Deposits beneath the Floodplain of Willow Creek below Creede
(3) Report on Characterization of Waste Rock and Tailings Piles above Creede, Colorado
(4) Report on Characterization of Fish and Aquatic Macroinvertebrates in Willow Creek
(5) Evaluation of Metal Loading to Streams near Creede, Colorado

These reports will provide the basis for choosing the remedial actions that will be evaluated (in terms of engineering and economic feasibility) for identifying and implementing watershed restoration activities.

This report presents the results of four synoptic sampling events which were conducted from 1999 to 2002. The sampling events included sampling of surface waters, mine waters and ground water. The sampling included flow measurements of stream water and mine discharges so that flow weighted mass loading could be calculated.

Methodology

Based on available data, metals concentrations in the Willow Creek watershed vary considerably under different flow regimes (MFG, 1999a). Therefore, surface water samples were collected during low flow (fall) and high flow (spring) conditions to help characterize metals loading in the watershed. Based on historical flow rates and weather conditions, low flow sampling was expected to occur in September and high flow was expected in May or June. Miscellaneous samples were also collected during the year to monitor water quality at specific sites or to characterize the effects of episodic storm events.

Sampling sites were selected to include stations that were: 1) upstream and downstream of areas of potential or historical metals loading; 2) at key points within these potential loading areas, including potential areas of groundwater influence; and 3) at specific adit discharges. A general map of the waste rock piles in the watershed is included as Appendix A. In some cases, sampling at a particular site was discontinued during dry conditions or when the data were not substantially different from nearby stations. Sites were added to the protocol when new sources were found or for more in-depth characterization of a reach.

Surface water collection followed the Sampling and Analysis Plan developed by MFG (1999b). Maps showing sampling sites in the Willow Creek watershed and on the Rio Grande are presented as Figures 1-5. These maps indicate all sites that were sampled at least once during the three-year characterization period. Unless otherwise dictated by field conditions or availability of personnel, sites were sampled from downstream to upstream sites to avoid contamination due to in-stream disturbances. Field data collection consisted of discharge, site conditions, and water quality parameters (pH, conductivity, temperature, and dissolved oxygen). In most cases, discharge was measured by the area-velocity method using a Marsh-McBirney Model 2000. A portable cutthroat flume was used at sites with insufficient size and velocity to use the flow meter accurately. Field water quality parameters were measured with a WTW Multiline P4 or a Beckman pH meter. All meters were calibrated prior to sampling as indicated in the SAP (MFG 1999b).

Water samples were collected as a composite across the stream when feasible. For composite samples, volunteers waded across the stream and used a clean dipper and composite bucket to collect at least 4 samples in a width-integrated fashion. When there were substantial flow differences across the stream, volunteers collected more samples from the high flow areas to create a more accurate flow-weighted composite. Grab samples were collected from the bank at extremely low flows and when depth or high flows prohibited crossing. All samples were collected upstream of the volunteer and any other instream activity. In cases where time did not permit delivery of the samples to the laboratory immediately, filtration was conducted in the field using a 0.45 μm membrane filter. Following filtration, samples identified for metals analyses were acidified with nitric acid as indicated in the SAP (MFG 1999b). All equipment was cleaned with nitric acid rinse and deionized water or replaced between sample sites. Field blanks and duplicates were collected as indicated in the SAP (MFG, 1999b).

Table Value Standards (TVS) were calculated from average hardness values for the downstream site on a given stream segment using the Year 2000 formulas of the Water Quality Control Division of the Colorado Department of Public Health and Environment. At sites with multiple sampling dates, hardness values were averaged. Dissolved metals concentrations were compared to the Chronic TVS for an evaluation of whether or not water quality exceeded recommended standards. Load estimates (lbs/day) were calculated based on the flow (CFS) and concentration (μg/L) at a given site. Loads were usually calculated for downstream sites as an indication of that tributary's contribution to the adjoining stream (ex. EW-A load represented East Willow Creek's contribution to the Mainstem).

Comparisons of duplicate samples are presented in Tables 1-3. As indicated in the SAP (MFG 1999b), duplicates were analyzed to evaluate sampling and analytical precision. A relative percent difference (rpd) among samples >30% was considered poor, and those data were interpreted with caution. Table 1 presents data from September 1999. During that sampling event, samples were analyzed at ACZ Laboratories (ACZ) and/or by River Watch labs (RW). Duplicates analyzed by the same lab generally differed by <20%. Samples that were analyzed by both labs were often similar, and only 10 of 168 pairs exceeded the 30% level of acceptability. These differences were primarily in aluminum and iron analyses. In May 2000, samples were analyzed by Sangre de Cristo (SDC), ACZ, and/or RW (Table 2). Duplicates analyzed for cations and anions were within 20% of each other. Duplication of heavy metals was not as good, and at least 18 out of 120 duplicated metals differed by more than 30%. Problems with duplication were pronounced in aluminum, copper, and iron results. Table 3 lists duplicates for May 2001 and 2002. The number of duplicated samples was smaller than in previous years due to a smaller number of samples collected. Samples were analyzed by ACZ and RW in 2001, and duplication was fair, with 3 out of 42 pairs differing by more than 30%.

Samples in 2002 were analyzed at SDC and/or RW, and overall duplication was fair, with 8 out of 94 pairs differing by more than 30%. Duplication within SDC or RW was good; however, duplication of metals data between RW and SDC was marginal, especially for total cadmium.

Table 4 presents data from field blanks collected in September 1999 and May 2001 and 2002. Overall, these data indicate that there was little to no contamination and less than 7% of the values were above the level of detection. The only constituents that were discovered at detectable levels in more than one sample were silica and iron. Table 5 lists the limits of detection for SDC and RW labs. Detection limits for ACZ lab vary with calibration and dilution, and therefore are not shown.

Results and Discussion

The results of the four main sampling events are discussed in the following sections. For convenience, a separate discussion is presented for East Willow Creek, West Willow Creek, Mainstem Willow, and the Rio Grande River. Surface tributaries and other significant inflows are discussed as appropriate for each of the main streams. For each of the four main segments of stream or river, there is a discussion of measured discharge rates, water chemistry, metals loading, significant inflows and potential contaminant sources.

Table 6 presents a sampling summary of the four main sampling events: September 1999, and May 2000, 2001, and 2002. The initial events, September 1999 and May 2000, involved a substantial number of sites and took at least four days to sample the majority of the sites. These two events gave a good indication of key sources and load estimates. Subsequent sampling efforts were scaled back and had the primary goal of monitoring concentrations and developing a database. In May 2001 and 2002, 23 and 24 sites, respectively, were completed by two teams of four people in just over one day. In 2001, high flows prevented wading and discharge measurements at many of the sites. The winter and spring preceding the May 2002 sampling were extremely dry, resulting in a high flow in the Rio Grande below the confluence with Willow Creek of only 303 cubic feet per second (Wason Bridge) as compared to 1030 CFS in May 2000. Because of the small number of sample sites and lack of flow measurements, May 2001 and 2002 data are not included in the load discussions in this report.

<u>East Willow</u>

The channel and inflow sites for East Willow Creek are listed in Table 7 with a description of their relative location and relevance. Main channel sites were identified with “EW” representing East Willow, and then a letter. The letter sequence began with A near the East and West Willow confluence, and proceeded to M, which was believed to be upstream of any mine influences and therefore representative of background conditions. In East Willow there were 13 main channel sites, 4 adits, 5 seeps/springs, 1 wetland, and 4 tributaries. The data from East Willow channel sites are presented in Table 8. Samples are listed chronologically for a given site. Blank areas indicate that no data was collected. The following discussions of discharge, water chemistry, and load only cover the major sampling events in which there were adequate data to make comparisons and draw conclusions.

Discharge

Discharge estimates for September 1999 and May 2000 are presented in Figure 6. Flows in East Willow in 1999 increased from 18.8 CFS at EW-M to 22 CFS at EW-A, with a maximum of 28.9 CFS at EW-I. In May 2000, discharge was 23.6 CFS at EW-M and 28.2 CFS at EW-A, with a maximum of 42.7 CFS at EW-F. In general, discharge values were variable in East Willow, suggesting the fluctuating influence of subsurface flows and the difficulty of obtaining precise and accurate measurements with a flow meter. Kimball (2000) did not any decreases in streamflow using a sodium bromide tracer to calculate discharge.

Water chemistry

Field parameters of pH, temperature, conductivity, and dissolved oxygen indicated slight changes from upstream to downstream sites during the major sampling events, but factors such as diurnal and day-to-day variations confounded clear linkages with inflows. In 1999, levels of pH in East Willow were at 7.5 at EW-M and 7.2 at EW-A, but values as low as 5.9 (EW-I) were noted in the intermediate stations. This variability in the pH data might have been due to the fact that sampling on East Willow was conducted over three days. In May 2000, pH was 7.1 at both EW-M and EW-A, and although values fluctuated between 6.6 and 7.3 along the segment, samples were collected over two days at different times of day. Levels of pH in May 2001 ranged from 6.3 to 7.8, but values at EW-A and EW-M were similar at 7.2 and 7.1, respectively. In May 2002, pH in East Willow was constant around 7.5.

During the main sampling events, temperatures in East Willow averaged 5.7^{o}C and generally showed a slight net increase (<2^{o}C) from EW-M to EW-A. Diurnal and day-to-day variations might have been the primary cause of these findings. This conclusion is confirmed by the fact that the least variability was seen in May 2002, when East Willow sites were sampled within a two-hour period on the same day. Conductivity measurements were only taken in September 1999 and May 2000. Conductivity ranged from 49 to 54 μS/cm in East Willow in September 1999, and showed a net increase of 3 μS/cm from EW-M to EW-A. In May 2000, conductivity ranged from 41 to 43 μS/cm and did not indicate a net increase from upstream to downstream. Dissolved oxygen ranged from 8.1 to 9.7 mg/L during the major sampling events and did not exhibit an obvious relation with site that could be isolated from diurnal or day-to-day influences.

Metals

Levels of silver, arsenic, copper, and selenium were near or below the limit of detection throughout East Willow. Using the average hardness at EW-A (17.33 mg $CaCO_3$/L) to calculate the chronic Table Values Standards (TVS), water quality at EW-A was above recommended concentrations of dissolved cadmium, lead, and zinc. Figure 7 presents the TVS and concentration data for cadmium, lead, and zinc for the four main sampling events. These diagrams indicate that the initial increases in concentration occurred primarily between EW-H and EW-G in the vicinity of the Solomon Mine (see Appendix A). Concentrations continued to steadily increase downstream to EW-A.

Figure 8 shows ion composition in September 1999 and May 2000. These graphs are included to illustrate similarities and differences along a stream, and to indicate the relative influences of inflows on composition. Ion composition was similar in September 1999 and May 2000, with calcium and bicarbonate constituting the greatest percentages. Ideally, the major cations (Ca, Mg, N, K) should balance the major anions (HCO_3, SO_4, Cl) and points should fall at 50% in the middle of the graph. Discrepancies are possibly due to analytical error, the omission of other ions such as NO_3 or SiO_2, or, in the case of the September 1999 data, the lack of sodium data. The East Willow inflows, particularly EW-SWD and EW-SMA, had notably lower levels of bicarbonate than the main channel sites. The contribution of these inflows did not substantially alter ion composition in the main channel, and main channel sites were relatively similar. The exception was EW-M, which had low bicarbonate levels. As the upstream site, this may have been due to the predominance of ground water influences.

Load estimates for calcium, magnesium, and selected heavy metals are presented in Figures 9-11. Calculated loads for calcium, magnesium, and aluminum are shown in Figure 9. Calcium (Ca) and magnesium (Mg) loads showed a slight increase (15-30%) from upstream to downstream sites, but values were variable and did not indicate consistent sources (Figures 9-A and 9-B). The majority of calcium and magnesium was present in the dissolved form. Load estimates of Ca and Mg were comparable for September 1999 and May 2000. As an indication of the East Willow contribution to Mainstem Willow Creek, the loads noted at EW-A were around 790 lbs Ca/day and 100 lbs Mg/day in 1999 and 2000.

Aluminum loads showed an overall increase from upstream to downstream in September 1999 and May 2000 (Figure 9-C). Potential sources of aluminum were upstream of EW-K, EW-F, and EW-D; however, aluminum dissipated after these inputs, indicating that instream solution reactions might have been responsible for fluctuations in aluminum loading. Dissolved fractions did not indicate a substantial change from upstream to downstream. Dissolved aluminum generally accounted for less than one half of the total. The aluminum load at EW-A was 15 lbs Al/day in September 1999 and 27 lbs Al/day in May 2000.

Cadmium loads indicated a substantial increase from around 0 lbs/day at EW-M to over 0.15 lbs/day at EW-A (Figure 10-A). This trend was noted in September 1999 and May 2000, and pointed to sources above EW-J, EW-G, and EW-D. The sources above EW-J and EW-G might be associated with the lower end of the Outlet tailings pile and the Solomon complex, respectively. Most of the cadmium was accounted for by the dissolved fraction. The greatest cadmium load at EW-A was 0.2 lbs Cd/day in September 1999.

Copper concentrations in East Willow were highly variable among years and fluctuated around the limit of detection. The error associated with such low levels might explain why dissolved fractions were sometimes higher than the totals. Sources of copper loading were not clear due to inconsistency among years, but it was evident that copper did not persist in the water column following spikes (Figure 10-B). The greatest copper load at EW-A was 0.13 lbs Cu/day (September 1999). Iron loading, whether in dissolved or total form, did not substantially change from upstream to downstream (Figure 10-C). Dissolved iron accounted for less than one half of the total. Iron loading at EW-A was highest in May 2000 at 17 lbs Fe/day. As with aluminum, fluctuations in iron loading might be related to instream solution reactions. This conclusion is further emphasized by comparing loading of the reactive metal, iron (Figure 10-C), with a relatively non-reactive metal, cadmium (Figure 10-A). Whereas cadmium was maintained in the water column, iron was gained and lost under the same chemical and flow conditions.

Figure 11 shows load estimates for manganese, lead, and zinc. Manganese loading occurred primarily near EW-G, indicating an association with the Solomon complex. Manganese tended to dissipate downstream. It was not discernable what percentage of the total was present as the dissolved fraction, because concentrations were near the limit of detection (10 ug Mn/L). The greatest load of manganese was near 3 lbs Mn/day at EW-G in September 1999 and May 2000. Manganese loads at EW-A were 1.76 lbs Mn/day in September 1999, but undetectable in May 2000. Lead loading also indicated a source associated with EW-G, potentially at the Solomon complex. Lead levels in September 1999 and May 2000 peaked near 3 lbs Pb/day at EW-D, then dropped to around 2 lbs Pb/day at EW-A. Levels of dissolved lead were around one-half of total levels. Zinc data indicated that sources initiated near the Solomon complex (EW-G) and loads increased downstream to EW-D. Zinc did not dissipate in the water column, and almost all of the zinc was present in the dissolved form. Zinc loading at EW-A peaked near 26 lbs Zn/day in September 1999 and near 18 lbs Zn/day in May 2000.

Inflows to East Willow Creek

Table 9 lists all of the data collected for inflows to East Willow Creek. Conductivities in discharges from the Solomon Mine adit (EW-SMA) and the Solomon wetlands (EW-SWD) were high relative to the other inflows, and pH data indicated that these sources were slightly acidic (range: 4.3-5.6). Figures 12-14 present load estimates based on measured discharges of East Willow inflows. The greatest loadings of calcium were at EW-N (16.6 lbs Ca/day; Sept. 1999) and EW-TRN (17.5 lbs Ca/day; May 2000) (Figure 12-A). The sum of all inflows accounted for <38% of the increase in calcium loading between EW-M and EW-A (Figure 9-A). Calcium in the inflows was present primarily in the dissolved form, and there was not a discernable relation of load to season. The high background levels of calcium indicated by the upstream site (EW-M) indicate that calcium loads were primarily a factor of geology and natural processes rather than specific inflows.

Primary sources of magnesium were EW-SWD and EW-SMA, as identified by maximum loads of 3.5 lbs Mg/day (September 1999) and 2.7 lbs Mg/day (May 2000), respectively (Figure 12-B). Magnesium was dissolved in the inflows, and loading was not clearly related to season. The sum of magnesium loading from all inflows accounted for <37% of the increase in magnesium loading between EW-M and EW-A. As with calcium, magnesium levels primarily appear to be a factor of natural influences and background levels. Aluminum loads were below 0.1 lbs Al/day in most of the inflows (Figure 12-C). In May 2000, levels of total aluminum were relatively high at EW-N (0.98 lbs Al/day) and at EW-TRN (3.18 lbs Al/day), which could explain some of the loading above EW-K in the channel data (Figure 9-C). Inflow data support the trends found in the East Willow channel data: that total aluminum was elevated in May 2000. The sum of aluminum loading from all inflows accounted for 15% (September 1999) and 94% (May 2000) of the net increase between EW-M and EW-A. This variable influence of the inflows on the channel was likely due to solution reactions, as shown in Figure 9-C.

Cadmium loads were very small in several of the inflows (<0.001 lbs Cd/day), but were substantial in EW-SWD (max.: 0.034 lbs Cd/day in September 1999) and EW-SMA (max.: 0.025 lbs Cd/day in May 2002) (Figure 13-A). These sites accounted for roughly 33% of the loading changes seen between EW-H and EW-G in September 1999 and May 2000. No other substantial sources were found to account for the loading downstream of EW-G. The loading from all inflows accounted for <20% of the cadmium loading in the channel at from EW-M to EW-A. Low background cadmium levels (EW-M) indicate that there were substantial unmeasured inflows. As with cadmium, copper loads in the inflows were small, with the exception of EW-SWD (max.: 0.01 lbs Cu/day), EW-SMA (max.: 0.004 lbs/ Cu/day), and to a lesser extent EW-SWI (max.: 0.002 lbs Cu/day) (Figure 11-B). Due to the variability of the data and the low levels of copper in the channel, it was difficult to locate source inflows which might relate to the inflow data; however, relatively high copper concentrations at EW-SWD (54.5 ug Cu/L) and EW-SMA (58.2 ug Cu/L) indicated that these sites had the potential to be substantial copper sources.

Iron loads in the inflows, like the channel data, showed patterns similar to aluminum loads (Figures 12-C and 13-C). Primary sources of iron were EW-N (max.: 0.42 lbs Fe/day), EW-TRN (max.: 1.13 lbs Fe/day), and EW-SMA (max.: 0.27 lbs Fe/day). The load from EW-TRN accounted for an estimated 15% of the load increase between EW-L and EW-K in May 2000. Iron in the main channel did not consistently increase or decrease downstream, indicating that iron sources were balanced by dissipation through solution reactions.

The only measured sources of manganese in East Willow were EW-SWD (max.: 1.2 lbs Mn/day in September 1999) and EW-SMA (max.: 1.0 lbs Mn/day in May 2002) (Figure 14-A). In all of the other inflows, manganese was undetectable. In September 1999, EW-SWD accounted for 45% of the manganese load increase between EW-H and EW-G. Although flow measurements were not taken at EW-SMA in September 1999, concentrations and historic flows indicate that it may have attributed a substantial amount of manganese also. In May 2000, manganese from EW-SWD (0.623 lbs Mn/day) and EW-SMA (0.124 lbs Mn/day) constituted only 27% of the maximum load in East Willow (2.75 lbs Mn/day). Low levels of manganese at EW-M, substantial increases near the Solomon Complex, and the small contribution of measured inflows indicate that the majority of sources in the Solomon area remain unmeasured. Lead loading occurred in several inflows including EW-PC (max.:0.05 lbs Pb/day), EW-SWD (max.: 0.28 lbs Pb/day), EW-SMA (max.:0.17 lbs Pb/day), and EW-SWI (max.:0.03 lbs Pb/day) (Figure 14-B). These sites partially explain the lead loading downstream of EW-I, but totaled <15% of the loading between EW-M and EW-A. In contrast with the main channel sites, lead in the inflows was primarily in the dissolved form.

Sites with measurable zinc loads were EW-PC (max.: 0.18 lbs Zn/day), EW-SWD (max.: 6.87 lbs Zn/day), EW-SMA (max.: 5.32 lbs Zn/day), and EW-SWI (max.: 0.82 lbs Zn/day) (Figure 14-C). EW-PC was a relatively constant source (avg.: 0.17 lbs Zn/day), although flows nearly doubled between September 1999 and May 2000. In September 1999, loading from EW-SWD potentially accounted for 58% of the increase in zinc load between EW-H and EW-G. Overall, calculated sources of zinc accounted for <30% of the zinc loading in the channel from EW-M to EW-A.

West Willow

The channel and inflow sites for West Willow Creek are listed in Table 10 with a description of their relative location and relevance. Main channel sites were identified with “WW” representing West Willow, and then a letter. The letter sequence began with A near the East and West Willow confluence, and proceeded to M, which was believed to be upstream of any mine influences and therefore representative of background conditions. In West Willow there were 14 main channel sites, 2 seeps, 2 adits, and 1 tributary. The data from West Willow channel sites are presented in Table 11. Samples are listed chronologically for a given site. Blank areas indicate that no data was collected. The following discussions of discharge, water chemistry, and load only cover the major sampling events in which there were adequate data to make comparisons and draw conclusions.

Discharge

Discharge values for September 1999 and May 2000 are presented in Figure 15. Discharge roughly doubled from WW-M to WW-A. Flows in West Willow in September 1999 increased from 6.3 CFS at WW-M to 13.9 CFS at WW-A, with a maximum of 14.9 CFS at WW-D. In May 2000, discharge was 13.6 CFS at EW-M and 27.3 CFS at EW-A, with a maximum of 29.2 CFS at WW-G. As compared with East Willow, discharge in West Willow was less variable and showed a relatively consistent increase from upstream to downstream. Increases in discharge occurred below the confluence with Deerhorn (WW-L) and Nelson Creeks (WW-I) and with other unquantified flows. Kimball (2000), using a sodium bromide tracer, noted a loss in streamflow between WW-D and WW-B, presumably due to a fault.

Water Chemistry

Field parameters of pH, temperature, conductivity, and dissolved oxygen indicated changes from upstream to downstream sites during the major sampling events, but factors such as diurnal and day-to-day variations confounded some linkages with inflows. In 1999, levels of pH in West Willow were at 7.4 at WW-M and 7.0 at WW-A, and values averaged 7.2 at the intermediate stations. In May 2000, pH was 6.9 at WW-M and 7.6 at WW-A. Although values fluctuated between 6.7 and 7.6 along the segment, samples were collected over three days at different times of day. Levels of pH ranged from 7.0 to 7.6 in May 2001 and 2002, and due to variability and the small number of sample sites, associations with inflows were not clear.

During the main sampling events, temperatures in West Willow averaged 7.0^{o}C (range: 3.0-10.1^{o}C) and generally showed a net increase (<5^{o}C) from WW-M to WW-A. Temperature increases primarily occurred below WW-G in association with drainage from Nelson and Commodore workings, but diurnal and day-to-day variations prohibit clear associations. Conductivity measurements were only taken in September 1999 and May 2000. In September 1999, conductivity ranged from 29 to 205 µS/cm in West Willow and indicated a substantial increase between WW-G and WW-F due to drainage and other flows from the Commodore/Nelson Complex. In May 2000, conductivity measurements clearly indicated an increase of >40 µS/cm between WW-G (63 µS/cm) and WW-F (110 µS/cm). Dissolved oxygen ranged from 8.0 to 13.1 mg/L during the major sampling events and did not exhibit an obvious relation with site that could be isolated from diurnal or day-to-day influences.

Metals

Levels of silver, arsenic, and selenium were near or below the limit of detection throughout West Willow. Using the average hardness at WW-A (76.5 mg $CaCO_3$/L) to calculate the chronic Table Values Standards, water quality at WW-A was above recommended concentrations of dissolved aluminum, cadmium, copper, lead, and zinc. Figures 16 and 17 present the TVS and concentration data for aluminum, cadmium, copper, lead, and zinc for the four main sampling events. In general, concentrations of these metals began to increase above WW-J and were above TVS in several cases by this point in the stream; however, it was between WW-G and WW-F around the Commodore/Nelson Complex that concentrations rose far above recommended levels.

Figure 18 shows ion composition in September 1999 and May 2000. Ion composition in the main channel was similar in September 1999 and May 2000, but sulfate accounted for a slightly higher percentage in 1999 (14-36%) than in 2000 (6-33%). Calcium constituted the greatest percentage of cations, and bicarbonate and sulfate were the primary anions. As with the East Willow data, the balances did not fall exactly as 50/50. The West Willow inflows (NC-A, WW-NT, WW-CT) had notably lower levels of bicarbonate than the main channel sites. In the Nelson Tunnel, there was practically no bicarbonate, and sulfate was the major anion. The contribution of Nelson and Commodore Tunnel inflows substantially altered ion composition in the main channel. The sites above these inflows (WW-M through WW-G) had high levels of bicarbonate (~35%) and intermediate levels of sulfate (~13%). In contrast, sites below the inflows (WW-F to WW-A) had intermediate levels of bicarbonate (~17%) and high levels of sulfate (~35%).

Figures 19-21 present calculated load values for calcium, magnesium, and selected heavy metals for September 1999 and May 2000. Calcium loads increased 3-fold from WW-M to WW-A, and were primarily in the dissolved form (Figure 19-A). Loading primarily occurred between WW-G and WW-D, potentially due to the influence of the Commodore/Nelson Complex. Calcium loads at WW-A were 1767 and 1875 lbs Ca/day in September 1999 and May 2000, respectively. Magnesium was present primarily in the dissolved form (Figure 19-B). Magnesium increased steadily from upstream to downstream, although September 1999 data indicated that greater levels of loading could be related to inflows near the Commodore/Nelson Complex. Magnesium loads at WW-A were around 200 lbs Mg/day in September 1999 and May 2000.

Aluminum loads increased in West Willow from upstream to downstream, but did not clearly indicate sources (Figure 19-C). Although aluminum loads were greater in May 2000 (avg.: 19.1 lbs Al/day) than September 1999 (avg.: 13.7 lbs Al/day), the dissolved proportion was substantially greater in September 1999 (~50%) than in May 2000 (~20%). These differences indicate that instream solution reactions might have been influenced by high flow versus low flow.

Cadmium loading in West Willow occurred primarily downstream of WW-G, potentially the result of loading from the Commodore/Nelson Complex (Figure 20-A). Cadmium was almost totally in dissolved form, and loading patterns were similar in September 1999 and May 2000. At WW-A, cadmium was around 2.3 lbs Cd/day during both sampling events. Copper, like cadmium, increased downstream of WW-G. In general, between 70% and 90% of copper was attributable to the dissolved fraction. Copper loads at WW-A were 1.7 and 1.5 lbs Cu/day in September 1999 and May 2000, respectively. Loading trends for iron were similar to aluminum, with no clear sources that were consistent among years (Figures 19-C and 20-C). Although iron loads were greater in May 2000 (avg.: 18 lbs Fe/day) than September 1999 (avg.: 13 lbs Fe/day), the dissolved proportion was substantially greater in September 1999 (~40%) than in May 2000 (~25%). These differences indicate that instream solution reactions might have been influenced by high flow versus low flow.

Data from West Willow clearly indicate a substantial manganese source (>50 lbs Mn/day) between WW-G and WW-F (Figure 21-A). Other sources of manganese downstream of WW-F were also suggested by the 1999 data. Manganese was predominantly present in the dissolved form. Manganese loads at WW-A were between 74 and 99 lbs Mn/day. Lead data revealed sources between WW-G and WW-D (Figure 21-B). Dissolved fractions accounted for <75% of the total. Lead loads at WW-A were 10 lbs Pb/day in September 1999 and May 2000.

The magnitude and sources of zinc loading were similar in September 1999 and May 2000. Substantial sources of zinc were noted below WW-G, probably in association with the Commodore/Nelson Complex (Figure 21-C). Zinc was mainly in dissolved form throughout West Willow. Loads at WW-A were 562 and 497 lbs Zn/day in September 1999 and May 2000, respectively.

<u>Inflows to West Willow Creek</u>

Nelson Tunnel

Table 12 presents data for sites that are inflows to West Willow Creek, with the exception of Nelson Creek. Nelson Tunnel (WW-NT) was the most contaminated and had the highest flows of these sites. Nelson Tunnel, with its adit among the Commodore waste rock piles (see Appendix A), acts as the drain tunnel for most of the workings on West Willow. Table 13 presents load estimates for Nelson Tunnel in September 1999 and May 2000 and 2002 as they compare to loading in West

Willow. Figures 22-24 show load estimates for inflows to West Willow. Calcium loading came primarily from Nelson Tunnel, and the other sources attributed <1% of the load found in the channel (Figure 22-A). Estimated loads from Nelson Tunnel accounted for 51-75% of the calcium increase in the channel between WW-M and WW-A. Flows at WW-NT were constant throughout 2002, and calcium concentrations in May were 488 lbs Ca/day. The maximum calcium load measured at WW-NT was 807 lbs Ca/day in February 2001. Magnesium followed a pattern similar to calcium in that it was only found in substantial levels at the Nelson Tunnel (Figure 22-B). In general, loading from the Nelson Tunnel constituted 46-73% of the increase in magnesium load between WW-M and WW-A (Table 13). The largest magnesium load at WW-NT was 154 lbs Mg/day (January 2001).

The aluminum loading data from September 1999 indicate that WW-CT (0.3), WW-NT (4.4), and WW-Seep (0.9 lbs Al/day) were potential sources to West Willow Creek (Figure 22-C). Although flow at WW-NT was not measured in 2001, concentrations of 4021 ug Al/L indicated that it might have been responsible for the spike seen in the channel between WW-G and WW-E. In quantified flow events, Nelson Tunnel accounted for 17-43% of aluminum loading between WW-M and WW-A (Table 13).

Cadmium loads were measured at WW-CT (0.02), WW-NT (1.01), and WW-Seep (0.20 lbs Cd/day) in September 1999 (Figure 23-A). Flows at CT and the Seep were minimal or nonexistent during the other sampling events. The Seep from the Commodore Tailings pile was flowing (0.03 CFS) in August 2000, and data indicated that it was not a substantial source of cadmium (<0.15 ug Cd/L). Nelson Tunnel was a substantial source of cadmium, especially in September 1999 (1.01) and May 2000 (1.37 lbs Cd/day) due to both high flows and concentrations. Loading from WW-NT could account for 45% (September 1999) to 63% (May 2000) of the cadmium increase downstream of WW-M (Table 13).

Copper was found in measurable quantities in all inflows; however, sources from WW-CT and WW-Tail 1 were minimal (<0.01 lbs Cu/day) (Figure 23-B). Copper loads at WW-NT ranged from 0.08 to 0.73 lbs Cu/day. Calculated loads for Nelson Tunnel could explain 26-50% of the copper increase between WW-M and WW-A (Table 13). A peak in copper at WW-NT during May 2001 (932 ug Cu/L) might have contributed substantially to the maximum load noted in the channel. Iron loads that could have been important sources to West Willow were found at WW-NT, but other sources were minimal (<0.15 lbs Fe/day) (Figure 23-C). As seen in the channel data, dissolved forms were a fraction of the total iron present at WW-NT. Due to the variability of the channel data, it is difficult to attribute load increases to particular sources, but with total load estimates from 2.2 to 5.3 lbs Fe/day, it is evident that WW-NT was influential in channel loading. The iron loads from Nelson Tunnel were 15-129% of the increase noted in the channel (WW-M to WW-A) during three sampling events (Table 13).

Potential sources of manganese to West Willow were WW-CT (max.: 1 lb Mn/day), WW-NT (max.: 81 lbs Mn/day), and WW-Seep (max.: 4 lbs Mn/day) (Figure 24-A). Manganese loads in the Nelson Tunnel were 82-105% of the increase noted in West Willow (Table 13). Lead sources were primarily from Nelson Tunnel (max.: 6.39 lbs Pb/day), but WW-CT (max.: 0.02 lbs Pb/day), WW-Seep (max.: 0.33 lbs

Pb/day), and WW-Tail 1 (max.: 0.02 lbs Pb/day) also contributed small amounts (Figure 24-B). In contrast with the channel data, lead from WW-NT was >90% dissolved. Lead from WW-NT could account for 64-69% of the increase between WW-M and WW-A (Table 13).

Data from WW-NT strongly indicate that it was a primary source of zinc to West Willow. Other inflows were minimal in comparison to WW-NT, but WW-Seep (33 lbs Zn/day) was a notable source. Zinc loads at WW-NT ranged from 20 to 375 lbs Zn/day. Nelson Tunnel could account for 34-74% of the zinc loading in West Willow (Table 13).

Nelson Creek

Table 14 presents sites along Nelson Creek that were sampled to determine influences of the Midwest Mine site (see Appendix A) and to calculate loading to West Willow. Table 15 presents data from Nelson Creek. NC-C was a site just east of NC-D and the Midwest Mine that was a seep or spring. Data indicate that NC-C possessed metals and other constituents at levels intermediate to NC-E and NC-D. NC-C is presented with data from the main channel sites, and therefore, the listing of the sites is not from upstream to downstream. The lateral positioning of NC-C and NC-D, and the fact that NC-C was an inflow to the main channel must be taken into account.

Discharge

As indicated in the data, Nelson Creek was subject to drought, and surface flows were low in September 1999 and virtually nonexistent in May 2002. The largest surface discharge to West Willow was 1.26 CFS in May 2001.

Water Chemistry

In May 2000, field parameters indicated that NC-D had a lower pH (3.7) and higher conductivity (200 µS/cm) than other sites on Nelson Creek (avg. pH: 6.0; avg. cond.: 58 µS/cm). Temperatures averaged 7.7^{o}C in Nelson Creek, and generally increased from upstream to downstream sites. Dissolved oxygen averaged 8.0 mg/L and did not indicate any trends.

Metals

Several metals were present at low levels, and with the small flows typically found in Nelson Creek, contributions to West Willow were relatively insubstantial. Maximum loads for these metals were: As=0.06 lbs/day; Cd=0.002 lbs/day; Cu=0.03 lbs/day; and Pb=0.03 lbs/day. Figures 25 and 26 present load estimates from sites on Nelson Creek for calcium, magnesium, and selected heavy metals. These data indicate that metal loading in Nelson Creek occurred primarily between NC-E and NC-D, probably in association with the Midwest Mine. Some loading also occurred in the stretch between NC-B and NC-A. Because flows nearly doubled in that reach and there were no evident sources of surface water or contamination, loading was likely attributable to subsurface inflows from the Midwest Mine. Calcium loads in Nelson Creek increased between NC-E and NC-A, and the data indicated that loading primarily occurred downstream of NC-B (Figure 25-A). Loading from the

Midwest was not clear due to variability between years, but was likely small. The contribution of calcium from Nelson Creek (max.: 3.8 lbs Ca/day in May 2000) was not substantial given the load in West Willow above the confluence (743-923 lbs Ca/day). Magnesium, like calcium, was not substantially influenced by the Midwest Mine, and primarily increased between NC-B and NC-A (Figure 25-B). The maximum magnesium load in Nelson Creek was 0.47 lbs Mg/day at NC-A in May 2000. Magnesium loads in Nelson Creek were <1% of loads in West Willow at WW-I during the quantified sampling events, and therefore were not a substantial source.

Aluminum loading in Nelson Creek was variable among years. Sources associated with the Midwest Mine were dissipated through solution reactions (Figure 25-C). As noted in the West Willow data, only a fraction of the aluminum was present in the dissolved form. The maximum aluminum load at NC-A was 0.6 lbs Al/day in May 2000. Generally, loading from Nelson Creek was not substantial and accounted for <5% of the aluminum load present in West Willow at WW-I.

Maximum levels of iron in Nelson Creek ranged from 0.32 (September 1999) to 1.26 lbs Fe/day (May 2000) (Figure 26-A). Iron loading appeared to be related to the Midwest Mine in May 2000, but associations were not clear in September 1999. Channel data from West Willow did not consistently indicate a substantial increase or persisting effects of iron loading from Nelson Creek. In May 2000, manganese in Nelson Creek increased from around 0 lbs Mn/day at NC-E to 0.26 lbs Mn/day at NC-B (Figure 26-B). Manganese loading at NC-B might have been associated with the Midwest Mine, but this was downstream of the loading point (NC-D) noted for some of the other parameters. Manganese in West Willow increased slightly (<2 lbs Mn/day) below the confluence with Nelson Creek, but estimated loads for Nelson Creek did not exceed 0.3 lbs/Mn day at NC-A.

The Midwest Mine area was a source of 0.06 lbs Zn/day in May 2000, but loading trends were not clear in September 1999 (Figure 21-C). The maximum quantified contribution of Nelson Creek to West Willow was 0.03 lbs Zn/day in May 2000, which was minimal, compared to the load increase between WW-J and WW-I (4 lbs Zn/day). Kimball et al. (2002) noted a similar increase between WW-J and WW-I (3.13 lbs Zn/day) that could have been attributable to Nelson Creek. Zinc loads were smaller in September 1999 with a maximum of only 0.01 lbs Zn/day at NC-A.

Mainstem Willow

Descriptions of the channel and other surface water sampling sites for Mainstem Willow Creek are given in Table 16. In contrast with East and West Willow, sites along the Mainstem were labeled starting upstream at W-A near the confluence of East and West Willow, and continuing down to W-I and W-J near the confluence with the Rio Grande. In Mainstem Willow there were 10 main channel sites, 2 seeps, and 1 tributary. Table 17 presents all of the data collected for sites along Mainstem Willow. Samples are listed chronologically for a given site. Blank areas indicate that no data was collected. The following discussions of discharge, water chemistry, and load only cover the major sampling events in which there were adequate data to make comparisons and draw conclusions.

Discharge

Discharge values for September 1999 and May 2000 are presented in Figure 27. As anticipated, flows during spring runoff (avg. 49 CFS) were greater than during the fall (avg. 32 CFS). Discharge values from upstream to downstream sites fluctuated slightly. The reach between W-E and the confluence with the Rio Grande is highly braided in areas, presenting difficulties in obtaining accurate measurements of surface flow (refer to Figure 3). Also in that reach, the presence of highly permeable alluvial materials indicated that fluctuations in measured surface flows were also due to flow through the hyporheic zone. In the reach between WW-G and W-I+J, discharge values decreased in both sampling events. The ditch to Wason Ranch is in this reach and the Ranch has a water right of 6 CFS. An additional explanation for the decrease in measured discharge is that Willow Creek had a greater percentage of subsurface flow as it entered the Rio Grande.

Water Chemistry

Field data indicate that pH values were generally between 7 and 8, and there was not a clear trend from upstream to downstream Willow Creek. Levels of pH were highest in May 2000, with a maximum of 9.0 at W-C. The minimum pH, 4.9, was noted at W-B in September 1999, but all other values were >6.4. Conductivity was measured in September 1999 and May 2000. Conductivities were greater in September 1999 (range: 102 µS/cm at W-J to 149 µS/cm at W-A) than in May 2000 (range: 79 µS/cm at W-B to 109 µS/cm at W-A). Samples from W-A had the highest conductivities during both sampling events. Temperatures in Mainstem Willow averaged 8.5^{o}C (range: 2.2-14.3^{o}C) and generally showed a net increase (<5^{o}C) from W-A to W-I+J. Increases in temperature might have been due to sun exposure in the wide, shallow braids of the lower floodplain, but diurnal changes were also a factor. Dissolved oxygen ranged from 7.8 to 13.6 mg/L during the major sampling events, with the highest values at W-B in both September 1999 and May 2000.

Metals

Levels of silver, arsenic, and selenium were near or below the limit of detection throughout Mainstem Willow. The average hardness at W-I and W-J (48.7 mg $CaCO_3$/L) was used to calculate the chronic Table Values Standards. Water quality in Willow Creek as it discharged into the Rio Grande was above recommended concentrations of aluminum, cadmium, copper, lead, and zinc. Figures 28 and 29 present the TVS and concentration data for aluminum, cadmium, copper, lead, and zinc for the four main sampling events. For cadmium, lead, and zinc, concentrations were well above TVS throughout Mainstem Willow during all sampling events.

Sites W-G-E and W-H were on individual braids of the eastern side of the stream. These sites were selected to monitor any influences in water quality that might be due to surface runoff or subsurface discharge from the Emperious Tailings Pile area. Based on concentrations, these sites (W-G-E and W-H) had slightly higher levels of magnesium, aluminum, cadmium, copper, manganese, and zinc than the sites upstream (W-E and W-D), which indicated sources in the pile area.

Figure 30 shows ion composition in September 1999 and May 2000. Ion composition was similar in September 1999 and May 2000, with calcium as the primary cation, and bicarbonate and sulfate constituting the greatest percentages of anions. The only inflow, Windy Gulch, had notably higher levels of calcium than the main channel sites. In May 2000, the high levels of calcium in Windy Gulch were not balanced by the major anions, and the ion composition diagram was skewed. The contribution of Windy Gulch did not substantially alter ion composition in the main channel, and main channel sites were relatively similar. The exception was W-D in September 1999, which had elevated calcium and bicarbonate levels. It is not clear why this different composition was seen.

Figures 31-33 show load estimates for calcium, magnesium, and selected heavy metals for Mainstem Willow Creek. Due to the difficulties in measuring discharge in a highly braided stream, load estimates for Mainstem Willow may have an unknown degree of error. W-G consisted of 3-4 braids that were sampled individually, but loads from the braids were summed to give an estimate for that reach of the stream (referred to as W-G SUM). W-I and W-J were located on the two primary channels draining into the Rio Grande, and load estimates from these sites were combined to represent the Willow Creek contribution to the river (referred to as W-I+J). Calcium loads in Willow Creek did not change substantially from upstream to downstream (Figure 31-A). Calcium levels were similar in September 1999 and May 2000, and did not indicate any sources or trends. Calcium loads to the Rio Grande were 1952 and 2328 lbs Ca/day in September 1999 and May 2000, respectively. Magnesium loading to the Rio Grande from Willow Creek averaged 252 lbs Mg/day (Figure 31-B). Loads were comparable in September 1999 and May 2000, and there were no clear sources along the Mainstem. Magnesium was present almost exclusively in the dissolved form.

Aluminum loading to the Rio Grande ranged from 38 lbs Al/day in September 1999 to 49 lbs Al/day in May 2000 (Figure 31-C). Aluminum loads remained relatively constant throughout the Mainstem, with slight increases around W-G SUM. Generally <50% of the aluminum was in the dissolved form, and this relative percentage did not change from upstream to downstream.

Cadmium loads in Willow Creek near the confluence with the Rio Grande ranged from 1.97 to 2.47 lbs Cd/day (Figure 32-A). Most of the cadmium load was present in dissolved form. As seen in the aluminum data, cadmium loads were elevated at W-G SUM. Copper loads in the Mainstem increased slightly near W-G in September 1999 and May 2000, indicating a possible source (Figure 32-B). Copper loading to the Rio Grande ranged from 1.19 lbs Cu/day in September 1999 to 1.53 lbs Cu/day in May 2000. Generally, 70-90% of copper in the Mainstem was present in the dissolved form.

Iron in Mainstem Willow near the confluence with the Rio Grande ranged from 13.3 (September 1999) to 23.3 lbs Fe/day (May 2000) (Figure 32-C). Iron loads decreased slightly from W-A to W-I and W-J during all sampling events. There were no apparent sources of iron in Mainstem Willow. The percentage of iron present in dissolved form was 38% in September 1999 and 16% in May 2000.

The manganese load in Mainstem Willow decreased between W-A and W-I+J by around 25% in September 1999 and May 2000 (Figure 33-A). Data from September 1999 and May 2000 indicate a potential manganese source near W-G. Manganese loading to the Rio Grande averaged 60.4 lbs Mn/day. Manganese was primarily in dissolved form. Lead decreased by 40-60% from upstream to downstream sites in Willow Creek in September 1999 and May 2000, and loads to the Rio Grande were <8 lbs Pb/day (Figure 33-B). Roughly one half of the lead was present in dissolved form, and there were no clear sources to the Mainstem.

Zinc loads near the confluence with the Rio Grande ranged from 371 lbs Zn/day in September 1999 to 537 lbs Zn/day in May 2000 (Figure 33-C). Zinc was primarily in the dissolved form. Neither zinc sources nor trends were clearly defined by the data for Mainstem Willow; however, as with some of the other metals, there was a slight increase at W-G SUM. Kimball (2000) found a net decrease in zinc in the lower floodplain of Willow Creek.

Inflows to Mainstem Willow Creek

Only two seeps that flow into Mainstem Willow Creek have been observed and sampled. The limited data from these sites was collected in May 2000, and are presented in Table 18. These data indicate that the seeps had elevated conductivities (avg. 2169 μS/cm) relative to the Creek in that area (89 μS/cm at W-E). Because no metals were analyzed for these samples and a flow was only measured for W-F seep, it is impossible to ascertain the influence that these sources might have had on the Mainstem; however, the sites were proximal to the Emperious Tailings Pile and should be further investigated as evidence of contaminated runoff or discharge from the contaminated alluvial aquifer in that area.

Windy Gulch

Table 19 lists descriptions for the two sites sampled on Windy Gulch. These sites were located at road crossings and were used to monitor water quality influences of the Bulldog waste rock piles. WNG-B was located at a weir above the Bachelor Loop crossing and was upstream of all Bulldog mines and waste rock piles. WNG-A was located where the creek enters Creede, and was downstream of all Bulldog workings and waste rock piles. Data from Windy Gulch are presented in Table 20.

Discharge

Discharge data indicate that much of the surface flow disappeared from upstream to downstream. In May 2000, surface flow decreased from 0.66 CFS at WNG-B to 0.11 CFS at WNG-A. In May 2002, surface discharge at WNG-B was only 0.04 CFS, and at WNG-A was non-detectable. Other accounts document the variability of flow in Windy Gulch. During a more thorough investigation of flows in Windy Gulch in November 2001, it was observed that flow existed at the upper weir (WNG-B) and entered the culvert under the road (SAIC 2002). Below the road, the creek entered a steep area consisting of coarse talus and alluvial materials, and there was no surface flow downstream to the confluence with Willow Creek. Water Management Consultants (1999) noted that surface flow was not observed on the talus slope, but that the stream reemerged below the 9,700-level waste rock pile and continued in a defined channel to the 9,360-level. Surface water then flowed through a culvert through the 9,360 waste rock pile and in a defined channel to the confluence with Willow Creek.

Water Chemistry

Levels of pH in Windy Gulch ranged from 7.0 to 7.6, with one value of 9.2 at WNG-A in May 2000. Temperatures were greater at the upstream site (range: 5.3-15.1 ^oC) than at the downstream site (range: 3.0-9.3 ^oC). Conductivities were >3 times higher at WNG-A than WNG-B. Maximum conductivity values were noted in September 1999 (WNG-B=100 µS/cm; WNG-A=341 µS/cm). Dissolved oxygen increased from upstream (avg. 7.3 mg/L) to downstream (avg. 8.9 mg/L).

Metals

Neither site indicated measurable sources of lead or selenium in Windy Gulch. Using the average hardness at WNG-A (96.7 mg $CaCO_3$/L) to compute the Table Values Standards, water quality was above recommended concentrations of dissolved cadmium (TVS=2.18 µg/L; avg. WNG-A=14.8 µg/L), copper (TVS=8.70 µg/L; avg. WNG-A=10 µg/L), and zinc (TVS=114.48 µg/L; avg. WNG-A=2569 µg/L).

The Windy Gulch load data for calcium, magnesium, and selected heavy metals are presented in Figures 34 and 35. Only data from 2000 are shown because flow measurements were not available at both sites for the other years. The loss in surface flow downstream must be taken into account in reviewing the load data, because in the case of manganese, calcium, and magnesium, concentrations in the water increased, but loads decreased. As a basis for comparison, the results of a tracer study done in September 2000 are also discussed (Kimball et al. 2002). Because of the substantial amount of subsurface flows, the study by Kimball et al. provided insight into Windy Gulch loading as it was reflected in the Mainstem Willow Creek data.

In Windy Gulch, calcium and magnesium, like the heavy metals, were in small loads relative to those in Willow Creek (Figure 34). Calcium loads at WNG-A were 17.39 lbs Ca/day, but were nearly twice as high at WNG-B (29.69 lbs Ca/day). In comparison, calcium in Willow Creek was 2280 lbs Ca/day at W-B. Magnesium loads were 2.26 lbs Mg/day at WNG-A and 4.53 lbs Mg/day at WNG-B in May 2000. These levels were <2% of loads present in Mainstem Willow (262 lbs Mg/day), and therefore Windy Gulch was not a substantial magnesium source.

The aluminum load at WNG-A was <0.1 lbs Al/day in May 2000; however, data from WNG-B indicate that loading could have been as high as 1 lb Al/day (Figure 35). Kimball et al. (2002) noted an increase of 0.39 lbs Al/day in Willow Creek in the reach including Windy Gulch. At those levels, Windy Gulch would have increased the aluminum load in Willow Creek <2%. At WNG-A in 2000, loads of arsenic (0.017 lbs As/day), cadmium (0.008 lbs Cd/day), and copper (0.006 lbs Cu/day) were small and were comparable to <1% of the loads present in Willow Creek.

Iron loads in Windy Gulch were 0.09 lbs Fe/day at WNG-A. Data from Mainstem Willow Creek did not indicate an increase in iron downstream of the confluence with Windy Gulch in May 2000. Kimball et al. (2002) noted an increase in Mainstem Willow of 0.70 lbs Fe/day in the vicinity of Windy Gulch in September 2000. Measured and estimated iron loads from Windy Gulch were <4% of the load present in Mainstem Willow. Manganese loads in Windy Gulch were 0.04 lbs Mn/day at WNG-A in May 2000. Loads measured upstream (0.16 lbs Mn/day) were around four times higher than at WNG-A, but constituted <1% of loads found in Willow Creek (58.54 lbs Mn/day at W-B). In contrast, Kimball et al. found an increase of 5.82 lbs Mn/day in Mainstem Willow downstream of Windy Gulch. If this load increase was attributable to Windy Gulch subsurface inflows, then Windy Gulch was a more substantial source than the May 2000 data indicated.

Zinc loads increased substantially from WNG-B (0 lbs Zn/day) to WNG-A (1.5 lbs Zn/day) indicating that the Bulldog waste rock piles were likely a source of zinc. Kimball et al. (2002) found an increase of 34 lbs Zn/day in Mainstem Willow below Windy Gulch. Although minor relative to loads in Willow Creek (406 lbs Zn/day at W-B), Windy Gulch was a notable source of zinc.

Rio Grande

Table 21 lists descriptions for main channel sites and inflows along the Rio Grande. Data for these sites were collected by the Willow Creek Reclamation Committee and the United States Geological Survey. Data for the main channel sites are presented in Table 22 starting with the site furthest upstream, Marshall Park (RG-7), and continuing to the downstream site at the 4UR Bridge (RG-9). The 4UR Bridge is near the Wagon Wheel Gap site used by the Water Quality Control Division of the Colorado Department of Public Health and Environment. Numbering of Rio Grande sites is not sequential from upstream to downstream due to the addition of intermediate sites at later dates.

Discharge

Discharge in the Rio Grande at RG-4 during high flow (May) ranged from 303 CFS (2002) to 1030 CFS (2000). Measurements were difficult to obtain during high flows because depth and velocity of the river prohibited wading. The only discharge measurements collected during low flows were around 63 CFS at RG-8 and RG-9 (August 2002).

Water Chemistry

Field data indicate that pH values were between 6 and 7 in September 1999, and between 7.5 and 8.5 during all other sampling events. There was not a clear trend in pH from upstream to downstream. Conductivities were greater in August 2002 (range: 138 μS/cm at RG-8 to 144 μS/cm at RG-9) than during the other sampling events (range: 63-81 μS/cm). Conductivities increased slightly (<11 μS/cm) below the confluence with Willow Creek. Temperatures in the Rio Grande averaged 9.7^{o}C (range: 5.0-13.6^{o}C). Increases in temperature were not distinguishable from potential diurnal influences. Dissolved oxygen ranged from 6.0 to 10.5 mg/L during the major sampling events.

Metals

Data from September 1999 and May 2000 showed substantial increases in cadmium, manganese, and zinc between RG-1 and RG-4, indicating that Willow

Creek was a source. In comparison with Table Values Standards, water quality at RG-4 in 2002 was above recommended concentrations of zinc (TVS=95.01 µg/L; avg. RG-4=189.25 µg/L). The Colorado Water Quality Control Division has also determined that the stretch of the Rio Grande below Willow Creek periodically has elevated levels of cadmium. During the major sampling events, hardness values below the confluence with Willow Creek ranged from 22 to 80 mg $CaCO_3$/L, and measured levels of cadmium (max.: 0.48 µg/L) from composite samples were substantially below calculated TVS (0.73-1.9 µg/L).

Flows were not taken in the Rio Grande in September 1999, and therefore, load calculations for metals were only available for May 2000 (Figure 36). Although mixing at RG-4 was not complete (see Figure 37), comparisons of loads at RG-1 and RG-4 give some indication of the changes in the Rio Grande from upstream to downstream of the confluence with Willow Creek. Aluminum loads in the Rio Grande increased by 181 lbs Al/day from RG-1 to RG-4, although only 49 lbs Al/day were measured in Willow Creek. Cadmium increased from undetectable levels at RG-1 to 2.2 lbs Cd/day at RG-4. This increase corresponded well with the levels measured in Willow Creek (2.47 lbs Cd/day), confirming that Willow Creek was probably the primary source of cadmium to the Rio Grande.

Copper loads in Willow Creek were 1.5 lbs Cu/day near the confluence with the Rio Grande in May 2000, but loads in the Rio Grande increased by 7.2 lbs Cu/day. Iron increased from 1520 (RG-1) to 1720 lbs Fe/day (RG-4) in the Rio Grande, but only 23 lbs Fe/day were measured in Willow Creek. Manganese loads in the Rio Grande increased from 94 to 177 lbs Mn/day from RG-1 to RG-4. This increase of 83 lbs Mn/day was higher than loads found in Willow Creek (58 lbs Mn/day). Although lead loading in Willow Creek was determined to be 7.28 lbs Pb/day, there were no detectable levels of lead in the Rio Grande.

Zinc loads in the Rio Grande increased substantially from around 0 lbs Zn/day at RG-1 to 611 lbs Zn/day at RG-4. The quantified load in Willow Creek (537 lbs Zn/day) accounted for almost 90% of the zinc found in the Rio Grande below the confluence. Table 23 presents a summary of zinc loading in Willow Creek as it compares to the Rio Grande. Data were only available for both Willow Creek and the Rio Grande in May 2000 and 2002. These analyses indicated that there was some variability between estimates, although in May 2000 it was <10%. The difference of 31% in May 2002 might have been due to the fact that flow measurements, sample collection, and laboratory analyses were conducted by different entities.

In May 2002, the United States Geological Survey (USGS) collected width-integrated and composite samples at RG-5, -4, -8 and -9 to determine the extent of mixing across the Rio Grande and to evaluate the accuracy of composite versus grab samples. Data from the USGS are show in Table 24 (see Appendix B). These samples were analyzed for field parameters and dissolved zinc. Zinc was chosen for analyses because it was the primary metal of concern. Figure 37 shows the data across the width of the channel and the values of the composite samples for each site. These data indicate that the channel was mixed at RG-5, -8, and -9, but not at RG-4. It is evident that a portion of the inflow from Willow Creek remained concentrated near the bank at RG-4, and that the reach in between the inflow and

RG-4 did not have the length, turbulence, or other factors to facilitate complete mixing. The composite at RG-4 (124 μg Zn/L) was comparable to an average of samples across the river; however, grab samples from either bank would not have been representative.

Also noted in the USGS data (Figure 37) was an increase in zinc between RG-8 and RG-9. Given the distance from Willow Creek, it was evident that another source was responsible for this increase. In August 2002, investigations were carried out to locate and quantify any potential sources to the Rio Grande between RG-8 and RG-9. Figure 38 presents load data from the USGS sampling in May and the additional sampling in August 2002. Both datasets indicate a source of zinc between RG-8 and RG-9 with no measured increase in discharge. Data from surface waters entering the Rio Grande above and below Willow Creek are presented in Table 25. Based on these data, Miner's Creek, Bellow's Creek, and Spring Gulch were not substantial contributors of metals to the Rio Grande. The seep discovered just below RG-8, called RG-Seep1, had minimal surface flow (<1 GPM), but metal concentrations (total zinc=703 μg/L) indicated that the area could be a source to the Rio Grande. Figure 39 presents the data from August 2002 for main channel sites between RG-8 and RG-9, and RG-Seep 1. Metals in the seep, in contrast with the channel, were not primarily in dissolved form.

Data Comparisons

Table 26 presents load comparisons between the sum of inflows and the next site downstream. Available data for this came from the confluence of: 1) East and West Willow; 2) Windy Gulch and Mainstem Willow; and 3) Willow Creek and the Rio Grande. These comparisons could give an indication of subsurface flow that was not measured in the inflows, but which discharged into the main channel. For most of the parameters in the May 2000 data, loads were comparable to slightly higher at the downstream sites. In 2002, load estimates differed by <10%.

Conclusions

The primary constituents of concern in East Willow were cadmium, lead, and zinc. Channel and tributary data support the conclusion that the Solomon Mine area was the primary source of these metals; however, loading from the sampled inflows (EW-SWD and EW-SMA) did not account for 100% of the load in the channel. Runoff from the Solomon and Ridge waste rock piles might have also had some influence on water quality.

In West Willow Creek, sample concentrations at WW-A were above recommended levels of aluminum (TVS=87 μg/L), cadmium (TVS=1.84 μg/L), copper (TVS=7.12 μg/L), lead (TVS=1.88 μg/L), and zinc (TVS=93.9 μg/L). Discharge from the Nelson Tunnel was clearly the source of the majority of these metals. Visual observations have confirmed that a substantial amount of flow at the Nelson Tunnel does not pass through the flume, and therefore discharge and loads are likely underestimated. Data from the WW-Seep (905 μg Cd/L; 153700 μg Zn/L) and WW-Tail (6162 μg Zn/L) also indicate that water flowing through the Commodore tailings pile was high in metals. The Midwest Mine area on Nelson Creek (NC-D) was acid-producing and contributed measurable levels of total cadmium (2.74 μg/L), copper (48.8 μg/L), manganese (107 μg/L), iron (3574 μg/L), and zinc (197.8 μg/L) to the channel. Between the Midwest and the mouth of Nelson Creek, flows increased and metal concentrations dropped. The overall contribution of Nelson Creek to the metal load in West Willow generally did not cause an increase that was consistent among years.

Water quality in Mainstem Willow Creek primarily reflected the contamination problems that originated in West Willow with the Nelson Tunnel. In general, metal loads were smaller in the Mainstem than they had been in East and West Willow, indicating that precipitation or sorption had occurred. Data from sites near the Emperious Tailings Pile indicate that it could be associated with increased levels of magnesium, aluminum, cadmium, copper, manganese, and zinc. Near the confluence with the Rio Grande, dissolved aluminum (range: 38-691 μg/L), cadmium (range: 6.9-19.4 μg/L), lead (range: 6-105 μg/L), and zinc (range: 1113-5238 μg/L) remained above Table Values Standards. Due to the small amount of data collected for Windy Gulch, it is difficult to determine the potential extent of its influence on water quality in Willow Creek. Based on one season of load data, Windy Gulch was a relatively minor contributor of metals. High concentrations (4188 μg Zn/L) and the variability of subsurface flows warrant further investigations in the Windy Gulch drainage before conclusions are drawn.

Willow Creek substantially increased levels of aluminum, cadmium, copper, iron, manganese, lead, and zinc in the Rio Grande River. The WCRC determined that mixing was not complete across the River at Wason Ranch (RG-4), but was complete at the 4UR Bridge (RG-9). Two datasets from 2002 corroborated the existence of a zinc source between RG-8 and RG-9, and field investigations pointed to a seep just downstream of RG-8 (dissolved zinc: 703 μg/L). Further investigations will seek to characterize the seep and a possible association with hot springs in the area. Based on the small WCRC dataset, zinc was the only metal above TVS in the Rio Grande; however, an extensive dataset from the Colorado Department of Public Health and the Environment/ Water Quality Control Division has also indicated that cadmium was a seasonal problem in the Rio Grande below Willow Creek.

Difficulties in obtaining accurate flow measurements are reflected in the projected loads from upstream to downstream, which varied for some elements. Kimball (2000), using a sodium bromide tracer to calculate discharge, exhibited a more efficient tool in identifying subtle changes in loading to Willow Creek.

Surface water characterization efforts by the WCRC identified sources, concentrations, and loads at several discharge levels in key areas in the Willow Creek and Rio Grande watersheds. These data will be combined with waste pile, groundwater, and biological data to prioritize reclamation efforts in the watershed. This information will also provide a baseline by which to assess the need for further investigations or to monitor the effectiveness of reclamation efforts.

References

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Water Management Consultants, Inc. 1999. Bulldog Mine, Windy Gulch Assessment. Report prepared for Peter Keppler, P.C., December 1999.

Tables

List of Tables

Table 1. Comparisons of duplicates collected in September 1999. Boldface represents levels below the Practical Quantitation Limit (ACZ) or detection limit. Underlining indicates values were below detection limits and considered the same. The relative percent difference (rpd) is calculated as $100[x_1 - x_2]/AVERAGE_x$. In the case of 3 or more values, the high and low values represent x_1 and x_2, respectively. Prefixes "d" and "t" represent dissolved and total, respectively.

Date	Site	Lab	TDS	rpd	TSS	rpd	dCa	rpd	tCa (ug/L)	rpd	dMg	rpd	tMg	rpd	dSi	rpd	tSi	rpd	dK	rpd	tK	rpd	dAl	rpd	tAl	rpd	dAs	rpd
Sep-99	EW-A	RW							6737	7			831	17											123	84		
		ACZ							6300				**700**												**50**			
Sep-99	EW-H	RW							6167	1			728	4											125	25		
		ACZ							6100				**700**												**160**			
Sep-99	EW-J	RW							6273	4			716	2											114	45		
		ACZ							6000				**700**												**180**			
Sep-99	WW-C	RW							24447	4			2675	11											254	29		
		ACZ							23500				2400												340			
Sep-99	WW-K	RW							11112	0			1337	3											167	27		
		ACZ							11100				1300												220			
Sep-99	W-I	RW							13926	8			1647	16											268	1		
		ACZ							12800				1400												270			
Sep-99	WNG-A	RW					48062	0	48066	12	5549	0	5197	10									36	5	231	6	**<15**	0
		RW					48265		48166		5561		5497										38		245		**<15**	
		ACZ	260	0	**5**	0									33.9	1	31.5	7	3.4	0	3.30	0						
		ACZ	260		**5**				42300				4700		34.3		29.5		3.4		3.30				230			
Sep-99	W-E	RW							13765	13			1588	20											195	3		
		ACZ							12100				1300												**190**			
Sep-99	SMA	RW					59726	1	59914	1	18483	0	18243	0									1522	0	1600	0	**<15**	0
		RW					59344		59165		18435		18330										1515		1604		**<15**	
Sep-99	WW-J	RW					11258	0	11362	3	1379	1	1384	2									70	58	173	2	**<15**	0
		RW					11207		11020		1359		1354										127		176		**<15**	
		ACZ	50	0	**<5**	0									16.7	1	16.4	4	**0.9**	0	**0.8**	0						
		ACZ	50		**<5**										16.8		17.1		**0.9**		**0.8**							
Sep-99	W-B	RW					13371	0	13413	0	1557	0	1548	1									74	9	180	8	**<15**	0
		RW					13387		13479		1556		1566										81		166		**<15**	
		ACZ	80	0	**<5**	0									20.4	2	18.7	4	**0.9**	0	**0.8**	13						
		ACZ	80		**<5**										20.8		19.5		**0.9**		**0.7**							

Table 1 (cont.)

Date	Site	Lab	tAs (ug/L)	rpd	dCd (ug/L)	rpd	tCd (ug/L)	rpd	dCu (ug/L)	rpd	tCu (ug/L)	rpd	dFe (ug/L)	rpd	tFe (ug/L)	rpd	dMn (ug/L)	rpd	tMn (ug/L)	rpd	dPb (ug/L)	rpd	tPb (ug/L)	rpd	dZn (ug/L)	rpd	tZn (ug/L)	rpd
Sep-99	EW-A	RW	<15	0			1.65	16			1.1	10			82	16			14.8	20			18.7	13			218.7	4
		ACZ	<40				1.4				1				70				18				16.4				210	
Sep-99	EW-H	RW	<15	0			0.33	19			1.2	-			94	32			<10	-			5	11			16.1	22
		ACZ	<40				0.4				<1				130				10				4.5				20	
Sep-99	EW-J	RW	<15	0			0.25	18			<1	0			99	19			10.6	6			<3	0			<1	-
		ACZ	<40				0.3				<1				120				10				0.4				10	
Sep-99	WW-C	RW	<15	0			31.12	18			22.4	6			222	16			1393.5	8			135.3	5			7771	22
		ACZ	<40				26.1				21				260				1290				128.8				6210	
Sep-99	WW-K	RW	<15	0			1.36	5			2.5	22			205	20			14.4	22			18.5	12			72	11
		ACZ	<40				1.3				2				250				18				16.4				80	
Sep-99	W-I	RW	<15	0			14.48	12			8.5	6			94	16			456.6	13			39.4	4			2774	21
		ACZ	<40				12.8				9				110				399				37.7				2240	
Sep-99	WNG-A	RW	48	25	22.97	2	24	25	9.9	10	21.4	28	22	20	513	11	225.6	3	230.4	14	<3	0	<3	0	4100	1	4198	25
		RW	47		23.51		24.06		10.9		21.2		27		517		233.4		231		<3		<3		4147		4188	
		ACZ																										
		ACZ	60				18.6				16				460				200				1.6				3230	
Sep-99	W-E	RW	<15	0			13.71	18			8.7	22			137	85			498.4	20			59.2	19			2852	25
		ACZ	<40				11.5				7				340				408				48.7				2210	
Sep-99	SMA	RW	<15	0	192.9	1	193.5	1	58.6	2	58.2	0	508	1	991	1	6482.9	1	6453.5	1	1434	1	1466	1	36900	1	37000	1
		RW	<15		190.5		191.2		57.4		58.2		504		983		6419.4		6392.5		1419		1458		36600		36500	
Sep-99	WW-J	RW	<15	0	2.41	0	2.53	4	2.9	7	3.6	6	85	40	208	3	11	10	16	2	12.2	32	26.8	5	135	3	141	1
		RW	<15		2.41		2.44		3.1		3.4		128		202		12.2		16.4		16.9		25.6		139		140	
		ACZ																										
		ACZ																										
Sep-99	W-B	RW	<15	0	13.45	1	13.61	1	6	13	8.7	2	35	23	128	3	525.8	0	531.8	1	33.3	8	59.6	1	3133	0	3196	1
		RW	<15		13.53		13.7		6.8		8.5		44		124		525.8		535.9		36		60.2		3142		3220	
		ACZ																										
		ACZ																										

Table 2. Comparisons of duplicates collected in May 2000. Values in boldface represent levels below the Practical Quantitation Limit (ACZ) or detection limit. Underlining indicates values were below detection limits and considered the same. The relative percent difference (rpd) is calculated as $100[x_1 - x_2]/AVERAGE_x$. In the case of 3 or more values, the high and low values represent x_1 and x_2, respectively.

Date	Site	Lab	Hard (mg/L)	rpd	TDS (mg/L)	rpd	TSS (mg/L)	rpd	dCa (ug/L)	rpd	tCa (ug/L)	rpd	dMg (ug/L)	rpd	tMg (ug/L)	rpd	dSi (mg/L)	rpd	tSi (mg/L)	rpd	dK (mg/L)	rpd	tK (mg/L)	rpd	Na (mg/L)	rpd	dAl (ug/L)	rpd	tAl (ug/L)	rpd
May-00	EW-GMA	RW							7939	3			424	5													39	5		
		ACZ							8178				402														37			
May-00	EW-C	SDC			44	15	1.7	30									16.4	4	18.1	5			0.98	2	2.3	0				
		SDC			38		2.3										17.1		17.3				1.00		2.3					
		RW	14	13					5044	7	5112	2	626	11	627	4											38	-	219	0
		ACZ	16						5400		5200		700		600												**<30**		220	
May-00	EW-F	SDC			44	5	**<1**	0									17.7	13	18.6	1			0.80	0	2.3	4				
		SDC			42		**<10**										15.6		18.4				0.80		2.2					
		RW	20	22					5005	6	5078	2	612	2	625	4											32	-	202	9
		ACZ	16						5300		5200		600		600												**<30**		220	
May-00	WW-H	SDC			50	4	**<1**	0									11.6	5	12.7	4			0.63	2	2.0	0				
		SDC			48		**<10**										12.3		13.2				0.64		2.0					
		RW	24	0					7521	6	7623	2	936	4	948	5											20	0	131	37
		ACZ	24						8000		7500		900		900												**<30**		190	
May-00	WW-L	SDC			56	17	**<1**	0									11.9	2	13.2	10			0.86	3	2.2	13				
		SDC			47		**<10**										11.6		11.9				0.89		2.5					
		RW	24	0					7575	7	7598	4	957	6	960	4											17	142	119	-
		ACZ	24						8100		7900		900		1000												100		**<60**	
May-00	W-J	SDC			64	13	2.2	13									16.6	0	17.0	3			0.80	8	3.3	0				
		SDC			73		2.5										16.6		17.6				0.74		3.3					
		RW	36	12					9936	7	9935	1	1196	0	1210	19											61	42	299	0
		ACZ	32						10700		10000		1200		1000												40		300	
May-00	W-E	SDC			83	8	2.7	0									16.8	8	17.4	9			1.02	18	2.9	16				
		SDC			90		2.7										15.6		15.9				0.85		3.4					
		RW	34	13					9445	8	9446	8	1081	2	1092	1											24	0	151	28
		ACZ	30						10200		10200		1100		1100												**<30**		200	
May-00	WNG-B	SDC			54	8	1.4	24									23.4	0	25.3	7			1.25	5	3.0	7				
		SDC			50		1.1										23.4		23.6				1.19		2.8					
		RW	38	38					7869	7	8322	1	1178	2	1271	6											42	-	278	38
		ACZ	26						8400		8400		1200		1200												**<30**		410	

Table 2 (cont.)

Date	Site	Lab	dAs (ug/L)	rpd	tAs (ug/L)	rpd	dCd (ug/L)	rpd	tCd (ug/L)	rpd	dCu (ug/L)	rpd	tCu (ug/L)	rpd	dFe (ug/L)	rpd	tFe (ug/L)	rpd	dMn (ug/L)	rpd	tMn (ug/L)	rpd	dPb (ug/L)	rpd	tPb (ug/L)	rpd	dZn (ug/L)	rpd	tZn (ug/L)	rpd
May-00	EW-GMA	RW	21	0			0.5	-			<1	0			20	42			<10	0			<3	0			13	-		
		ACZ	**<30**				**<0.5**				**<3**				13				**<5**				**<0.5**				**<10**			
May-00	EW-C	SDC																												
		SDC																												
		RW	**<15**	0	**<15**	0	0.76	24	0.95	5	1.4	124	**<1**	-	27	30	138	1	**<10**	0	11.9	174	6.2	12	12.6	5	100	0	110	9
		ACZ	**<30**		**<60**		0.6		1		6		6		20		140		6		170		5.5		12		100		120	
May-00	EW-F	SDC																												
		SDC																												
		RW	**<15**	0	**<15**	0	0.36	0	0.45	0	**<1**	0	**<1**	0	28	33	137	2	**<10**	0	11.9	0	3.8	3	9.4	16	49	1	50	19
		ACZ	**<30**		**<60**		**<0.5**		**<1.0**		**<3**		**<5**		20		140		5		**<30**		3.7		8		50		60	
May-00	WW-H	SDC																												
		SDC																												
		RW	**<15**	0	**<15**	0	1.64	2	1.8	57	1.6	126	2	120	37	21	127	10	**<10**	0	**<10**	0	5.3	20	13.3	12	93	7	99	11
		ACZ	**<30**		**<60**		1.6		1		7		8		30		140		5		**<30**		6.5		15		100		110	
May-00	WW-L	SDC																												
		SDC																												
		RW	**<15**	0	**<15**	0	**<0.15**	0	**<0.15**	0	**<1**	-	**<1**	-	42	102	147	114	**<10**	0	10.1	0	**<3**	0	**<3**	0	**<1**	0	**<1**	0
		ACZ	**<30**		**<60**		**<0.5**		**<1.0**		10		5		130		40		9		**<30**		1.6		1		**<10**		**<50**	
May-00	W-J	SDC																												
		SDC																												
		RW	**<15**	0	**<15**	0	12.06	7	12.19	30	5.2	54	7.1	91	14	-	132	38	268.8	1	276.4	18	12.9	3	43.2	8	2496	8	2603	22
		ACZ	**<30**		**<60**		11.2		9		9		19		**<10**		90		272		230		12.5		40		2310		2080	
May-00	W-E	SDC																												
		SDC																												
		RW	**<15**	0	**<15**	0	8.37	3	8.54	20	3.3	58	4.1	75	17	-	106	20	244.2	2	248.9	17	15.5	3	34.3	2	1851	7	1875	25
		ACZ	**<30**		**<60**		8.1		7		6		9		**<10**		130		249		210		15.9		35		1720		1460	
May-00	WNG-B	SDC																												
		SDC																												
		RW	**<15**	0	**<15**	0	**<0.15**	0	**<0.15**	0	**<1**	-	**<1**	0	53	28	347	12	29.4	2	45.1	12	**<3**	0	**<3**	0	**<1**	0	**<1**	0
		ACZ	**<40**		**<80**		**<0.5**		**<1.0**		4		**<5**		40		390		30		40		**<0.5**		1		**<10**		**<50**	

Table 3. Comparisons of duplicates collected in May 2001 and 2002. Values in boldface represent levels below the Practical Quantitation Limit (ACZ) or detection limit. Underlining indicates values were below detection limits and considered the same. The relative percent difference (rpd) is calculated as $100[x_1-x_2]/(AVERAGE_x)$. In the case of 3 or more values, the high and low values represent x_1 and x_2, respectively.

Date	Site	Lab	Alk (mg/L)	rpd	Hard (mg/L)	rpd	TDS (mg/L)	rpd	TSS (mg/L)	rpd	dCa (ug/L)	rpd	tCa (ug/L)	rpd	dMg (ug/L)	rpd	tMg (ug/L)	rpd	dSi (mg/L)	rpd	tSi (mg/L)	rpd	dK (mg/L)	rpd	tK (mg/L)	rpd	Na (mg/L)	rpd	dAl (ug/L)	rpd	tAl (ug/L)	rpd
May-01	EWJ	ACZ			12						5100		5000		**600**		**<1000**												**<30**		**300**	
		RW				15					4499	14	4584	9	534	12	552	0											18	0	146	74
		RW			14						4438		4560		554		568												19		177	
May-01	WWA	ACZ			27						8800		9000		1000		**1000**												**40**		**200**	
		RW				4					7630	15	7598	17	972	3	987	1												2		10
		RW			28						7697		7610		987		986												41		220	
May-02	W-C	SDC	18	11	68	3	99	1	**<1**	0									**<0.2**	-	**<0.2**	-	**<0.5**	0	**<0.5**	0	4.3	0			14	
		SDC	20		66		98		**<1**										7.8		9.3		**<0.5**		**<0.5**		4.3					112
		RW									17300	0	17360	0	1712	0	1727	0											**<15**	0	71	
		RW									17352		17324		1720		1722												**<15**		70	
May-02	WNG-B	SDC	36	6	36	0	87	2	2	0									9.5	17	11.3	14	0.5	0	0.50	0	3.4	0			188	
		SDC	34		36		85		2										8.0		9.8		0.5		0.50		3.4					4
		RW									10268	1	10387	0	1403	1	1420	0											**<15**	0	195	
		RW									10399		10426		1415		1420												**<15**		196	
May-02	EW-A	SDC																													6	164
		RW																													63	
May-02	EW-G	SDC	20	0	26	17	42	24	2	0									9.3	29	12.6	3	**<0.5**	0	**<0.5**	0	2.4	4				
		SDC	20		22		33		2										12.4		13.0		**<0.5**		**<0.5**		2.5					
		RW									5716	0	5776	1	595	1	612	4											**<15**	0	72	3
		RW									5708		5746		592		590												**<15**		70	

Table 3 (cont.)

Date	Site	Lab	dAs (ug/L)	rpd	tAs (ug/L)	rpd	dCd (ug/L)	rpd	tCd (ug/L)	rpd	dCu (ug/L)	rpd	tCu (ug/L)	rpd	dFe (ug/L)	rpd	tFe (ug/L)	rpd	dMn (ug/L)	rpd	tMn (ug/L)	rpd	dPb (ug/L)	rpd	tPb (ug/L)	rpd	dZn (ug/L)	rpd	tZn (ug/L)	rpd
May-01	EWJ	ACZ	**<1**		**<1**		**0.8**		**<0.2**		**<10**		**<50**		**20**		**180**		**<5**		**<30**		**<0.2**		**0.5**		**30**		**<50**	
		RW	**<15**	0	**<15**	0	**<0.15**	-	**<0.15**	0	**<1**	0	**<1**	0	16	23	131	33	**<10**	0	13.3	0	**<3**	0	**<3**	0	**<1**	-	**<1**	0
		RW	**<15**		**<15**		**<0.15**		**<0.15**		**<1**		**<1**		16		139		**<10**		12.4		**<3**		**<3**		**<1**		**<1**	
May-01	WWA	ACZ	**<1**		**3**		12.3		13.3		**20**		**<50**		**20**		**260**		233		220		10.5		76.6		1460		1580	
		RW	**<15**	0	**<15**	0	13.0	7	13.8	4	9	83	14.1	0	16	23	322	22	195	18	213	4	10.5	10	73.0	13	1501	3	1624	2
		RW	**<15**		**<15**		13.2		13.9		10		14		16		265		196		212		11.6		67.2		1499		1593	
May-02	W-C	SDC			9.9				5.1				4.6				142				604				47				6156	
		RW	**<15**	0	**<15**	0	14.9	1	15.1	85	5.0	4	6.0	27	13	8	82	58	556	1	568	6	30	5	60.6	25	4285	0	4331	37
		RW	**<15**		**<15**		14.8		15.1		5.2		6.1		12		84		562		569		31.6		58.2		4296		4371	
May-02	WNG-B	SDC			10.5				1.3				**<1**				456				61				**<2**				**<5**	
		RW	**<15**	0	**<15**	0	0.19	0	0.28	194	**<1**	0	**<1**	0	42	13	371	22	68.8	2	76	21	**<3**	0	**<3**	0	**<1**	0	**<1**	0
		RW	**<15**		**<15**		0.19		0.17		**<1**		**<1**		37		370		70.1		76		**<3**		**<3**		**<1**		**<1**	
May-02	EW-A	SDC			4	0			6.3	72			**<1**				141	83			**<10**	0			23	7			376	6
		RW			**<15**				2.96				1.1				58				**<10**				24.6				400	
May-02	EW-G	RW	**<15**	0	**<15**	0	0.45	7	0.61	10	**<1**	0	**<1**	0	22	10	62	2	**<10**	0	**<10**	0	10.9	0	15.9	2	60	3	62	1
		RW	**<15**		**<15**		0.42		0.55		**<1**		**<1**		20		61		**<10**		**<10**		10.9		16.2		61.5		62	

Table 4. Data from blanks collected in September 1999, May 2001, and May 2002. Values below the laboratory-determined detection limit at presented with "<".

Date	Site	Lab	Alk (mg/L)	Hard (mg/L)	TDS (mg/L)	TSS (mg/L)	dCa (ug/L)	tCa (ug/L)	dMg (ug/L)	tMg (ug/L)	dSi (mg/L)	tSi (mg/L)	dK (mg/L)	tK (mg/L)	Na (mg/L)	dAl (ug/L)	tAl (ug/L)
Sep-99	SMA	ACZ, RW			<10	<5	<100	<100	<100	<100	<0.2	<0.2	<0.3	<0.3		<15	<15
	WW-J				<10	<5	<100	<100	<100	<100	<0.2	<0.2	<0.3	<0.3		15	18
	WNG-A				40	<5	<100	<100	<100	<100	<0.2	0.3	<0.3	<0.3		<15	<15
	RG3				<10	<5	<100	<100	<100	<100	<0.2	0.3	<0.3	<0.3		<15	<15
May-01	WW-A	RW														<15	<15
	EW-J															<15	<15
May-02	WNG-B	SDC,RW	0	0	<1	<1	<100	<100	<100	<100	<0.2	0.4	<0.5	<0.5	<1	<15	<15
	EW-G		0	0			<100	<100	<100	<100						<15	<15
	W-C		0	0	<1	<1	<100	<100	<100	<100	<0.2	0.4	<0.5	<0.5	<1	<15	<15

Table 4 (cont.)

Date	Site	Lab	dAs (ug/L)	tAs (ug/L)	dCd (ug/L)	tCd (ug/L)	dCu (ug/L)	tCu (ug/L)	dFe (ug/L)	tFe (ug/L)	dMn (ug/L)	tMn (ug/L)	dPb (ug/L)	tPb (ug/L)	dZn (ug/L)	tZn (ug/L)
Sep-99	SMA	ACZ, RW	<15	<15	<0.15	<0.15	<1	<1	<10	<10	<10	<10	<3	<3	<1	<1
	WW-J		<15	<15	<0.15	<0.15	2.1	<1	47	<10	<10	<10	<3	<3	<1	<1
	WNG-A		<15	<15	<0.15	<0.15	<1	1.2	16	102	<10	<10	<3	<3	<1	<1
	RG3		<15	<15	<0.15	<0.15	<1	<1	<10	<10	<10	<10	<3	<3	<1	<1
May-01	WW-A	RW	<15	<15	<0.15	<0.15	<1	<1	<10	<10	<10	<10	<3	<3	12.9	<1
	EW-J		<15	<15	<0.15	<0.15	<1	<1	<10	10	<10	<10	<3	<3	<1	<1
May-02	WNG-B	RW	<15	<15	<0.15	0.46	<1	<1	<10	<10	<10	<10	<3	<3	<1	<1
	EW-G		<15	<15	<0.15	<0.15	<1	<1	<10	<10	<10	<10	<3	<3	<1	<1
	W-C		<15	<15	<0.15	<0.15	<1	<1	<10	<10	<10	<10	<3	<3	<1	<1

Table 5. Laboratory detection limits for Sangre de Cristo and River Watch labs. Detection limits for ACZ lab vary with calibration and dilution, and therefore are not shown.

Lab	Year	Hard (mg/L)	TDS (mg/L)	TSS (mg/L)	DOC	dSO4 (mg/L)	tSO4 (mg/L)	tCl (mg/L)	dCa (ug/L)	tCa (ug/L)	dMg (ug/L)	tMg (ug/L)	tSi (mg/L)	dSi (mg/L)	tK (mg/L)	Na (mg/L)	dAl (ug/L)	tAl (ug/L)
SDC	2000	1	1.0	1.0	1.0	1.0	1.0	1.0	1000	1000	500	500	0.0005	0.0005	0.5	1.0	3	3
	2001		1.0	1.0	1.0	1.0	1.0	1.0	1000		500		0.01	0.01	0.5	0.5	3	
	2002		1.0	1.0		1.0	1.0	1.0	1000		500		0.2	0.2	0.5	1.0	3	
RW			1	1					100	100	100	100					15	15

Table 5 (cont.)

Lab	Year	dBa (ug/L)	dAs (ug/L)	tAs (ug/L)	dCd (ug/L)	tCd (ug/L)	dCu (ug/L)	tCu (ug/L)	dFe (ug/L)	tFe (ug/L)	dPb (ug/L)	tPb (ug/L)	dMn (ug/L)	tMn (ug/L)	dSe (ug/L)	tSe (ug/L)	dZn (ug/L)	tZn (ug/L)
SDC	2000	2	1	1	0.1	0.1	1.0	1.0	10.0	10.0	1.0	1.0	10.0	10.0			5.0	5.0
	2001		1		0.1		1.0		10.0		1.0		10.0				5.0	
	2002				0.1		1.0		10.0		2.0		10.0				5.0	
RW			15	15	0.15	0.15	1	1	10	10	3	3	10	10	2	2	1	1

Table 6. Sampling summary of the four main sampling events: September 1999 and May 2000, 2001, and 2002. Days and manhours reflect the amount of time required to collect and process all samples. Manhours are approximated. Main channel is defined as the Rio Grande River and East, West, and Mainstem Willow. Tributary channels are Nelson Creek, Windy Gulch, and Miners Creek. Springs and seeps include any minor tributaries and other isolated inflows. Parameters include all field and laboratory analyses.

Date	**Type**	**Days**	**Manhours**	**# of Samples**						**Total # of Parameters Analyzed**
				Main Channel	Tributary Channel	Adits	Springs/ Seeps	Wetlands	**TOTAL**	
Sep-99	Low Flow	4	242	43	6	6	7	1	**63**	38
May-00	High Flow	4	242	40	7	6	8	1	**62**	37
May-01	High Flow	2	82	14	5	2	2	0	**23**	33
May-02	High Flow	2	82	15	2	2	5	0	**24**	39

Table 7. Surface water and mine water sampling locations in the drainage of East Willow Creek. Main channel sites were locations of direct sampling from East Willow Creek. Other inflows include tributaries, seeps, springs, and adits discharges that were potential sources to East Willow Creek.

Main Channel Site	Other Inflows	Miles from Confluence w/ West Willow	Location	Notes
EW-A		0.04	~150 ft u/s of conf. w/ West Willow	d/s of Mammoth Adit
EW-B		0.28	u/s of North Creede townsite	d/s of Mammoth Adit
	EW-MA	0.42	Mammoth Adit pipe discharge	Mammoth Adit discharge
EW-C		0.47	~60 ft u/s of Mammoth Adit discharge	u/s of Mammoth Adit
	EW-SWISp	0.55	Along road just south of SWI	Spring flow (source unknown)
	EW-SWI	0.57	Flow entering channel through diversion box	Possible spring flow
EW-D		0.66	u/s of surface water intake and diversion box	u/s of surface water intake
EW-E		0.8	near Kentucky Belle Mine	btwn Solomon and Mammoth Mines
EW-F		0.95	below Solomon Mine	btwn Solomon and Mammoth Mines
EW-G		1.04	~150 ft d/s of Solomon Mine	d/s of Solomon Mine
	EW-PS		West side of channel at Park Area	Spring flow (source unknown)
	EW-SMA	1.14	Solomon Adit	Solomon Adit discharge
	EW-SWD	1.17	Solomon wetland near discharge pipe or seep along road	Solomon wetland discharge
EW-H		1.21	u/s of Solomon Wetland; d/s of Payne's culvert	u/s of Solomon Mine
	EW-PC	1.25	Payne's Culvert discharge; u/s of Solomon Wetland on east bank	Spring flow (source unknown)
EW-I		1.42	u/s of waterfall near Ridge Mine	u/s of Ridge Mine
EW-J		1.93	d/s of Outlet Mine waste rock; u/s of culvert	d/s of Outlet Mine
EW-K		2.16	u/s of Outlet Mine; d/s of TRS	u/s of Outlet Mine
	EW-TRS	2.18	tributary entering channel from east	
	EW-TRN	2.37	tributary entering channel from east	
	EW-Trib 3		East side of road, north of TRN and south of culvert	
EW-L		2.58	d/s of Phoenix Park; ~5 ft u/s road culvert	d/s of Phoenix Park Mill Site
EW-M		2.84	u/s of Phoenix Park	u/s location
	EW-Sp	2.94	spring adjacent to EWN	potentially u/s groundwater location
	EW-N	2.94	tributary to channel; u/s of Phoenix Park	u/s location
	EW-PMA		Phoenix Mine Adit	Phoenix Mine Adit discharge
	EW-GMA		seep near Gormax Mine Adit	Gormax Mine discharge

Table 8. All data collected for main channel sites in East Willow Creek. Units are in ( ). The prefixes "d" and "t" represent dissolved and total fractions, respectively. Values below the laboratory-determined detection limit are indicated by "<".

Date	Site	Flow (CFS)	pH	Temp (C)	Alk (mg/L)	Hard (mg/L)	Cond (uS/cm)	DO (mg/L)	ORP (mV)	TDS (mg/L)	TSS (mg/L)	DOC (mg/L)	NO3 (ug/L)	dSO4 (mg/L)	tSO4 (mg/L)	tCl (mg/L)	dCa (ug/L)	tCa (ug/L)	dMg (ug/L)	tMg (ug/L)	dSi (mg/L)	tSi (mg/L)	dK (mg/L)	tK (mg/L)	Na (mg/L)
9/18/99	EW-A	22.0	7.2	6.3	20	17	53	8.6	166	20	20	1	210		1.9	2	6783	6737	817	831	19.7	19.2	0.9	0.9	
5/16/00	EW-A	28.2	7.1	8.0	16	14	43	9.0		34	1		200		0	2		5103		629	16.68	17.38		0.63	2.2
7/2/00	EW-A		7.8	12.3			56	7.4																	
8/16/00	EW-A	9.2	7.7	8.8	24	21	59	8.5																	
8/23/00	EW-A	22.2	7.8	7.3	20	16	52	8.8		52	15.4			5.2	7.1	5.5	7900	7900	<100	<100	15.63	18.23		1.17	2.6
5/22/01	EW-A	122.4	7.2		18	14		8.9					0		7	2	4368	4433	522	536					
5/2/02	EW-A	8.2	7.5	5.0	20	22									2.0	0	5952	5973	660	692					
9/18/99	EW-B	23.5	7.1	7.5	22	18	53	8.2	179	10	5	1			1.9	2	6571	6555	821	827	20.8	19.1	0.9	0.9	
5/16/00	EW-B	31.9	7.2	8.8	18	14	43	9.6		21	2.4				0	3	5036	5066	612	621	16.2	18.18		0.71	2.2
9/18/99	EW-C	24.5	7.2	7.5	21	18	53	8.3	199	30	5	1			1.9	1	6457	6506	805	820	19.7	20.8	0.8	0.6	
5/16/00	EW-C	32.2	7.2	9.3	16	14	43	9.3		44	1.7				0	3	5044	5112	626	627	16.35	18.1		0.98	2.3
9/18/99	EW-D	27.6	7.2	7.6	21	18	52	8.1	159	40	5	1			1.9	2	6319	6402	806	813	20	20.1	0.8	0.7	
5/16/00	EW-D	37.7	7.1	8.4	16	22	43	9.3		32	0				0	2	5037	5124	618	638	17.03	18.43		0.84	2.3
9/19/99	EW-E	18.4	7.0	4.4	22	18	54	8.9	176	50	5	1			1.9	2	6341	6352	819	823	19.9	20.5	0.7	0.7	
5/16/00	EW-E	37.5	7.2	8.1	16	24	43	8.9		28	3				0	2	5019	5072	616	637	17.43	17.53		0.78	2
9/19/99	EW-F	26.4	7.4	4.5	22	18	53	8.8	117	40	5	1	190		1.9	2	6462	6403	781	789	20.4	20.3	0.8	0.8	
5/16/00	EW-F	42.7	7.3	7.5	20	20	43	9.4		44	0		200		0	2	5005	5078	612	625	17.68	18.58		0.8	2.3
9/19/99	EW-G	24.2	7.3	4.6	21	17	52	8.9	103	40	5	1			0	2	6452	6391	781	790	20.2	20.3	0.7	0.7	
5/17/00	EW-G	32.5	6.6	1.5	16	18	42	9.6		56	0				2	2	4983	5088	609	625	14.45	17.7		0.87	2.4
8/23/00	EW-G		7.8	12.6	20	16	48	11.0						4.1	6.7	3.5	9700	10000	870	870					
5/22/01	EW-G		7.8	8.0	18	14		9.1					0		0	1	4585	4624	572	579					
5/2/02	EW-G	6.9	7.5	4.5	20	26				42	2				0.0	0	5716	5776	595	612	9.3	12.6	<0.5	<0.5	2.4
9/19/99	EW-H	24.5	6.3	6.0	22	17	50	8.3	201	20	5	2			1.9	2	6227	6167	717	728	20.2	19.9	0.9	0.7	
5/17/00	EW-H	28.0	6.8	2.0	18	16	42	9.7		58	1.9				2	3	4950	5009	582	603	12.55	17.4		0.72	2
9/18/99	EW-I	28.9	5.9	6.1	22	16	50	8.5	214	10	5	2	170		1.9	2	6253	6198	725	721	20.7	19.8	0.9	0.8	
5/16/00	EW-I	30.1	6.9	2.6	14	12	42	9.6		76	0				2	2	4923	4976	594	611	18.15	18.2		0.65	2
8/16/00	EW-I	6.4	7.9	8.6	24	18	53	8.6																	
8/23/00	EW-I		7.8	12.0	20	16	47	10.5						20.2	30.2	5.4	7900	7900	4820	4820					
5/22/01	EW-I		6.3	6.9	16	14		9.2					0		0	1	4509	4554	544	557					
5/2/02	EW-I	7.95	7.5	4.0	20	32				37	1				0.0	0	5637	5684	582	584	7.2	8.5	<0.5	<0.5	2.5
9/18/99	EW-J	25.80	5.9	6.5	21	16	49	8.4	232	20	5	1	150		1.9	2	6136	6273	710	716	21.2	20.4	0.9	0.8	
5/17/00	EW-J	32.77	7.0	2.7	14	16	41	9.6		35	0				1	2	4915	4963	591	608	18.1	18.25		0.69	2.1
8/23/00	EW-J		7.8	11.7	20	16	47	11.0						13.7	19.2	7.1	9500	10300	4820	7230					
5/22/01	EW-J		7.7	6.5	18	14		9.1					0		0	2	4438	4560	554	568					
5/2/02	EW-J	8.19	7.6	4.0	20	28				50	1				0.0	0	5587	5647	575	598	8	9.8	<0.5	<0.5	2.5
9/20/99	EW-K	18.30	7.0	4.7	21	17	50	8.3	251	40	5	1	190		1.9	2	6170	6198	717	734	19.9	20.8	0.7	0.7	
5/17/00	EW-K	37.31	7.2	3.8	14	15	41	9.0		46	1.2				1	3	4869	4917	581	606	16.75	17.85		0.98	2.1
9/20/99	EW-L	16.60	7.1	5.0	22	17	49	8.3	237						1.9	2	6176	6227	740	753					
5/17/00	EW-L	28.46	7.1	5.9	16	16	43	8.7		10	1.2				2	2	4985	5013	603	619	15.3	16.15		0.9	2.2
8/23/00	EW-L		8.0	11.7	19	16	47	11.2						20	22	5.7	6400	7900	5790	5790					
9/20/99	EW-M	18.80	7.5	5.7	20	17	50	8.3	221				530		1.9	2	6196	6191	754	727					
5/17/00	EW-M	23.62	7.1	6.3	12	18	43	8.7		74	1.9				10	3	4973	5024	600	614	9.6	17.5		1.38	2.2
5/22/01	EW-M		7.1	6.3	18	12		8.9					0		2	1	4595	4677	572	581					
5/2/02	EW-M	7.68	7.5	4.0	1	24				56	<1				0.0	0	5541	5574	581	614	6.9	8.7	<0.5	<0.5	2.5

Table 8 (cont.)

Date	Site	dAg (ug/L)	dAl (ug/L)	tAl (ug/L)	dAs (ug/L)	tAs (ug/L)	dCd (ug/L)	tCd (ug/L)	dCu (ug/L)	tCu (ug/L)	dFe (ug/L)	tFe (ug/L)	dMn (ug/L)	tMn (ug/L)	dPb (ug/L)	tPb (ug/L)	dSe (ug/L)	tSe (ug/L)	dZn (ug/L)	tZn (ug/L)
9/18/99	EW-A		71	123	<15	<15	1.65	1.65	<1	1.1	80	82	13.3	14.8	11.1	18.7			207.7	218.7
5/16/00	EW-A			179		<15		0.98		<1		111		<10		13.6				121
7/2/00	EW-A																			
8/16/00	EW-A	<0.2					1		1						11				224	
8/23/00	EW-A		184	289	4	4	1	1	<1	<1	262	413	32	50	19	28			216	235
5/22/01	EW-A		22	242	<15	<15	0.58	0.63	<1	<1	13	116	<10	<10	3.1	11.1	<2	<2	130.5	143.2
5/2/02	EW-A		0	63	<15	<15	3	3.0	1.0	1.1	18.0	58	<10	<10	16	25	<2	3.2	389.6	400
9/18/99	EW-B		53	124	<15	<15	1.54	1.61	<1	<1	32	82	12.3	15	9.6	18.9			191.3	195.9
5/16/00	EW-B		37	209	<15	<15	0.84	0.86	<1	<1	27	122	<10	<10	7.5	12.6			105.2	113.2
9/18/99	EW-C		53	118	<15	<15	1.47	1.57	<1	1.1	37	82	13	15.4	10.7	18.4			187.3	194
5/16/00	EW-C		38	219	<15	<15	0.76	0.95	1.4	<1	27	138	<10	11.9	6.2	12.6			100.2	109.8
9/18/99	EW-D		49	122	<15	<15	1.33	1.41	<1	<1	34	87	13.3	16.4	9.7	19.5			167	176.5
5/16/00	EW-D		36	217	<15	<15	0.68	0.99	1.1	1.9	28	137	<10	12.1	5	13.2			88.5	96.9
9/19/99	EW-E		54	124	<15	<15	1.17	1.19	<1	<1	31	82	15	17.1	8.3	15.9			153.4	156.7
5/16/00	EW-E		34	199	<15	<15	0.66	0.62	<1	1.4	27	134	<10	11.5	3.6	13			78.8	84
9/19/99	EW-F		67	156	<15	<15	0.97	1.02	1.1	<1	47	93	17.1	19.7	11.3	17.4			112.8	119
5/16/00	EW-F		32	202	<15	<15	0.36	0.45	<1	<1	28	137	<10	11.9	3.8	9.4			49.4	49.6
9/19/99	EW-G		68	129	<15	<15	0.93	1	1.4	1.3	135	88	21.7	20.2	10	16.6			115.8	109.2
5/17/00	EW-G		33	186	<15	<15	0.27	0.32	<1	<1	37	127	<10	<10	3.9	6.7			31.2	33.6
8/23/00	EW-G		114	258	<1	<1	0.3	0.4	<1	<1	139	212	15	23	11	13			49	51
5/22/01	EW-G		24	160	<15	<15	0.45	0.44	<1	<1	16	112	<10	15.4	4.4	11.3	<2	<2	70.8	76.5
5/2/02	EW-G		<15	72	<15	<15	0.45	0.6	<1	<1	22.0	62	<10	<10	11	16	<2	<2	59.6	62
9/19/99	EW-H		69	125	<15	<15	0.31	0.33	3.2	1.2	73	94	<10	<10	<3	5			18.7	16.1
5/17/00	EW-H		38	206	<15	<15	<0.15	<0.15	<1	<1	35	134	<10	<10	<3	3.5			14.6	15.1
9/18/99	EW-I		85	127	<15	<15	0.27	0.26	1.1	<1	62	100	<10	<10	<3	<3			<1	<1
5/16/00	EW-I		39	211	<15	<15	<0.15	<0.15	<1	<1	34	128	<10	<10	<3	<3			<1	<1
8/16/00	EW-I	0.2					0.3		2						20				141	
8/23/00	EW-I		164	217	<1	13	0.1	0.1	<1	<1	113	178	<10	14	1	3			<5	6
5/22/01	EW-I		22	132	<15	<15	<0.15	<0.15	<1	<1	18	98	<10	<10	<3	<3	2	<2	<1	<1
5/2/02	EW-I		<15	87	<15	<15	0.30	<0.15	<1	<1	23	76	<10	<10	<3	<3	<2	<2	<1	<1
9/18/99	EW-J		53	114	<15	<15	0.29	0.25	<1	<1	39	99	<10	10.6	<3	<3			<1	<1
5/17/00	EW-J		40	229	<15	<15	0.16	<0.15	<1	1.2	35	139	<10	<10	<3	<3			10.8	11.1
8/23/00	EW-J		232	252	<1	<1	0.1	0.1	<1	<1	140	166	<10	<10	2	3			<5	<5
5/22/01	EW-J		19	177	<15	<15	<0.15	<0.15	<1	<1	16	139	<10	12.4	<3	<3	<2	<2	<1	<1
5/2/02	EW-J		<15	90	<15	<15	<0.15	0.29	<1	<1	30	86	<10	<10	<3	<3	<2	<2	<1	<1
9/20/99	EW-K		52	117	<15	<15	<0.15	<0.15	<1	<1	38	92	<10	<10	<3	<3			<1	<1
5/17/00	EW-K		33	218	<15	<15	<0.15	<0.15	<1	<1	32	136	<10	<10	<3	<3			<1	<1
9/20/99	EW-L		51	86	<15	<15	<0.15	<0.15	<1	<1	48	83	<10	<10	<3	<3			<1	<1
5/17/00	EW-L		31	176	<15	<15	<0.15	<0.15	<1	<1	35	129	<10	<10	<3	<3			<1	<1
8/23/00	EW-L		102	194	1	1	<0.1	0.1	<1	<1	103	157	<10	<10	2	3			<5	<5
9/20/99	EW-M		37	77	<15	<15	<0.15	<0.15	<1	<1	46	85	<10	<10	<3	<3			<1	<1
5/17/00	EW-M		42	174	<15	<15	<0.15	<0.15	<1	<1	38	126	<10	<10	<3	<3			<1	<1
5/22/01	EW-M		19	121	<15	<15	<0.15	<0.15	<1	<1	19	121	<10	10.5	<3	<3	2	<2	<1	<1
5/2/02	EW-M		<15	81	<15	<15	0.21	0.21	<1	<1	40	101	<10	<10	<3	<3	<2	2.6	<1	<1

Table 9. All data collected for inflows in the East Willow drainage. Units are in ( ). The prefixes "d" and "t" represent dissolved and total fractions. Values below the laboratory-determined detection limit are indicated by "<".

Date	Site	Flow (CFS)	pH	Temp (C)	Alk (mg/L)	Hard (mg/L)	Cond (uS/cm)	DO (mg/L)	ORP (mV)	TDS (mg/L)	TSS (mg/L)	DOC (mg/L)	NO3 (ug/L)	tSO4 (mg/L)	tCl (mg/L)	dCa (ug/L)	tCa (ug/L)	dMg (ug/L)	tMg (ug/L)	dSi (mg/L)	tSi (mg/L)	dK (mg/L)	tK (mg/L)	Na (mg/L)
9/18/99	EW-MA	0.16	7.3	14.2	26	16	65	7.21	190	40	5	1		1.9	4	6391	6430	684	686	26.2	23	1	0.8	
5/16/00	EW-MA	0.17	6.8	15.1	28	16	66	7.9		51	0			0	3	6184	6172	646	641	25.28	26.38		0.82	6
5/22/01	EW-SWISp	0.48	7.5	4.1	18	16		9.5					0	3	1	5195	5191	658	694					
5/2/02	EW-SWISp	0.15	7.7	4.0	20	19				62	<1									19.7	24	<0.5	0.5	3
9/18/99	EW-SWI	0.13	7.3	7.9	18	22	69	8.41	202	40	5	1		11	2	7768	7821	1010	1024	19.7	19.2	0.9	0.9	
5/16/00	EW-SWI	0.05	6.8	6.3	18	16	52	9.8		40	0			1	2	5636	5646	722	739	16.7	17.3		0.86	2.3
5/22/01	EW-SWI	0.42	7.5	3.7	16	16		9.2					0			4257	4411	488	515					
5/2/02	EW-SWI	0.14	7.2	4.0	20	22				41	<1			0.0	0	6053	6063	689	687.0	12.5	13.5	<0.5	<0.5	2.9
5/2/02	EW-PS	0.06	7.1		22	36								8.0	0	9362	9504	1104	1105.0					
9/18/99	EW-SMA		4.3		0	296				520	5	1		329	2	59726	59914	18483	18243	32	34.2	5.1	4.9	
5/17/00	EW-SMA	0.004	4.6	6.3	0	290	585	8.4		428	1.3					50145	49971	15108	15029	27.63	31.2		4.58	8.2
8/13/00	EW-SMA																							
5/22/01	EW-SMA		4.4	7.9	0			4.1					0	342	1	53764	51938	16608	16399					
5/2/02	EW-SMA	0.03	4.6	5.0	0					438	5			260	0	52902	53037	16542	16473	12.4	14.8	3.5	3.5	11.8
9/19/99	EW-SWD	0.035	5.1	7.3	0	292	660	9.29	181	510	5	1		329	2	59597	58881	18380	18319	31.8	33.6	5.3	5	
5/17/00	EW-SWD	0.02	5.6	3.9	2	280	560	8.8		445	1			290	2	52933	52682	15780	15761	19.08	26.95		4.82	8.5
9/18/99	EW-PC	0.035	6.1	7.0	23	27	78	7.84	192	30	5	1		15	2	9463	9576	1107	1128	20.5	19.4	1	0.9	
5/17/00	EW-PC	0.08	6.6	3.6	16	16	50	8.7		28	0			1	2	5682	5677	660	657	17.4	17.43		0.79	2.5
5/2/02	EW-PC	0.08	7.2	3.0	20	36				39	<1			0.0	0	6180	6180	671	681	5.3	6.3	<0.5	<0.5	2.5
9/20/99	EW-TRS	0.0083	7.1	6.4	24	17	54	8.33	231															
5/17/00	EW-TRS	0.009	7.0	5.5	16	14	43	9.2		62	8.9			3	4					21.48	21.55		0.76	2.6
9/20/99	EW-TRN	0.47	7.0	5.2	22	18	50	8.47	224	40	5	2								20.4	22.7	0.8	0.9	
5/17/00	EW-TRN	0.63	7.0	3.7	16	12	40	9.2		56	9.3			2	2	4683	5134	420	549	22.4	23		0.71	2.6
5/5/02	EW-Trib 3	0.2-0.5	7.7	4.0	12	12																		
9/20/99	EW-Sp	0.002	7.4	7.2	27	20	66	7.11	224	60	5	1		1.9	2	8358	8490	773	808	22.5	28.1	0.9	1.1	
5/17/00	EW-Sp	0.006	6.9	4.9	20	18	53	7.3		126	0			3	3	6329	6533	571	722	18.1	20.35		0.66	3.1
9/20/99	EW-N	0.58	7.5	6.9	18	21	45	7.97	226					1.9	2	5216	5294	448	457					
5/17/00	EW-N	0.75	7.1	4.7	14	14	35	8.9		40	0			2	3	3924	3982	327	348	17.8	19.3		0.61	2.7
9/18/99	EW-PMA	dry																						
5/17/00	EW-PMA	0.001	7.6	4.8	12	12	37	8.3		42	0			3	2	4174	4378	335	459	17.5	17.85		0.87	1.8
9/20/99	EW-GMA	0.0037	7.3	7.1	32	29	85	7.77	192	30	5	2		7	3	11370	11593	561	591	21.7	23	1.1	1.1	
5/17/00	EW-GMA	0.04	6.9	6.6	22	22	62	7.8		76	10.8			3	3	8178	8251	402	505	16.05	19.2		0.92	3.3

Table 9 (cont.)

Date	Site	dAg (ug/L)	dAl (ug/L)	tAl (ug/L)	dAs (ug/L)	tAs (ug/L)	dCd (ug/L)	tCd (ug/L)	dCu (ug/L)	tCu (ug/L)	dFe (ug/L)	tFe (ug/L)	dMn (ug/L)	tMn (ug/L)	dPb (ug/L)	tPb (ug/L)	dSe (ug/L)	tSe (ug/L)	dZn (ug/L)	tZn (ug/L)
9/18/99	EW-MA		<15	<15	23	23	0.42	0.44	<1	<1	<10	<10	<10	<10	<3	<3			<1	<1
5/16/00	EW-MA		23	21	35	37	0.16	0.34	<1	<1	<10	<10	<10	<10	<3	<3			<1	<1
5/22/01	EW-SWISp		18	563	<15	<15	3.49	3.5	1.7	2.5	10	241	<10	<10	10.3	29.8	<2	<2	574.3	609.4
5/2/02	EW-SWISp																			
9/18/99	EW-SWI		121	153	<15	<15	7.35	7.39	1.5	2.2	53	70	<10	<10	41.4	48.7			1160.3	1173.3
5/16/00	EW-SWI		31	211	<15	<15	5.35	5.32	1.9	2.6	14	95	<10	<10	42.5	58.1			796.1	803.9
5/22/01	EW-SWI		18	222	<15	<15	4.56	4.93	<1	1.6	<10	102	<10	<10	30.1	53.5	<2	<2	1095.1	1166.6
5/2/02	EW-SWI		<15	48.00	<15	<15	4.74	4.96	2.3	2.2	23	38	<10	<10	35.0	43.4	<2	<2	854.8	837.6
5/2/02	EW-PS		<15	<15	<15	<15	9.46	9.52	2.0	1.7	<10	10	<10	<10	11.8	11.7	<2	<2	1568.2	1612.3
9/18/99	EW-SMA		1522	1600	<15	<15	192.9	193.5	58.6	58.2	508	991	6482.9	6453.5	1434	1466			36900	37000
5/17/00	EW-SMA		974	995	<15	19	148.58	148.54	27.9	28.2	314	791	5800.4	5719.5	907.6	924.4			22500	22700
8/13/00	EW-SMA	<0.2					<0.1		4						24				6277	
5/22/01	EW-SMA		1457	1896	<15	19	162.64	156.64	45	45	741	1605			1458.2	1445.5	3	3	24936	24184
5/2/02	EW-SMA		1070	1143	<15	<15	155.7	157.1	22.6	23.8	503	1674	6067	6173	995	1067	2.8	6.5	32460	32780
9/19/99	EW-SWD		1418	1824	<15	<15	180.4	178.2	48.3	54.5	192	908	6336.9	6269.7	1395	1490			36300	36200
5/17/00	EW-SWD		703	790	<15	<15	129.42	129.62	4.6	20.5	164	345	5818	5759.7	832.4	858.4			21000	22000
9/18/99	EW-PC		68	83	<15	<15	5.44	5.51	1.6	1.6	32	43	<10	<10	112.2	124.1			945.9	958
5/17/00	EW-PC		30	166	<15	<15	2.28	2.44	1.5	1.7	18	81	<10	<10	82	106.3			373.9	377.8
5/2/02	EW-PC		<15	53	<15	<15	2.05	2.13	1.4	1.7	12	32	<10	<10	74.3	93.6	3.2	<2	420.2	427.4
9/20/99	EW-TRS																			
5/17/00	EW-TRS																			
9/20/99	EW-TRN																			
5/17/00	EW-TRN		35	935	<15	<15	<0.15	<0.15	<1	<1	10	331	<10	<10	<3	<3			<1	10.1
5/5/02	EW-Trib 3																			
9/20/99	EW-Sp		379	586	<15	<15	<0.15	0.19	<1	<1	146	298	<10	13.4	<3	<3			<1	<1
5/17/00	EW-Sp		36	1936	<15	<15	<0.15	<0.15	<1	1.2	12	720	<10	<10	<3	<3			<1	<1
9/20/99	EW-N		129	158	<15	<15	<0.15	<0.15	<1	<1	49	64	<10	<10	<3	<3			<1	<1
5/17/00	EW-N		76	241	<15	<15	<0.15	<0.15	<1	<1	27	103	<10	<10	<3	<3			<1	<1
9/18/99	EW-PMA																			
5/17/00	EW-PMA		54	1535	<15	16	1.01	1.3	4.5	8	23	598	<10	12.1	25.1	83.6			22.7	32.7
9/20/99	EW-GMA		117	561	<15	<15	<0.15	0.18	<1	<1	46	177	<10	<10	<3	<3			<1	10.6
5/17/00	EW-GMA		37	1404	<15	<15	<0.15	<0.15	<1	<1	13	490	<10	<10	<3	<3			<1	<1

Table 10. Surface water and mine water sampling locations in the drainage of West Willow Creek. Main channel sites were locations of direct sampling from West Willow Creek. Other inflows include tributaries, seeps, springs, and adit discharges that were potential sources to West Willow Creek. Nelson Creek is further characterized in Table 14.

Main Channel Site	Other Inflows	Miles from Confluence w/ East Willow	Location	Notes
WW-A		0.02	~30 ft u/s of conf. w/ East Willow	d/s of Commodore Mine area
WW-B		0.23	~25 ft u/s road culvert (near stop #2 on Bachelor Loop)	d/s of Commodore Mine area
WW-C		0.3	~100 yds u/s WWB	d/s of Commodore Mine area
WW-D		0.36	below first loadout building on east side of road	d/s of Commodore Mine area
WW-E		0.42	below discharge pipe from Commodore waste rock	d/s of Commodore Mine area
	WW-Seep	0.45	d/s Nelson Adit; on western side of rock pile	d/s Nelson Adit
WW-F		0.47	d/s Nelson Adit; u/s discharge pipe through waste rock	d/s Nelson Adit
	WW-NT	0.48	Nelson Adit surface discharge; 6" Parshall flume	Nelson Adit discharge
	WW-Tail 1		Commodore Tailings seep	Commodore Tailings seep
	WW-CT	0.54	Commodore Tunnel surface discharge	Commodore Tunnel discharge
WW-G		0.57	u/s wooden box culvert and trash gate	u/s of Commodore Mine area
WW-H		0.8	d/s Black Pitch section; d/s Stop #3 on Bachelor Loop	btwn Commodore and Amethyst Mines
WW-HH		1.02	u/s first road culvert after crossing Burro Bridge	btwn Commodore and Amethyst Mines
WW-I		1.44	d/s Amethyst waste rock; d/s confluence w/Nelson Creek	d/s of Amethyst Mine and Nelson Creek
	Nelson Creek	1.46	~150 ft u/s of conf. w/ West Willow	u/s of confluence w/ West Willow
WW-J		1.55	d/s Amethyst waste rock; u/s confluence w/Nelson Creek	d/s of Amethyst Mine; u/s of Nelson Creek
WW-K		1.7	~100 ft d/s of Amethyst Tunnel	d/s of Amethyst Tunnel
WW-L		1.8	u/s Amethyst Tunnel; ~100 yds u/s Last Chance Mine	u/s Last Chance Mine
WW-M		3.69	u/s Allen's Crossing	u/s location

Table 11. All data collected for main channel sites in West Willow Creek. Units are in ( ). The prefixes "d" and "t" represent dissolved and total fractions, respectively. Values below the laboratory-determined detection limit are indicated by "<".

Date	Site	Flow (CFS)	pH	Temp (C)	Alk (mg/L)	Hard (mg/L)	Cond (uS/cm)	DO (mg/L)	TDS (mg/L)	TSS (mg/L)	DOC (mg/L)	NO3 (ug/L)	dSO4 (mg/L)	tSO4 (mg/L)	dCl (mg/L)	tCl (mg/L)	dCa (ug/L)	tCa (ug/L)	dMg (ug/L)	tMg (ug/L)	dSi (mg/L)	tSi (mg/L)	dK (mg/L)	tK (mg/L)	Na (mg/L)
9/18/99	WW-A	13.90	7.0	8.6	24	27	80	9.4	120	5	1	80		51		2	24347	23517	2704	2681	18.1	18.1	1.1	1.1	
5/16/00	WW-A	27.27	7.6	7.8	18	44	119	9.9	88	2		100		31		1	12704	12720	1418	1422	9.25	10.5		0.75	3.4
7/2/00	WW-A	6.42	7.4	13.2			337	7.4																	
8/16/00	WW-A	5.19	7.1	10.9	24	160	412	8.1																	
8/23/00	WW-A	11.60	7.3	8.9	26	90	233	8.6	164	18.1			76	82.6		3.4	3020	3330	2890	3370	15.6	17.15		1.5	6.4
5/22/01	WW-A	58.55	7.5	8.0	20	28						0		19		1	7697	7610	987	986					
5/2/02	WW-A	6.05	7.0	6.1	22	110			155	<1				98		0	29134	29520	2784	2804	5.1	6.6	0.5	0.5	6.5
9/18/99	WW-B	13.90	7.3	10.1	22	36	29	8.8	130	5	1			56		2	24041	24181	2670	2683	18.4	17.9	1.2	1.2	
5/16/00	WW-B	24.92	7.2	8.8	20	46	120	13.1	99	3.1				32		3	12663	12684	1412	1426	10.2	13.58		0.98	3.4
9/18/99	WW-C	13.10	7.5	9.7	22	79		8.9	120	5	1			57		2	24447	24094	2701	2675	18.7	18.6	1.4	1.3	
5/16/00	WW-C	28.43	7.4	8.9	18	44	119	12.4	76	2.1				31		2	12629	12571	1438	1435	12	12.58		0.78	3.5
9/18/99	WW-D	14.90	7.1	9.1	23	76	205	8.9	100	5	2			54		2	23674	23604	2642	2652	17.9	17.6	1.2	1.2	
5/16/00	WW-D	24.13	7.4	9.0	20	44	120	9.9	82	3.1				32		1	12654	12650	1440	1440	12.78	12.8		0.9	3.4
9/18/99	WW-E	11.00	7.0	8.7	22	76	202	9.1	120	5	1			59		1	23323	23194	2591	2578	17.8	17.9	1.2	1.2	
5/16/00	WW-E	25.32	7.4	8.6	18	44	116	8.0	71	2				32		2	12389	12681	1394	1398	12.45	14.23		0.83	3.3
8/23/00	WW-E		6.9	11.3	26	93	229	11.6					89.3	91.2		3.4	31700	33300	3370	4050					
5/22/01	WW-E	67.53	7.0	8.6	20	26						0		21		2	7299	7609	979	893					
5/2/02	WW-E	8.31	7.2	5.7	22	94			149	2				39		0	26521	26773	2509	2527	4.3	5.4	<0.5	0.5	5.5
9/18/99	WW-F	10.10	7.3	8.6	24	81	191	8.9	120	5	3			49		2	21825	21858	2385	2378	17.9	16.9	1.2	1	
5/16/00	WW-F	24.70	7.5	8.5	18	42	110	9.0	93	<1				30		2	12037	11961	1357	1354	10.38	10.58		0.84	3.2
9/19/99	WW-G	10.90	7.1	5.3	23	35	91	9.5	50	5	2	80		13		2	11105	11205	1364	1372	16.5	17.2	0.9	1	
5/16/00	WW-G	29.18	6.8	8.1	20	24	63	8.2	54	1.2		100		4		2	7709	7806	959	961	11.7	12.38		1.28	2.2
8/16/00	WW-G	5.07	8.0	10.2	30	38	98	8.2																	
8/23/00	WW-G		8.0	11.5	28	39	104	11.5					27.3	27.4		7	15900	16700	5300	5790					
5/22/01	WW-G	68.78	7.4	8.8	18	26		8.2				0		8		1	6744	6854	875	880					
5/2/02	WW-G	8.02	7.6	4.6	26	38			44	<1				13		0	10011	10107	1179	1197	3.2	5.1	<0.5	<0.5	2.7
9/19/99	WW-H	11.00	7.2	5.3	26	29	85	9.5	60	5	3			14		2	11080	11152	1363	1373	16.1	17.8	0.8	0.9	
5/17/00	WW-H	26.60	6.9	4.5	18	24	61	10.2	50	<1				3		2	7521	7623	936	948	11.63	12.7		0.63	2
9/19/99	WW-HH	13.50	7.1	5.5	29	32	84	9.5	60	5	1			13		2	11390	11600	1393	1395	16.3	17.3	0.8	0.9	
5/17/00	WW-HH	25.26	7.0	5.3	18	26	60	10.0	46	<1				5		2	7501	7545	950	959	12.8	12.93		0.65	2.3
9/19/99	WW-I	12.40	7.5	6.2	27	30	86	8.8	60	5	2	60		12		1	11240	11395	1380	1377	16.4	17.4	0.9	0.8	
5/17/00	WW-I	26.33	7.4	6.5	20	24	61	10.9	60	1.4		100		4		2	7485	7609	944	953	12.28	12.35		0.73	2.3
8/23/00	WW-I		8.0	12.1	28	40	108	10.9					18.7	23.6		3.4	17500	17500	1930	1930					
9/19/99	WW-J	12.10	7.5	7.0	26	32	86	8.5	50	5	2			13		2	11258	11362	1379	1384	16.7	16.4	0.9	0.8	
5/17/00	WW-J	21.90	7.5	6.5	22	24	61	10.1	77	1.3				4		2	7617	7800	946	966	12.73	13.15		0.68	2
9/19/99	WW-K	13.20	7.4	7.3	25	32	86	8.5	50	5	3	250		11		2	10979	11112	1353	1337	16.4	17.4	0.9	1	
5/17/00	WW-K	22.21	7.0	6.9	20	26	62		21	<1		100		5		3	7523	7564	950	952	12.45	13.1		0.75	2.2
5/22/01	WW-K	76.87	7.6	8.4	20	20						0		6		2	6827	6963	863	877					
5/2/02	WW-K	7.05	7.6	4.4	26	34			47	1				13		0	10258	10347	1183	1206	2.8	5.6	<0.5	<0.5	2.5
9/19/99	WW-L	11.50	7.1	7.7	26	29	84	8.4	50	5	2			11		2	11126	11172	1384	1381	16.9	16.9	0.9	0.8	
5/17/00	WW-L	24.57	6.7	6.8	24	24	60	10.1	56	1.4				4		2	7575	7598	957	960	11.88	13.15		0.86	2.2
8/23/00	WW-L		8.0	12.7	32	36	104	11.0					16.3	21.5		2.8	17500	17900	0	1450					
9/19/99	WW-M	6.30	7.4	7.4	28	34	99	8.1	50	5	1	50		16		2	13896	13987	1619	1627	14.5	14.1	0.8	0.8	
5/18/00	WW-M	13.57	6.9	3.0	22	34	66	8.7	54	<1		200		8		2	8603	8631	1055	1068	10.98	11.7		0.6	2.3
5/22/01	WW-M	18.14	7.1	4.0	22	22						0		6		1	7161	7151	896	923					
5/2/02	WW-M	5.10	7.5	3.3	28	36			39	<1				14		0	11180	11391	1315	1336	4.8	6	<0.5	<0.5	2.4

Table 11 (cont.)

Date	Site	dAg (ug/L)	dAl (ug/L)	tAl (ug/L)	dAs (ug/L)	tAs (ug/L)	dCd (ug/L)	tCd (ug/L)	dCu (ug/L)	tCu (ug/L)	dFe (ug/L)	tFe (ug/L)	dMn (ug/L)	tMn (ug/L)	dPb (ug/L)	tPb (ug/L)	dSe (ug/L)	tSe (ug/L)	dZn (ug/L)	tZn (ug/L)
9/18/99	WW-A		124	259	<15	<15	31.2	30.1	16.6	22.8	90	211	1366	1320	79	129			7484	7485
5/16/00	WW-A		40	173	<15	<15	14.4	14.8	8.6	9.9	29	142	499	505	37	66			3326	3373
7/2/00	WW-A																			
8/16/00	WW-A	<0.2					15.0		13						78				6263	
8/23/00	WW-A		554	730	<1	4	19.0	21.0	20	23	694	745	1263	1270	199	210			5098	5113
5/22/01	WW-A		41	220	<15	<15	13.2	13.9	9.9	14.1	16	265	196	212	12	67	<2	<2	1499	1593
5/2/02	WW-A		23	91	<15	<15	26.7	27.3	9.4	11.2	13.0	143	1399	1397	73	120	<2	<2	9192	9506
9/18/99	WW-B		141	253	<15	<15	30.4	31.0	15.7	22.4	67	218	1378	1392	83	136			7449	7712
5/16/00	WW-B		36	174	<15	<15	14.3	14.4	9.2	9.4	29	144	507	513	46	69			3344	3370
9/18/99	WW-C		138	254	<15	<15	31.3	31.1	16.2	22.4	91	222	1407	1394	82	135			7617	7771
5/16/00	WW-C		41	169	<15	<15	14.2	14.3	7.6	9	29	142	510	514	38	69			3290	3331
9/18/99	WW-D		160	287	<15	<15	30.7	30.8	16.5	22.2	86	243	1358	1360	93	139			7595	7761
5/16/00	WW-D		39	163	<15	<15	14.3	14.5	8.4	9.2	30	140	513	519	41	70			3342	3369
9/18/99	WW-E		100	239	<15	<15	22.7	22.8	10.2	14	50	223	1210	1205	72	125			6317	6382
5/16/00	WW-E		34	155	<15	<15	12.0	12.0	6.3	8.2	31	147	473	482	38	72			2974	3087
8/23/00	WW-E		355	482	3	3	14.0	18.0	6	6	20	32	1374	1382	77	93			4893	4936
5/22/01	WW-E		30	338	<15	54	12.6	13.7	7.8	23.4	17	1505	211	239	7	399	<2	<2	1350	1549
5/2/02	WW-E		26	90	<15	<15	20.4	20.7	6.1	7.4	21	185	1249	1265	75	111	3.8	2.4	7367	7467
9/18/99	WW-F		131	210	<15	<15	19.2	19.4	9.7	11.4	81	226	1056	1062	79	112			5289	5315
5/16/00	WW-F		33	154	<15	<15	10.6	11.0	6.6	6.4	32	146	433	435	38	59			2717	2671
9/19/99	WW-G		98	230	<15	<15	4.0	4.1	4.3	5.2	85	197	<10	13	18	34			226	236
5/16/00	WW-G		19	153	<15	<15	1.9	2.0	2	1.8	34	139	<10	<10	6	17			123	114
8/16/00	WW-G	<0.2					<0.1		3						15				282	
8/23/00	WW-G		260	308	<1	<1	11.0	16.0	7	8	254	327	22	24	85	98			416	422
5/22/01	WW-G		25	210	<15	<15	1.2	1.5	1.7	2.1	26	252	14	27	3	16	<2	<2	84	104
5/2/02	WW-G		<15	63	<15	<15	3.0	3.2	1.8	2.2	24.0	89	<10	<10	9	20	<2	<2	175	183
9/19/99	WW-H		112	203	<15	<15	4.1	4.2	4	4.6	92	183	10	13	17	32			229	238
5/17/00	WW-H		20	131	<15	<15	1.6	1.8	1.6	2	37	127	<10	<10	5	13			93	99
9/19/99	WW-HH		60	207	<15	<15	4.2	4.4	3.9	4.6	58	197	11	15	11	31			235	248
5/17/00	WW-HH		17	118	<15	<15	1.7	1.7	1.6	1.6	38	127	<10	<10	5	12			108	113
9/19/99	WW-I		54	153	<15	<15	3.6	4.0	3.6	5.2	65	205	12	18	11	29			184	199
5/17/00	WW-I		19	123	<15	<15	1.1	1.2	1.2	1.9	42	140	<10	11	<3	12			72	81
8/23/00	WW-I		287	395	<1	<1	15.0	19.0	8	9	315	406	35	59	117	165			489	500
9/19/99	WW-J		70	173	<15	<15	2.4	2.5	2.9	3.6	85	208	11	16	12	27			135	141
5/17/00	WW-J		17	124	<15	<15	0.7	0.8	<1	1.1	44	141	<10	<10	3	9			52	56
9/19/99	WW-K		100	167	<15	<15	1.2	1.4	2.2	2.5	114	205	<10	14	12	19			67	72
5/17/00	WW-K		19	130	<15	<15	0.2	0.2	<1	<1	40	139	<10	<10	<3	4			20	23
5/22/01	WW-K		18	175	<15	<15	<0.15	0.3	<1	<1	26	270	15	31	<3	5	<2	<2	14	20
5/2/02	WW-K		<15	71	<15	<15	0.3	0.2	<1	<1	30	101	10	<10	4	7	<2	<2	59	29
9/19/99	WW-L		49	158	<15	<15	<0.15	<0.15	<1	<1	71	195	<10	14	<3	4			<1	11
5/17/00	WW-L		17	119	<15	<15	<0.15	<0.15	<1	<1	42	147	<10	10	<3	<3			<1	<1
8/23/00	WW-L		254	357	<1	<1	16.0	20.0	<1	1	336	391	40	47	101	147			84	95
9/19/99	WW-M		32	77	<15	<15	<0.15	<0.15	<1	<1	46	105	<10	<10	<3	<3			<1	<1
5/18/00	WW-M		31	96	<15	<15	<0.15	<0.15	<1	<1	29	84	<10	<10	<3	<3			<1	<1
5/22/01	WW-M		19	137	<15	<15	<0.15	<0.15	<1	<1	19	191	<10	21	<3	<3	<2	<2	<1	<1
5/2/02	WW-M		<15	24	<15	<15	<0.15	<0.15	<1	<1	25	53	<10	<10	<3	<3	2.3	2.3	<1	<1

Table 12. All data collected for inflows in the West Willow drainage. Units are in ( ). The prefixes "d" and "t" represent dissolved and total fractions. Values below the laboratory-determined detection limit are indicated by "<".

Date	Site	Flow (CFS)	pH	Temp (C)	Alk (mg/L)	Hard (mg/L)	Cond (uS/cm)	DO (mg/L)	TDS (mg/L)	TSS (mg/L)	DOC (mg/L)	NO3 (ug/L)	dSO4 (mg/L)	tSO4 (mg/L)	dCl (mg/L)	tCl (mg/L)	dCa (ug/L)	tCa (ug/L)	dMg (ug/L)	tMg (ug/L)	dSi (mg/L)	tSi (mg/L)	dK (mg/L)	tK (mg/L)	Na (mg/L)
9/19/99	WW-CT	0.04	5.85	5.5	2	88	246	8.55	180	5	1			122		4	21623	21443	2799	2730	27.7	27	2.8	2.8	
5/16/00	WW-CT	0.01	6.29	1.2	6	42	152	6.8	110	0				53		4	11899	11693	1446	1434	21.35	22.8		1.84	9.4
4/24/01	WW-CT												103.9		1.9		28300		12100						
11/7/02	WW-CT		7.38	1.4																					
9/18/99	WW-NT	0.77	3.73	16.5	0	708	1374	6.58	1300	5	1			708		2	157540	157939	15935	16313	34.8	29.3	5.2	4.2	
5/16/00	WW-NT	0.98	5.12	16.5	2	650	1314	7.07	1089	0				703		3	126304	125907	12397	12350	27.5	28.9		4.4	42.4
11/22/00	WW-NT																251900	271100	41520	46190					
1/22/01	WW-NT	0.58	4.36	17	0	920	1654						821				255200		49270						
2/12/01	WW-NT	0.54	4.34	17.1			1627						965				276600		40330						
3/15/01	WW-NT												879.5				308300		38410						
4/24/01	WW-NT												1518.8		1.2		314600		48980						
5/22/01	WW-NT		4.67	13.7	0							0		281		1	51622	51003	6238	6153					
7/6/01	WW-NT												860.5		0		205500		14000						
8/16/01	WW-NT												659.2		0		200200		13800						
9/27/01	WW-NT												995			1.1	245000								
5/2/02	WW-NT	0.47	4.3	16.8	0				1399	4				950		0	191997	191110	15876	15610	17	19.8	3.8	3.8	42.6
9/5/02	WW-NT	0.47	4.4	17.3		854	1625										324700		10500						
11/7/02	WW-NT	0.47	4.4	17.1																					
9/18/99	WW-Seep	0.04		8.2			851	8.5	810	5	1			553		4	52605	52512	10976	10721	23.3	22.8	3	3	
8/16/00	WW-Tail 1	0.03	7.05	11	24	152	391	7.8																	

Table 12 (cont.)

Date	Site	dAg (ug/L)	dAl (ug/L)	tAl (ug/L)	dAs (ug/L)	tAs (ug/L)	tBa (ug/L)	dCd (ug/L)	tCd (ug/L)	dCu (ug/L)	tCu (ug/L)	dFe (ug/L)	tFe (ug/L)	dMn (ug/L)	tMn (ug/L)	dPb (ug/L)	tPb (ug/L)	dSe (ug/L)	tSe (ug/L)	dZn (ug/L)	tZn (ug/L)
9/19/99	WW-CT		524	1297	<15	<15		103.9	103.3	37	41	86	572	3853	3831	46	80			9771	9701
5/16/00	WW-CT		69	117	<15	<15		23.87	23.5	4	5	10	33	789	773	7	17			3100	3055
4/24/01	WW-CT			899		16	25		40.3		56		406		3355		43				7718
11/7/02	WW-CT		54.5	267				7.1	7.4	5	6	67	114	589	596	8	13			2078	2089
9/18/99	WW-NT		1028	1065	<15	<15		241.8	243.4	107	107	281	1273	19290	19500	1440	1491			89800	90100
5/16/00	WW-NT		559	575	<15	<15		259.24	259	137	139	<10	418	14630	14730	1184	1206			32362	31890
11/22/00	WW-NT		<15	38	<1	56		54	88	23	62	91	108	13520	13700	<1	<1			5550	6610
1/22/01	WW-NT			923		74	452		66		42		1540		13580		417				6240
2/12/01	WW-NT			<15		53	11		81		43		1160		11300		284				7990
3/15/01	WW-NT			215		20	404		63		47		1750		11500		470				6050
4/24/01	WW-NT			775		16	22		57		56		1210		12032		364				81860
5/22/01	WW-NT		3956	4021	<15	<15		870.37	892.86	911	932	50	197	13380	13630	1044	1046	4	3	83100	85300
7/6/01	WW-NT		1347		15		29	61		71		1360		17130		300				47040	
8/16/01	WW-NT		262		19		6	104.7		70		1350		15388		406				77650	
9/27/01	WW-NT			267		21	0		64.1		48		1760		12427		334				62855
5/2/02	WW-NT		399	395	<15	<15		214	212.6	45.0	45.5	41.0	1632	16600	16710	1022	1057	6	5.5	88390	89960
9/5/02	WW-NT	<0.2	350		5			80.6		99		139		11690		412				11500	
11/7/02	WW-NT		480	571				121.5	127.4	33	31.9	33	1780	9993	13690	716	784			69970	71230
9/18/99	WW-Seep		3781	3934	<15	<15		862.6	905.3	872	920	23	116	19460	19430	1532	1509			154000	153700
8/16/00	WW-Tail 1	0						<0.15		10						104				6162	

Table 13. Comparison of loads between Nelson Tunnel and West Willow. Percentages are estimated assuming that the total load from Nelson Tunnel was transferred to West Willow.

Metal	Date	Load from Nelson Tunnel (lbs/day)	Load difference between WW-M and WW-A (lbs/day)	Percent of loading in West Willow attributable to Nelson Tunnel
Ca	**September 1999**	657	1291	**51%**
	May 2000	667	1242	**54%**
	May 2002	485	651	**75%**
Mg	**September 1999**	68	146	**46%**
	May 2000	65	131	**50%**
	May 2002	40	55	**73%**
Al	**September 1999**	4.4	16.8	**26%**
	May 2000	3.0	18.5	**17%**
	May 2002	1.0	2.3	**43%**
Cd	**September 1999**	1.0	2.3	**45%**
	May 2000	1.4	2.2	**63%**
	May 2002	0.5	0.9	**61%**
Cu	**September 1999**	0.4	1.7	**26%**
	May 2000	0.7	1.5	**50%**
	May 2002	0.1	0.4	**32%**
Fe	**September 1999**	5.3	12.3	**43%**
	May 2000	2.2	14.8	**15%**
	May 2002	4.1	3.2	**129%**
Mn	**September 1999**	81	99	**82%**
	May 2000	78	74	**105%**
	May 2002	42	46	**93%**
Pb	**September 1999**	6.2	9.7	**64%**
	May 2000	6.4	9.7	**66%**
	May 2002	2.7	3.9	**69%**
Zn	**September 1999**	375	562	**67%**
	May 2000	169	497	**34%**
	May 2002	229	311	**74%**

Table 14. Surface water sampling locations in Nelson Creek, a tributary of West Willow Creek. Main channel sites were locations of direct sampling from Nelson Creek.

Main Channel Site	Other Inflows	Miles from Confluence w/ West Willow	Location	Notes
NC-A		0.02	~150 ft u/s of conf. w/ West Willow	u/s of confluence w/ West Willow
NC-B		0.42	d/s of Midwest Mine; ~100 yds u/s road	d/s of Midwest Mine
	NC-C	0.66	seep/spring d/s Midwest waste rock pile (east of NC-D)	d/s of Midwest Mine
NC-D		0.66	d/s Midwest waste rock pile (adjacent to NC-C)	d/s of Midwest Mine
NC-E		0.7	~150 ft u/s of Midwest Mine	u/s location

Table 15. All data collected for main channel sites in Nelson Creek. Units are in ( ). The prefixes "d" and "t" represent dissolved and total fractions, respectively. Values below the laboratory-determined detection limit are indicated by "<".

Date	Site	Flow (CFS)	pH	Temp (C)	Alk (mg/L)	Hard (mg/L)	Cond (uS/cm)	DO (mg/L)	TDS (mg/L)	TSS (mg/L)	DOC (mg/L)	NO3 (ug/L)	tSO4 (mg/L)	tCl (mg/L)	dCa (ug/L)	tCa (ug/L)	dMg (ug/L)	tMg (ug/L)	dSi (mg/L)	tSi (mg/L)	dK (mg/L)	tK (mg/L)	Na (mg/L)
9/20/99	NC-A	0.038	6.9	9.2	10	23	80	7.8	60	5	3		21	3	7546	7695	886	907	20.6	25.8	1.4	1.7	
5/17/00	NC-A	0.125	6.8	10.2	4	32	59	8.9	69	0			22	3	5623	5642	666	700	17.4	17.6		1.38	1.9
5/22/01	NC-A	1.260	7.5	10.3	8	14		8.9				0	14	1	4173	4230	475	497					
5/2/02	NC-A	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry
9/20/99	NC-B	0.001	5.3	16.5	0	19	71	6.9	60	5	6		24	1	6033	5940	622	472	18.6	20.5	1.4	1.4	
5/17/00	NC-B	0.071	4.9	3.4	0	18	87	7.3	38	8.1			27	2	4507	4641	400	366	16.9	17.9		1.26	1.4
5/22/01	NC-B	0.750	6.6	8.5	4	14		7.3				0	15	2	3714	3728	420	430					
5/2/02	NC-B	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry
9/20/99	NC-C	0.023	4.8	6.7	0	22	86	8.1	30	5	3		26	2	7555	7429	917	741	22.8	28.3	1.6	1.8	
5/18/00	NC-C	0.003	5.9	4.8	10	16	48	7.7	44	3.7			13	3	4483	4765	510	559	14.1	14.6		0.5	1.5
7/16/00	NC-C								44	3.7			9.5	0		5500		0	14.1	14.6		1.09	1.5
9/20/99	NC-D	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry
5/18/00	NC-D	0.055	3.7	3.7	0	26	200	7.6	80	12.3			55	3	5785	5766	305	289	22.1	22.5		1.28	1.8
9/20/99	NC-E	0.007	7.0	8.4	22	19	87	7.6	30	5	4		3	2	7171	7312	879	906	15.8	21.7	1.5	1.7	
5/18/00	NC-E	0.041	6.6	4.2	12	16	37	8.8	43	1.9			3	3	4663	4839	517	657	14.1	14.3		0.98	1.2
5/22/01	NC-E	0.708	7.5	6.2	16	12		8.8				0	4	1	4544	4606	470	549					
5/2/02	NC-E	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry

Table 15 (cont.)

Date	Site	dAl (ug/L)	tAl (ug/L)	dAs (ug/L)	tAs (ug/L)	dCd (ug/L)	tCd (ug/L)	dCu (ug/L)	tCu (ug/L)	dFe (ug/L)	tFe (ug/L)	dMn (ug/L)	tMn (ug/L)	dPb (ug/L)	tPb (ug/L)	dSe (ug/L)	tSe (ug/L)	dZn (ug/L)	tZn (ug/L)
9/20/99	NC-A	258	842	<15	<15	0.3	0.3	2.8	3.3	106	453	47.8	52.6	<3	9.1			29.3	33.5
5/17/00	NC-A	<15	902	16	26	0.99	1.4	5.7	7.5	65	493	224.6	230.8	<3	4.2			43.8	49.9
5/22/01	NC-A	34	547	<15	<15	0.27	0.35	2.6	4.1	18	339	57.5	65.3	<3	3.8	<2	2	18.3	23.5
5/2/02	NC-A	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry
9/20/99	NC-B	325	582	25	54	0.83	1.09	13.4	15.1	952	2145	375.2	368.7	<3	<3			60.4	60.3
5/17/00	NC-B	487	796	64	80	1.44	1.22	14.9	15.6	1357	1853	663.8	677.1	<3	2.1			76.5	78.4
5/22/01	NC-B	51	625	<15	15	0.31	0.29	4.2	5.3	45	445	91.2	95.6	<3	<3	<2	<2	27.5	33.6
5/2/02	NC-B	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry
9/20/99	NC-C	708	2031	<15	32	1.16	1.37	27.8	28.9	324	2587	75.3	80.3	<3	6.9			96.4	98.2
5/18/00	NC-C	44	1245	20	27	0.61	0.27	3.4	2.8	37	708	<10	21.2	<3	15			33.2	36.6
7/16/00	NC-C																		
9/20/99	NC-D	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry
5/18/00	NC-D	1762	3199	<15	72	2.59	2.74	49.1	50.7	3042	4245	111.2	118	5.7	11.2			194.5	197.8
9/20/99	NC-E	1003	1504	<15	<15	<0.15	<0.15	<1	<1	362	525	<10	<10	<3	<3			<1	<1
5/18/00	NC-E	61	1776	<15	<15	<0.15	<0.15	1.3	1.9	25	671	<10	10.7	<3	<3			<1	<1
5/22/01	NC-E	26	881	<15	<15	<0.15	<0.15	<1	<1	12	344	<10	<10	<3	<3	<2	<2	<1	<1
5/2/02	NC-E	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry

Table 16. Surface water sampling locations in the drainage of Mainstem Willow Creek. Main channel sites were locations of direct sampling from Mainstem Willow Creek. Other inflows include tributaries and seeps that were potential sources to Mainstem Willow Creek.

Main Channel Site	Other Inflows	Miles from Confluence w/ Rio Grande	Location	Notes
W-A		3.13	~100 yds d/s of confluence of East and West Willow	d/s of confluence
W-B		2.94	u/s of gravel settling ponds	u/s of settling ponds
	WNG		Windy Gulch	influenced by Bulldog Mine workings and waste rock piles
W-C		2.58	at gaging station; u/s of flume	u/s of flume
W-D		1.61	~200 ft d/s of flume at RR crossing	d/s of flume
W-E		1.52	u/s of braided channel; d/s of Creede	channel near Emperious Tailings
	W-EESeep	~1.36	d/s W-E; near white staining	possible leaching area
W-F		1.33	side channel on east side (possibly ephemeral)	side channel
	W-FSeep		u/s of railroad bridge area	
W-G		0.85	braided channel sections d/s of Emperious Tailings	d/s of Emperious Tailings
W-H		0.49	channel diversion to Wasson irrigation ditch	u/s of headgate
W-I		0.02	West channel, ~150 ft u/s of conf. w/ Rio Grande at bridge crossing	discharge to Rio Grande
W-J		0.02	East channel, ~150 ft u/s of conf. w/ Rio Grande at bridge crossing	discharge to Rio Grande

Table 17. All data collected for main channel sites in Mainstem Willow Creek. Units are in ( ). The prefixes "d" and "t" represent dissolved and total fractions, respectively. Values below the laboratory-determined detection limit are indicated by "<".

Date	Site	Flow (CFS)	pH	Temp (C)	Alk (mg/L)	Hard (mg/L)	Cond (uS/cm)	DO (mg/L)	ORP (mV)	TDS (mg/L)	TSS (mg/L)	DOC (mg/L)	NO3 (ug/L)	dSO4 (mg/L)	tSO4 (mg/L)	dCl (mg/L)	tCl (mg/L)	dCa (ug/L)	tCa (ug/L)	dMg (ug/L)	tMg (ug/L)	dSi (mg/L)	tSi (mg/L)
9/18/99	W-A	29.60	6.9	6.9	22	45	149	9.2	140	70	5	1			26		2	13430	13424	1544	1558	19.5	18.8
5/16/00	W-A	62.53	7.6	7.2	18	28	109	11.9		35	0							8483	8560	1013	1005	14.9	16.1
5/22/01	W-A		7.4	6.5	20	20		9.0					0		12		1	6053	6049	757	778		
5/2/02	W-A	13.35	7.3	6.3	20	64				96	<1				44		0	17443	17958	1712	1833	4.7	5.6
9/22/99	W-B	31.40	4.9	3.2	23	24	116	10.9	296	80	5	2	210		31		1	13371	13413	1557	1548	20.4	18.7
5/16/00	W-B	49.18	7.7	6.1	20	32	79	13.6		43	1.8		200		20		2	8270	8577	972	987	12.0	16.6
9/20/99	W-C	37.70	6.4	5.5	22	42	114	9.1	259	80	5	2			28		2	12975	12815	1512	1516	19.0	20.5
5/16/00	W-C	47.19	9.0	2.2	18	34	90	11.2		36	1.9				22		3	9495	9584	1089	1092	15.5	15.7
8/16/00	W-C	14.62	7.5	11.6	22	64	183	8.3															
4/3/01	W-C	11.60	7.1	2.8	20	72	223	9.8							69.4		0	28500		3940			
5/23/01	W-C		7.6	8.8	16	20	57	8.8					0		11		1	5985	6073	765	766		
5/2/02	W-C	14.09	7.1	5.5	18	68				99	<1				50		0	17300	17360	1712	1727	<0.2	<0.2
9/21/99	W-D	31.30	7.5	8.8	24	42	104	8.1	248	80	5	2	210		1.9		2	13764	13831	1585	1588	20.5	19.3
5/16/00	W-D	47.12	7.9	9.6	18	32	88	9.8		83	1.4		201		20		2	9485	9538	1087	1088	16.4	16.8
8/23/00	W-D	35.98	7.5	10.4	21	44	123	8.5		95	3			30.7	34.7	<1	6.2	16200	18300	870	1350	14.3	18.5
9/21/99	W-E	30.50	7.8	9.7	22	44	103	8.0	276	80	5	2			33		2	13830	13765	1594	1588	20.1	17.8
5/16/00	W-E	47.46	7.6	9.2	20	34	89	9.6		83	2.7				29		2	9445	9446	1081	1092	16.8	17.4
9/21/99	W-F	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry
9/21/99	W-G-E	4.75	7.5	11.7	20	44	109	8.6	163	80	5	4			34		2	14195	13997	1715	1727	19.9	19.4
5/16/00	W-G-E	10.00	7.9	8.4	16	34	96	10.2		53	2.4				27		2	9657	9720	1179	1198	16.4	16.9
9/21/99	W-G-M	27.40	7.5	12.5	18	42	105	8.5	189	70	5	2			31		2	13756	14186	1626	1672	19.9	19.2
5/16/00	W-G-M	33.60	8.2	8.3	18	34	91	10.2		63	0				22		3	9530	9616	1122	1118	15.9	16.4
9/21/99	W-G-W	0.26	7.5	13.9	20	44	103	8.2	212	60	5	1			31		1	13654	13720	1614	1614	19.3	19.2
5/16/00	W-G-W	5.03	8.2	8.7	20	34	92	9.9		85	0				25		2	9822	9805	1092	1101	14.0	16.2
9/21/99	W-G-FW	1.56	7.4	14.3	20	43	107	8.0	211						33		2	14292	14281	1609	1612		
9/21/99	W-H	4.12	7.6	11	18	44	108	8.8	186	70	5	2			31		2	14069	13876	1715	1710	19.9	19.3
5/16/00	W-H	9.87	8.2	8.7	16	34	94	10.4		72	1.7				27		2	9626	9667	1180	1179	15.4	16.5
9/21/99	W-I	22.60	7.9	8.9	20	43	104	8.6	174	40	5	2	150		30		2	13852	13926	1647	1647	19.8	18.3
5/16/00	W-I	34.57	8.3	6.7	18	36	92	10.3		66	0		200		25		2	9800	9783	1123	1131	15.3	15.4
8/23/00	W-I	22.08	7.7	10.7	22	48	145	8.3		106	2.3			38.1	49.4	<1	4.1	17500	17600	2999	4820	16.3	19.5
4/3/01	W-I	7.45	7.4	5.7	20	80	234	8.9							74.4		1.5	30700		7300			
5/23/01	W-I	134.32	7.5	11.1	14	20		7.8					0		13		1	6181	6203	789	783		
5/2/02	W-I	11.33	7.0	6	14	62				99	<1				46		3	17177	17144	1825	1821	7.5	8.2
9/21/99	W-J	3.40	7.8	11.9	18	39	102	8.7	159	80	5	1	190		34		2	13763	13633	1648	1646	19.4	18.4
5/16/00	W-J	9.31	8.6	7.3	16	36	97	9.6		64	2.2		200		24		3	9936	9935	1196	1210	16.6	17.0
8/23/00	W-J	17.44	7.3	9.6	20	48	141	8.6		103	12.8			36.3	39.6	<1	4.8	17500	19100	2410	3090	15.8	18.7
4/3/01	W-J	7.00	7.0	6.2	12	86	253	9.0							87.8		1.2	32400		5280			
5/23/01	W-J	25.29	7.5	11.2	18	22		8.7					0		15		2	6462	6545	837	849		
5/2/02	W-J	3.161	7.0	6	18	64				93	1				49		0	17229	17328	1831	1854	6.9	7.6

Table 17 (cont.)

Date	Site	dK (mg/L)	tK (mg/L)	Na (mg/L)	dAg (ug/L)	dAl (ug/L)	tAl (ug/L)	dAs (ug/L)	tAs (ug/L)	tBa (ug/L)	dCd (ug/L)	tCd (ug/L)	dCu (ug/L)	tCu (ug/L)	dFe (ug/L)	tFe (ug/L)	dMn (ug/L)	tMn (ug/L)	dPb (ug/L)	tPb (ug/L)	dSe (ug/L)	tSe (ug/L)	dZn (ug/L)	tZn (ug/L)
9/18/99	W-A	0.9	1.1			92	210	<15	<15		13.0	13.3	6	9	53	147	525	532	30	61			2950	3041
5/16/00	W-A		0.7	2.6		28	159	<15	<15		7.0	7.3	4	4	24	121	232	236	17	37			1589	1634
5/22/01	W-A					33	187	<15	<15		6.6	7.0	5	7	16	172	93	104	8	40	<2	<2	769	822
5/2/02	W-A	<0.5	<0.5	4.2		<15	82	<15	<15		14.8	15.3	5	6	15	101	658	704	40	70	2	<2	4447	4946
9/22/99	W-B	0.9	0.9			74	180	<15	<15		13.5	13.6	6	9	35	128	526	532	33	60			3133	3196
5/16/00	W-B		0.8	2.6		45	172	<15	<15		6.7	7.2	4	4	28	123	207	220	16	34			1455	1526
9/20/99	W-C	1.0	1.0			91	183	<15	<15		12.6	12.5	6	9	57	137	463	459	33	56			2831	2846
5/16/00	W-C		0.9	2.9		30	183	<15	<15		8.5	8.6	4	5	20	124	248	254	16	37			1874	1912
8/16/00	W-C				0.2						<0.15		7						41				3814	
4/3/01	W-C						181		8	37		19.6		11		220		832		69				6340
5/23/01	W-C					28	144	<15	<15		5.7	6.1	4	6	15	125	70	81	8	34	<2	<2	710	762
5/2/02	W-C	<0.5	<0.5	4.3		<15	71	<15	<15		14.8	15.1	5	6	12	84	562	569	32	58	<2	<2	4296	4371
9/21/99	W-D	1.0	1.0			68	180	<15	<15		14.1	14.3	5	9	33	127	506	511	27	54			2918	3032
5/16/00	W-D		0.8	3.1		26	169	<15	<15		8.5	8.7	4	5	17	111	238	246	16	38			1779	1819
8/23/00	W-D		1.3	4		243	334	<15	3		9.0	11.0	10	12	212	492	389	418	135	327			2602	2839
9/21/99	W-E	1.0	0.9			68	195	<15	<15		13.5	13.7	5	9	35	137	497	498	26	59			2744	2852
5/16/00	W-E		1.0	2.9		24	151	<15	<15		8.4	8.5	3	4	17	106	244	249	16	34			1851	1875
9/21/99	W-F	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry
9/21/99	W-G-E	0.9	0.9			168	482	<15	<15		16.9	16.9	7	14	28	135	698	692	17	60			3196	3400
5/16/00	W-G-E		1.0	2.7		93	412	<15	<15		13.0	13.3	7	11	19	149	471	479	8	41			2649	2785
9/21/99	W-G-M	1.0	0.9			158	311	<15	<15		12.9	13.8	9	11	97	109	512	540	26	50			2311	2603
5/16/00	W-G-M		0.7	3.3		58	234	<15	<15		9.8	10.2	5	7	16	108	294	295	11	37			1987	2078
9/21/99	W-G-W	1.1	1.0			111	294	<15	<15		11.5	12.1	7	12	26	114	474	484	17	50			1800	2097
5/16/00	W-G-W		0.9	3.2		40	169	<15	<15		12.0	12.0	5	5	12	90	199	203	10	32			2197	2245
9/21/99	W-G-FW					79	219	<15	<15		18.3	18.8	6	10	90	82	356	359	15	43			2892	3102
9/21/99	W-H	1.0	1.0			187	440	<15	<15		15.4	16.0	7	13	54	115	656	661	17	50			2793	3089
5/16/00	W-H		0.8	3.2		92	389	<15	<15		12.5	12.9	7	10	18	136	458	465	7	37			2513	2663
9/21/99	W-I	0.9	0.9			107	268	<15	<15		14.0	14.5	6	9	35	94	451	457	11	39			2533	2774
5/16/00	W-I		0.8	3.3		50	181	<15	<15		10.0	9.9	6	6	14	89	228	234	9	27			2098	2174
8/23/00	W-I		0.0	4.5		331	522	3	3		10.0	13.0	8	8	182	238	380	393	105	159			3378	3536
4/3/01	W-I						849		10	33		25.7		19		340		816		45				7862
5/23/01	W-I					38	174	<15	<15		6.9	7.2	4	6	15	126	81	91	7	34	<2	<2	1113	1181
5/2/02	W-I	0.8	0.8	4.3		79	171	<15	<15		19.2	19.2	6	7	20	70	360	364	11	25	<2	3	4842	4918
9/21/99	W-J	1.0	0.8			90	278	<15	<15		10.4	10.7	4	8	15	97	398	401	10	44			1425	1764
5/16/00	W-J		0.8	3.3		61	299	<15	<15		12.1	12.2	5	7	14	132	269	276	13	43			2496	2603
8/23/00	W-J		1.3	4.2		691	1349	1	4		11.0	16.0	13	16	240	324	774	807	75	93			4000	4099
4/3/01	W-J						982		19	28		30.5		32		493		1391		83				9448
5/23/01	W-J					45	244	<15	<15		7.8	8.4	5	8	<10	177	141	159	6	50	<2	2	1320	1485
5/2/02	W-J	0.9	0.9	4.3		72	177	<15	<15		19.35	19.73	5.5	7.4	19	75	371	373	11.6	28.6	<2	<2	5238	5360

Table 18. All data collected for seeps in the Mainstem Willow floodplain. Units are in ( ). The prefixes "d" and "t" represent dissolved and total fractions. Values below the laboratory-determined detection limit are indicated by "<".

Date	Site	Flow (CFS)	pH	Temp (C)	Alk (mg/L)	Hard (mg/L)	Cond (uS/cm)	DO (mg/L)	TDS (mg/L)	TSS (mg/L)	tSO4 (mg/L)	tCl (mg/L)	dSi (mg/L)	tSi (mg/L)	tK (mg/L)	Na (mg/L)
5/18/00	W-EE seep		5.9	10.6	6	46	2148	9.4	84	13.2	45	2	17.05	17.75	0.78	3.3
5/18/00	W-F seep	0.034	3.3	9.7	0	690	2190	4.96	1760	5.2	1036	58	67.65	68.85	3.1	11.2

Table 19. Surface water sampling locations in Windy Gulch, a tributary of Mainstem Willow Creek. Main channel sites were locations of direct sampling from Windy Gulch.

Main Channel Site	Miles from Confluence w/ Willow Creek	Location	Notes
WNG-A	0.01	at flume; ~150 ft u/s confluence w/ Willow Creek	Windy Gulch contribution to Willow Creek; d/s of Bulldog workings and waste rock piles
WNG-B	1.52	u/s Bachelor Loop road crossing	u/s of Bulldog workings and waste rock piles

Table 20. All data collected for main channel sites in Windy Gulch. Units are in ( ). The prefixes "d" and "t" represent dissolved and total fractions, respectively. Values below the laboratory-determined detection limit are indicated by "<".

Date	Site	Flow (CFS)	pH	Temp (C)	Alk (mg/L)	Hard (mg/L)	Cond (uS/cm)	DO (mg/L)	ORP (mV)	TDS (mg/L)	TSS (mg/L)	DOC (mg/L)	NO3 (ug/L)	tSO4 (mg/L)	tCl (mg/L)
9/20/99	WNG-A		7.0	8.7	12	140	341	7.9	261	260	5	4		98	3
5/18/00	WNG-A	0.11	9.2	3.0	12	98	251	10.4		156	0			8	3
5/23/01	WNG-A		7.6	9.3	14	52		8.6					0	49	2
5/2/02	WNG-A	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry
9/20/99	WNG-B		7.1	10.0	50	42	100	7.0	222	90	5	6		2	2
5/18/00	WNG-B	0.66	7.1	5.3	32	38	64	8.9		54	1.4			2	2
5/23/01	WNG-B		7.0	15.1	24	24		6.2					0	3	1
5/2/02	WNG-B	0.04	7.5	6.2	36	36				87	2			0	3

Table 20 (cont.)

Date	Site	dAl (ug/L)	tAl (ug/L)	dAs (ug/L)	tAs (ug/L)	dCd (ug/L)	tCd (ug/L)	dCu (ug/L)	tCu (ug/L)	dFe (ug/L)	tFe (ug/L)	dMn (ug/L)	tMn (ug/L)	dPb (ug/L)	tPb (ug/L)	dSe (ug/L)	tSe (ug/L)	dZn (ug/L)	tZn (ug/L)
9/20/99	WNG-A	38	245	<15	47	23.5	24.1	11	21	27	517	233	231	<3	<3			4147	4188
5/18/00	WNG-A	35	150	17	28	13.2	13.5	7	10	19	154	66	68	<3	<3			2496	2539
5/23/01	WNG-A	69	578	21	44	7.6	8.0	12	19	46	516	175	182	<3	<3	<2	<2	1064	1144
5/2/02	WNG-A	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	dry
9/20/99	WNG-B	482	656	<15	<15	<0.15	<0.15	<1	<1	417	617	36	58	<3	<3			<1	<1
5/18/00	WNG-B	42	278	<15	<15	<0.15	<0.15	<1	<1	53	347	29	45	<3	<3			<1	<1
5/23/01	WNG-B	39	285	<15	<15	<0.15	<0.15	<1	<1	35	192	14	18	<3	<3	<2	<2	<1	<1
5/2/02	WNG-B	<15	195	<15	<15	0.19	0.17	<1	<1	37	370	69	76	<3	<3	<2	2	<1	<1

Table 20 (cont.)

Date	Site	dCa (ug/L)	tCa (ug/L)	dMg (ug/L)	tMg (ug/L)	dSi (mg/L)	tSi (mg/L)	dK (mg/L)	tK (mg/L)	Na (mg/L)
9/20/99	WNG-A	48265	48186	5561	5497	34.3	29.5	3.4	3.3	
5/18/00	WNG-A	29184	29247	3779	3804	24.2	27.9		3.0	4.5
5/23/01	WNG-A	15839	15378	2210	2204					
5/2/02	WNG-A	dry	dry	dry	dry	dry	dry	dry	dry	dry
9/20/99	WNG-B	13908	13872	2058	2043	31.8	33.3	1.5	1.5	
5/18/00	WNG-B	7869	8322	1178	1271	23.4	25.3		1.25	3
5/23/01	WNG-B	6602	6641	1000	1007					
5/2/02	WNG-B	10268	10387	1403	1420	9.5	11.3	0.5	0.5	3.4

Table 21. Surface water sampling locations in the Rio Grande River and selected tributaries. Main channel sites were locations of direct sampling from the Rio Grande. Other inflows include tributaries and seeps that were sources to the Rio Grande.

Channel Site	Other Inflows	Description	Location	Notes
RG-7		Marshall Park	Bridge near Marshall Park Campground	u/s site
	MC-1	Miners Creek	near confluence w/ Rio Grande	tributary to Rio Grande btwn Deep Creek and Marshall Park
RG-5		Deep Cr. Bridge	u/s of Deep Creek	LAT 37 49 00N LONG 106 54 51W
RG-1		d/s Deep Cr.	d/s of bridge crossing and confluence with Deep Creek	d/s of tributary source
RG-2		Upstream of Willow	u/s of confluence w/ west channel of Willow Creek	
RG-3		Downstream of Willow	d/s of confluence w/ east channel of Willow Creek	
RG-4		Wason Bridge		LAT 37 49 21N LONG 106 53 19W
	BC-1	Bellows Creek	near confluence w/ Rio Grande	tributary to Rio Grande near La Garita Bridge
RG-8		La Garita Bridge	u/s of Spring Creek	LAT 37 46 39N LONG 106 50 12W
	RG-Seep1	Seep d/s La Garita	seep on west bank of Rio Grande	LAT 37 46 54N LONG 106 50 11W
RG-10		Below seep	d/s of seep	d/s of potential tributary source
	SG-1	Spring Gulch	u/s of bridge on La Garita access road	tributary to Rio Grande near La Garita Bridge
RG-11		Railroad Bridge	in between La Garita and 4UR Bridges	
RG-12		Above gulch	u/s of dry gulch on west bank	u/s of potential tributary source
RG-13		Below gulch	d/s of dry gulch on west bank	d/s of potential tributary source
RG-9		4UR Bridge	u/s of Wagon Wheel Gap	LAT 37 46 01N LONG 106 49 51W

Table 22. Data collected for main channel sites in the Rio Grande. The prefixes "d" and "t" represent dissolved and total. The abbreviations "d/s" and "u/s" refer to downstream and upstream. Values below the detection limit are indicated by "<".

Date	Site	Description	Type	Flow (CFS)	pH	Temp (C)	Alk (mg/L)	Hard (mg/L)	Cond (uS/cm)	DO (mg/L)	ORP (mV)	TDS (mg/L)	TSS (mg/L)	DOC (mg/L)	tSO4 (mg/L)	tCl (mg/L)
5/2/02	RG-7	Marshall Park	Composite	244	7.6	5.0	26	34				70	2		0	0
5/3/02	RG-5	Deep Cr. Bridge	Composite	295	8.0	9.5			70	8.0						
9/20/99	RG-1	d/s Deep Cr.	Grab		6.3	7.2	30	26	69	10.2	243	50	5	2	2	1
5/15/00	RG-1	d/s Deep Cr.	Composite	990	7.9	5.8	22	20	60	6.0		68	3		2	2
9/22/99	RG-2	u/s of Willow	Grab		6.7	7.8	31	25	70	10.5	258	40	5	3	2	2
9/22/99	RG-3	d/s of Willow	Grab		6.6	8.8	29	27	81	10.5	276	40	5	4	10	2
9/22/99	RG-4	Wason Bridge	Grab		6.8	9.3	32	28	71	9.9	232	50	5	2	3	2
5/15/00	RG-4	Wason Bridge	Composite	1030	7.8	6.5	22	22	63	9.4		59	2		1	2
5/3/02	RG-4	Wason Bridge	Composite	303	7.9	9.0			77	8.2						
5/3/02	RG-8	La Garita Bridge	Composite	338	7.8	10.5			78	8.2						
8/20/02	RG-8	La Garita Bridge	Composite	63	8.2	13.4	49.7	73.1	138							
8/20/02	RG-10	Below seep	Composite		8.1	13.6	49.7	73.7	138							
8/20/02	RG-11	Railroad Bridge	Composite		8.0	13.4	52	76.7	141							
8/20/02	RG-12	Above gulch	Composite		8.0	13.4	51.5	80.4	142							
8/20/02	RG-13	Below gulch	Composite		8.0	13.3	52	79.9	143							
5/3/02	RG-9	4UR Bridge	Composite	333	7.7	5.8			77	9.0						
8/20/02	RG-9	4UR Bridge	Composite	62	7.8	12.5	51.5	77.6	144							

Table 22 (cont.)

Date	Site	Description	dAl (ug/L)	tAl (ug/L)	dAs (ug/L)	tAs (ug/L)	dCd (ug/L)	tCd (ug/L)	dCu (ug/L)	tCu (ug/L)	dFe (ug/L)	tFe (ug/L)	dMn (ug/L)	tMn (ug/L)	dPb (ug/L)	tPb (ug/L)	dZn (ug/L)	tZn (ug/L)
5/2/02	RG-7	Marshall Park	<15	65	<15	<15	<0.15	<0.15	<1	<1	61	154	<10	18.5	<3	<3	<1	<1
5/3/02	RG-5	Deep Cr. Bridge															<1	
9/20/99	RG-1	d/s Deep Cr.	36	141	<15	<15	<0.15	<0.15	<1	<1	86	258	0	16.7	<3	<3	<1	<1
5/15/00	RG-1	d/s Deep Cr.	22	191	<15	<15	<0.15	<0.15	<1	<1	63	284	0	17.5	<3	<3	<1	<1
9/22/99	RG-2	Upstream of Willow																
9/22/99	RG-3	Downstream of Willow	71	140	<15	<15	1.86	2.02	1.2	1.5	108	206	65.9	75.2	3	6	301	332
9/22/99	RG-4	Wason Bridge	31	123	<15	<15	0.48	0.57	<1	<1	59	212	21.2	30.1	<3	<3	67	82
5/15/00	RG-4	Wason Bridge	<15	216	<15	<15	0.29	0.40	1	1.3	61	309	20.1	31.8	<3	<3	91	110
5/3/02	RG-4	Wason Bridge															124	
5/3/02	RG-8	La Garita Bridge															107	
8/20/02	RG-8	La Garita Bridge					0.30	0.33	<1	<1			<10	<10			161.7	318.1
8/20/02	RG-10	Below seep					0.23	0.34	<1	<1			<10	10.5			169	332.5
8/20/02	RG-11	Railroad Bridge					0.36	0.37	1.2	<1			<10	<10			265	361
8/20/02	RG-12	Above gulch					0.23	0.68	<1	<1			<10	35.3			274	360.1
8/20/02	RG-13	Below gulch					0.25	0.38	<1	<1			<10	13.8			271	375.1
5/3/02	RG-9	4UR Bridge															147	
8/20/02	RG-9	4UR Bridge					0.31	0.34	<1	<1			<10	<10			231.5	389.3

Table 22 (cont.)

Date	Site	Description	dCa (ug/L)	tCa (ug/L)	dMg (ug/L)	tMg (ug/L)	dSi (mg/L)	tSi (mg/L)	dK (mg/L)	tK (mg/L)	Na (mg/L)
5/2/02	RG-7	Marshall Park	8103	8160	1541	1558	6.8	8.0	0.6	0.6	3.0
5/3/02	RG-5	Deep Cr. Bridge									
9/20/99	RG-1	d/s Deep Cr.	8924	8980	1553	1560	20.6	19.5	1.4	1.3	
5/15/00	RG-1	d/s Deep Cr.	6430	6447	1120	1128	10.3	17.0		1.5	2.4
9/22/99	RG-2	Upstream of Willow					21.0	20.0	1.3	1.3	
9/22/99	RG-3	Downstream of Willow	9423	9576	1577	1579	20.6	20.0	1.3	1.3	
9/22/99	RG-4	Wason Bridge	8796	9013	1558	1573	20.4	20.2	1.3	1.2	
5/15/00	RG-4	Wason Bridge	6815	6915	1199	1205	14.6	19.0		1.5	2.4
5/3/02	RG-4	Wason Bridge									
5/3/02	RG-8	La Garita Bridge									
8/20/02	RG-8	La Garita Bridge									
8/20/02	RG-10	Below seep									
8/20/02	RG-11	Railroad Bridge									
8/20/02	RG-12	Above gulch									
8/20/02	RG-13	Below gulch									
5/3/02	RG-9	4UR Bridge									
8/20/02	RG-9	4UR Bridge									

Table 23. Summary table of zinc loads calculated for the outlet of Willow Creek and for sites on the Rio Grande below the confluence with Willow Creek. Loads are calculated from total zinc concentrations except where noted as dissolved "(d)". Zinc loads in the Rio Grande above Willow Creek were 0 lbs Zn/day.

Date	**Willow Creek (W-I+W-J)**	**Rio Grande**	
	Zinc Load (lbs/day)	Zinc Load (lbs/day)	Site
Sep-99	371	na	
May-00	537	611	RG-4
Aug-00	808	na	
Apr-01	674	na	
May-01	1060	na	
May-02	386 (d)	203 (d) (USGS data)	RG-4
Aug-02	na	108	RG-8

Table 24. Width-integrated sampling data for the Rio Grande. Samples were collected by the USGS in May 2002. Sites from upstream to downstream were RG-5 Deep Creek Bridge, RG-4 Wason Bridge, RG-8 La Garita Bridge, and RG-9 4UR Bridge.

Site	Date	Time	Feet from Bank	DO	pH	Specific conductance	Water temp	dZn (ug/L)
RG-5	5/3/2002	1953	6	7.9	8.0	71	9.4	--
RG-5	5/3/2002	1954	18	7.9	8.0	71	9.5	<1
RG-5	5/3/2002	1955	30	7.9	8.0	71	9.5	--
RG-5	5/3/2002	1956	42	8.0	8.0	71	9.5	<1
RG-5	5/3/2002	1957	54	8.0	8.0	71	9.6	--
RG-5	5/3/2002	1958	66	7.9	8.0	70	9.6	--
RG-5	5/3/2002	1959	78	7.9	8.0	70	9.6	<1
RG-5	5/3/2002	2000	90	7.9	8.0	71	9.6	--
RG-5	5/3/2002	2001	102	7.9	8.0	71	9.5	--
RG-5	5/3/2002	2002	114	7.9	8.0	71	9.5	<1
RG-4	5/3/2002	1731	4	8.1	7.9	79	9.1	155
RG-4	5/3/2002	1732	13	8.1	7.9	78	9.1	154
RG-4	5/3/2002	1733	22	8.2	7.9	77	9.1	167
RG-4	5/3/2002	1734	31	8.3	7.9	76	9.0	129
RG-4	5/3/2002	1735	40	8.2	7.9	75	9.0	105
RG-4	5/3/2002	1736	49	8.2	7.9	75	9.0	100
RG-4	5/3/2002	1737	58	8.2	7.9	75	9.0	97
RG-4	5/3/2002	1738	67	8.1	7.9	75	9.0	96
RG-4	5/3/2002	1739	76	8.0	7.9	75	9.0	97
RG-4	5/3/2002	1740	85	8.0	7.9	75	8.9	96
RG-8	5/3/2002	1431	10	8.2	7.8	78	10.8	110
RG-8	5/3/2002	1432	19	8.3	7.8	77	10.6	107
RG-8	5/3/2002	1433	27	8.3	7.8	77	10.6	110
RG-8	5/3/2002	1434	36	8.3	7.9	77	10.5	107
RG-8	5/3/2002	1435	45	8.3	7.9	77	10.5	103
RG-8	5/3/2002	1436	54	8.3	7.9	77	10.5	107
RG-8	5/3/2002	1437	84	8.1	7.9	78	10.8	105
RG-8	5/3/2002	1438	93	8.2	7.8	78	10.6	104
RG-8	5/3/2002	1439	102	8.3	7.9	78	10.7	104
RG-8	5/3/2002	1440	111	8.2	7.9	79	10.9	105
RG-9	5/3/2002	1116	10	8.9	7.7	77	5.9	151
RG-9	5/3/2002	1117	20	9.0	7.7	77	5.6	152
RG-9	5/3/2002	1118	30	9.0	7.7	77	5.6	155
RG-9	5/3/2002	1119	40	9.0	7.7	77	5.7	151
RG-9	5/3/2002	1120	50	9.0	7.7	77	5.7	148
RG-9	5/3/2002	1121	60	9.0	7.7	77	5.7	151
RG-9	5/3/2002	1122	70	9.0	7.7	77	5.7	149
RG-9	5/3/2002	1123	80	9.0	7.7	77	5.7	149
RG-9	5/3/2002	1124	90	9.0	7.7	78	5.8	146
RG-9	5/3/2002	1125	100	8.9	7.7	78	6.0	143
RG-8	5/3/2002	1429	BLANK	--	--	--	--	<1
RG-9	5/3/2002	1146	DUPLICATE	--	--	--	--	149

Table 25. All data collected for inflows to the Rio Grande. Units are in ( ). The prefixes "d" and "t" represent dissolved and total fractions. Values below the laboratory-determined detection limit are indicated by "<".

Date	Site	Description	Type	Flow (CFS)	pH	Temp (C)	Alk (mg/L)	Hard (mg/L)	Cond (uS/cm)	DO (mg/L)	ORP (mV)	TDS (mg/L)	TSS (mg/L)	DOC (mg/L)	tSO4 (mg/L)	tCl (mg/L)
5/2/02	MC-1	Miner's Creek	Composite	8.41	7.6	7.5	22	24				67	2		5.0	0
8/20/02	BC-1	Bellow's Creek	Composite	7.02	8.3	13.5	35	37	74							
8/20/02	SG-1	Spring Gulch	Composite		8.4	11.0	115	142	234							
8/20/02	RG-Seep1	Seep d/s La Garita	Composite		8.2	13.0	114	220	392							

Table 25 (cont.)

Date	Site	Description	dAl (ug/L)	tAl (ug/L)	dAs (ug/L)	tAs (ug/L)	dCd (ug/L)	tCd (ug/L)	dCu (ug/L)	tCu (ug/L)	dFe (ug/L)	tFe (ug/L)	dMn (ug/L)	tMn (ug/L)	dPb (ug/L)	tPb (ug/L)	dZn (ug/L)	tZn (ug/L)
5/2/02	MC-1	Miner's Creek	<15	77	<15	<15	<0.15	0.55	<1	4.6	54	149	11.2	15.6	<3	<3	<1	15.7
8/20/02	BC-1	Bellow's Creek					<0.1	<0.1	<1	<1			<10	<10			<5	<5
8/20/02	SG-1	Spring Gulch					<0.1	<0.1	<1	<1			<10	<10			<5	<5
8/20/02	RG-Seep1	Seep d/s La Garita					<0.1	4	<1	1.9			98.1	334.3			<5	703

Table 25 (cont.)

Date	Site	Description	dCa (ug/L)	tCa (ug/L)	dMg (ug/L)	tMg (ug/L)	dSi (mg/L)	tSi (mg/L)	dK (mg/L)	tK (mg/L)	Na (mg/L)
5/2/02	MC-1	Miner's Creek	6286	6500	673	706	12.1	14.1	0.7	0.7	2.8
8/20/02	BC-1	Bellow's Creek									
8/20/02	SG-1	Spring Gulch									
8/20/02	RG-Seep1	Seep d/s La Garita									

Table 26. Load comparisons between the sum of tributaries and the next site downstream. Loads are presented for dissolved (d) and total (t) fractions in lbs/day. % change is calculated as $(x_{upstream} - x_{downstream})/x_{upstream} * 100$. Values in red indicate that loads at downstream sites were smaller than the sum of tributaries. No % change was calculated if either value was "0".

Date	Site	dCa	tCa	dMg	tMg	dAl	tAl	dCd	tCd	dCu	tCu	dFe	tFe	dMn	tMn	dPb	tPb	dZn	tZn
Sep-99	East Willow + West Willow (EW-A+WW-A)	2636	2568	300	300	17.8	34.1	2.54	2.46	1.25	1.84	16.3	25.6	104.2	100.9	7.28	11.91	587	588
	Mainstem Willow below confluence (W-A)	2149	2148	247	249	14.7	33.6	2.08	2.13	0.88	1.46	8.5	23.5	84.0	85.1	4.85	9.78	472	487
	% Change	**-18**	**-16**	**-18**	**-17**	**-17**	**-1**	**-18**	**-13**	**-29**	**-21**	**-48**	**-8**	**-19**	**-16**	**-33**	**-18**	**-20**	**-17**
May-00	East Willow + West Willow (EW-A+WW-A)	1873	2653	209	305	5.9	52.8	2.13	2.32	1.27	1.46	4.3	37.9	73.6	74.4	5.41	11.82	490	516
	Mainstem Willow below confluence (W-A)	2867	2893	342	340	9.5	53.7	2.35	2.45	1.28	1.42	8.1	40.9	78.5	79.7	5.58	12.34	537	552
	% Change	**53**	**9**	**64**	**11**	**61**	**2**	**11**	**6**	**1**	**-3**	**90**	**8**	**7**	**7**	**3**	**4**	**10**	**7**
May-00	Mainstem Willow + Windy Gulch (W-B+WNG-A)	2216	2297	261	265	12.0	45.8	1.79	1.93	0.96	1.12	7.5	32.8	55.1	58.6	4.23	9.01	388	407
	Mainstem Willow below confluence (W-C)	2422	2445	278	279	7.7	46.7	2.16	2.20	0.97	1.22	5.1	31.6	63.3	64.8	4.16	9.44	478	488
	% Change	**9**	**6**	**7**	**5**	**-36**	**2**	**20**	**14**	**1**	**9**	**-32**	**-4**	**15**	**11**	**-2**	**5**	**23**	**20**
May-00	Rio Grande + Willow Creek (RG-1+W-I+W-J)	36740	36828	6264	6309	130.1	1071	2.48	2.47	1.31	1.53	340	1543	56.1	151.2	2.35	7.28	518	537
	Rio Grande below confluence (RG-4)	37943	38500	6676	6709	0.0	1203	1.61	2.23	5.57	7.24	340	1720	111.9	177.0	0.00	0.00	506	611
	% Change	**3**	**5**	**7**	**6**	**-**	**12**	**-35**	**-10**	**326**	**372**	**0**	**11**	**100**	**17**	**-**	**-**	**-2**	**14**
May-02	East Willow + West Willow (EW-A+WW-A)	1217	1230	120	122	0.8	5.8	1.00	1.02	0.35	0.42	1.2	7.2	45.8	45.7	3.08	5.00	318	329
	Mainstem Willow below confluence (W-A)	1259	1296	124	132	0.0	5.9	1.07	1.10	0.32	0.44	1.1	7.3	47.5	50.8	2.87	5.02	321	357
	% Change	**3**	**5**	**3**	**8**	**-**	**3**	**7**	**8**	**-8**	**6**	**-11**	**1**	**4**	**11**	**-7**	**0**	**1**	**9**

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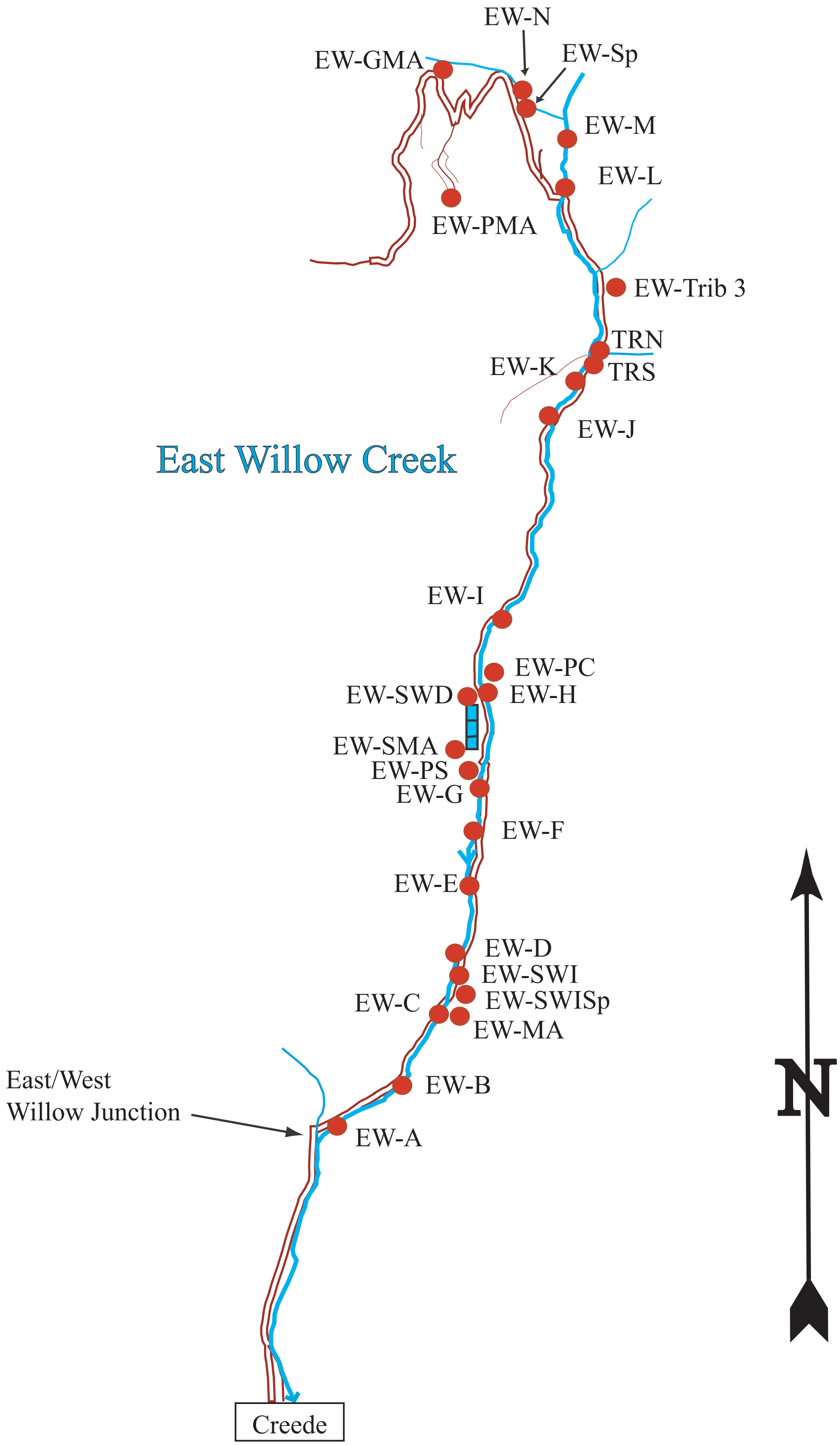


Figure 1. Surface water sampling locations for East Willow Creek. Sites are marked with red circles.

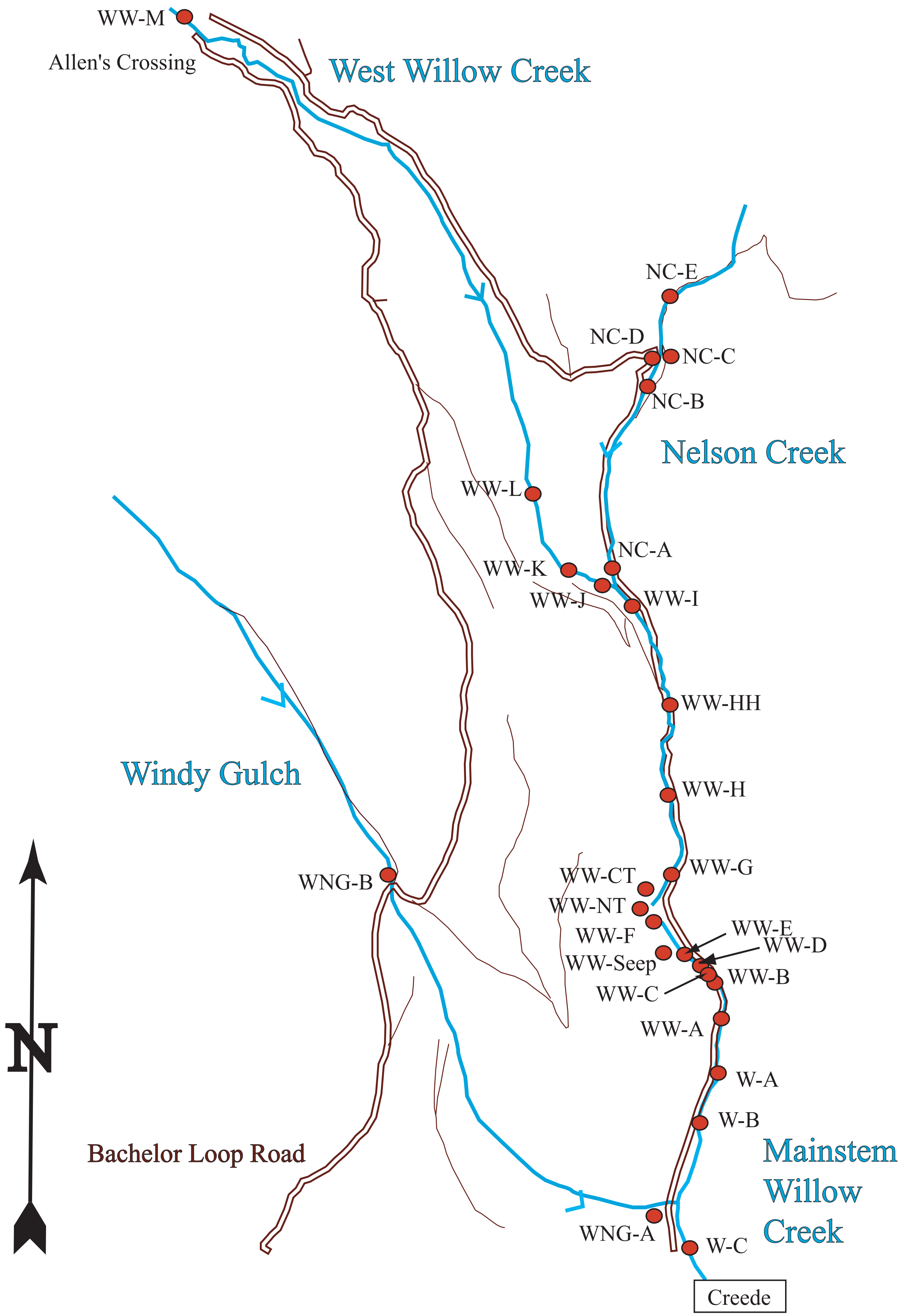


Figure 2. Surface water sampling sites on West Willow, Windy Gulch, and upper Mainstem Willow Creeks.

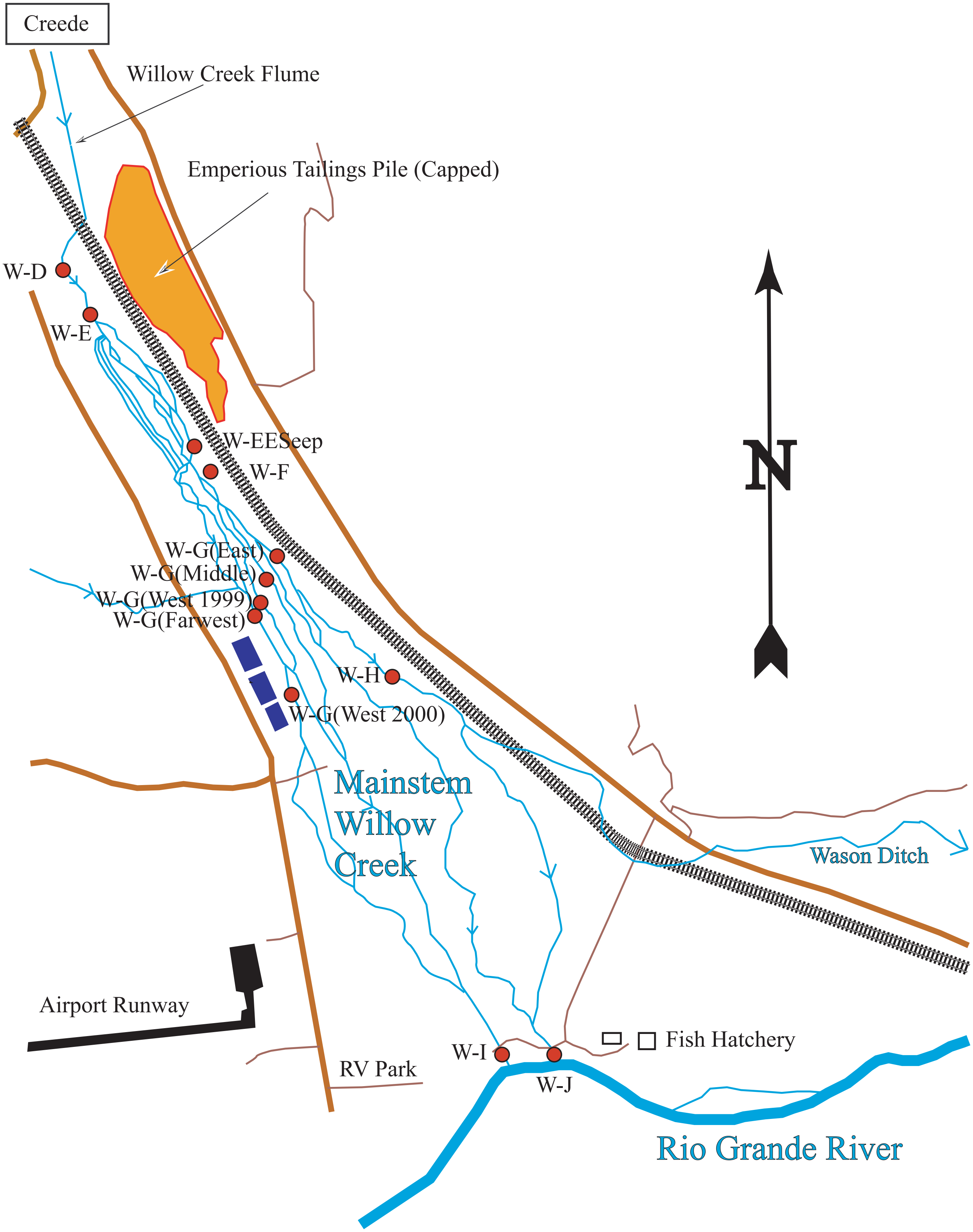


Figure 3. Surface water sampling locations for Mainstem Willow Creek below Creede.

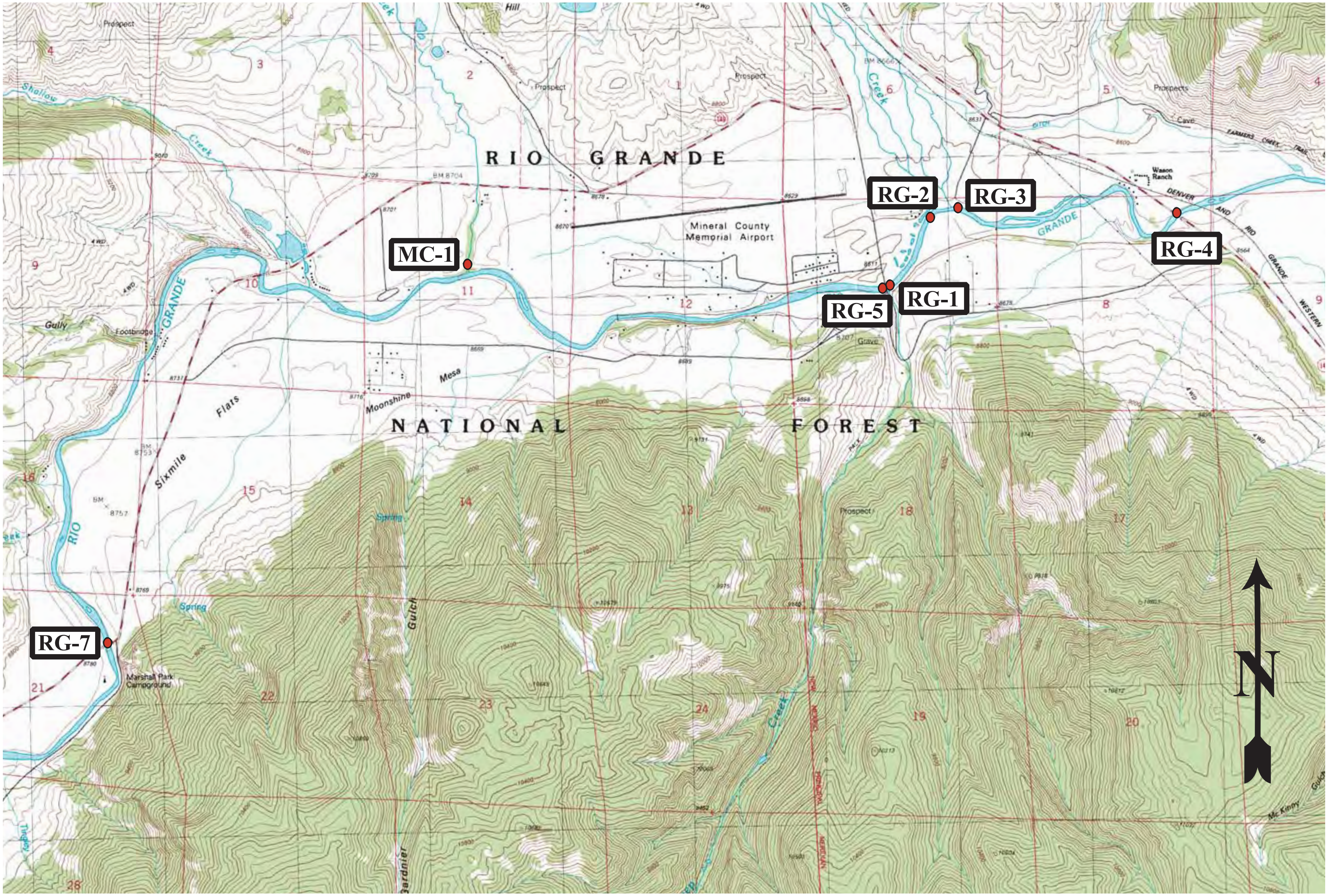
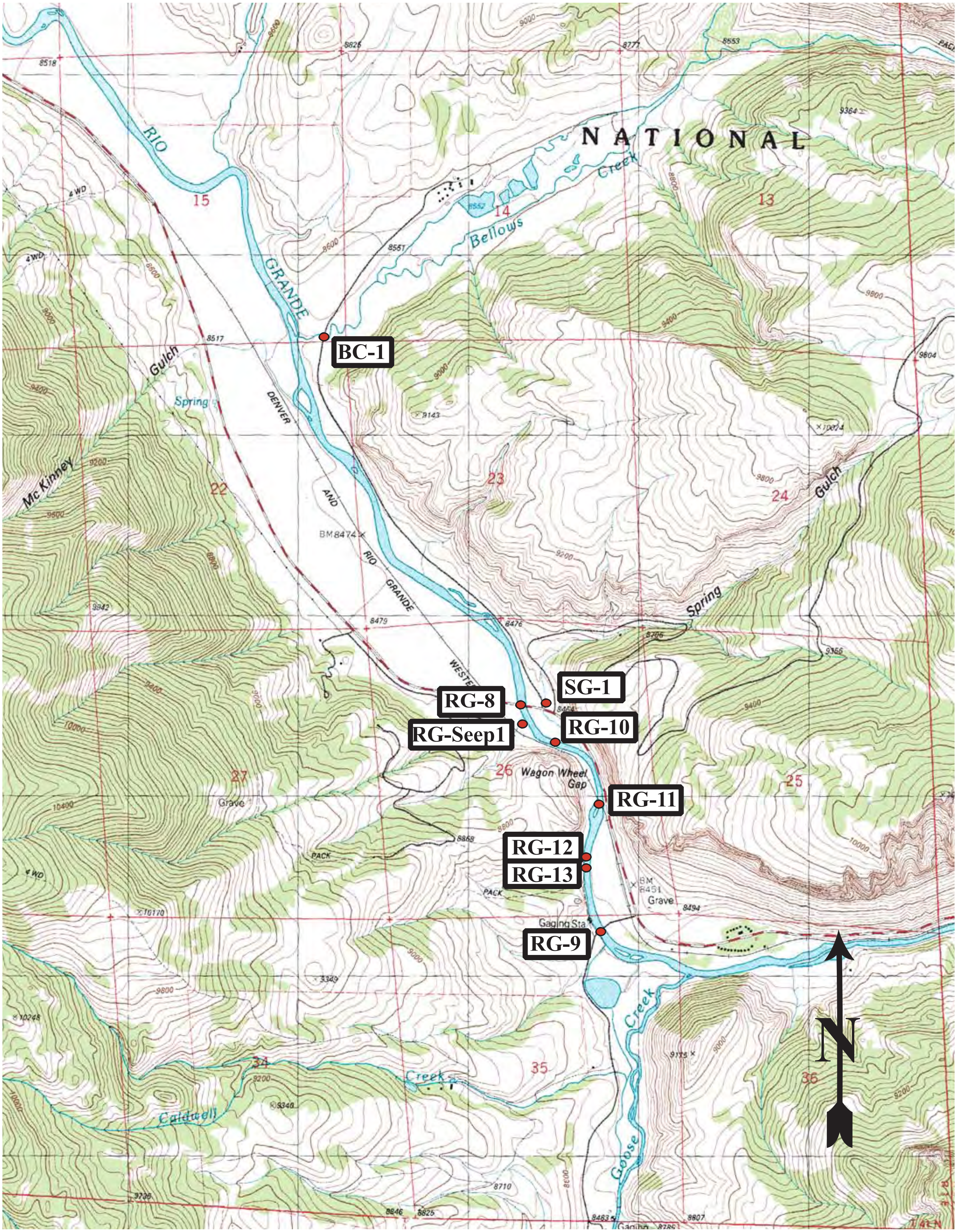


Figure 4. Rio Grande sites upstream and immediately downstream of the confluence with Willow Creek.



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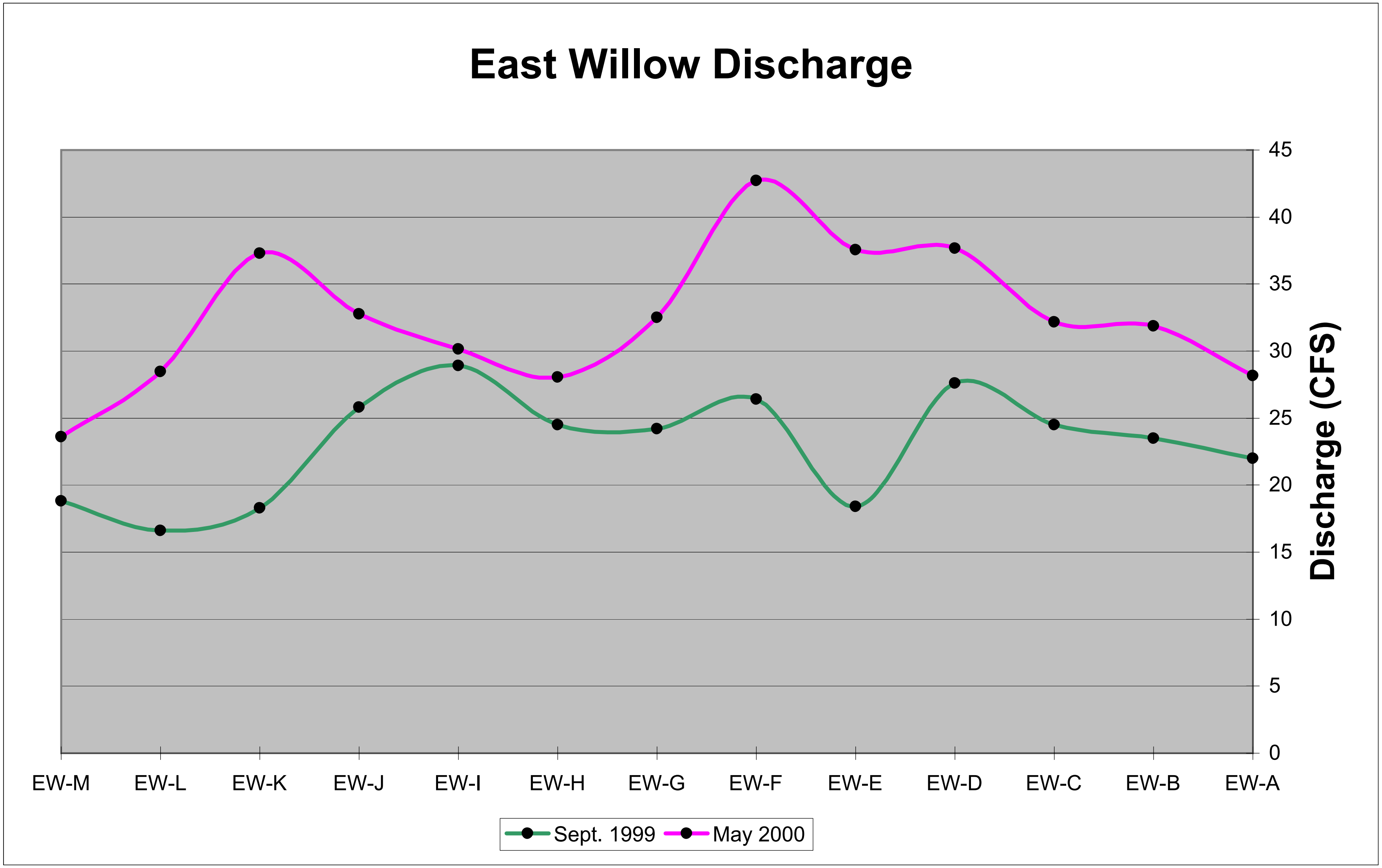
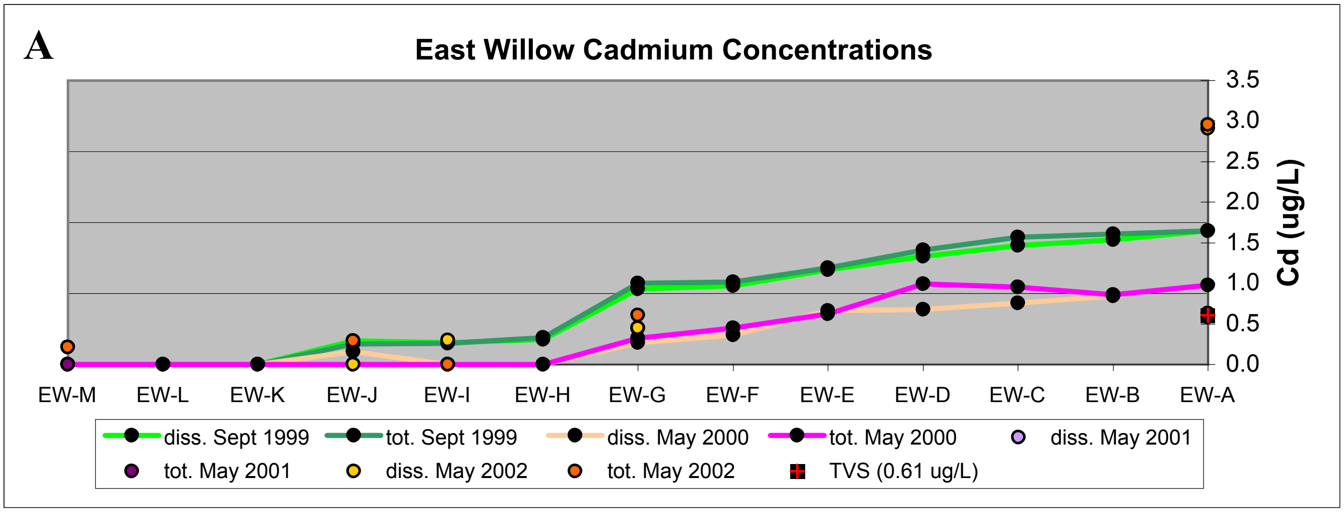
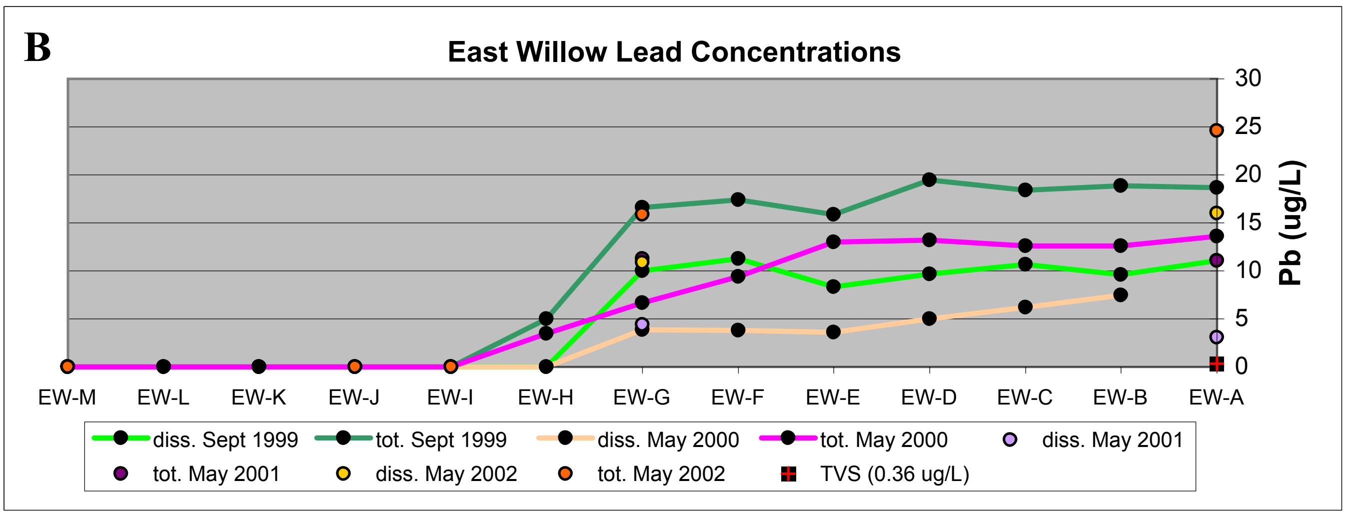


Figure 6. Discharge measurements in cubic feet per second for East Willow Creek in September 1999 and May 2000.





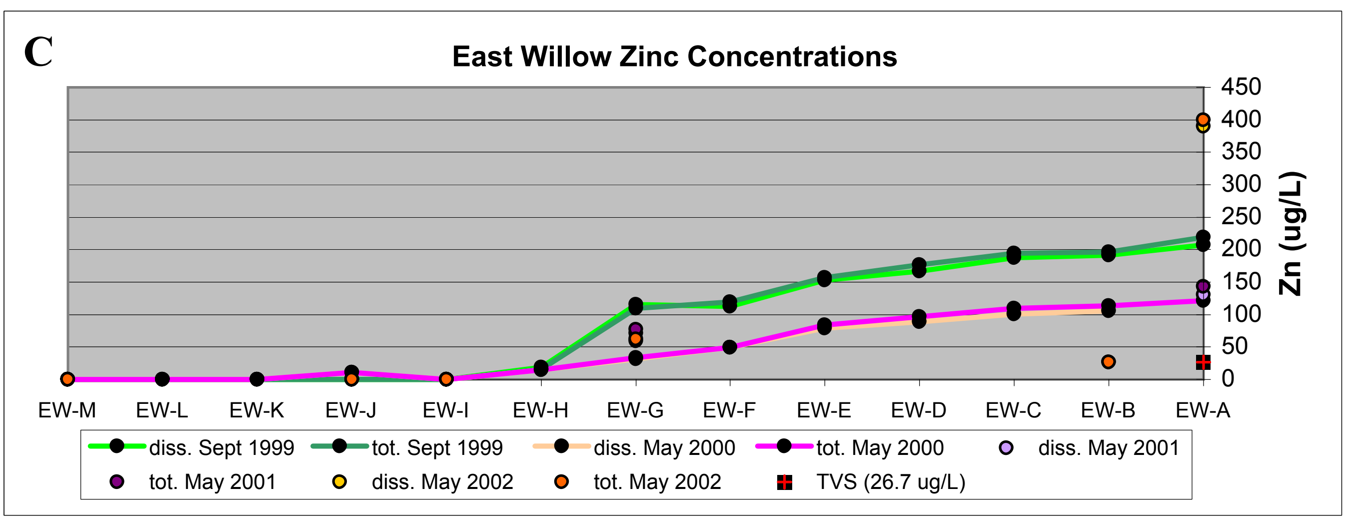
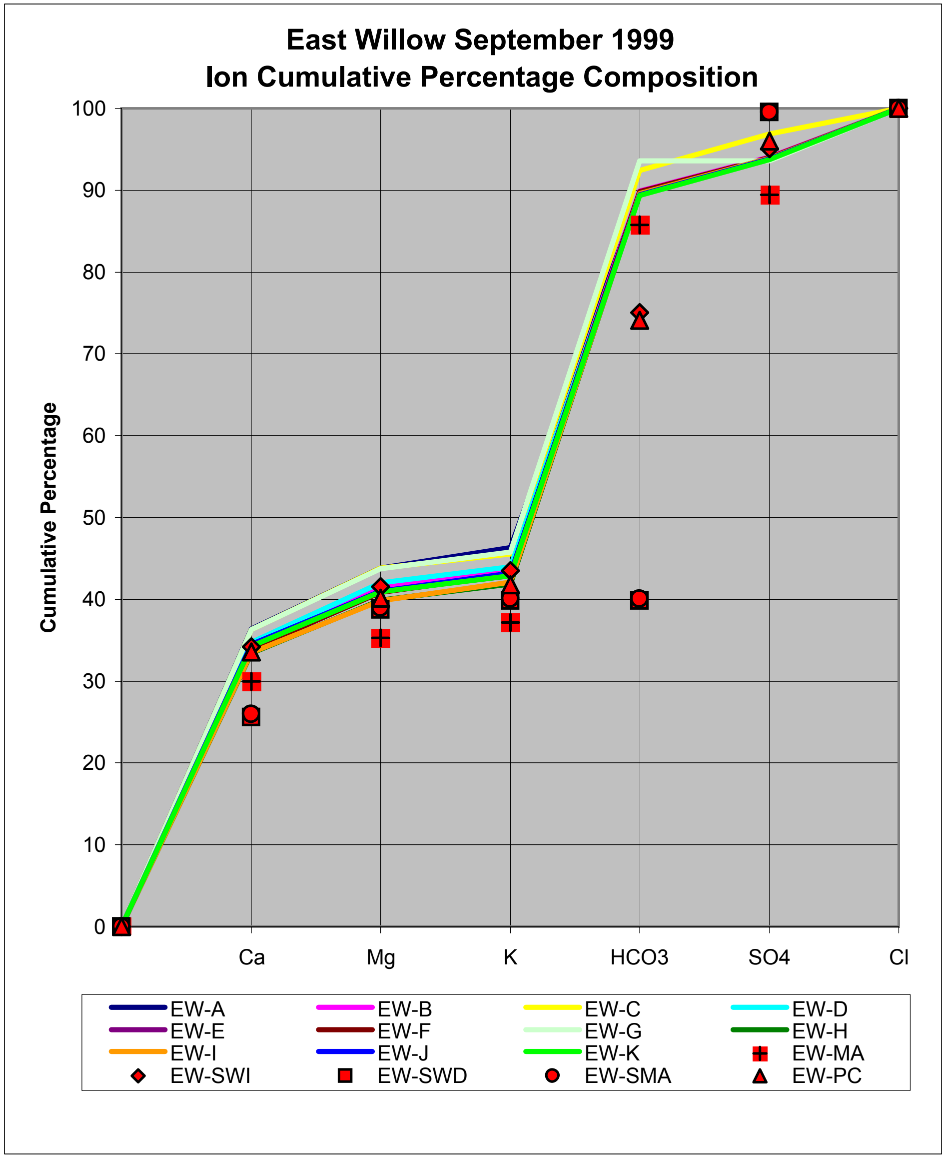


Figure 7. Concentrations of A) cadmium, B) lead, and C) zinc in East Willow in September 1999, and May 2000, 2001, and 2002. Values are presented in ug/L. Table Value Standards (TVS) are based on an average hardness of 17.33 mg $CaCO_3$/L at EW-A.



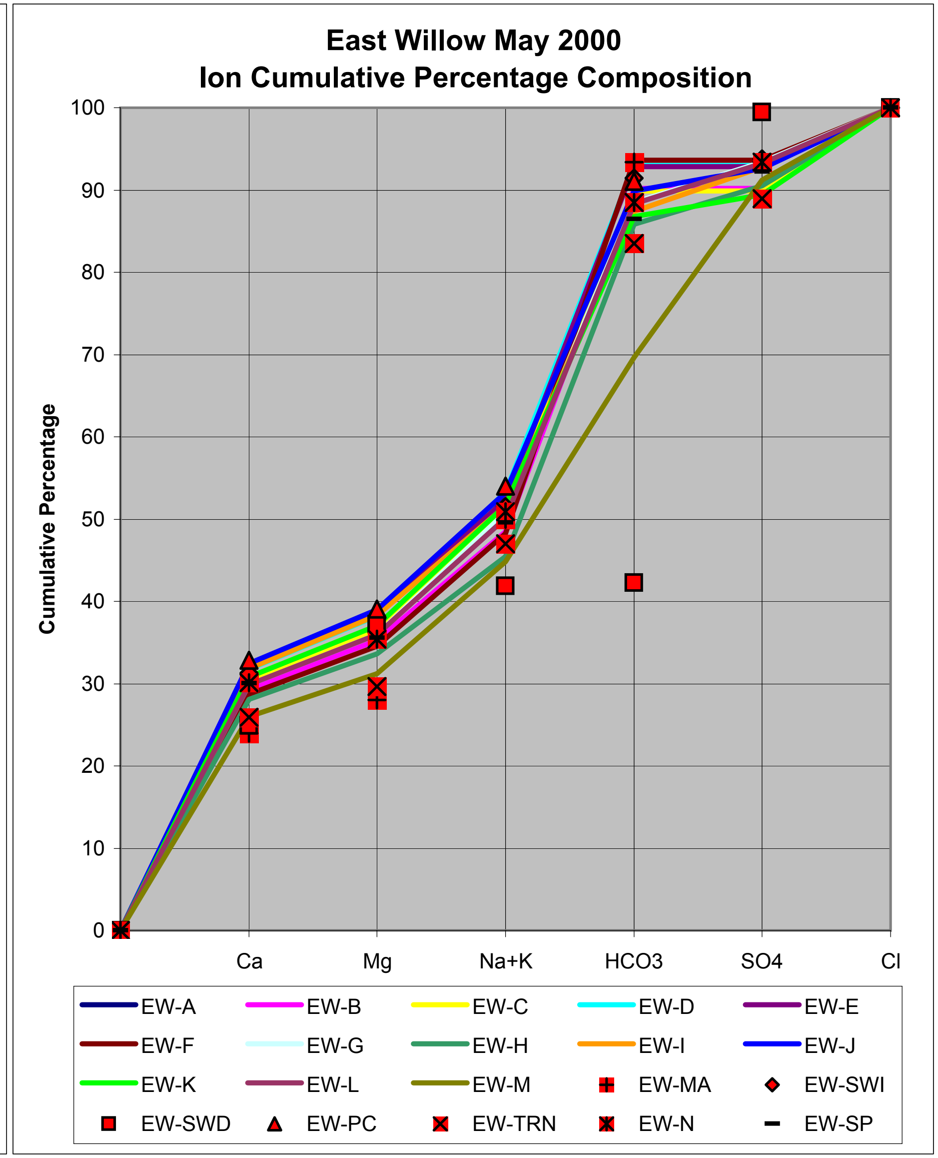


Figure 8. East Willow ion composition for September 1999 and May 2000. Inflows to East Willow are shown with symbols. No data for sodium (Na) were collected in September 1999. Calculations are based on meq/L.

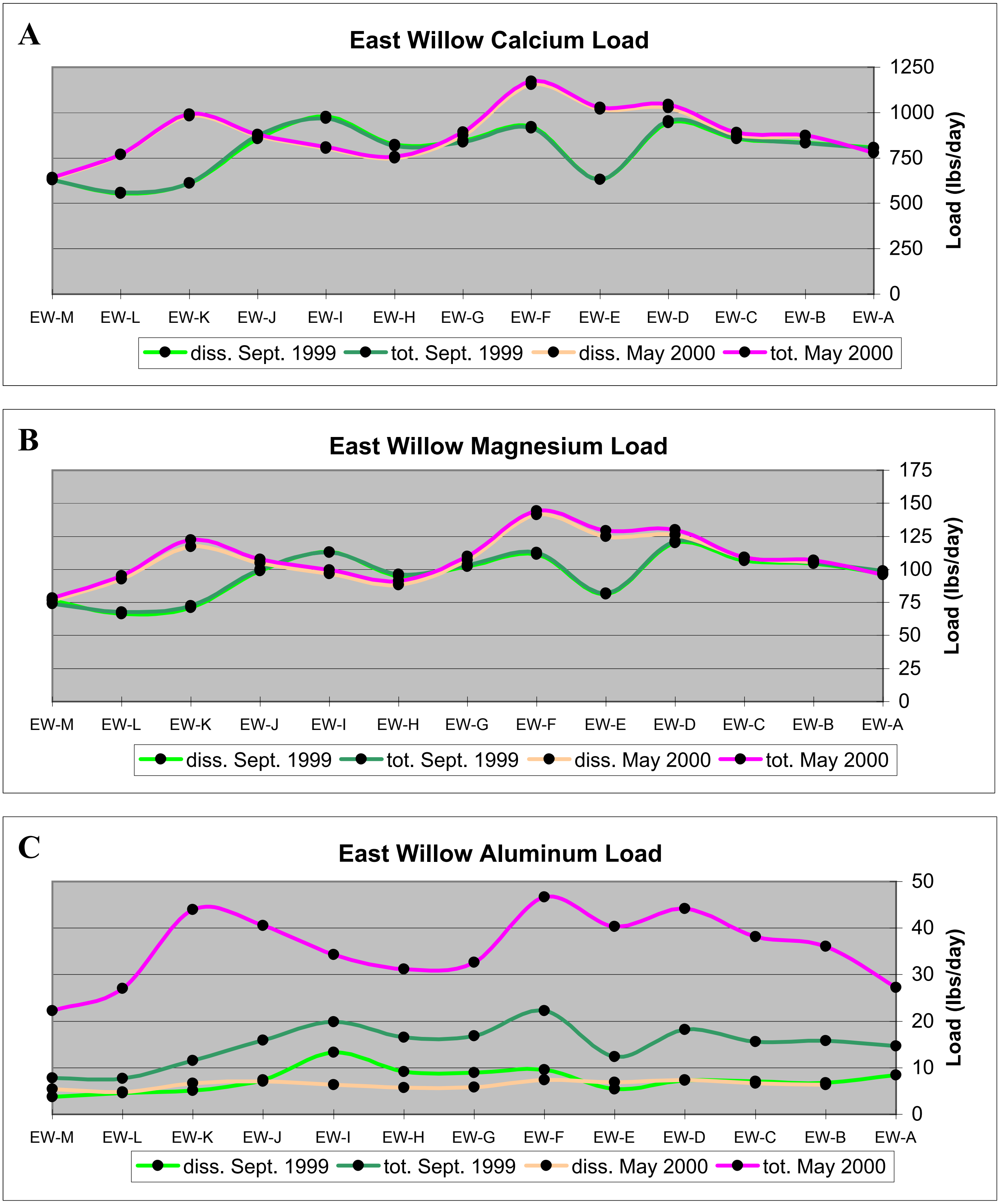


Figure 9. Estimated loads of A) calcium, B) magnesium, and C) aluminum in East Willow Creek. Samples were collected in September 1999 and May 2000. Sites are presented from upstream to downstream.

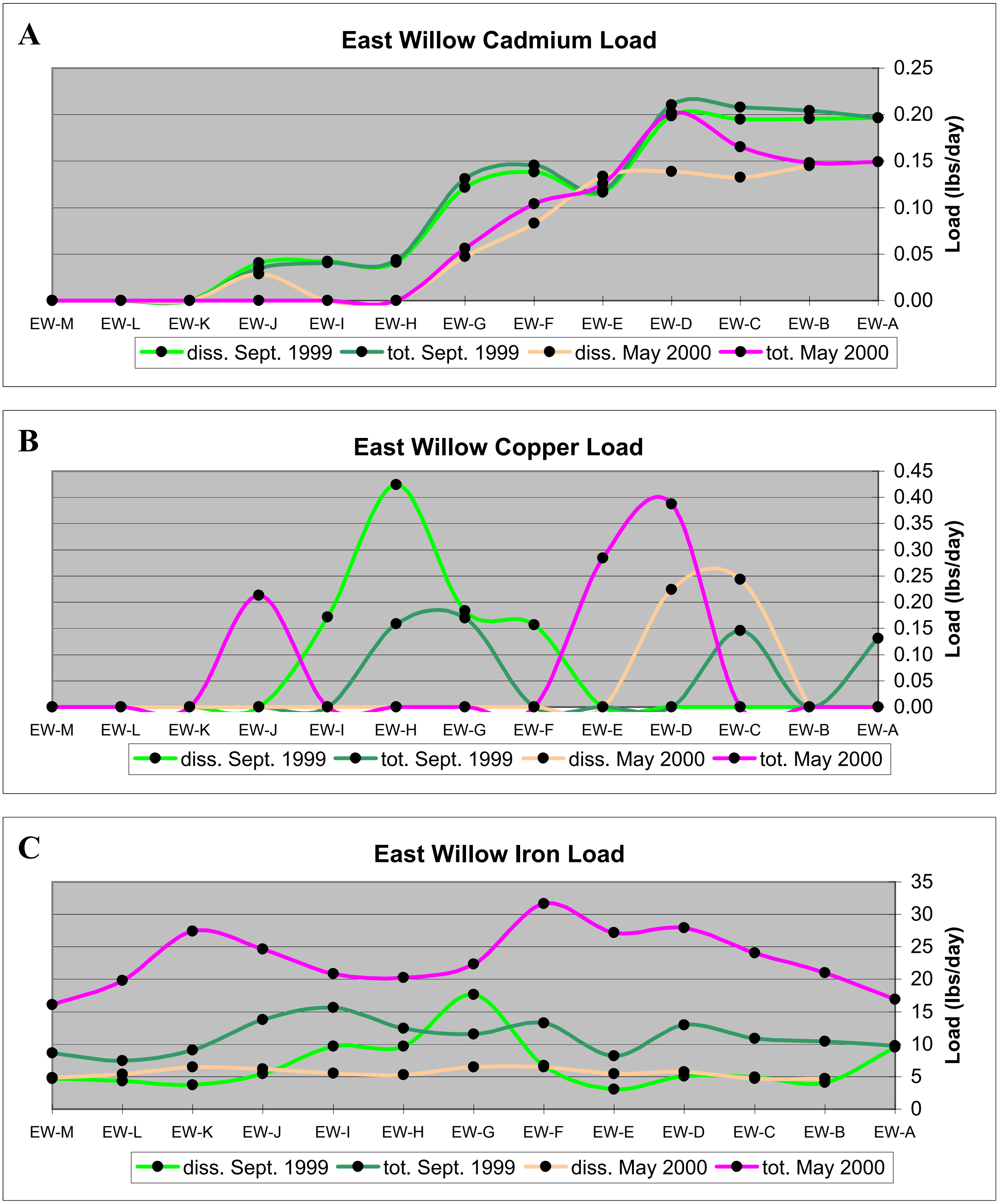


Figure 10. Estimated loads of A) cadmium, B) copper, and C) iron in East Willow Creek. Samples were collected in September 1999 and May 2000. Sites are presented from upstream to downstream.

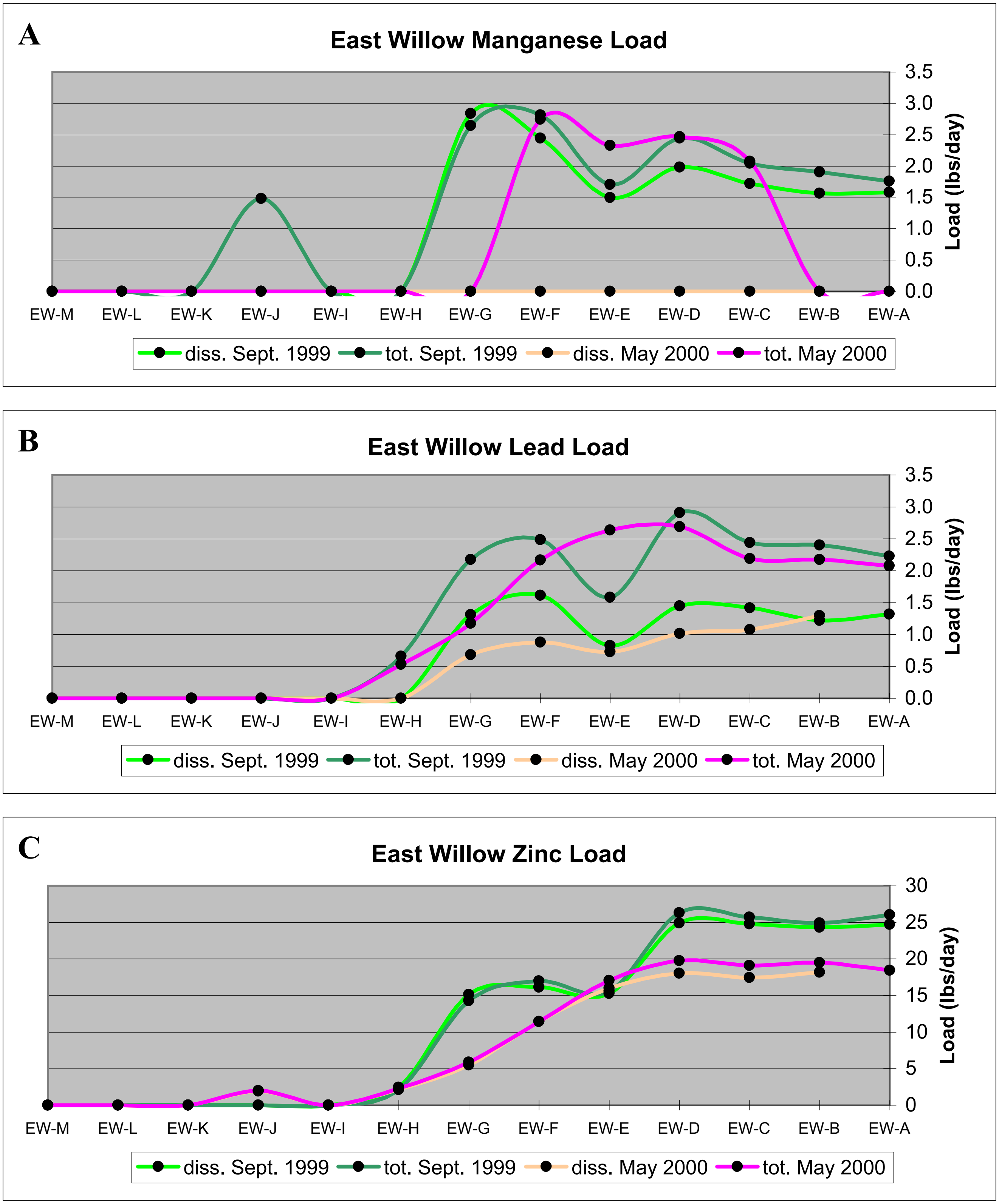


Figure 11. Estimated loads of A) manganese, B) lead, and C) zinc in East Willow Creek. Samples were collected in September 1999 and May 2000. Sites are presented from upstream to downstream.

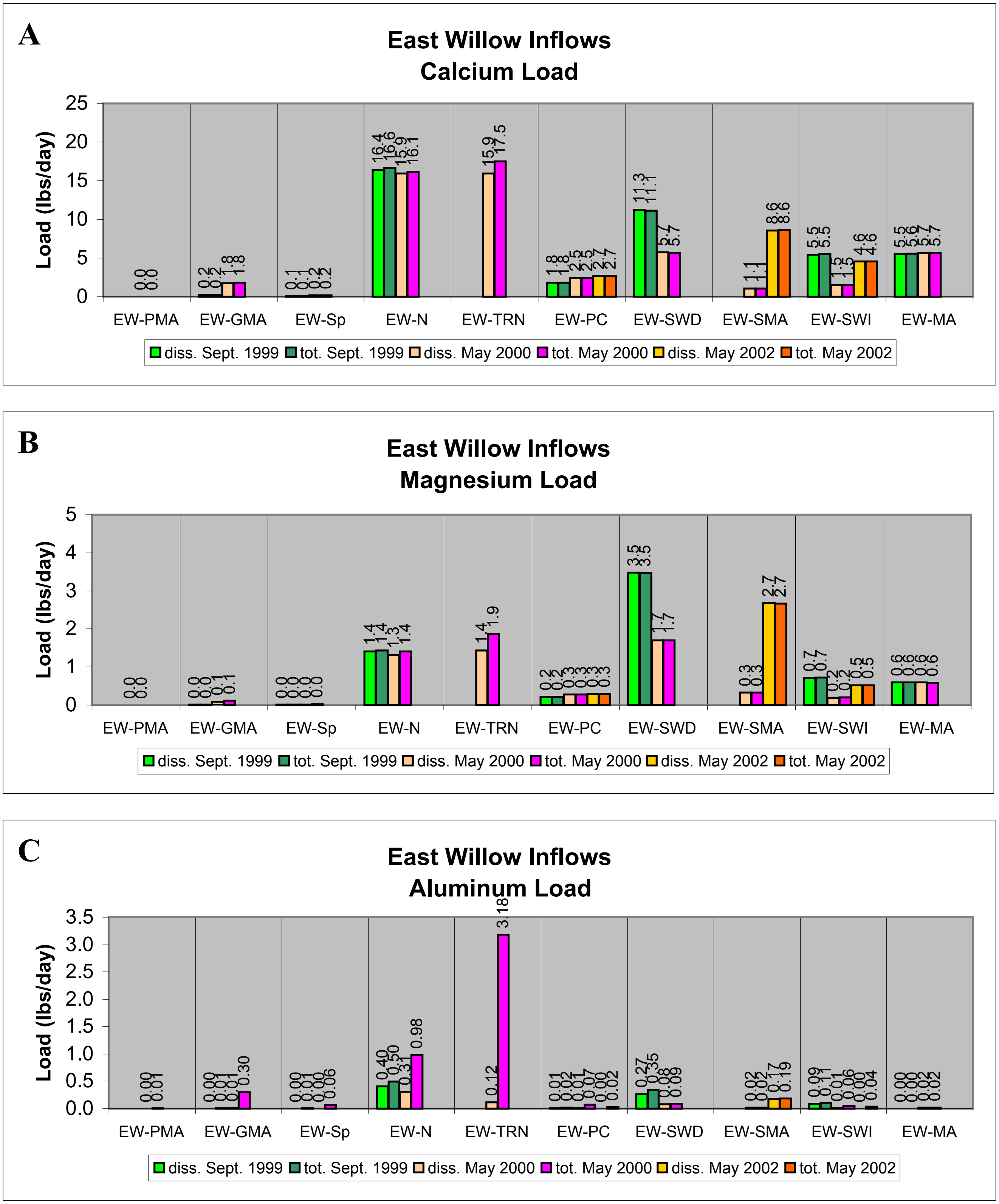


Figure 12. Estimated loads of A) calcium, B) magnesium, and C) aluminum in East Willow Inflows. Samples were collected in September 1999, May 2000, and May 2002.

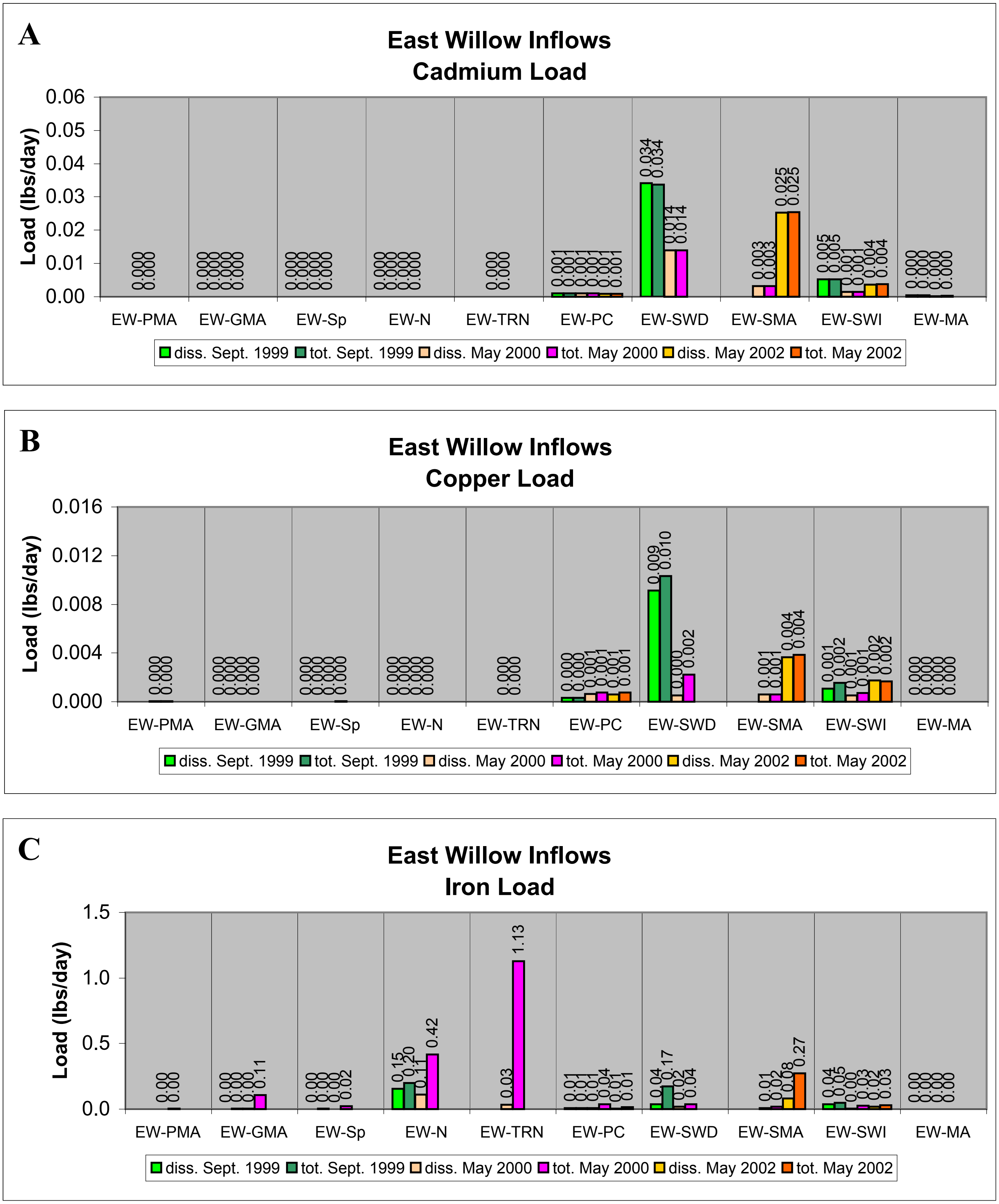


Figure 13. Estimated loads of A) cadmium, B) copper, and C) iron in East Willow Inflows. Samples were collected in September 1999, May 2000, and May 2002.

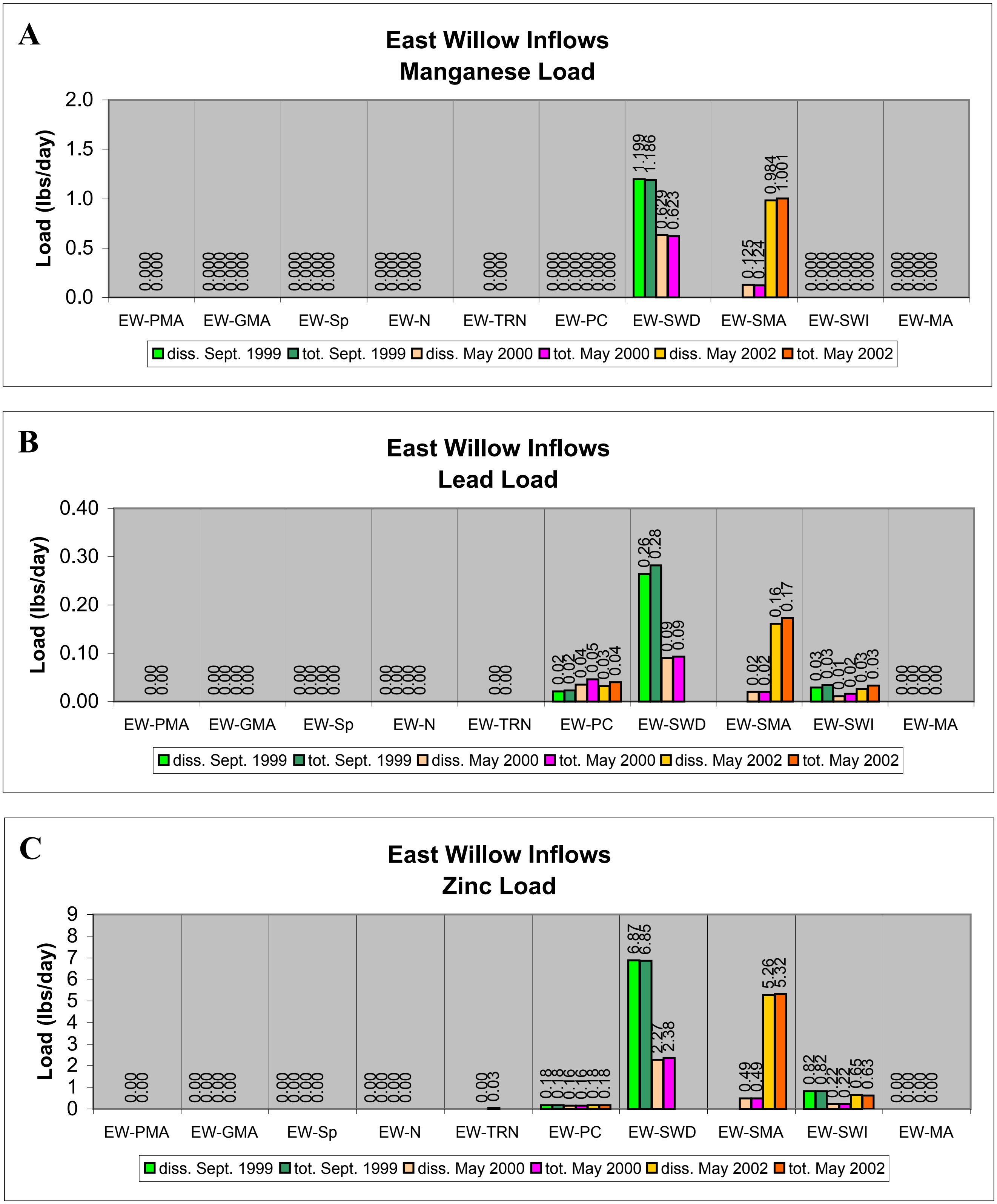


Figure 14. Estimated loads of A) manganese, B) lead, and C) zinc in East Willow Inflows. Samples were collected in September 1999, May 2000, and May 2002.

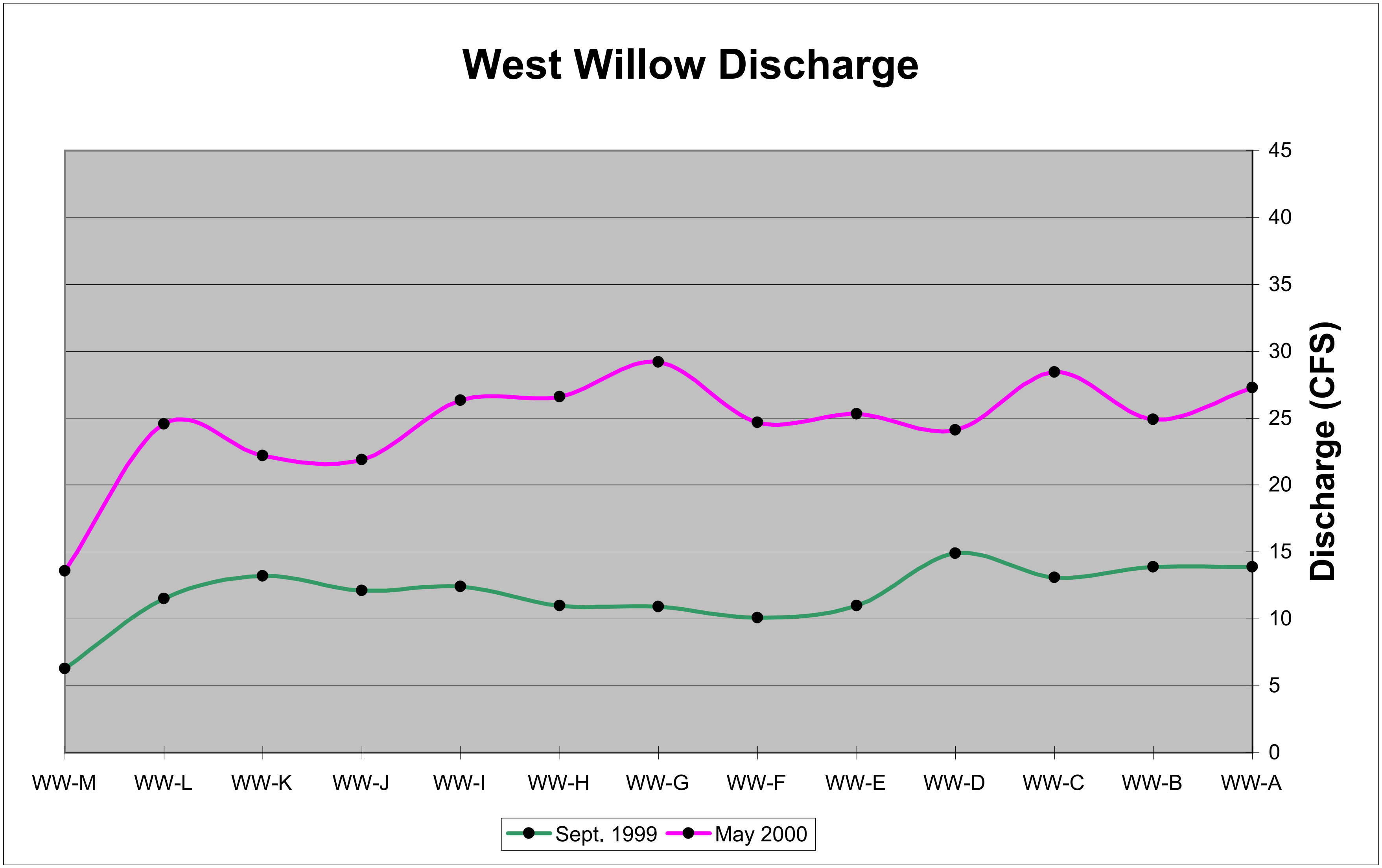


Figure 15. Discharge measurements for West Willow Creek in September 1999 and May 2000.

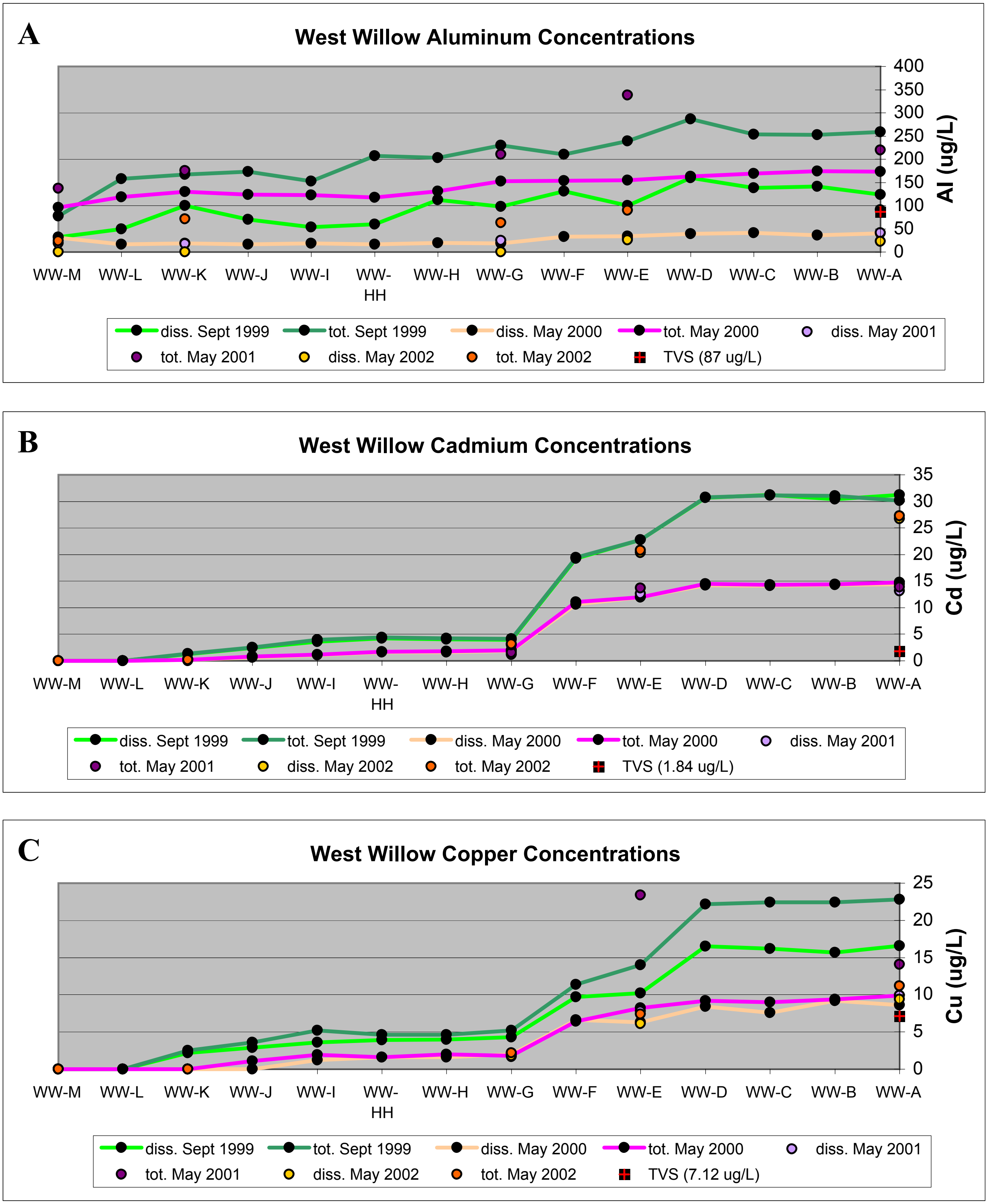
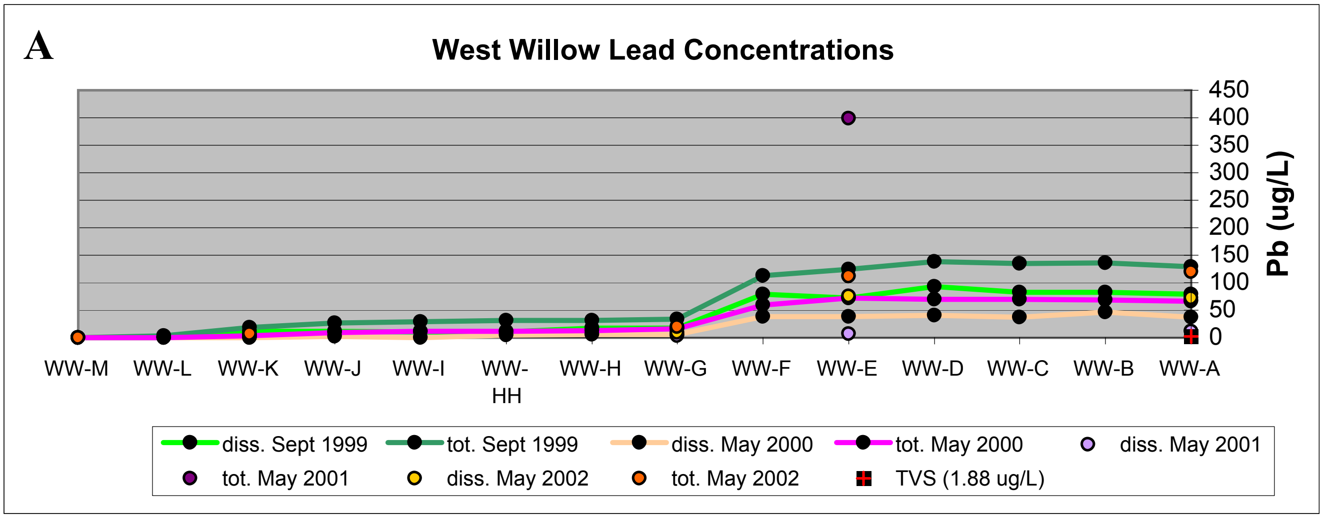
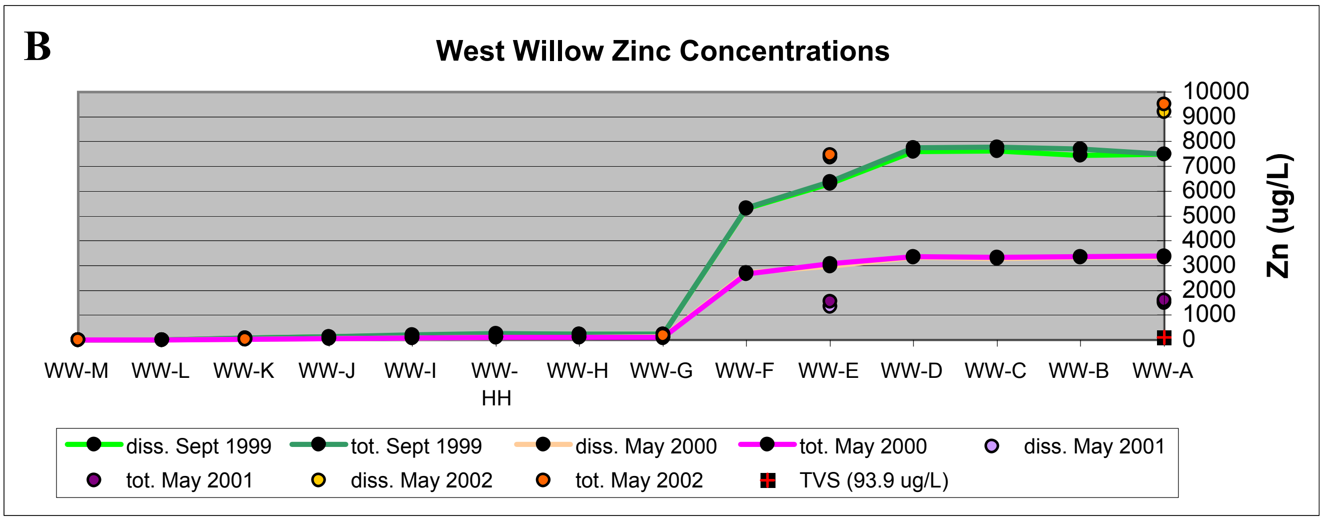


Figure 16. Concentrations of A) aluminum, B) cadmium, and C) copper in West Willow in September 1999, and May 2000, 2001, and 2002. Values are presented in ug/L. Table Value Standards (TVS) are based on an average hardness of 76.5 mg $CaCO_3$/L at WW-A.





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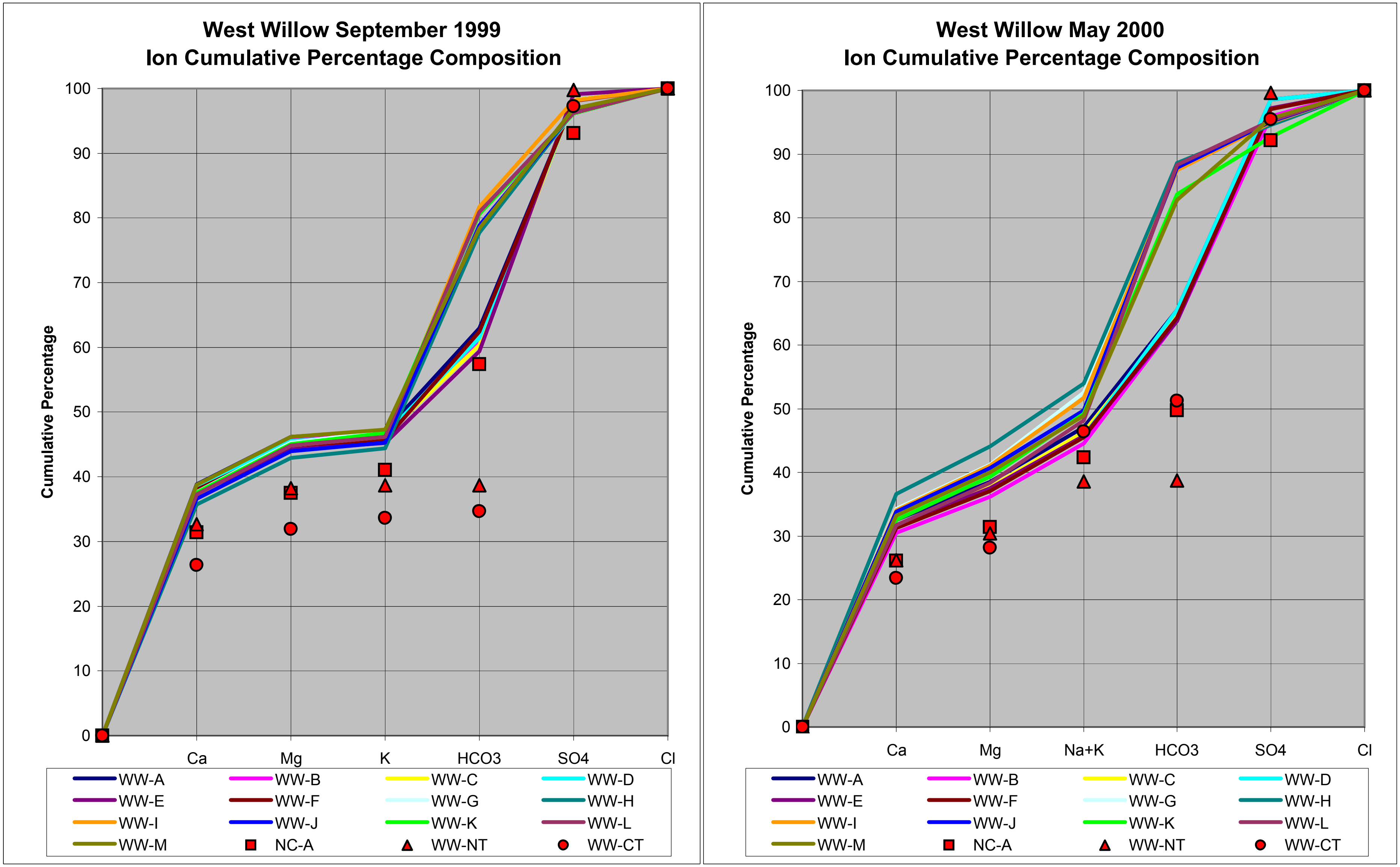
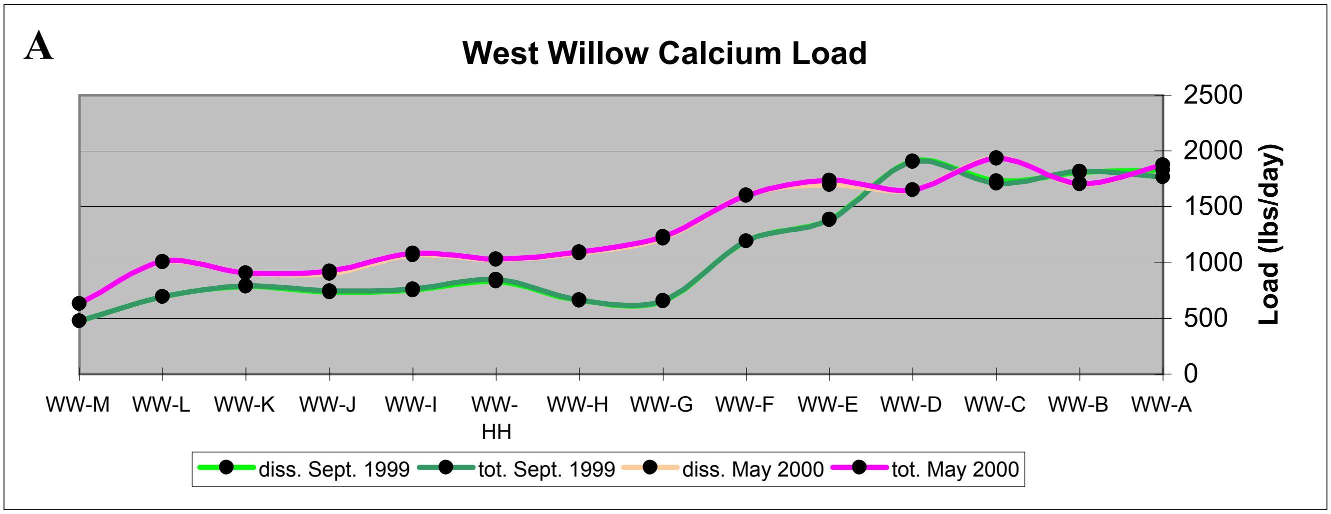
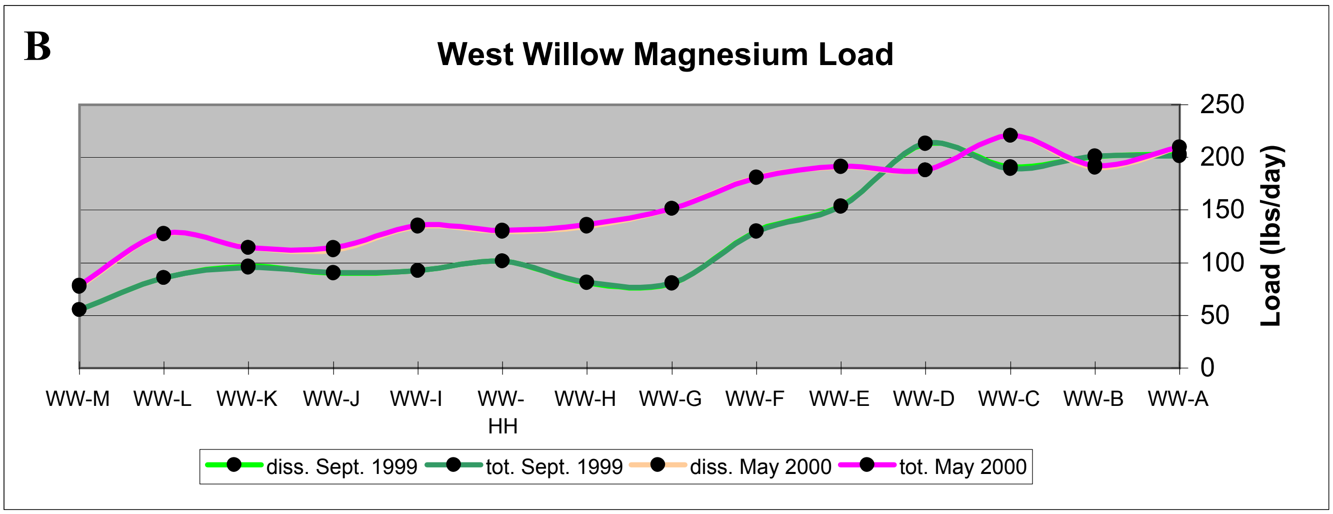


Figure 18. West Willow ion composition for September 1999 and May 2000. Inflows to West Willow are shown with symbols. No data for sodium (Na) were collected in September 1999. Calculations are based on meq/L.





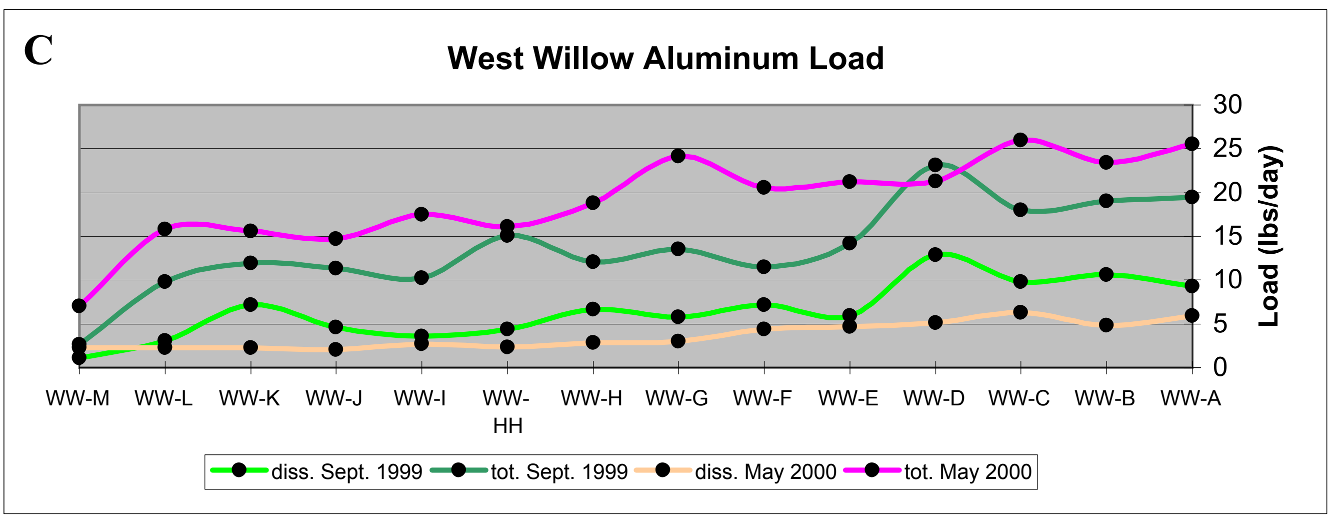
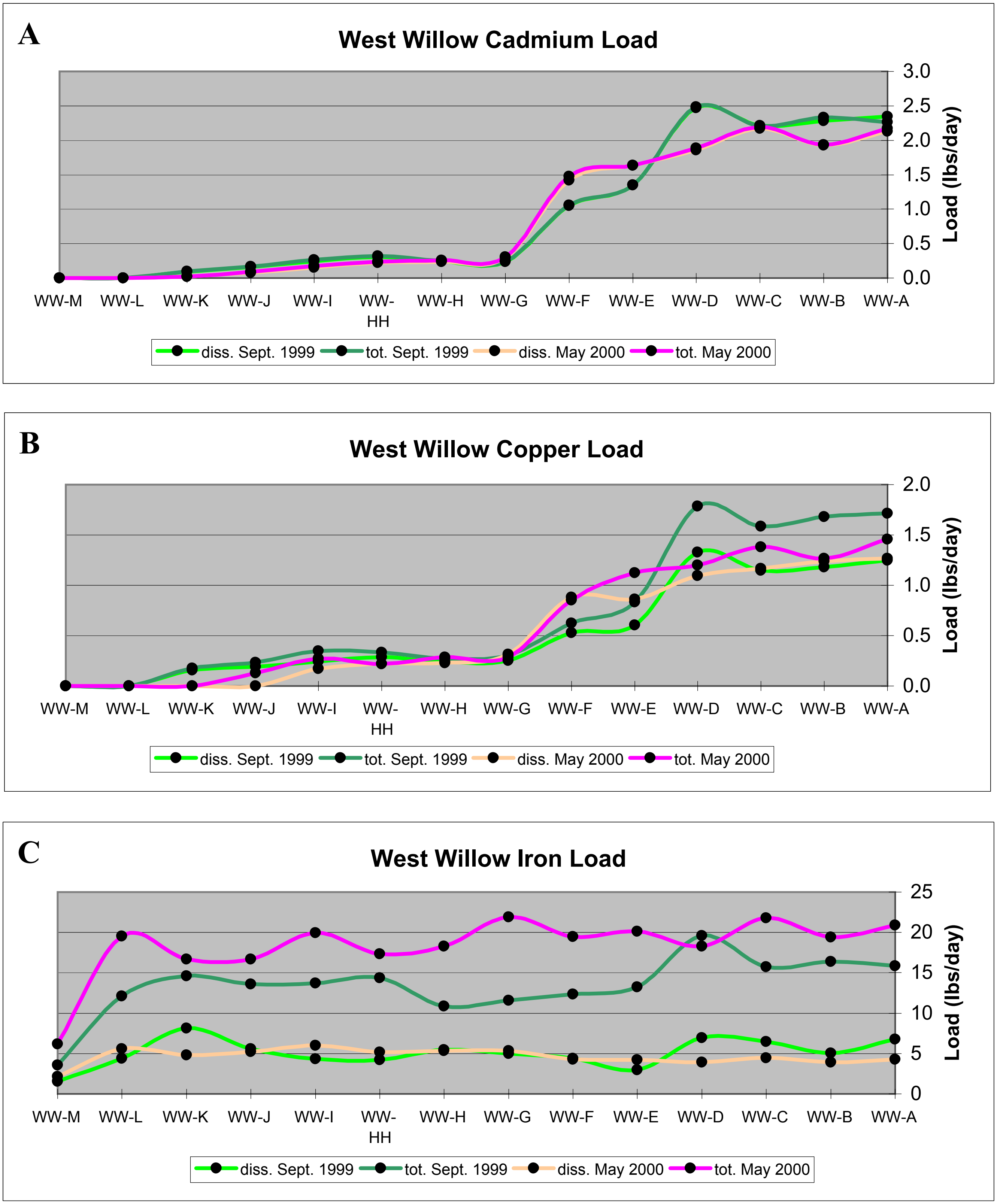


Figure 19. Estimated loads of A) calcium, B) magnesium, and C) aluminum from upstream to downstream West Willow Creek. Samples were collected in September 1999 and May 2000.



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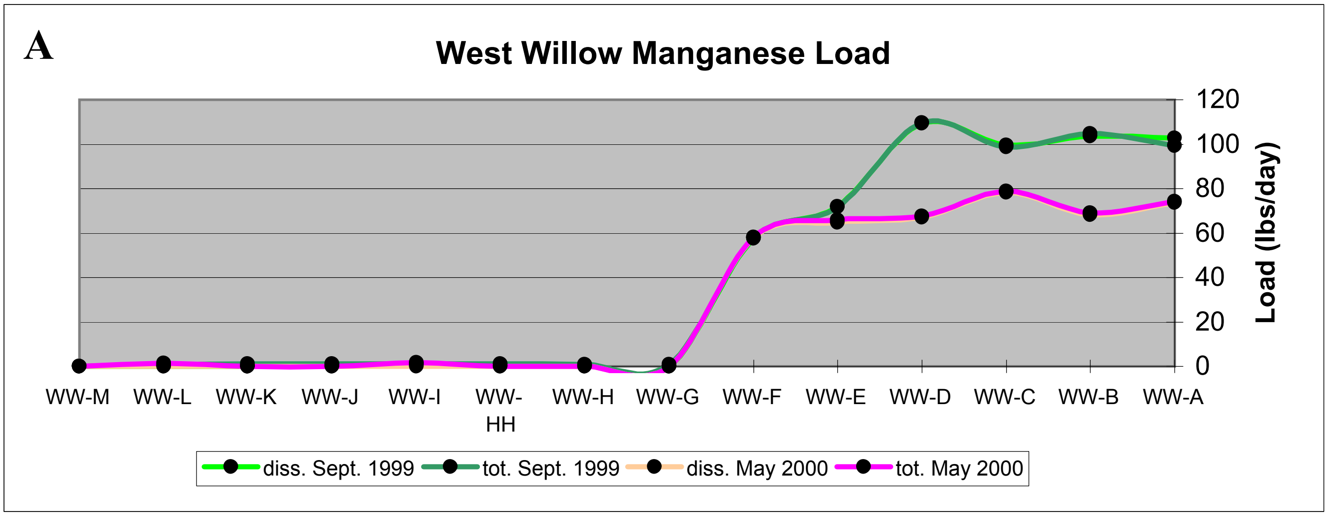
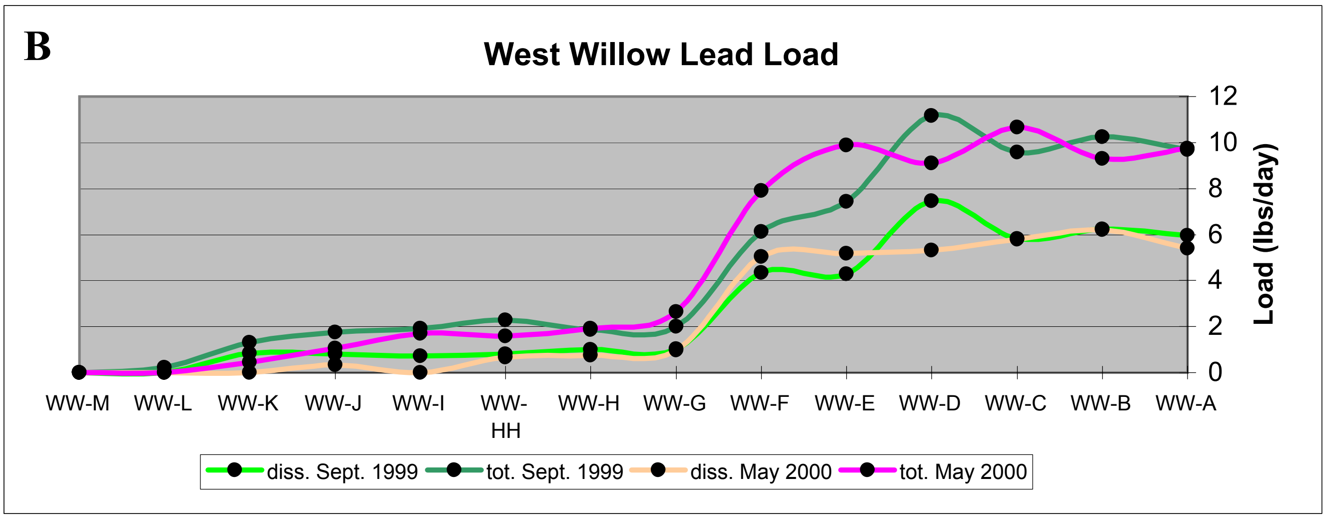




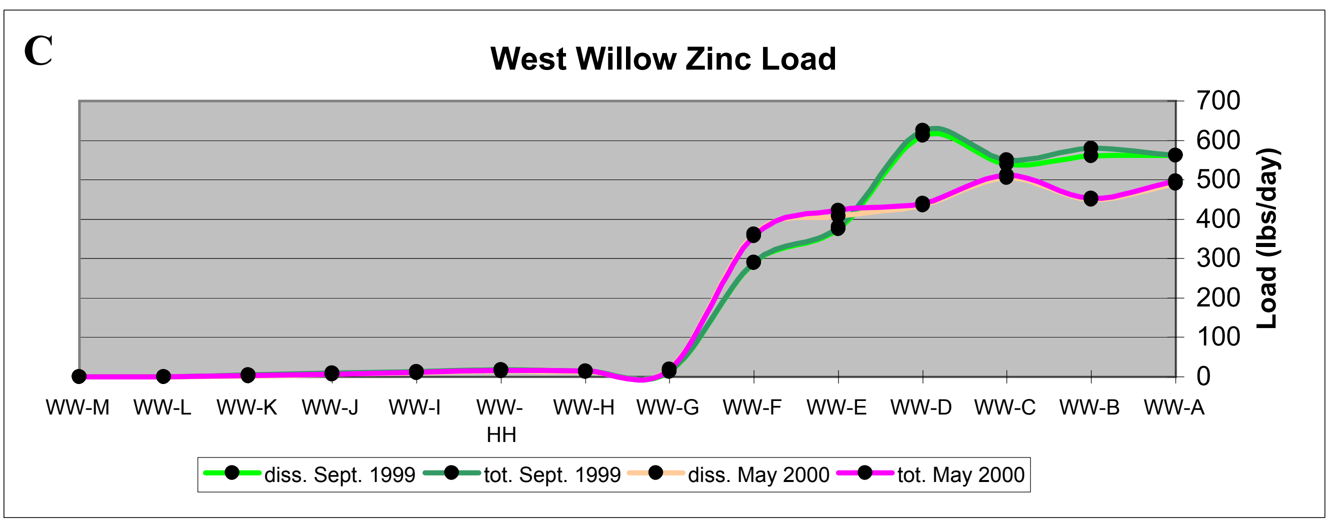
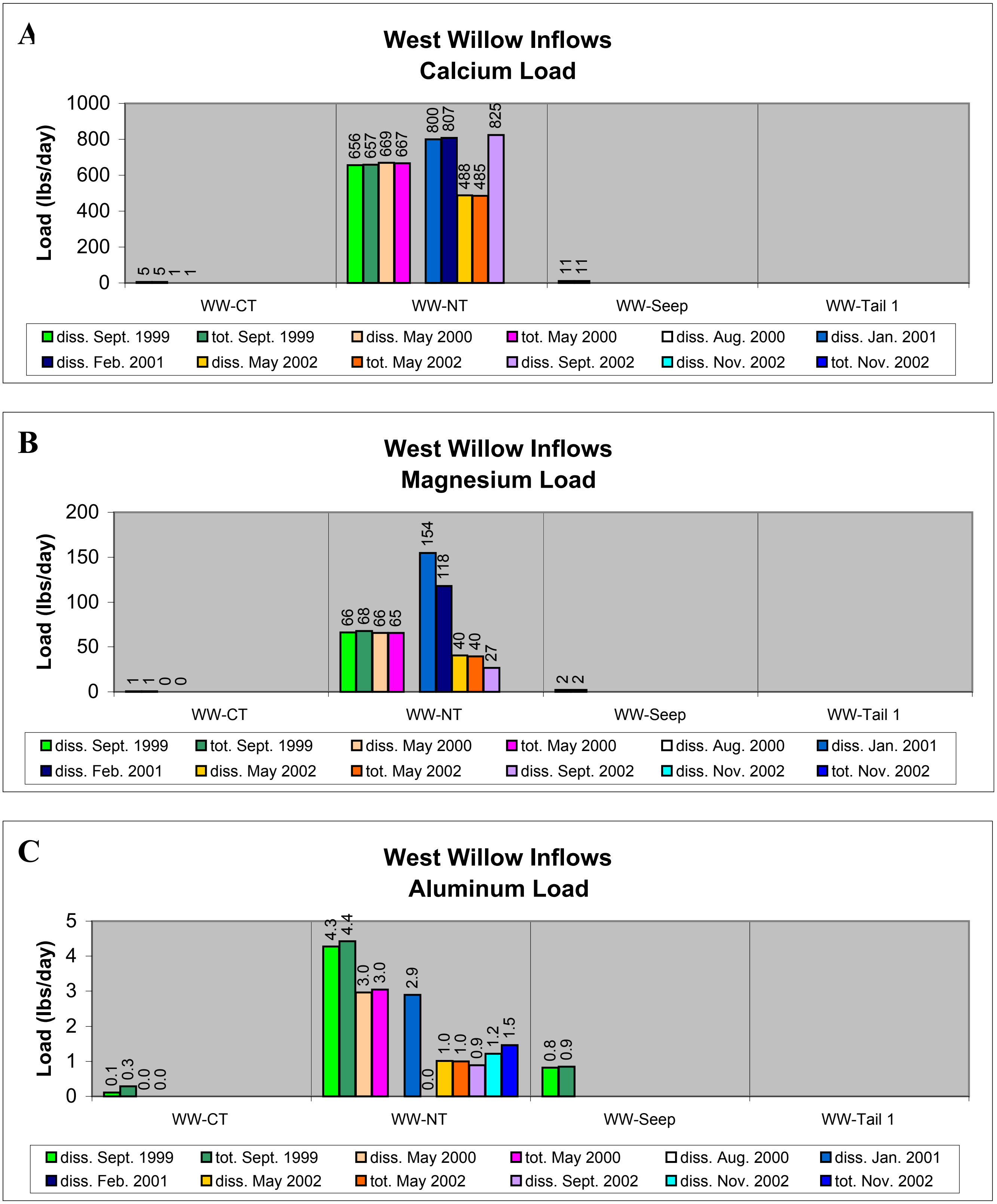


Figure 21. Estimated loads of A) manganese, B) lead, and C) zinc from upstream to downstream West Willow Creek. Samples were collected in September 1999 and May 2000.



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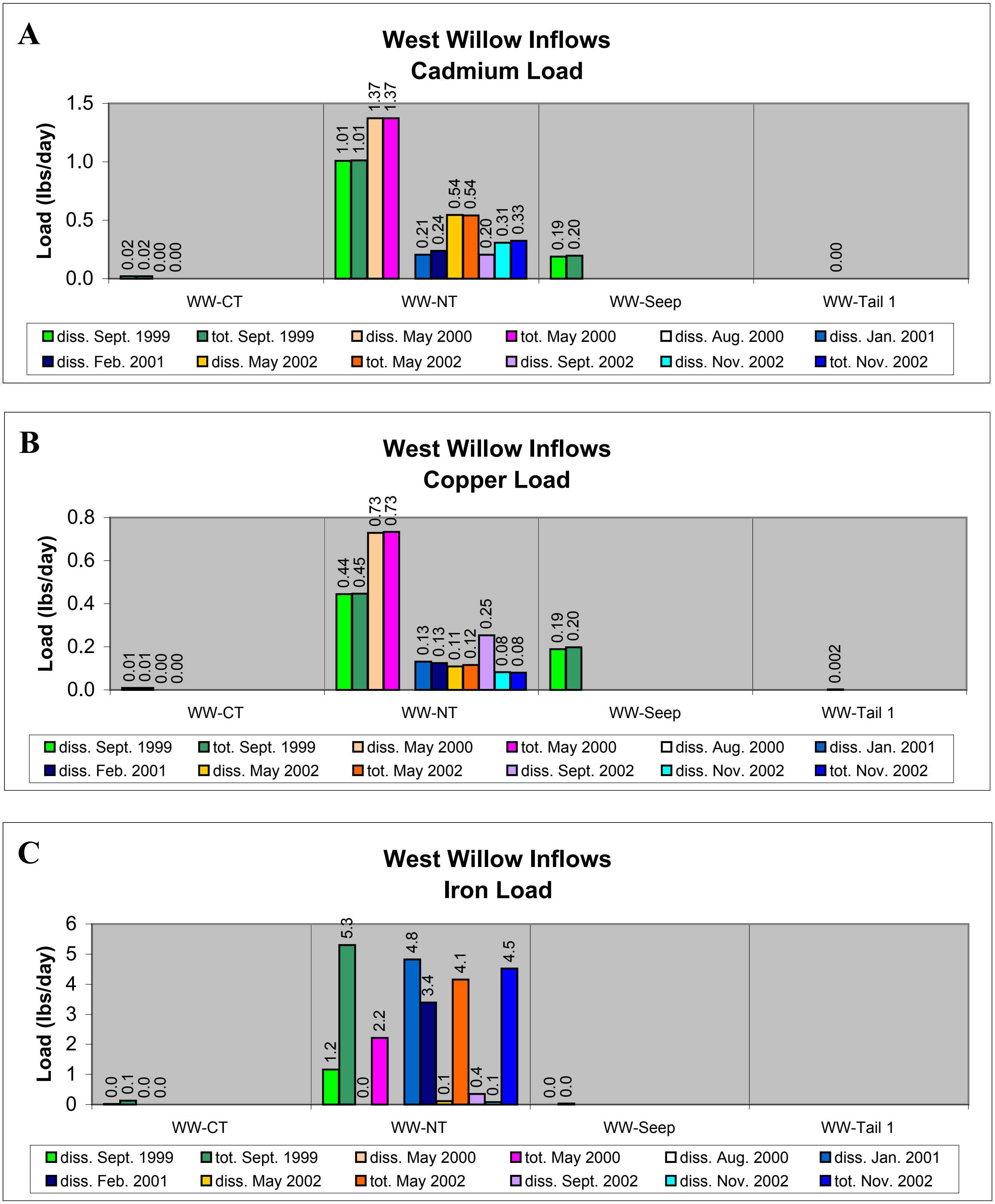


Figure 23. Estimated loads of A) cadmium, B) copper, and C) iron in West Willow Inflows. Samples were collected in September 1999, May and August 2000, January and February 2001, and May, September, and November 2002.

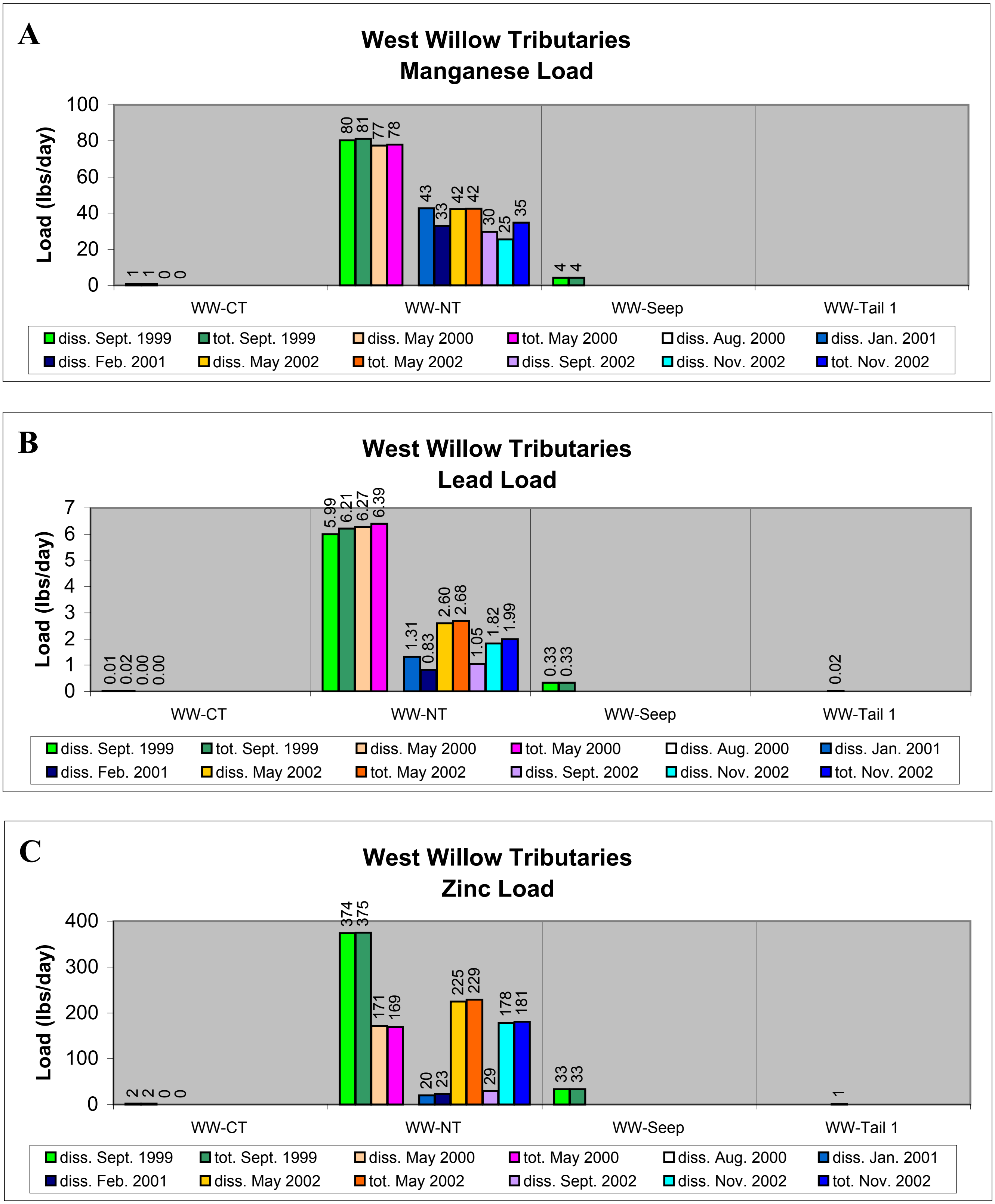


Figure 24. Estimated loads of A) manganese, B) lead, and C) zinc in West Willow Inflows. Samples were collected in September 1999, May and August 2000, January and February 2001, and May, September, and November 2002.

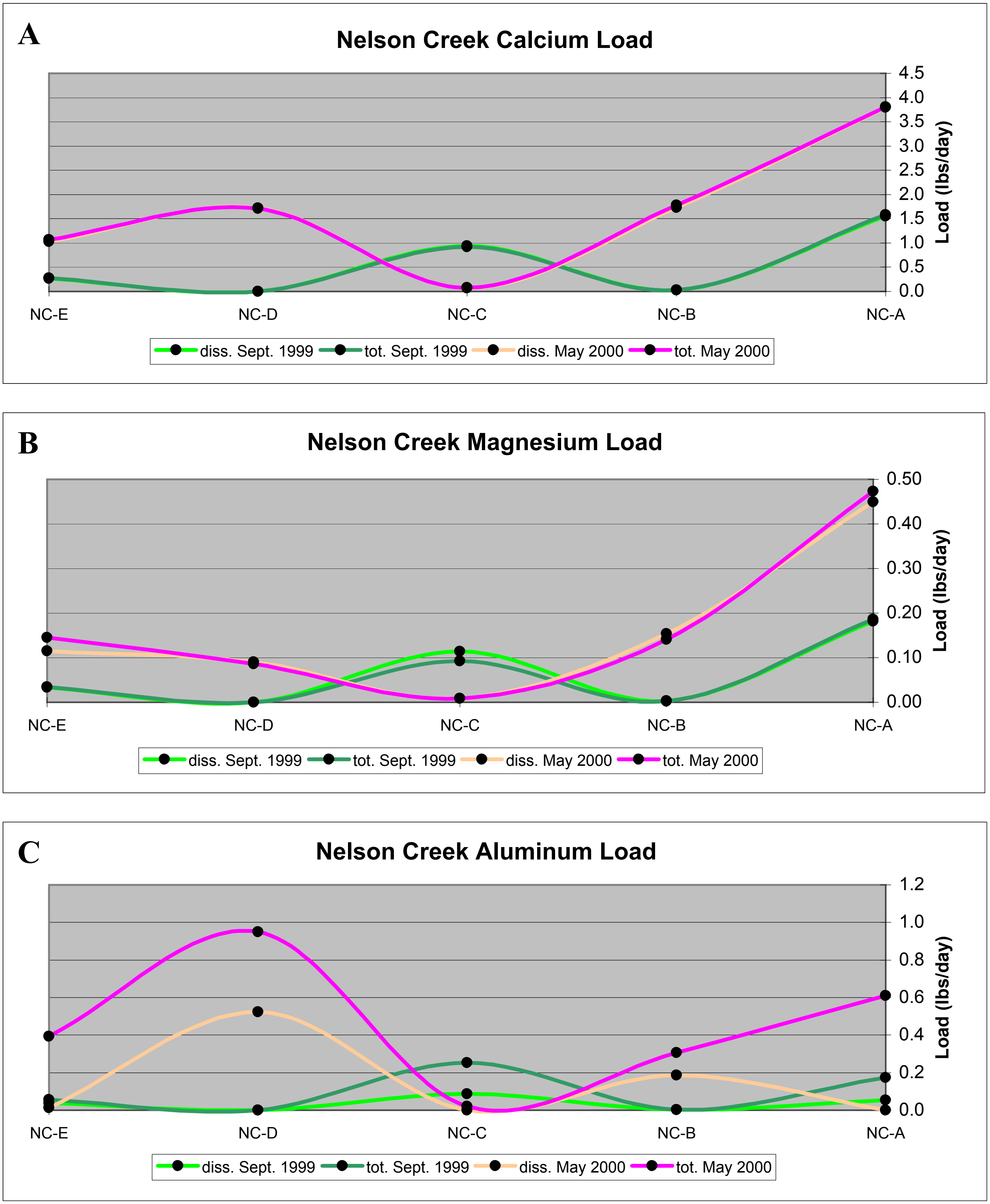
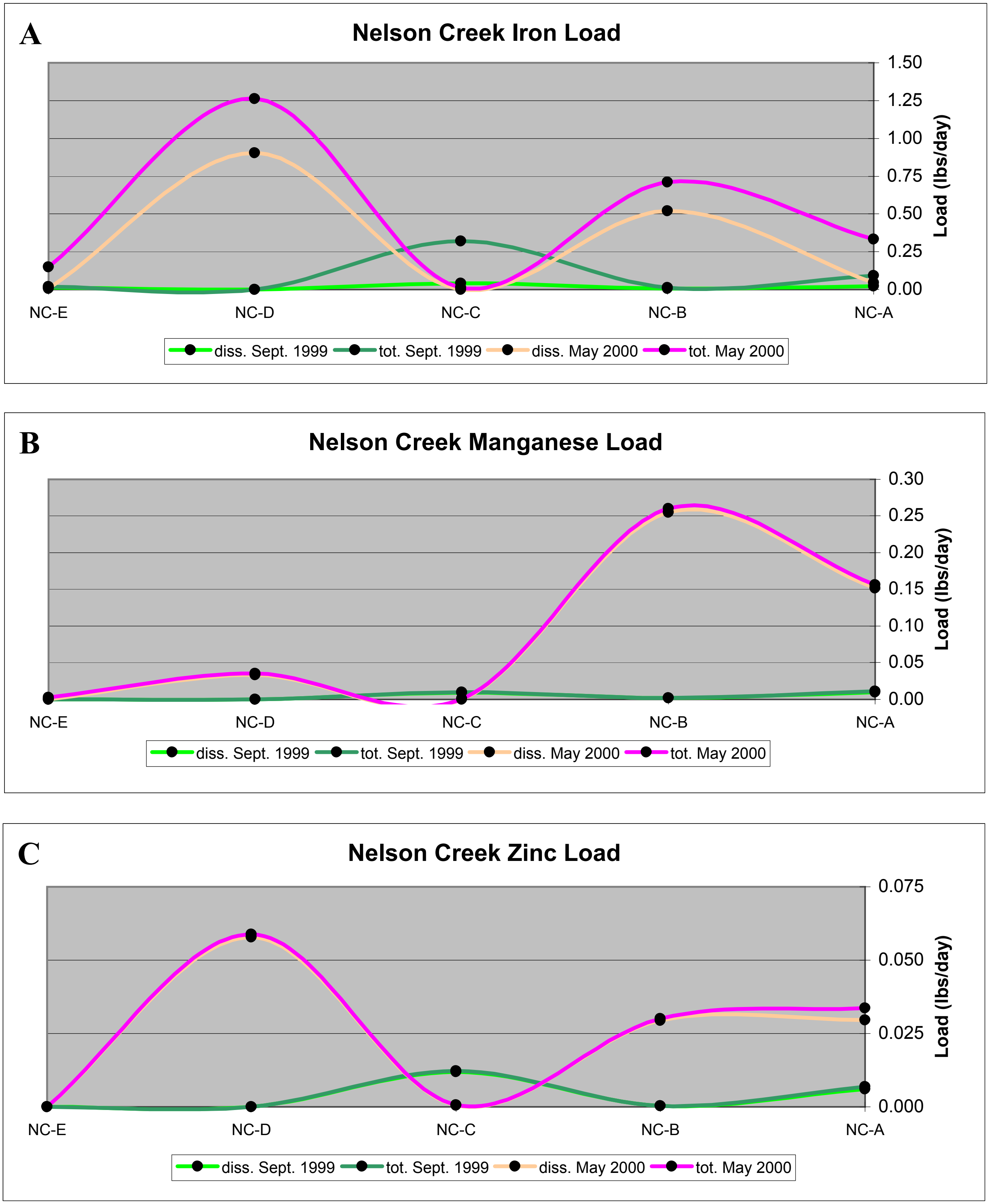


Figure 25. Estimated loads of A) calcium, B) magnesium, and C) aluminum in Nelson Creek and the seep/spring NC-C. Samples were collected in September 1999 and May 2000, and analyzed for dissolved and total fractions.



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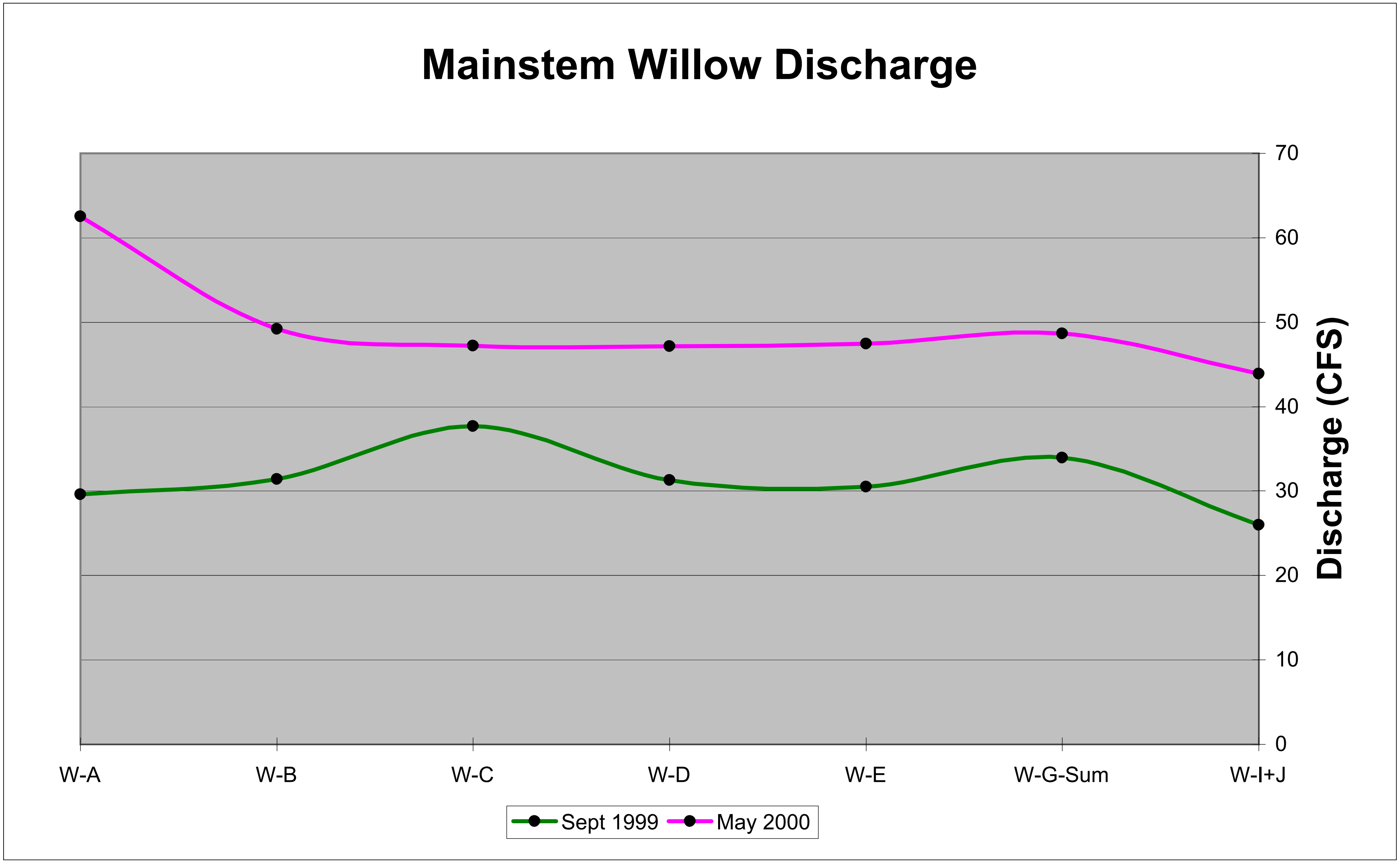
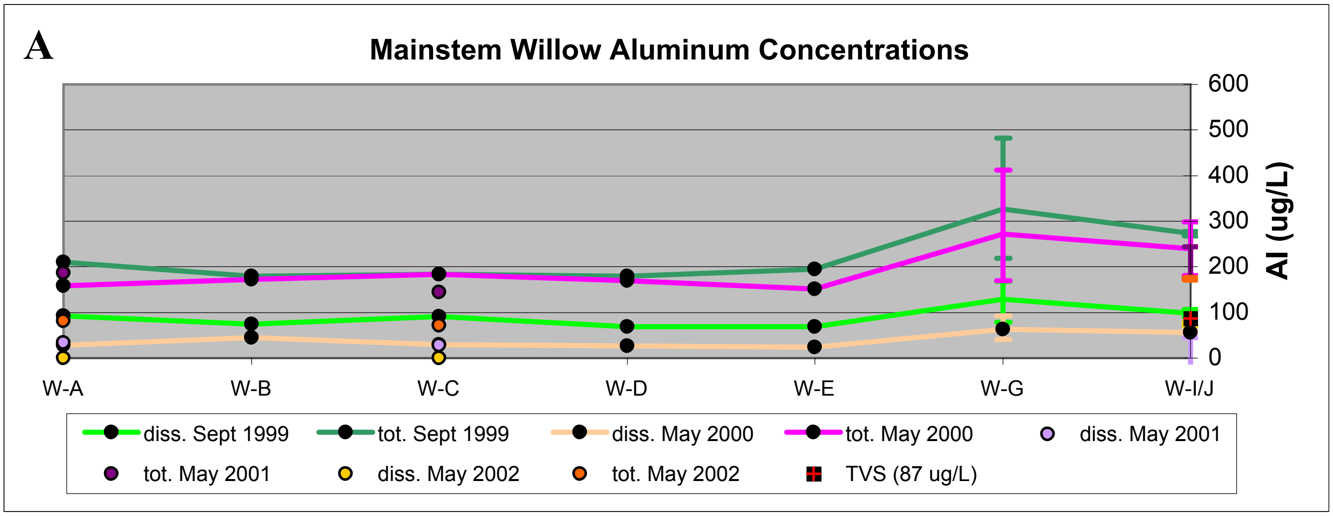
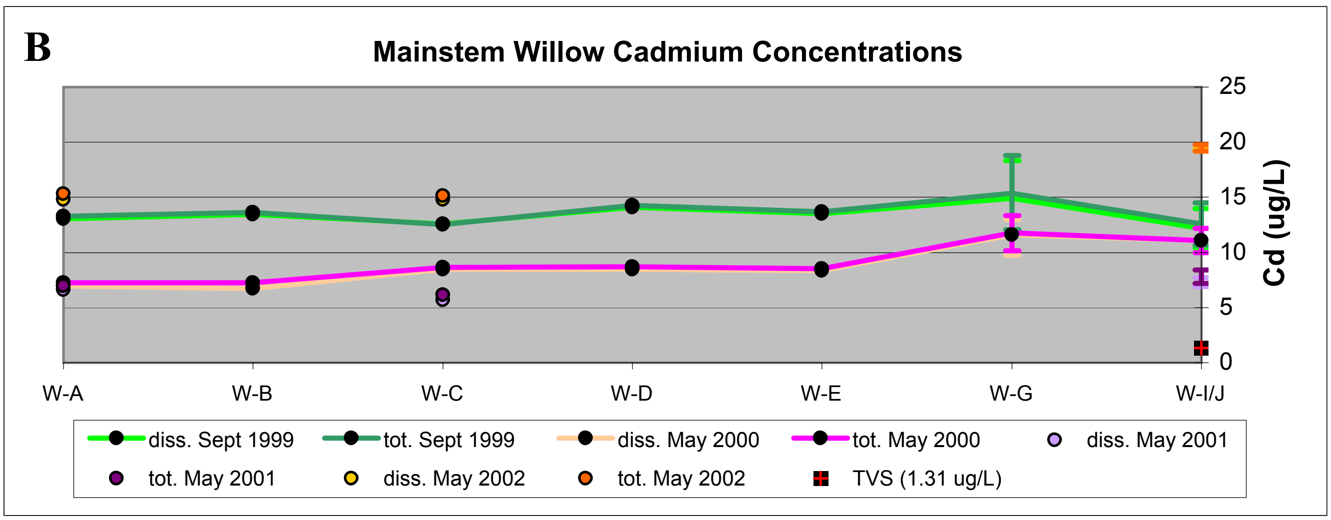


Figure 27. Discharge measurements for Mainstem Willow Creek in September 1999 and May 2000. Discharge measurements were totaled for braided areas of the stream at W-G and at W-I/W-J.





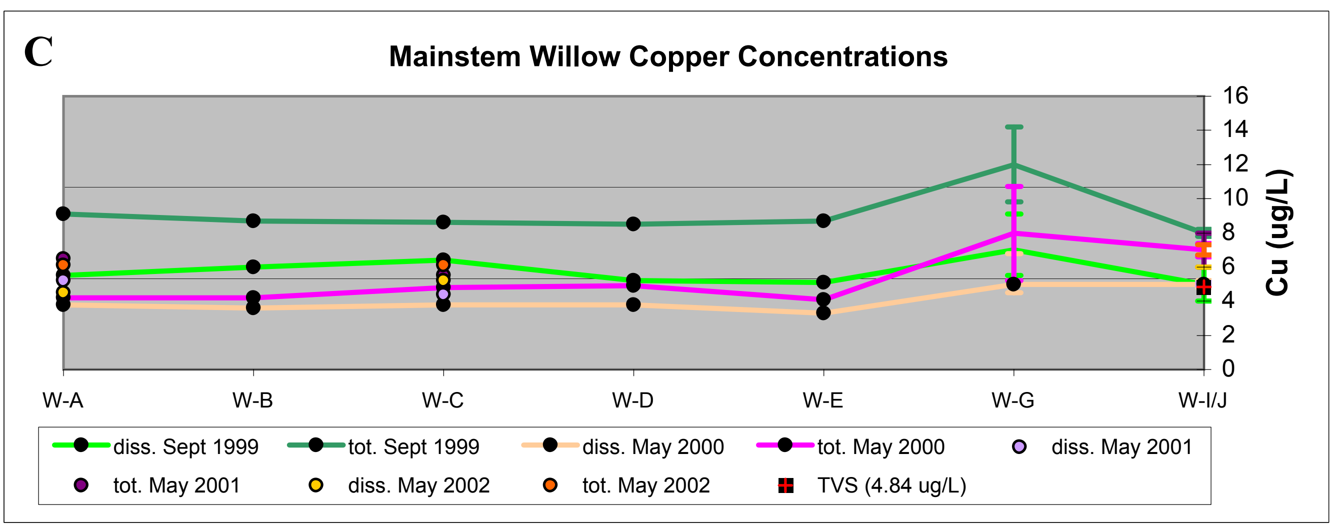
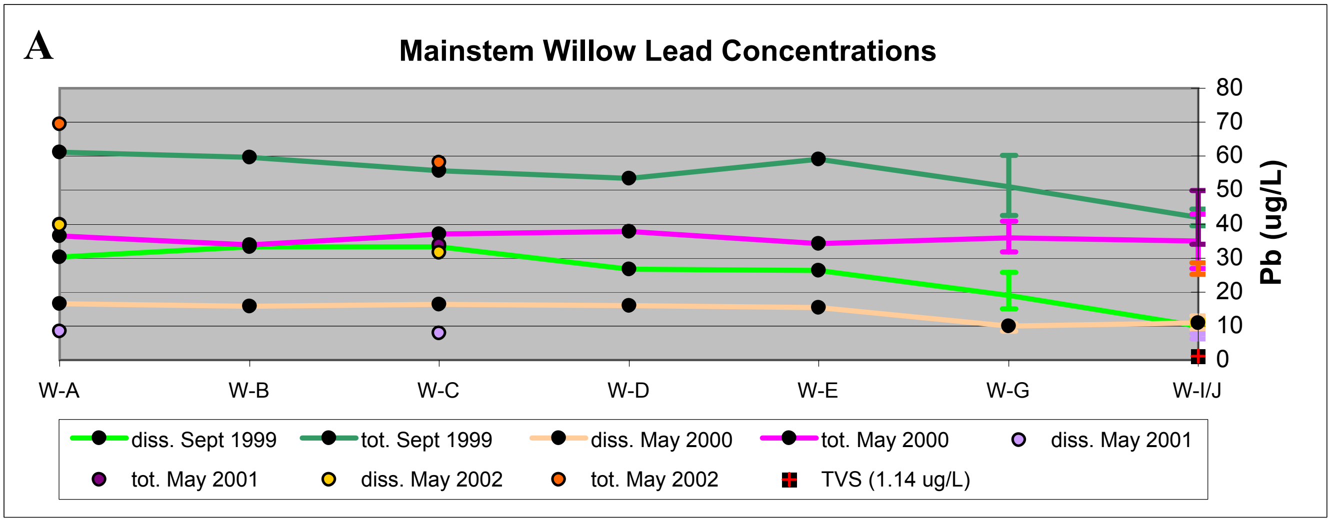


Figure 28. Concentrations of A) aluminum, B) cadmium, and C) copper in Mainstem Willow in September 1999, and May 2000, 2001, and 2002. Values are presented in ug/L. Values from braided sites were averaged. Vertical bars indicate maximum and minimum values at braided sites. Table Value Standards (TVS) are based on an average hardness of 48.7 mg $CaCO_3$/L at W-I/J.



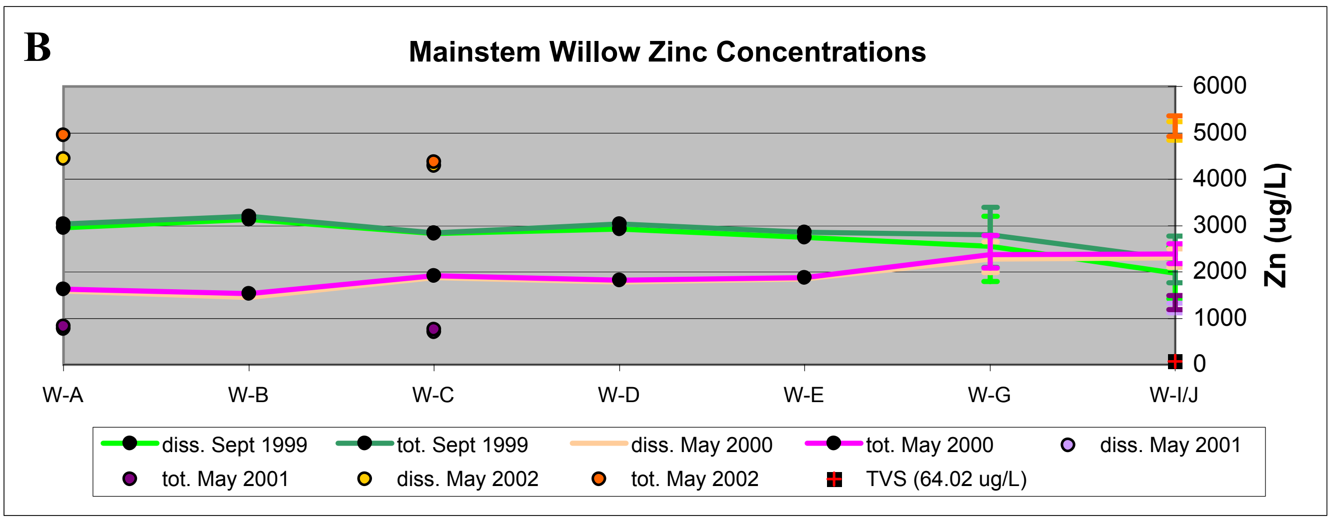


Figure 29. Concentrations of A) lead and B) zinc in Mainstem Willow in September 1999, and May 2000, 2001, and 2002. Values are presented in ug/L. Values from braided sites were averaged. Vertical bars indicate maximum and minimum values at braided sites. Table Value Standards (TVS) are based on an average hardness of 48.7 mg $CaCO_3$/L at W-I/J.

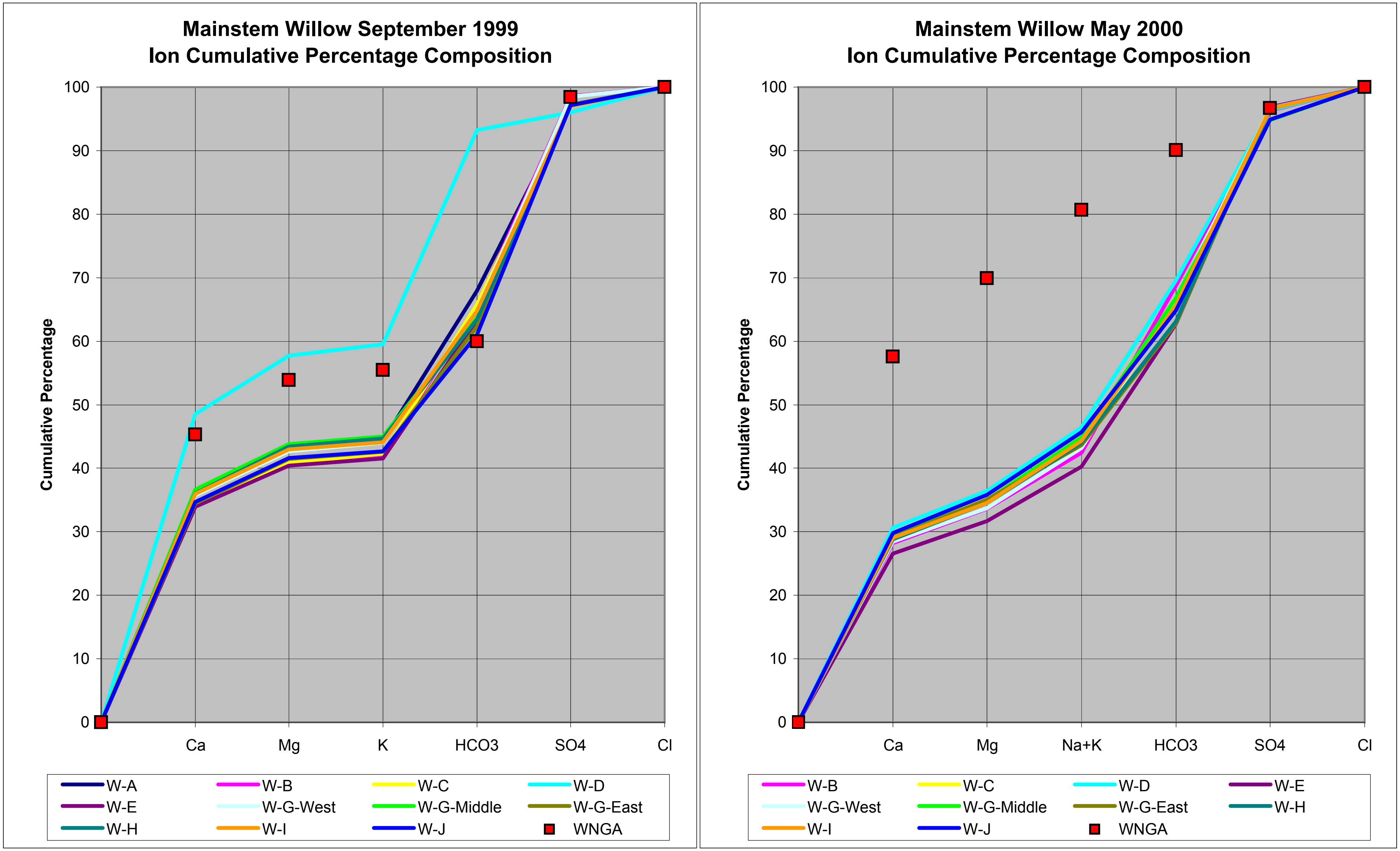
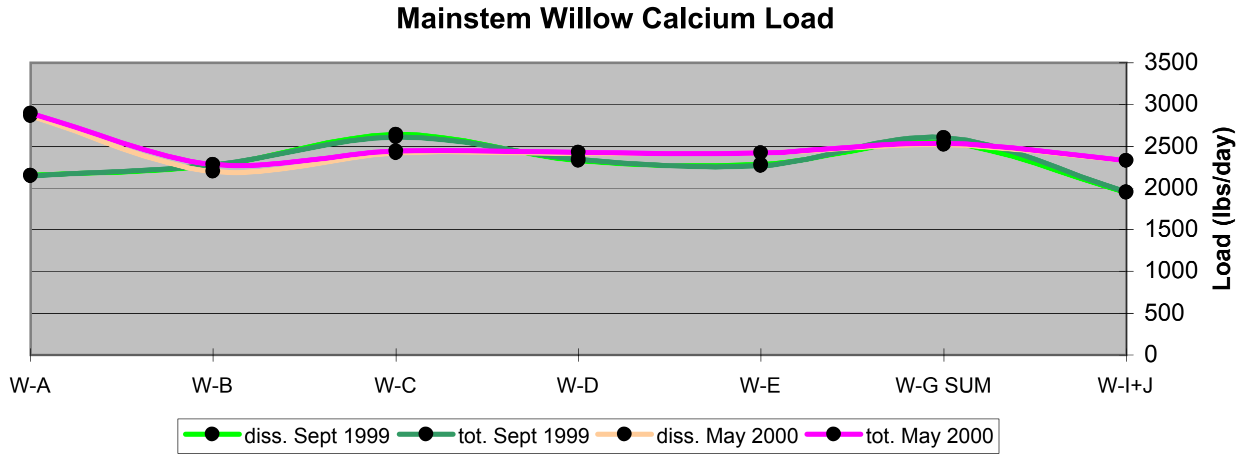


Figure 30. Mainstem Willow ion composition for September 1999 and May 2000. Inflows to Mainstem Willow are shown with symbols. No data for sodium (Na) were collected in September 1999. Calculations are based on meq/L.

A



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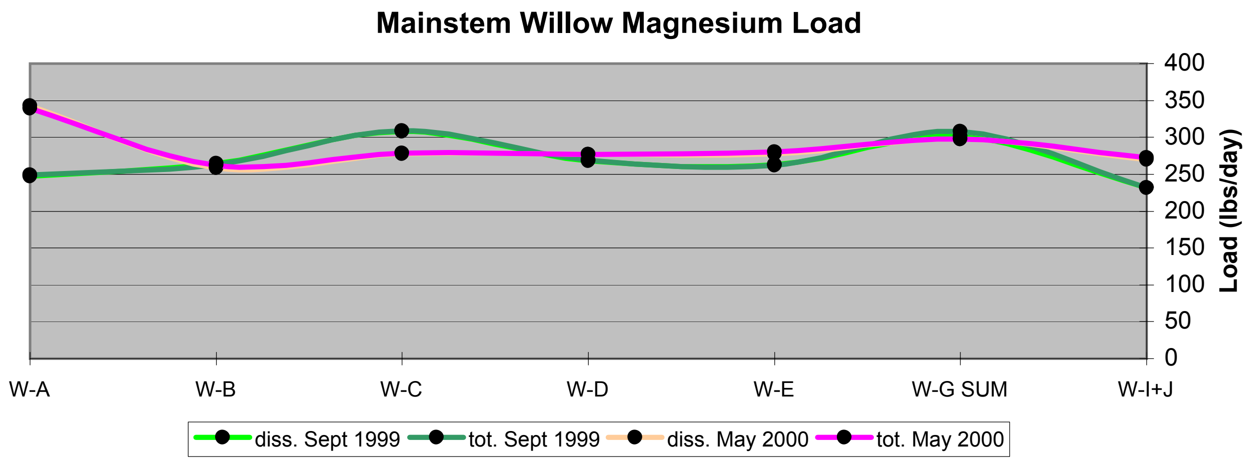


C

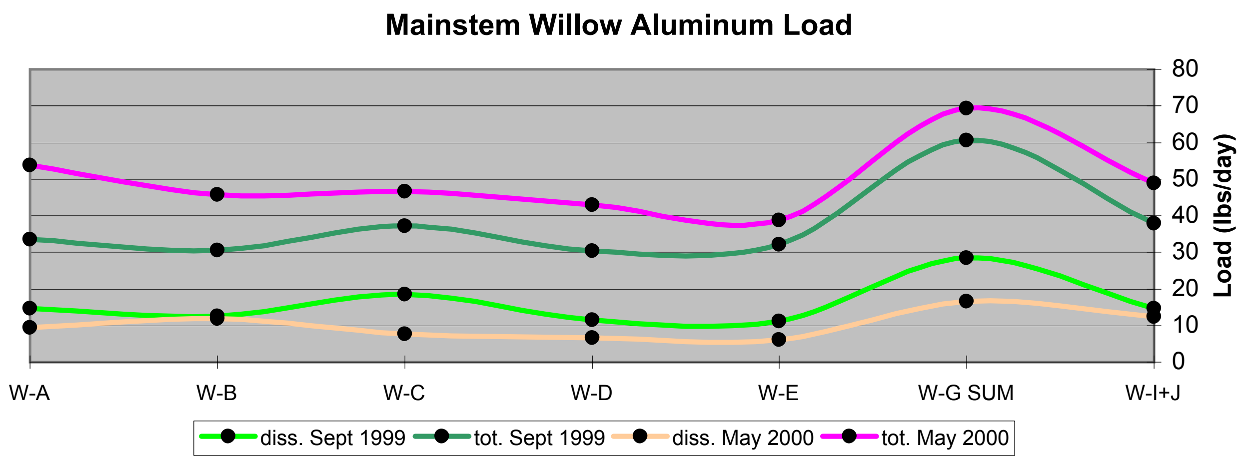


Figure 31. Estimated loads of A) calcium, B) magnesium, and C) aluminum in Mainstem Willow Creek. Samples were collected in September 1999 and May 2000. Samples were analyzed for dissolved and total fractions.

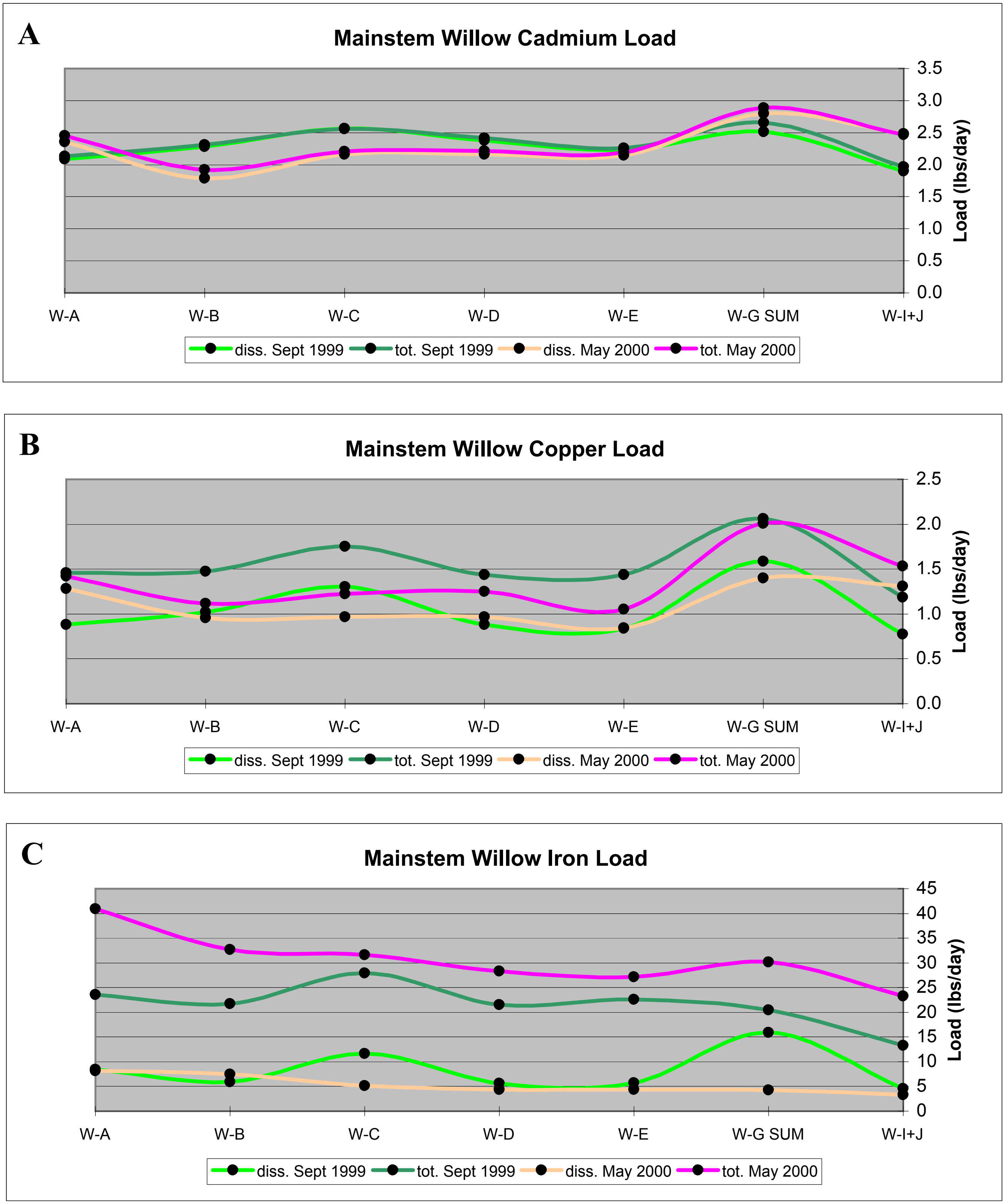
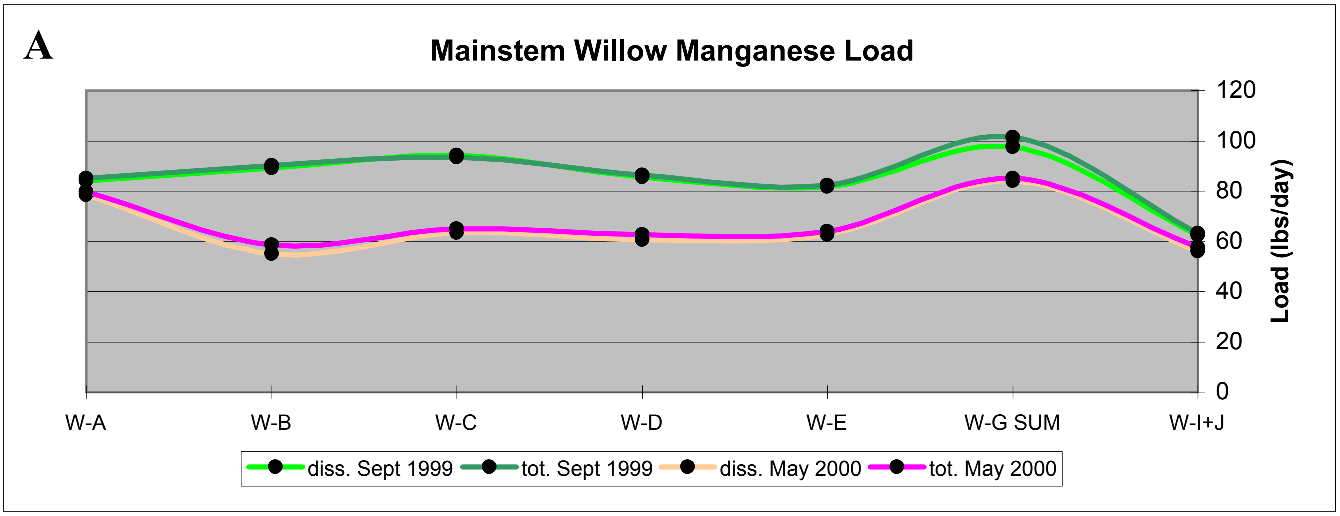
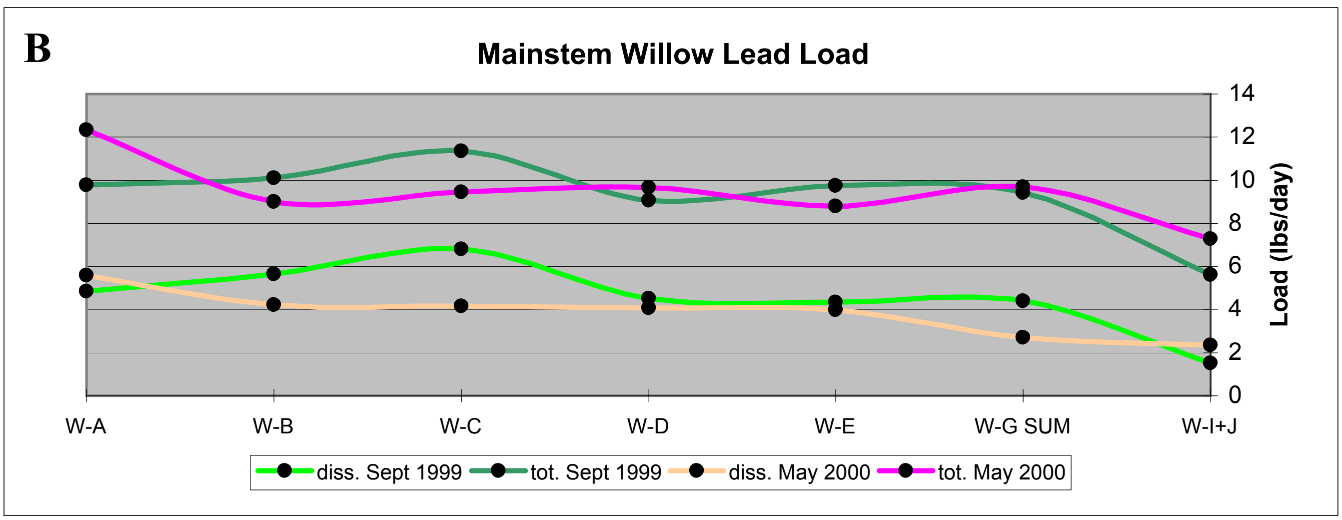


Figure 32. Estimated loads of A) cadmium, B) copper, and C) iron in Mainstem Willow Creek. Samples were collected in September 1999 and May 2000. Samples were analyzed for dissolved and total fractions.





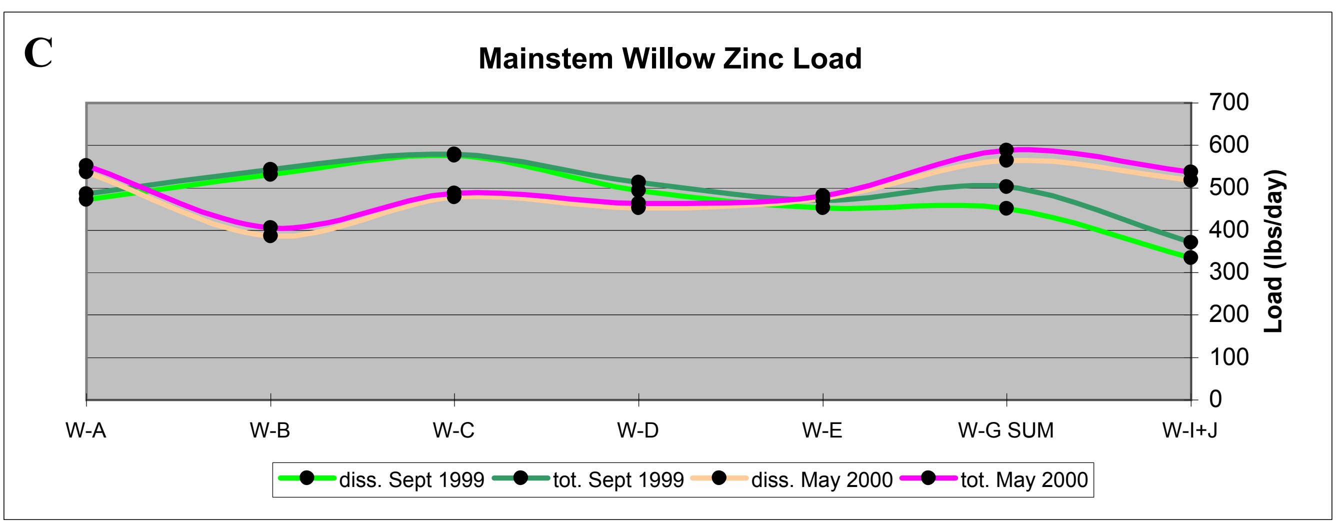


Figure 33. Estimated loads of A) manganese, B) lead, and C) zinc in Mainstem Willow Creek. Samples were collected in September 1999 and May 2000. Samples were analyzed for dissolved and total fractions.

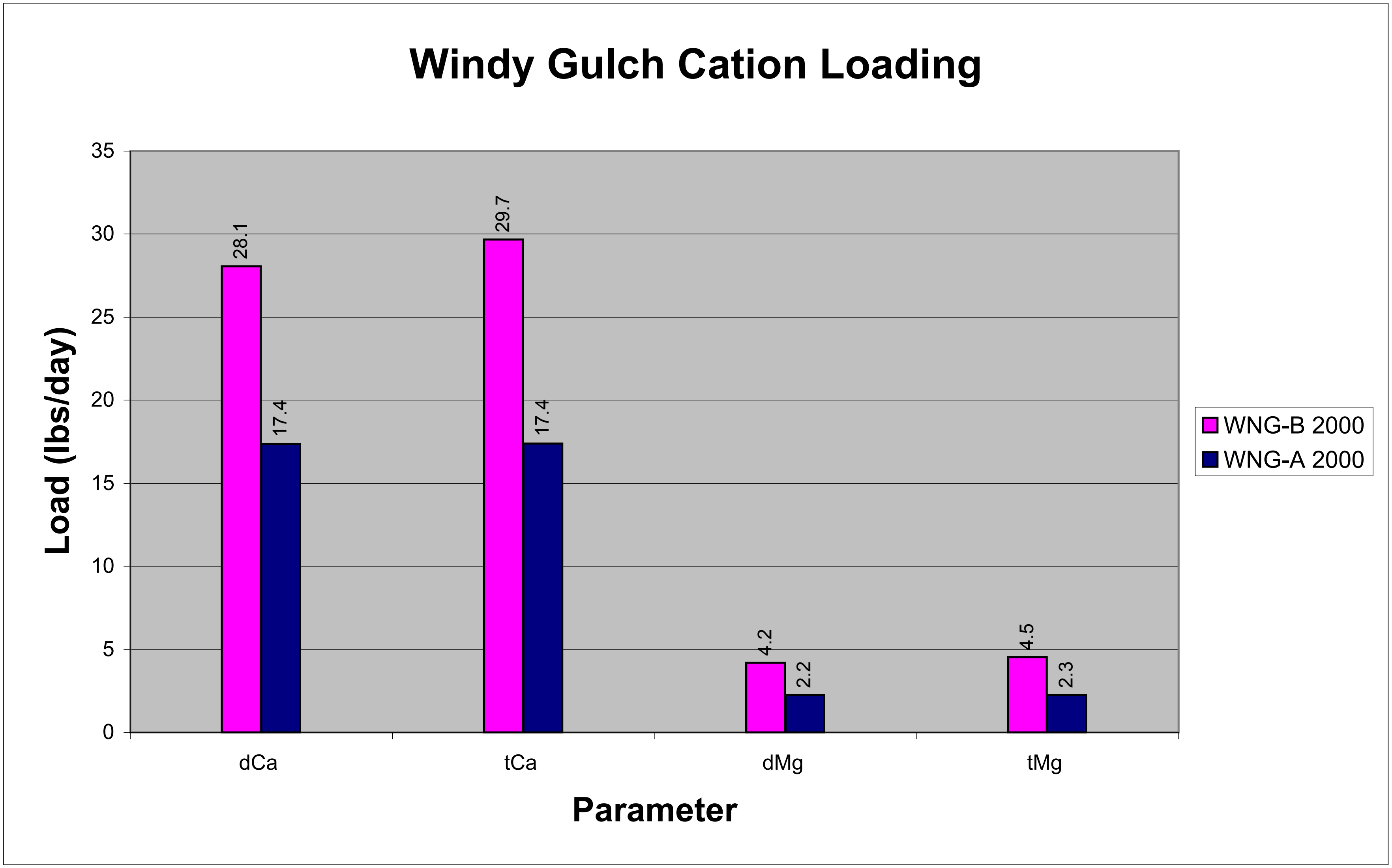


Figure 34. Windy Gulch loading of calcium (Ca) and magnesium (Mg) based on flow and concentration values from May 2000. Windy Gulch B is upstream of A. Prefixes of "d" and "t" indicate dissolved and total fractions, respectively.

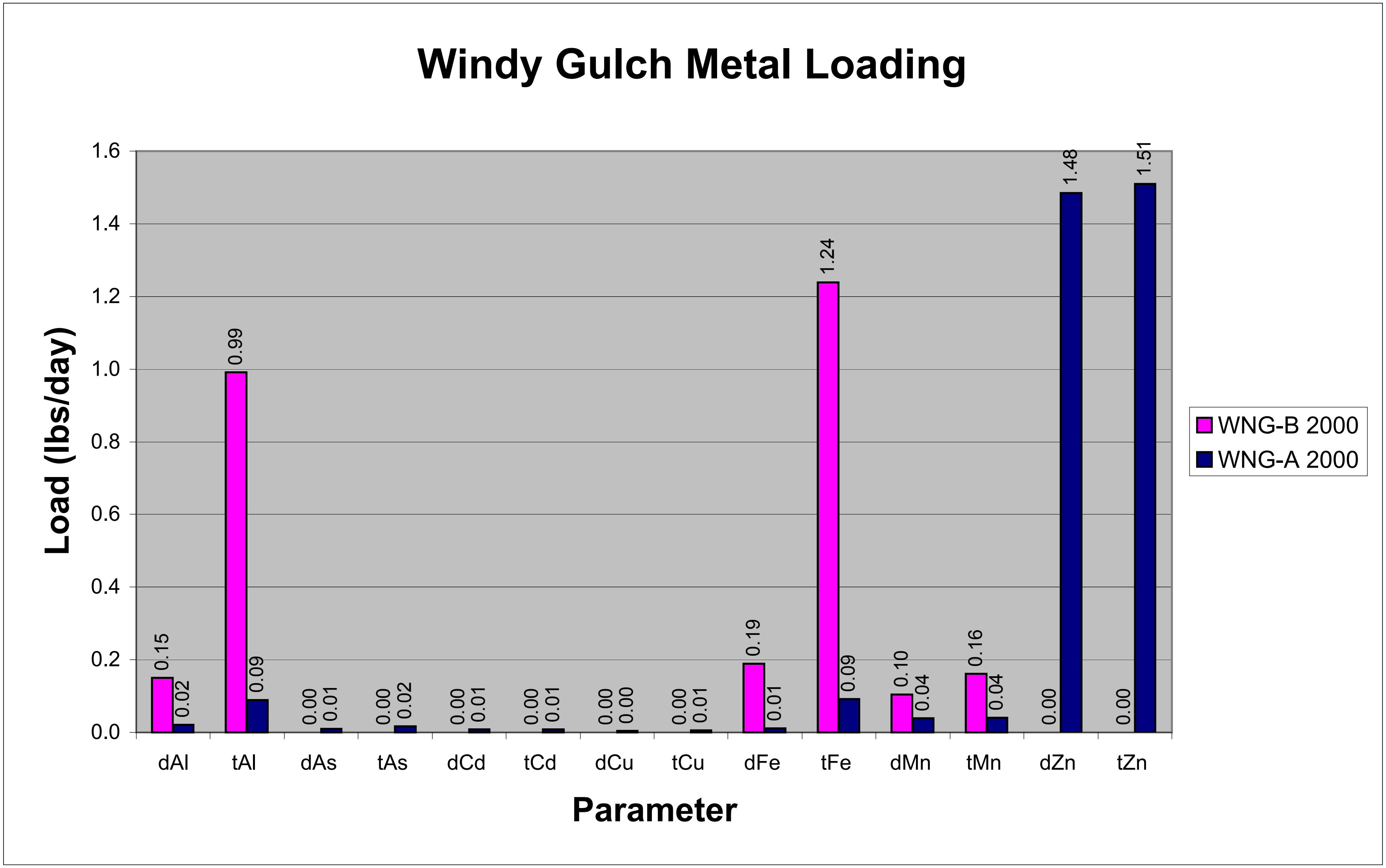


Figure 35. Windy Gulch metal loading based on flow and concentration values from May 2000. Windy Gulch B is upstream of A. Prefixes of "d" and "t" indicate dissolved and total fractions, respectively.

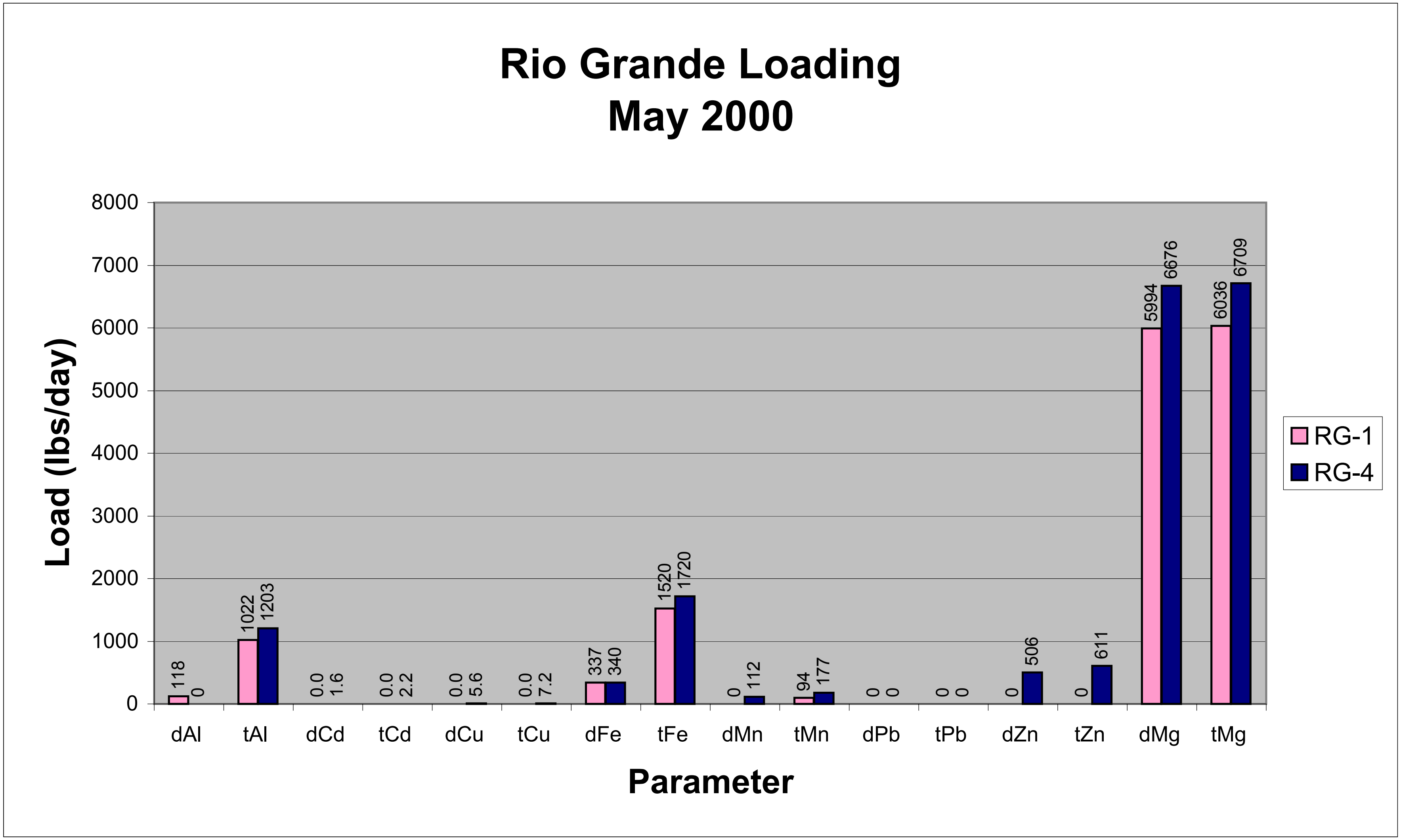


Figure 36. Rio Grande loading based on flow and concentration values from May 2000. Rio Grande 1 (RG-1) is upstream of the confluence with Willow Creek. RG-4 is at Wason Ranch and below the confluence with Willow Creek. Prefixes of "d" and "t" indicate dissolved and total fractions, respectively.

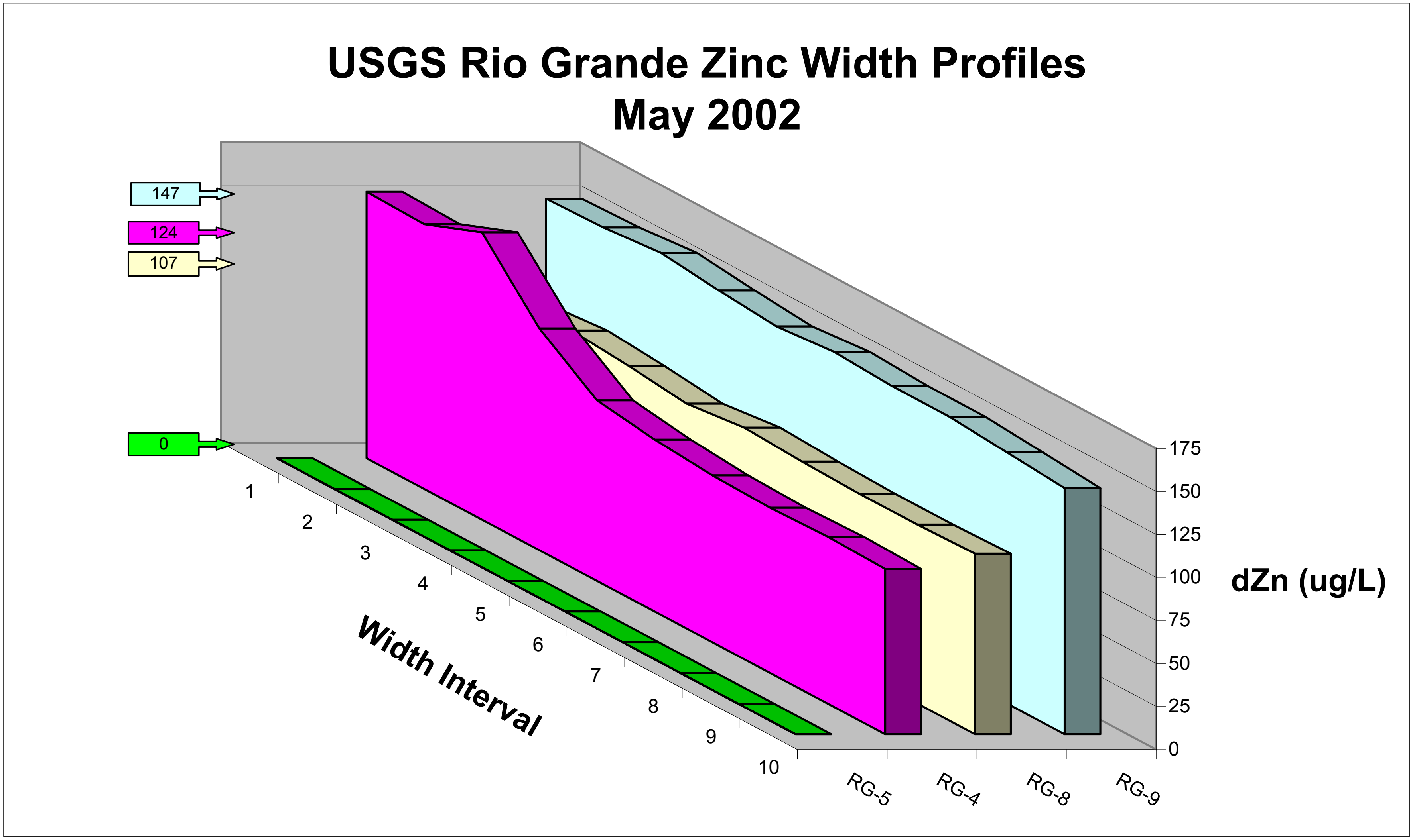
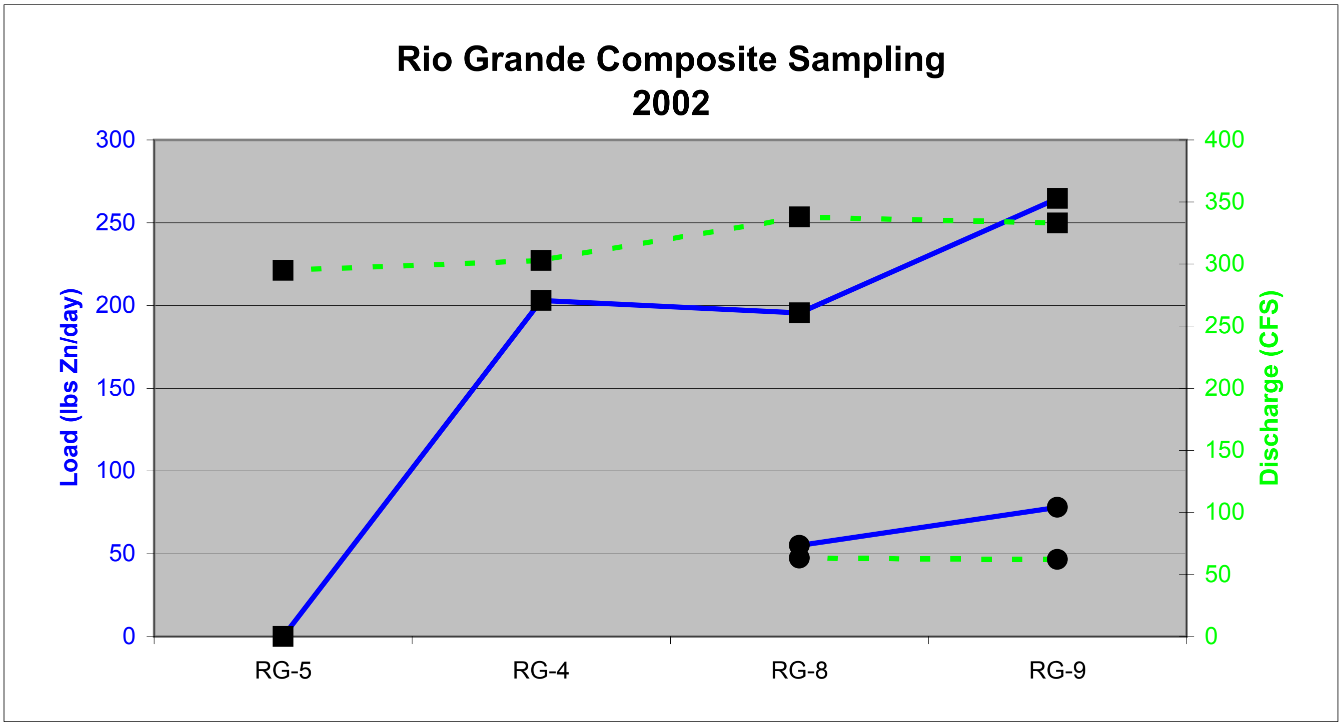


Figure 37. Width-integrated zinc concentrations at four sites on the Rio Grande. Samples were collected by the USGS in May 2002. Sites from upstream to downstream were RG-5 Deep Creek Bridge, RG-4 Wason Bridge, RG-8 La Garita Bridge, and RG-9 4UR Bridge. Boxes indicate composite zinc concentrations.



Site	Date	Time	Sample Type	Discharge (CFS)	DO (mg/L)	pH	Specific Conductance	Water Temp	dZn (ug/L)	Load (lbs Zn/day)
RG-5	5/3/2002	2000	composite	295	8.0	8.0	70	9.5	<1	0
RG-4	5/3/2002	1745	composite	303	8.2	7.9	77	9.0	124	203
RG-8	5/3/2002	1445	composite	338	8.2	7.8	78	10.5	107	195
RG-9	5/3/2002	1145	composite	333	9.0	7.7	77	5.8	147	265
RG-8	8/20/2002	1246	composite	63		8.2	138	13.4	162	55
RG-9	8/20/2002	917	composite	62		7.8	144	12.5	232	78

Figure 38. Discharge (dash line) and the estimated zinc load (solid line) from composite samples collected and analyzed by the USGS in May 2002 (square) and by WCRC in August 2002 (circle). Sites from upstream to downstream were RG-5 Deep Creek Bridge, RG-4 Wason Bridge, RG-8 La Garita Bridge, and RG-9 4UR Bridge.

Site	ID	Time	Flow (cfs)	pH	Temp (C)	Cond. (uS/cm)	Alk.	Hard.	dCd (ug/L)	tCd (ug/L)	dCu (ug/L)	tCu (ug/L)	dMn (ug/L)	tMn (ug/L)	dZn (ug/L)	tZn (ug/L)	dZn load	tZn load
LG Bridge	RG-8	12:46	63.44	8.19	13.4	138	49.7	73.1	0.30	0.33	<1	<1	<10	<10	162	318	55	109
LG-RR	RG-10	12:20		8.14	13.6	138	49.7	73.7	0.23	0.34	<1	<1	<10	10.5	169	333		
RR Bridge	RG-11	11:29		8.04	13.4	141	52.0	76.7	0.36	0.37	1.2	<1	<10	<10	265	361		
RR-4UR (above)	RG-12	11:13		8.03	13.4	142	51.5	80.4	0.23	0.68	<1	<1	<10	35.3	274	360		
RR-4UR (below)	RG-13	10:55		8.02	13.3	143	52.0	79.9	0.25	0.38	<1	<1	<10	13.8	271	375		
4UR Bridge	RG-9	9:17	62.25	7.83	12.5	144	51.5	77.6	0.31	0.34	<1	<1	<10	<10	232	389	78	131
Seep below LG	RG-Seep1	12:31		8.17	13.0	392	114.2	219.8	<0.1	3.51	<1	1.9	98.1	334.3	<5	703		

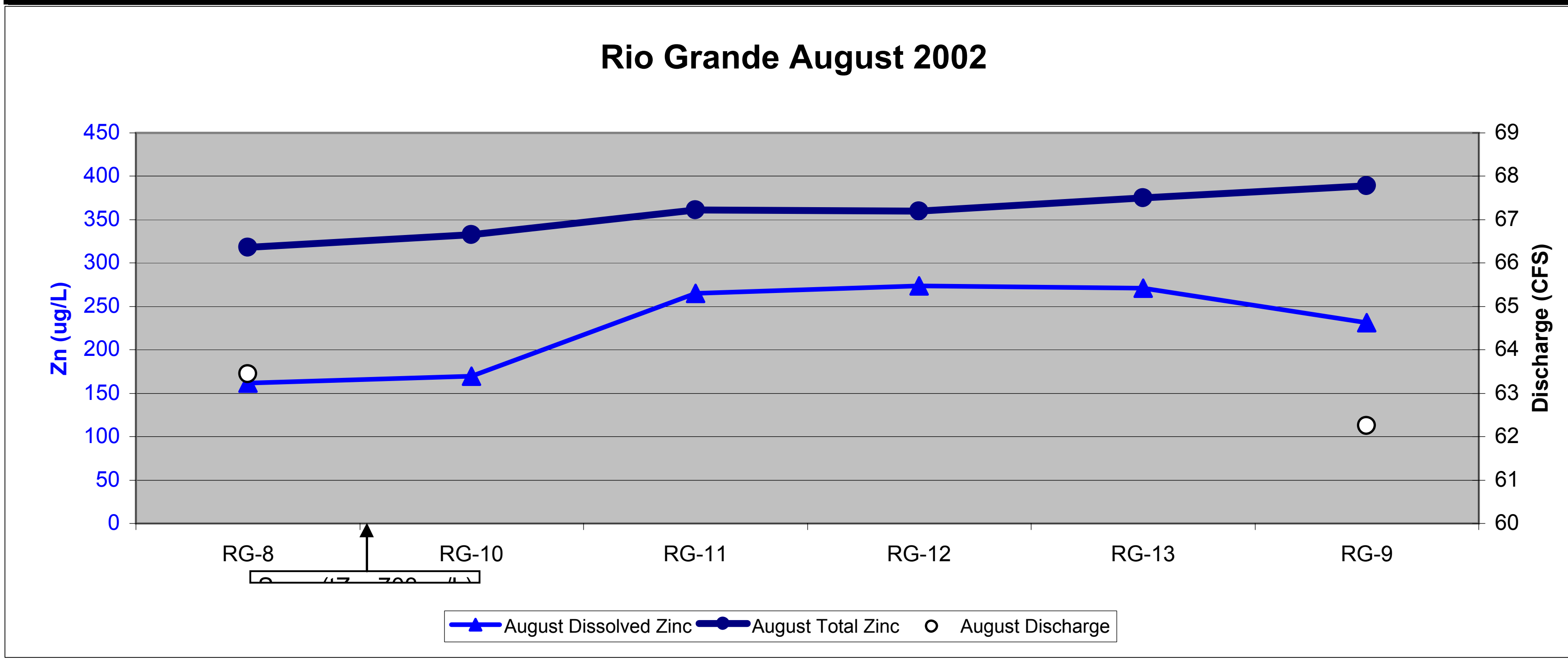
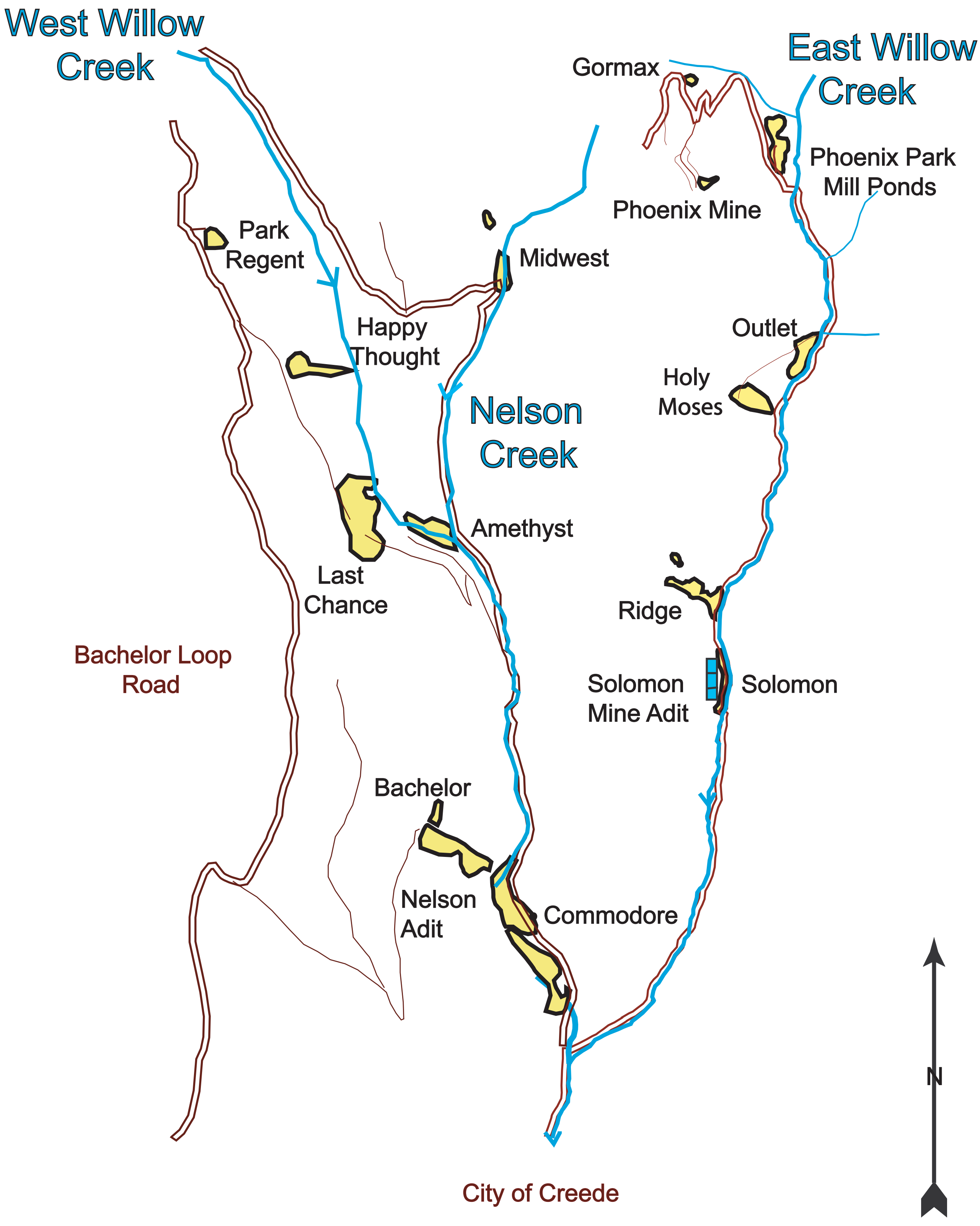


Figure 39. Rio Grande and seep data from August 2002. The table presents measured parameters and estimated loads. The graph shows changes in zinc concentrations from upstream to downstream. Discharge (O) was only measured at RG-8 and RG-9. The relative location of the seep in the downstream order is indicated by the arrow. Visible flow at the seep was <1 GPM.

Appendix A

Map of Waste Rock Piles



Appendix A. Map of waste rock sites. Individual piles are shown in yellow.

Appendix B

USGS Data and Summary

July 16, 2002

Leigh Anne Vradenburg
Willow Creek Restoration Committee
P.O. Box 518
Creede, CO 81130

Leigh Anne,

I am writing in regards to the water-quality sampling that the USGS conducted for the Willow Creek Restoration Project. As you may be aware, the USGS collected water-quality samples and streamflow data at four sites on the Rio Grande on May 3, 2002. The Project had requested that dissolved zinc data be collected at as many as 10 discrete locations across the river to evaluate river mixing at each of the 4 sites. Included with these data were in-stream measurements of water temperature, pH, dissolved oxygen, and specific conductance. A single depth- and width-integrated composite sample also was processed and analyzed at each site. Additionally, quality-assurance samples including duplicates and blanks were collected at selected sites.

Samples were collected in an upstream order as described in the sample plan. Without steady-state streamflow conditions, it is difficult to make between-site comparisons of zinc concentrations; there was a 17 percent change in streamflow on May 3rd (see attached hydrograph).

The analytical data have been released by the USGS National Water Quality Laboratory and have been reviewed in our office. I am including a table of these data. Some explanation of the data format is needed. At each site, each discrete sample location is identified by an unique time and sample location (measured from the left bank looking downstream). The medium code for these samples is an "R". Composite samples are identified by a medium code of "9" and contain a corresponding discharge value. The only exception to this is the duplicate composite sample collected at Wagon Wheel Gap at 11:46 hours. A medium code of "Q" designates a blank sample analysis.
A summary of the results at the four sites (in downstream order) follows:

1) **Rio Grande above Deep Creek** (upstream of Willow Creek inflow) had in-stream dissolved oxygen, pH, and specific conductance values that were relatively consistent across the cross-section. Dissolved-zinc concentrations were all less than the reporting limit of 1 microgram per liter. The zinc concentration in the composite sample also was reported as less than the reporting limit. Streamflow measured at 8:00 p.m. was 295 cubic feet per second.

2) **Rio Grande at Wason** (first site below Willow Creek inflow) had in-stream dissolved oxygen, pH, and specific conductance values that were relatively consistent across the cross-section. Dissolved-zinc concentrations varied across the cross-section with the highest

concentrations along the left bank (Willow Creek side) and decreasing towards the right bank. Overall, there was about a 38 percent decrease in concentration from left to right bank. The zinc concentration in the composite sample was about the average of the maximum and minimum concentrations. Streamflow measured at 5:45 p.m. was 303 cubic feet per second.

3) **Rio Grande above Spring Creek** had in-stream dissolved oxygen, pH, and specific conductance values that were relatively consistent across the cross-section. Dissolved-zinc concentrations also where relatively consistent across the cross-section with less than a 5 percent change in concentration. The zinc concentration in the composite sample was about the average of the maximum and minimum concentrations. An equipment blank was collected at this site; no indication of contamination was observed. Streamflow measured at 2:45 p.m. was 338 cubic feet per second.

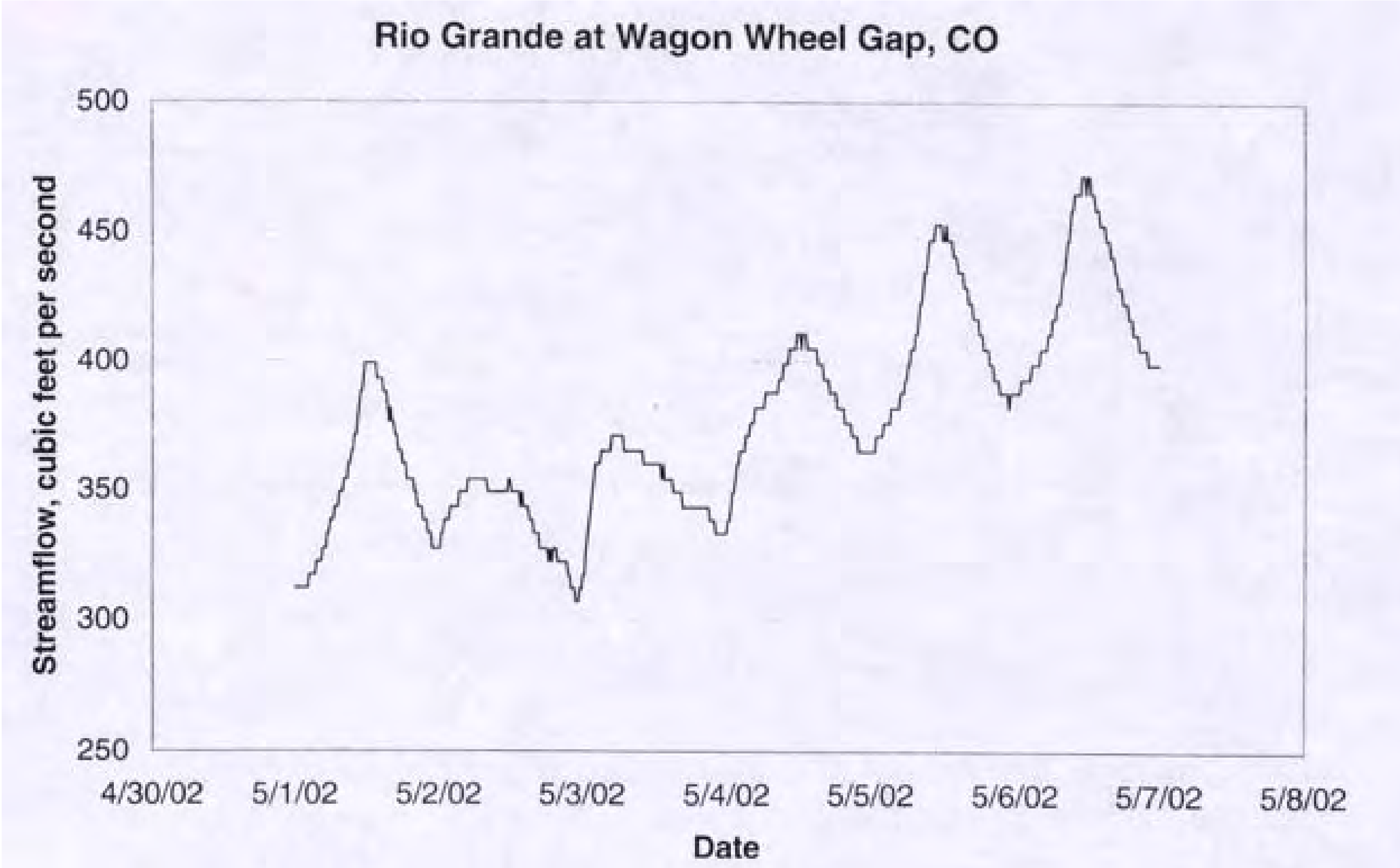
4) **Rio Grande at Wagon Wheel Gap** (at State compliance point) had in-stream dissolved oxygen, pH, and specific conductance values that were relatively consistent across the cross-section. Dissolved-zinc concentrations where relatively consistent across the cross-section with less than an 8 percent change in concentration. The zinc concentration in the composite sample was about the average of the maximum and minimum concentrations. A duplicate of the composite sample was submitted for analysis and results were similar. Streamflow measured at 11:45 a.m. was 333 cubic feet per second.

Sincerely,

Rodger Ortiz
Hydrologist

Enclosure: Table of water-quality results for sites on Rio Grande
Streamflow hydrograph for Rio Grande at Wagon Wheel Gap site

copy to: Keith Lucey, USGS, Pueblo
Pat Edelmann, USGS, Pueblo
Bill Payne, USGS, Pueblo


Rio Grande at Wagon Wheel Gap, CO
Streamflow, cubic feet per second
500
450
400
350
300
250
4/30/02
5/1/02
5/2/02
5/3/02
5/4/02
5/5/02
5/6/02
5/7/02
5/8/02
Date

374900106545100 RIO GRANDE AB DEEP C NR CREEDE, CO. (LAT 37 49 00N LONG 106 54 51W)

DATE	DATE	TIME	DIS-CHARGE, INST. CUBIC FEET PER SECOND	OXYGEN, DIS-SOLVED (MG/L)	PH WATER WHOLE FIELD (STAND-ARD UNITS)	SPE-CIFIC CON-DUCT-ANCE (US/CM)	TEMPER-ATURE WATER (DEG C)	ZINC, DIS-SOLVED (UG/L AS ZN)	SAMPLE LOC-ATION, CROSS SECTION (FT FM L BANK)	MEDIUM CODE	REMARK
MAY 2002											
03...	2002-05-03	1953	--	7.9	8.0	71	9.4	--	6	R	
03...	2002-05-03	1954	--	7.9	8.0	71	9.5	<1	18	R	
03...	2002-05-03	1955	--	7.9	8.0	71	9.5	--	30	R	
03...	2002-05-03	1956	--	8.0	8.0	71	9.5	<1	42	R	
03...	2002-05-03	1957	--	8.0	8.0	71	9.6	--	54	R	
03...	2002-05-03	1958	--	7.9	8.0	70	9.6	--	66	R	
03...	2002-05-03	1959	--	7.9	8.0	70	9.6	<1	78	R	
03...	2002-05-03	2000	--	7.9	8.0	71	9.6	--	90	R	
03...	2002-05-03	2000	295	8.0	8.0	70	9.5	<1	--	9	COMPOSITE
03...	2002-05-03	2001	--	7.9	8.0	71	9.5	--	102	R	
03...	2002-05-03	2002	--	7.9	8.0	71	9.5	<1	114	R	

08217000 RIO GRANDE AT WASON, BELOW CREEDE, CO. (LAT 37 49 21N LONG 106 53 19W)

DATE	DATE	TIME	DISCHARGE	OXYGEN	PH	SPECIFIC CONDUCTANCE	TEMPERATURE	ZINC	SAMPLE LOCATION	MEDIUM CODE	REMARK
MAY 2002											
03...	2002-05-03	1731	--	8.1	7.9	79	9.1	155	4	R	
03...	2002-05-03	1732	--	8.1	7.9	78	9.1	154	13	R	
03...	2002-05-03	1733	--	8.2	7.9	77	9.1	167	22	R	
03...	2002-05-03	1734	--	8.3	7.9	76	9.0	129	31	R	
03...	2002-05-03	1735	--	8.2	7.9	75	9.0	105	40	R	
03...	2002-05-03	1736	--	8.2	7.9	75	9.0	100	49	R	
03...	2002-05-03	1737	--	8.2	7.9	75	9.0	97	58	R	
03...	2002-05-03	1738	--	8.1	7.9	75	9.0	96	67	R	
03...	2002-05-03	1739	--	8.0	7.9	75	9.0	97	76	R	
03...	2002-05-03	1740	--	8.0	7.9	75	8.9	96	85	R	
03...	2002-05-03	1745	303	8.2	7.9	77	9.0	124	--	9	COMPOSITE

374639106501201 RIO GRANDE ABOVE SPRING CREEK NEAR WAGON WHEEL GAP (LAT 37 46 39N LONG 106 50 12W)

DATE	DATE	TIME	DISCHARGE	OXYGEN	PH	SPECIFIC CONDUCTANCE	TEMPERATURE	ZINC	SAMPLE LOCATION	MEDIUM CODE	REMARK
MAY 2002											
03...	2002-05-03	1429	--	--	--	--	--	<1	--	Q	BLANK
03...	2002-05-03	1431	--	8.2	7.8	78	10.8	110	10	R	
03...	2002-05-03	1432	--	8.3	7.8	77	10.6	107	19	R	
03...	2002-05-03	1433	--	8.3	7.8	77	10.6	110	27	R	
03...	2002-05-03	1434	--	8.3	7.9	77	10.5	107	36	R	
03...	2002-05-03	1435	--	8.3	7.9	77	10.5	103	45	R	
03...	2002-05-03	1436	--	8.3	7.9	77	10.5	107	54	R	
03...	2002-05-03	1437	--	8.1	7.9	78	10.8	105	84	R	
03...	2002-05-03	1438	--	8.2	7.8	78	10.6	104	93	R	
03...	2002-05-03	1439	--	8.3	7.9	78	10.7	104	102	R	
03...	2002-05-03	1440	--	8.2	7.9	79	10.9	105	111	R	
03...	2002-05-03	1445	338	8.2	7.8	78	10.5	107	--	9	COMPOSITE

08217500 RIO GRANDE AT WAGON WHEEL GAP, CO (LAT 37 46 01N LONG 106 49 51W)

DATE	DATE	TIME	DISCHARGE	OXYGEN	PH	SPECIFIC CONDUCTANCE	TEMPERATURE	ZINC	SAMPLE LOCATION	MEDIUM CODE	REMARK
MAY 2002											
03...	2002-05-03	1116	--	8.9	7.7	77	5.9	151	10	R	
03...	2002-05-03	1117	--	9.0	7.7	77	5.6	152	20	R	
03...	2002-05-03	1118	--	9.0	7.7	77	5.6	155	30	R	
03...	2002-05-03	1119	--	9.0	7.7	77	5.7	151	40	R	
03...	2002-05-03	1120	--	9.0	7.7	77	5.7	148	50	R	
03...	2002-05-03	1121	--	9.0	7.7	77	5.7	151	60	R	
03...	2002-05-03	1122	--	9.0	7.7	77	5.7	149	70	R	
03...	2002-05-03	1123	--	9.0	7.7	77	5.7	149	80	R	
03...	2002-05-03	1124	--	9.0	7.7	78	5.8	146	90	R	
03...	2002-05-03	1125	--	8.9	7.7	78	6.0	143	100	R	
03...	2002-05-03	1145	333	9.0	7.7	77	5.8	147	--	9	COMPOSITE
03...	2002-05-03	1146	--	--	--	--	--	149	--	R	DUPLICATE

Remark codes used in this report:
< -- Less than