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The effect of acidic, metal-enriched drainage from the Wightman Fork and Alamosa River on the composition of selected wetlands in the San Luis Valley, Colorado

by

Laurie S. Balistrieri,* Larry P. Gough,** R. C. Severson,**
María Montour,** P. H. Briggs,** Betty Adrian,**
Joe Curry,**David Fey,** Phil Hageman,** and Clara Papp**

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*USGS, University of Washington, School of Oceanography, Box 357940, Seattle, WA 98195-7940
**USGS, Box 25046, MS 973, Denver Federal Center, Denver, CO 80225-0046

U.S. Department of the Interior
Bruce Babbitt, *Secretary*
U.S. Geological Survey
Gordon Eaton, *Director*

For additional information write to:
Branch Chief
Branch of Geochemistry
Box 25046, MS 973
Denver Federal Center
Denver, CO 80225

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Abstract

The biogeochemistry of selected wetlands in the San Luis Valley, Colorado, was examined to assess the effect of acidic, metal-enriched water draining mineralized areas near and around the Summitville Mine. The sampling protocols, analytical methods, and chemical composition of water and stream bed sediment from the Wightman Fork and Alamosa River as well as water, surface sediment or cores, and rooted aquatic vegetation from wetland sites within and west of the Alamosa National Wildlife Refuge are presented. The data indicate that As, Co, Cr, Cu, Ni, and Zn are tracers of drainage from mineralized areas around the Summitville Mine. Sediments and aquatic plants in wetlands in the San Luis Valley that receive surface water from the Alamosa River tend to have larger concentrations of certain tracer elements (e.g., Co and Cu) than wetlands that receive water from other sources. Larger concentrations of Cu, Ni, and Zn in the sediments of wetlands receiving Alamosa River water appear to be related to the presence of larger amounts of Fe oxyhydroxides. However, there is little to no variation in the concentrations of tracer elements with depth in wetlands that receive Alamosa River water. This observation suggests that the geochemistry of these wetlands has not been significantly affected by recent mining activities at the Summitville Mine.

Introduction

Underground workings and open-pit gold mining activities at the Summitville Mine located in the southwestern San Juan Mountains of Colorado have produced acidic (pH 1.2-3.2) and metal-enriched waters (e.g., As, Be, Cd, Cr, Co, Cu, Ga, Ge, Li, Ni, Se, Te, Th, V, Zn and rare-earth elements) (Plumlee and others, 1993). Some of this water enters the Wightman Fork. This stream and other tributaries draining mineralized areas south and southeast of Summitville flow into the Alamosa River and downstream to the San Luis Valley (Fig. 1). Within the Valley, this water is used for irrigation of alfalfa, barley, and other crops (Erdman and others, 1995) and is a source of water for livestock and certain wetlands near the Alamosa National Wildlife Refuge. Because these wetlands are seasonal hosts to migratory birds such as the endangered whooping crane, the U.S. Fish and Wildlife Service is concerned about the possible impact of metal-enriched drainage on the stability, productivity, and quality of these wetland ecosystems.

This work was part of the U. S. Geological Survey Environmental Geoscience Studies of the Summitville Mine (Posey and others, 1995). Our particular study was designed to assess the impact of acid drainage on selected wetlands in the San Luis Valley, particularly those located in the Alamosa National Wildlife Refuge, and provide useful information for management of wildlife within this area. To make this assessment, our plan was to compare the biogeochemistry of wetlands that receive surface water from the Alamosa River with wetlands that receive surface water from sources that carry little or no drainage from mineralized areas (e.g., Rio Grande River). We collected and analyzed water and stream-bed sediment from the Wightman Fork and Alamosa River to identify elements that are indicative of drainage from mineralized areas (i.e., indicator or tracer elements) and to assess the extent of their transport throughout the Alamosa River system. We also collected and analyzed water, sediment, and rooted aquatic vegetation from wetlands that receive surface water from several sources - Alamosa River, La Jara Creek, and Rio Grande River. This report summarizes field and analytical methods and biogeochemical results. A preliminary assessment is made of the impact of acidic, metal-enriched drainage carried by the Alamosa River on selected wetlands in the San Luis Valley.

Field Methods

River samples

Stream-bed sediment and water were collected from the Wightman Fork and ten locations along the Alamosa River during June 24-26, 1993 (Fig. 1; Table 1). Site B was in the Wightman Fork just above the confluence with the Alamosa River. Site C was in the Alamosa River just above the confluence with the Wightman Fork, whereas site D was in the Alamosa River just below the confluence. Sites E, F, and G were located in the Alamosa River between Wightman Fork and Terrace Reservoir. Jasper, Burnt, and Silver Creeks enter the Alamosa River between sites E and F. Sites H, A, I, J, and K were located in the Alamosa River downstream of Terrace Reservoir. The Alamosa River begins to be diverted into canals downstream of site A and does not flow in a single, well-defined channel between site J and the Rio Grande River.

Stream-bed sediments were collected by scooping the upper 2 centimeters into polyethylene specimen containers. The sediment was allowed to settle, the supernatant was decanted, and the containers were packed in plastic bags for return to the laboratory. The sediments in the Alamosa River downstream of the confluence with the Wightman Fork were "panned" for the heavy fraction. Qualitative observations suggested decreasing concentrations of pyrite downstream. Stream-bed sediments at site H were collected from a small pool away from the main channel and are likely influenced by natural sorting.

River water was collected near the bank and placed in 60 mL polyethylene bottles (2/site) that were well rinsed with river water and 250 mL polyethylene bottles (1/site) that were acid cleaned and well rinsed with both distilled, de-ionized water and river water. Field measurements of pH were made using a model 290A Orion pH meter and Ag/AgCl combination electrode following standardization with pH buffers of 4.0, 7.0, and 10.0. Conductivity was also measured in the field using a model 124 Orion conductivity meter with a 4-electrode conductivity cell after standardization with 1,000 and 10,000 μS/cm solutions. Water samples in the 250 mL bottles were filtered through 47 mm, 0.22 μm Nuclepore filters within 10 hours of collection. Subsamples were taken for chloride and sulfate determinations and placed in clean 60 mL polyethylene bottles. The remaining solution was acidified to pH 2 using ultra-clean, concentrated nitric acid. Distilled, deionized water was run through the filtering system, acidified in the same manner as the river samples, and treated as a filter blank. All sample containers were packed in plastic bags for return to the laboratory.

Wetland samples

Sediment, water, and aquatic wetland plants were collected from nine areas within wetlands just west of (sites O, P1, P2, Q, and R) or within (sites L, M, N, and S) the

Alamosa National Wildlife Refuge during June 27-29, 1993 (Fig. 1; Table 2). The character of the wetlands was variable and included permanent (M and S) and small evaporative (P2) ponds, wetlands along sloughs (L), oxbows (O), ditches (P1), or canals (N and R), and flooded fields (Q). The wetlands received surface water from different sources. The wetlands within the Refuge appeared to be topographically isolated from receiving surface water from the Alamosa River or La Jara Creek and, most likely, received surface water from the Rio Grande River. The wetlands west of the Refuge appeared to receive surface water from the Alamosa River or a combination of Alamosa River and La Jara Creek waters.

Surface sediments at wetland sites L, P1, and P2 were collected by scooping the upper 2 centimeters into polyethylene specimen containers. The surface water was decanted and the containers packed in plastic bags for transport to the laboratory. Qualitative observations during sampling indicated that surface sediments at sites L and P1 were black, organic-rich material with plant roots, whereas a reddish floc (possibly iron oxyhydroxides) was present on the surface sediments at site P2.

Sediment cores were collected at sites O, M, and N by pushing a 10.2 centimeter diameter, acrylic butyrate core liner into the sediments. About 30 centimeters of sediment were collected in the core liner at the sites; a deeper sample (33-42 centimeters) was obtained at site O using a peat corer. The cores were maintained in an upright position and then extruded and sectioned into 2 or 5 centimeter intervals and placed into polyethylene specimen containers within 8 hours of collection. Subsamples of cores from sites O and M were taken in the field for ^{210}Pb analyses. All specimen containers were packed in plastic bags for transport to the laboratory.

Sediment samples from sites Q and R were collected with a tiling spade as it was impossible to push the core liner into the sediments. The sediments at these sites fell into distinct intervals and smelled strongly of hydrogen sulfide. Samples at site Q were taken from a black, organic-rich root mat (0-5 cm), a grey-black silt (10-15 cm), and a grey-green silt with red mottles (15-25 cm). Samples at site R included a black, organic-rich root mat (0-10 cm), a mixed organic-rich and sandy mineral layer with red staining (10-15 cm), a sandy layer with red staining (12-22 cm), and a silt and salt (gypsum ?) layer with red staining (22-32 cm). Samples were placed in polyethylene specimen containers and packed in plastic bags for transport to the laboratory.

Water samples from the wetlands were collected, processed, and packaged exactly the same as the water samples from the Wightman Fork and Alamosa River.

The aquatic wetland plant *Persicaria amphibia (L.) S. Gray* (smartweed) was collected at sites L, S, O, P1, Q, and R. In addition, the aquatic wetland plant *Potamogeton natans L.* (pondweed) was collected at sites L, M, N, and P1. The stems, leaves, and flowers were rinsed during collection and placed in cloth Hubco bags for transport to the laboratory. Roots, rhizomes, and attached sediment were removed during collection. Each plant sample was composed of five to ten individual plants.

Laboratory Methods

The methods for preparation and analyses of the sediment (excluding ^{210}Pb analyses), water (excluding chloride and sulfate analyses), and plant samples are summarized in

Arbogast (1990). Only brief descriptions are given here.

Sediment samples were dried overnight in a forced-air drying oven set at 30°C. The sediment was disaggregated in a ceramic mortar and passed through a 10-mesh (1.7 mm) sieve. The material passing the sieve was pulverized in an agate shatter box to 100-mesh or less (<150 μm). The pulverized material was decomposed using a mixture of acids (HCl, HNO_3, $HClO_4$, and HF) and analyzed for 40 major and trace elements by inductively coupled plasma-atomic emission spectrometry (ICP-AES). Concentrations of As and Se in the digested samples were measured by flow injection hydride generation atomic absorption spectrophotometry (HG-AAS). Mercury concentrations were determined in digested samples by continuous flow-cold vapor-atomic absorption spectrophotometry (CV-AAS). Total sulfur and total carbon contents of sediments were determined by high-temperature combustion in an oxygen atmosphere. The evolved sulfur and carbon dioxides were measured by infrared detection using a LECO sulfur or carbon analyzer. Carbonate carbon was determined by coulometric titration of carbon dioxide evolved upon acidification of the sample. Organic carbon was determined as the difference between total and carbonate carbon.

The moisture contents of selected wetland cores (site O core 1 and site M core 2) were determined by the difference between wet and dried (100°C) sediment weights. Portions of these dried sediment samples were analyzed for ^{210}Pb following the method of Flynn (1968). Briefly, a yield tracer (^{209}Po) was added to the sediment samples. The sediment was leached using a series of hot acids (HNO_3, $HClO_4$, HCl) and then made up in ~0.3N HCl. Ascorbic acid was added to complex iron. ^{210}Po (the daughter of ^{210}Pb) was autoplated onto silver disks and counted by alpha spectrometry.

The major, minor, and trace element composition of the filtered and acidified water samples was determined by ICP-AES. Samples were not concentrated. Dissolved chloride concentrations were determined by silver nitrate titrations using an automated chloridometer (Grasshoff, 1976). Dissolved sulfate concentrations were determined by barium sulfate precipitation (Grasshoff, 1976). Excess dissolved barium was measured by atomic absorption spectrophotometry.

The aquatic plant samples were washed of any visible sediment in tap water (about 5 rinses) and then rinsed twice with distilled water. The washed plants were placed in clean Hubco bags and dried in a forced-air oven at 35-40°C for 24 hours. The dried material was then ground in a Wiley mill to pass a 2 mm sieve. The samples were ashed in Vicor crucibles at 450-500°C for 18 hours. Subsamples of the ashed plants were digested in hot acids, like the sediment samples, and the elemental composition of the ash was determined by ICP-AES. Using unashed, digested plant samples, concentrations of As were measured by HG-AAS whereas Hg concentrations were determined by CV-AAS.

Chain of Custody, Quality Control, and Quality Assurance

Chain of custody procedures were followed during the collection, transport, analysis, and storage of these samples.

The quality control (QC) and quality assurance (QA) procedures of the USGS Analytical Chemistry Services Group are summarized in Arbogast (1990). In addition to the laboratory QA/QC procedures, the field study quality control included submission of procedural blanks for the water samples, splits of sediment and aquatic plant samples, and NIST standard reference materials (SRM) (sediments and plants) to the laboratory. These samples were analyzed in the same manner as the respective field samples.

The concentrations of elements in the procedural blanks for water sampling are generally below detection limits (Table 3). The laboratory splits of sediment and plant samples indicate very good reproducibility (Tables 4, 6-10, 12-13). In general, there is also good agreement between the laboratory analyses for NIST standard reference materials for sediments and plants and the certified values from the NIST Certificate of Analysis (Tables 14 and 15).

Results and Discussion

River samples

Water: The composition of water in the Wightman Fork and Alamosa River during June 1993 is summarized in Table 3. Water in the Wightman Fork (site B) was characterized by low pH values and elevated concentrations of dissolved major (Na, Ca, Mg, Cl, and SO_4) and minor (Al, B, Co, Cu, Fe, Mn, Ni, Sr, and Zn) ions relative to water in the Alamosa River above the confluence with the Wightman Fork (site C). The Wightman Fork had a distinct influence on the composition of Alamosa River water downstream of the confluence. Values of pH were lower and dissolved concentrations of major (Na, Ca, Cl, and SO_4) and minor (Al, Cu, Fe, Mn, Sr, and Zn) ions were elevated in the Alamosa River just below (site D) as compared to above (site C) the confluence. Elevated dissolved concentrations of major (Na, Ca, Cl, and SO_4) and certain minor (Cu, Mn, Sr, and Zn) ions persisted far downstream (at least 49 km) in Alamosa River water. Dilution plays the major role in attenuating dissolved concentrations of ions downstream of the confluence; however, dissolved Cu concentrations far downstream also appear to be affected by a removal process such as sorption (Balistrieri and others, 1995). The dissolved chemical characteristics of the Wightman Fork and Alamosa River are variable with time and highly dependent on pH (Ward and Walton-Day, 1995; Walton-Day and others, 1995). Hence, our sampling during June 1993 only provides a single, instantaneous picture of the dissolved chemical characteristics of these rivers.

Sediment: The composition of stream-bed sediments from the Wightman Fork and Alamosa River is summarized in Table 4. The data indicate that sediments in the Wightman Fork (site B) have higher concentrations of Fe, S, As, Cr, Cu, Hg, Pb, and Zn relative to sediments in the Alamosa River above the confluence with the Wightman Fork (site C). Of these elements, Cu and As show the greatest enrichment (13.5 to 14.2 x). Sediments in the Alamosa River downstream of the confluence with the Wightman Fork tend to have higher concentrations of As, Co, Cr, Cu, Ni, and Zn relative to sediments above the confluence (site C) (Fig. 2). Higher concentrations of Co, Ni, and Zn in Alamosa River sediments tend to occur much farther downstream (>18-29 km from the confluence) than the other elements.

The composition of water and sediments in the Wightman Fork most likely reflects drainage from the Summitville Mine; however, enrichments of elements in the Alamosa River downstream of the confluence with the Wightman Fork also include elements supplied by other streams (e.g., Jasper and Burnt Creeks) and from diffuse runoff. Based on the compositional data of Wightman Fork and Alamosa River, the following elements appear to be indicative of drainage from mineralized areas in this watershed: Al, As, B, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, S, Sr, Zn. Some of the minor elements (e.g., As, Co, Cr, Cu, Ni, and Zn) are enriched far downstream of the confluence with the Wightman Fork. This latter group of elements is used as potential tracers or indicator elements for assessing the impact of drainage from mineralized areas on wetlands in the San Luis Valley.

Wetland samples

Water: The composition of surface water in selected wetlands in the San Luis Valley is summarized in Table 5. In June 1993, the wetlands were basic ($pH > 7$), had variable dissolved major ion (e.g., Na, K, Ca, Mg, Cl, and SO_4) concentrations, and low concentrations of many minor ions (e.g., Co, Cu, Ni, and Zn). Variations in the major ion chemistry of the water and our observations of salt crusts in the vicinity of many wetlands suggest that evaporation was occurring and causing the concentration and precipitation of certain dissolved elements. The low concentrations of the minor cations are consistent with their ability to sorb onto particles or precipitate at higher pH values (Stumm and Morgan, 1981). In contrast, the mobility of anions, like As, is usually greater at the higher pH values observed in the wetlands due to lower sorption of anions at high pH (Pierce and Moore, 1982). Dissolved concentrations of As tended to be higher in wetlands within the Refuge as compared to wetlands outside of the Refuge. This observation may, in part, reflect different source waters as well as the effects of evaporative concentration.

Differences in the ratio of two conservative elements, Na and Cl, between the wetlands and Alamosa River water below Terrace Reservoir provide support for different source waters (Fig. 3). The ratio in Alamosa River water (Na/Cl = 100±4) is less than half of the ratio in wetland waters within the Alamosa National Wildlife Refuge (Na/Cl = 229+19). The ratio for wetlands west of the Refuge ranges from 114 to 189 and suggests input from the Alamosa River.

Sediment: The composition of wetland sediments is summarized in Tables 6-10. The concentrations of the indicator elements (i.e., As, Co, Cr, Cu, Ni, and Zn) are plotted for selected wetland sediments that receive water from different sources (Fig. 4). The plots indicate that sediments in wetlands that receive some Alamosa River water clearly have higher concentrations of Cu, Ni, and Zn than wetlands receiving surface water from other sources. In addition, the metal contents of sediments in wetlands receiving Alamosa River water do not significantly change with depth. If wetlands receiving Alamosa River water received additional metals from drainage derived from open-pit mining activities at Summitville, then the downcore composition of wetland sediments should change significantly - provided that the collected sediment represents a timeframe that brackets the beginning of open-pit mining activities at Summitville Mine (i.e., before and after 1984-1986) (Pendleton and others, 1995).

Two wetland cores (site O core 1 and site M core 2) were age dated using ^{210}Pb techniques. Mass accumulation rates were determined from ^{210}Pb activity and water content as a function of depth using a one-dimensional, two-layer, steady-state sedimentation model in which mixing occurs only in the surface mixed layer (Robbins and Edgington, 1975; Carpenter and others, 1982). The model assumptions are that (1) the sedimentation rate is constant; (2) there is no post-depositional mobility of ^{210}Pb; (3) the flux of unsupported ^{210}Pb to the interface is constant; and (4) the deepest sample represents the amount of supported ^{210}Pb in this area and is constant throughout the core. The porosities (Φ) of the two cores were calculated from water-content data and by assuming that the density (ρ) of the dried sediment was 2.5 g cm^{-3}. The supported ^{210}Pb in the sediments was estimated to be 0.8 dpm g^{-1}. The accumulation rate of the sediment, S (g cm^{-2} y^{-1}), was determined from the equation $S = -\lambda/m$, where m is the slope of the line defined by the natural log of unsupported ^{210}Pb (i.e., excess ^{210}Pb) versus sediment accumulation, A (g cm^{-2}), in the core as a function of depth below the surface mixed layer and λ is the decay constant for ^{210}Pb (0.03113 y^{-1}) (Fig. 5). Sediment accumulation was determined from the equation $A = z*(1-\Phi)*\rho$ and accounts for the natural compaction of the sediment as a function of depth. The resulting accumulation rates are 0.74 g cm^{-2} y^{-1} at site M (core 2) and 0.70 g cm^{-2} y^{-1} at site O (core 1). Sedimentation rates in cm y^{-1} do not include natural compaction and, hence, decrease with depth. The sedimentation rates are between 0.33 and 0.52 (average = 0.38) cm yr^{-1} for site M (core 2) and 0.33 and 0.43 (average = 0.35) cm yr^{-1} for site O (core 1). Table 11 includes the approximate age of the depth intervals for the two cores.

Accumulation rates of the indicator elements were calculated by multiplying the metal content at a given depth by the mass accumulation rates and plotted for two time periods at sites M and O (Fig. 6). These time periods represent pre- and post-open pit mining activities at Summitville Mine. Only site O receives surface water from the Alamosa River. The first observation is that variations in the metal contents of the two cores collected at a given site result in a range of element accumulation rates for that site (also see Tables 7 and 9). Second, the site that receives Alamosa River water (site O) tends to have higher accumulation rates of As, Co, Cu, Ni, and, possibly, Zn. And third, there is little difference between accumulation rates at the site receiving Alamosa River water (site O) for pre- and post-open pit mining activities at Summitville Mine because there are no significant changes in metal contents downcore.

Increases in certain indicator elements (i.e., Co, Cr, Cu, and Ni) in the wetlands receiving Alamosa River water compared to those that receive surface water from other sources may be related to the accumulation of Fe in the wetlands. Iron oxyhydroxides have a strong affinity for many elements and, thus, can sequester trace elements in the sediments. Higher Fe contents and accumulation rates are observed for wetlands receiving Alamosa River water (Fig. 7). There are good correlations between the concentrations of Fe and certain indicator elements in almost all wetland sediments (Fig. 8).

Aquatic plants: The chemical composition of the aquatic wetland plants, *P. amphibia* and *P. natans*, is tabulated in Tables 12 and 13. The same species of aquatic plant was not present in all of the wetlands; however, each species came from wetlands that received water from different sources.

Rooted aquatic macrophytes can assimilate dissolved metals from the water through their leaves, but most uptake is thought to occur through their roots. Therefore, their chemical composition often reflects the geochemistry of the sediments in the wetlands (Pip and Stepaniuk, 1992; Flessa, 1994).

The concentrations of the indicator elements on a dry weight basis in the aquatic wetland plants are compared for wetlands receiving surface water from different sources in figures 9 and 10. Both *P. amphibia* and *P. natans* tend to have higher concentrations of Co and Cu, if they are growing in wetlands receiving Alamosa River water. Zn also appears to be enriched in *P. amphibia* in wetlands receiving Alamosa River water. These observations are consistent with the enrichment of these elements, particularly Cu and Zn, in the sediments of wetlands receiving Alamosa River water. In contrast, aquatic plant concentrations of As tend to be higher in wetlands receiving water from other sources. Dissolved concentrations of As also tended to be higher in these wetlands.

Summary

The chemical composition of water and sediment from the Wightman Fork and Alamosa River during June 1993 was used to identify the following elements - As, Co, Cr, Cu, Ni, and Zn - as possible tracers of acidic, metal-enriched drainage from mineralized areas in the Alamosa River watershed. These elements appeared to be transported throughout the Alamosa River system downstream of its confluence with the Wightman Fork.

The composition of surface water in selected wetlands in the San Luis Valley appeared to be affected by evaporation during June 1993. These waters tended to be basic and have low dissolved concentrations of all of the indicator elements, except As.

The chemical composition of sediments in wetlands receiving surface water from the Alamosa River or Alamosa River and La Jara Creek tended to be enriched in Fe, Cu, Ni, and Zn relative to sediments of wetlands receiving surface water from other sources. A comparison of metal accumulation rates in two wetlands receiving water from different sources indicates that the wetland receiving surface water from the Alamosa River has higher accumulation rates of Fe, As, Co, Cu, and Ni. The higher concentrations and accumulation rates of certain indicator elements in wetlands receiving some surface water from the Alamosa River appear to be related to the content and accumulation of Fe. However, there are no major differences in the accumulation rates or downcore concentrations of indicator elements during the past 70 to 100 years in wetlands receiving Alamosa River water. Unless the age dating of the wetland cores is incorrect, the effects of recent mining activities (e.g., open-pit mining at Summitville) on wetland sediment geochemistry is not readily apparent.

Aquatic wetland plants (i.e., *Persicaria amphibia* and *Potamogeton natans*) tend to have higher concentrations of certain indicator elements (i.e., Co, Cu, and Zn) in wetlands receiving Alamosa River water. These enrichments reflect similar enrichments observed in the sediments of these wetlands.

Finally, a direct link between specific mining activities at the Summitville Mine and the geochemistry of the studied wetlands was not found. However, the studied wetlands west of the Alamosa National Wildlife Refuge that receive Alamosa River water tended to have higher concentrations of indicator elements, except As, in their sediment and aquatic plants relative to the studied wetlands within the Refuge that receive surface water from other sources. In addition, Cu appears to be the best overall indicator element for wetlands that receive water from the Alamosa River.

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Table 1. Location of river sampling sites during June 1993.

Site	Latitude deg	 min	 sec	Longitude deg	 min	 sec	Description
B	37	24	22	106	31	21	Wightman Fork (WF) 0.1 km upstream of AR
C	37	24	04	106	31	30	Alamosa River (AR) 0.5 km upstream of WF
D	37	24	27	106	30	54	Alamosa River 0.5 km downstream of WF
E	37	24	49	106	30	09	Alamosa River 2 km downstream of WF
F	37	23	46	106	25	30	Alamosa River 11 km downstream of WF
G	37	22	48	106	20	51	Alamosa River 18 km downstream of WF
H	37	19	52	106	13	48	Alamosa River 29 km downstream of WF
A	37	19	52	106	12	45	Alamosa River 31.5 km downstream of WF
I	37	19	03	106	10	21	Alamosa River 36.5 km downstream of WF
J	37	17	15	106	05	24	Alamosa River 44 km downstream of WF
K	37	17	46	106	02	15	Alamosa River 49 km downstream of WF

Table 2. Location of wetland sampling sites during June 1993.

Site	Latitude			Longitude			Description
	deg	min	sec	deg	min	sec	
L	37	22	37	105	45	25	southern ANWR[a] Big Slough
M	37	23	09	105	46	27	southern ANWR kidney-shaped pond
N	37	26	15	105	45	55	northern ANWR main feeder canal just west of road
S	37	27	10	105	46	19	northern ANWR pond just north of North Refuge Road, east of main canal
O	37	22	21	105	47	51	2.3 km due west of ANWR old oxbow of La Jara Creek
P1	37	23	04	105	49	12	3.8 km due west of ANWR North Seamans Ditch
P2	37	23	04	105	49	12	3.8 km due west of ANWR small evaporative pond just north of Seamans Ditch
Q	37	22	45	105	49	15	3.8 km due west of ANWR flooded field north of South Seamans Ditch
R	37	22	16	105	53	37	11.2 km due west of ANWR seasonal wetland between Alamosa River and its old channel

[a] Alamosa National Wildlife Refuge

Table 3. Water composition of Wightman Fork (site B) and Alamosa River, CO in June 1993.
DUP = duplicate field sample

Site	pH	Conduct. uS/cm	Na ppm	K ppm	Ca ppm	Mg ppm	Cl ppm	SO4 ppm	Al ppm	As ppb	B ppb	Ba ppb	Co ppb	Cu ppb	Fe ppm	Mn ppb	Ni ppb	Si ppm	Sr ppb	Zn ppb
B	4.54	654	48	<1	44	8	8.9	380	12	<2	110	24	97	8500	17	2400	100	6	170	1700
B DUP	4.55	851	47	5	44	8	8.9	390	12	<2	110	29	92	8600	17	2400	95	8	170	1700
C	7.18	56	1	<1	7	1	0.81	26	<1	<2	<50	<20	<40	<40	<1	65	<40	4	64	<40
D	5.03	246	13	<1	18	3	3.1	120	3	<2	<50	20	<40	2800	6	810	<40	5	96	540
E	5.61	142	8	<1	12	2	1.6	74	<1	<2	<50	<20	<40	1100	3	400	<40	4	80	250
F	5.96	145	7	<1	15	2	1.3	75	<1	<2	<50	22	<40	890	2	400	<40	5	100	220
G	6.28	138	6	<1	13	2	1.6	67	<1	<2	<50	<20	<40	360	<1	310	<40	4	93	180
H	6.08	139	5	<1	14	2	1.7	64	<1	<2	<50	24	<40	490	<1	380	<40	5	100	190
A	no water sample																			
I	5.98	139	5	<1	14	2	1.9	65	<1	<2	<50	24	<40	480	<1	390	<40	5	110	190
J	5.88	139	5	<1	14	2	1.8	62	<1	<2	<50	24	<40	420	<1	380	<40	5	110	180
K	5.83	158	5	<1	17	3	1.7	66	<1	<2	<50	28	<40	260	<1	370	<40	5	130	160
Filter Blank			<1	<1	<1	<1			<1	<2	<50	<20	<40	<40	<1	<40	<40	<1	<40	<40

All samples below detection limits for the following elements:

Ag	<40 ppb	Mo	<80 ppb
Be	<20 ppb	Pb	<80 ppb
Bi	<200 ppb	Sn	<100 ppb
Cd	<40 ppb	Ti	<100 ppb
Cr	<40 ppb	V	<40 ppb
Ga	<80 ppb	Zr	<40 ppb
Li	<40 ppb		

Table 4. Composition of bed sediments from the Wightman Fork (site B) and Alamosa River in June 1993. (Based on dry weights)
DUP = duplicate filed sample; s = laboratory split

Site	Al wt%	Ca wt%	Fe wt%	K wt%	Mg wt%	Na wt%	P wt%	Ti wt%	Mn ppm	S wt%	As ppm	Ba ppm	Ce ppm	Co ppm	Cr ppm	Cu ppm
B	7.5	0.61	6.5	2.2	0.47	1.6	0.19	0.4	600	0.51	50	670	68	13	13	330
B DUP	7.5	0.6	6.3	2.3	0.48	1.6	0.18	0.4	580	0.48	70	680	67	13	15	310
C	7.9	1.8	4.5	2	0.84	1.2	0.12	0.39	660	0.39	5.1	590	69	14	6	23
C s	7.9	1.8	4.5	2	0.85	1.2	0.12	0.41	660	0.41	3.8	670	69	13	9	22
D	7.3	1	5.5	2.1	0.7	1	0.13	0.41	540	0.76	8.3	690	66	13	10	200
E	7.3	0.6	5.5	2.1	0.73	1.2	0.12	0.42	430	0.38	15	690	72	6	10	300
F	7.3	0.73	4	2.3	0.68	1.3	0.12	0.38	550	0.21	12	720	71	12	9	290
G	7.2	0.88	5.8	2.2	0.73	1.2	0.14	0.55	620	0.27	8.5	880	75	15	16	430
H	6.4	1.3	13	2.1	0.73	1.5	0.12	1.3	1600	0.1	8.2	840	81	40	50	310
A	7.5	1.2	4.2	2.4	0.68	1.7	0.11	0.4	860	0.13	7.2	800	73	23	10	340
A DUP	7.4	1.2	4.7	2.2	0.72	1.6	0.11	0.46	790	0.21	13	790	74	21	16	380
I	7.4	1.2	4.9	2.1	0.74	1.5	0.11	0.51	710	0.14	11	760	77	18	16	300
J	7.2	1.1	4.4	2.3	0.69	1.5	0.11	0.44	790	0.15	8.1	760	71	21	14	310
J s	7.2	1.1	4.3	2.3	0.68	1.6	0.11	0.43	760	0.14	7.7	750	71	20	11	310
K	7.3	1.3	4.4	2.3	0.69	1.6	0.11	0.46	620	0.16	13	830	73	16	14	410

Site	Ga ppm	Hg ppm	La ppm	Li ppm	Nb ppm	Nd ppm	Ni ppm	Pb ppm	Se ppm	Sc ppm	Sr ppm	Th ppm	V ppm	Y ppm	Yb ppm	Zn ppm
B	16	0.16	36	13	12	27	7	70	0.8	10	410	10	110	13	1	110
B DUP	16	0.2	36	12	13	29	8	66	0.8	10	400	11	110	13	1	110
C	17	0.04	34	10	12	27	6	25	1.5	11	420	10	110	16	2	76
C s	17	0.04	34	10	12	28	6	23	1.5	11	420	10	110	17	1	76
D	16	0.06	33	9	11	26	5	25	2.3	11	330	7	120	14	1	76
E	16	0.02	37	20	17	31	4	37	2	11	270	15	120	14	1	71
F	15	<0.02	37	11	11	28	6	31	1.3	10	360	10	100	15	1	75
G	17	0.02	39	11	12	31	9	40	1.3	11	380	12	160	15	1	110
H	19	<0.02	40	11	15	34	23	27	0.5	12	400	10	410	16	2	290
A	15	<0.02	40	12	14	30	10	32	0.7	9	450	8	100	18	2	110
A DUP	15	0.06	39	12	13	29	10	33	0.8	10	440	8	110	18	2	120
I	16	0.02	39	11	14	33	10	40	0.8	11	450	11	130	17	2	120
J	15	<0.02	38	11	14	31	11	32	0.7	10	440	11	110	16	1	110
J s	15	<0.02	38	12	12	30	10	28	0.7	10	440	9	110	16	1	110
K	15	<0.02	38	11	12	31	10	32	0.8	10	490	12	110	16	2	120

All samples below detection limits for the following elements:

Ag	<2 ppm	Ho	<4 ppm
Au	<8 ppm	Mo	<2 ppm
Bi	<10 ppm	Sn	<5 ppm
Cd	<2 ppm	Ta	<40 ppm
Eu	<2 ppm	U	<100 ppm

Table 5. Water composition of wetlends in San Luis Valley, CO during June 1993.
DUP = duplicate field samples

Site	pH	Conduct. uS/cm	Na ppm	K ppm	Ce ppm	Mg ppm	Cl ppm	SO4 ppm	Al ppm	As ppb	B ppb	Ba ppb	Co ppb	Cu ppb	Fe ppm	Mn ppb	Ni ppb	Si ppm	Sr ppb	Zn ppb
L	9.89	412	75	6	16	2	12	43	<1	51	880	33	<40	<40	<1	<40	<40	9	140	<40
L DUP	9.94	422	74	6	16	2	12	38	<1	33	880	34	<40	<40	<1	<40	<40	9	140	<40
M	10.46	168	11	<1	13	1	1.5	19	<1	3	<50	21	<40	<40	<1	<40	<40	5	110	<40
N	8.77	2444	560	23	28	8	89	270	<1	90	3600	79	<40	<40	<1	<40	<40	22	350	<40
S	no water sample																			
O	7.56	716	45	6	80	17	14	200	<1	3	<50	37	<40	<40	<1	83	<40	10	640	<40
P1	7.45	771	47	7	92	17	11	300	<1	<2	<50	33	<40	<40	<1	50	<40	8	790	<40
P2	9.34	1928	190	44	180	35	49	900	<1	2	210	70	<40	<40	<1	73	<40	6	2300	<40
Q	8.01	1259	130	16	100	32	24	450	<1	<2	78	30	<40	<40	<1	79	<40	9	1100	<40
R	8.19	369	13	3	47	7	2.7	110	<1	<2	<50	23	<40	<40	<1	<40	<40	4	380	<40

Sites O, P1, P2, Q, and R receive some surface water from the Alamosa River.
Sites L, M, N, and S receive surface water from other sources.

See Table 3 for filter blank.

All samples below detection limits for the following elements:

Ag	<40 ppb	Mo	<60 ppb
Be	<20 ppb	Pb	<80 ppb
Bi	<200 ppb	Sn	<100 ppb
Cd	<40 ppb	Ti	<100 ppb
Cr	<40 ppb	V	<40 ppb
Ga	<80 ppb	Zr	<40 ppb
Li	<40 ppb		

Table 6. Composition of wetland surface sediments at sites L, P1, and P2 in June 1993. (Based on dry weights)
DUP = duplicate field sample; s = laboratory split

Site	Depth cm	Al wt%	Ca wt%	Fe wt%	K wt%	Mg wt%	Na wt%	P wt%	Ti wt%	Mn ppm	S wt%	tot C wt%	org C wt%	As ppm	Ba ppm	Ce ppm	Co ppm	Cr ppm
L	0-2	8.2	2.1	2.1	3	0.41	2.4	0.07	0.27	340	0.15	0.3	0.3	7.1	1000	88	14	8
L DUP	0-2	8	2.1	2.3	2.9	0.43	2.2	0.08	0.27	540	0.27	0.98	0.95	5.9	1000	91	16	8
L DUP s	0-2	7.9	2.2	2.4	3	0.42	2.3	0.08	0.28	550	0.27	0.87	0.84	7.3	1000	82	17	8
P1	0-2	7.6	1.3	4.4	2.1	0.87	1.1	0.19	0.37	500	0.26	3.44	3.42	26	670	64	18	18
P2	0-2	6.8	3	3.6	2.3	1.2	1.4	0.18	0.4	870	0.57	2.1	1.62	4.9	760	58	15	18

Site	Depth cm	Cu ppm	Ga ppm	Hg ppm	La ppm	Li ppm	Nb ppm	Nd ppm	Ni ppm	Pb ppm	Sc ppm	Se ppm	Sr ppm	Th ppm	V ppm	Y ppm	Yb ppm	Zn ppm
L	0-2	8	16	<0.02	50	13	11	39	4	28	7	<0.1	500	15	45	22	2	52
L DUP	0-2	8	15	<0.02	53	14	11	40	4	30	8	<0.1	480	15	49	22	2	62
L DUP s	0-2	7	16	<0.02	48	14	13	36	5	33	7	<0.1	490	13	50	22	2	62
P1	0-2	170	16	0.28	33	20	13	29	12	110	11	1.2	410	6	100	17	1	170
P2	0-2	31	14	<0.02	30	14	13	27	12	31	9	1.6	540	7	100	13	1	97

All samples below detection limits for the following elements:

Ag	<2 ppm	Ho	<4 ppm
Au	<8 ppm	Mo	<2 ppm
Bi	<10 ppm	Sn	<5 ppm
Cd	<2 ppm	Ta	<40 ppm
Eu	<2 ppm	U	<100 ppm

Table 7. Composition of wetland sediments at site M in June 1993 (Based on dry weights)
A, B = field splits; s = laboratory splits

Site	Depth cm	Al wt%	Ca wt%	Fe wt%	K wt%	Mg wt%	Na wt%	P wt%	Ti wt%	Mn ppm	S wt%	tot C wt%	org C wt%	As ppm	Ba ppm	Ce ppm	Co ppm	Cr ppm
M core 1	0-2A	7.8	1.9	2.2	2.9	0.48	2.1	0.08	0.31	350	0.13	1.84	1.62	3	900	73	7	11
M core 1	0-2B	7.9	2.1	2.3	2.8	0.57	2.1	0.07	0.32	400	0.12	1.85	1.8	3	910	72	6	12
M core 1	2-4A	7.7	1.9	2.2	2.9	0.46	2.1	0.08	0.3	360	0.17	1.81	1.81	3.4	900	72	7	10
M core 1	2-4B	7.9	2	2.2	2.9	0.48	2.1	0.09	0.31	380	0.19	2.02	2.02	4.7	930	71	7	11
M core 1	4-6A	7.9	1.9	2.2	3.1	0.46	2.1	0.09	0.31	380	0.17	1.61	1.61	4	920	74	7	11
M core 1	4-6B	7.9	1.7	1.9	2.9	0.4	2	0.08	0.26	320	0.16	1.27	1.27	3.9	870	82	5	8
M core 1	6-11A	7.8	1.7	1.9	3.1	0.37	2.1	0.07	0.26	310	0.15	0.94	0.94	4.3	930	79	5	7
M core 1	6-11B	8.2	1.5	1.7	3	0.36	2	0.06	0.23	270	0.14	0.64	0.64	3.2	870	80	4	6
M core 1	11-16A	8.1	1.5	2.9	2.8	0.57	1.8	0.05	0.36	320	0.06	1.36	1.36	3.7	840	83	7	16
M core 1	11-16B	8	1.6	2.6	2.8	0.54	1.8	0.05	0.33	310	0.07	1.34	1.34	3.1	850	81	7	13
M core 1	16-21A	8	1.5	3	2.8	0.54	1.8	0.06	0.34	340	<0.05	1.21	1.21	3.5	840	81	7	15
M core 1	16-21A s	8.1	1.5	3	2.8	0.54	1.8	0.06	0.34	340	<0.05	1.28	1.28	5.8	850	82	8	14
M core 1	16-21B	8.1	1.6	2.9	2.8	0.56	1.8	0.05	0.34	330	<0.05	1.36	1.36	2.9	870	81	7	12
M core 2	0-2B	7.2	1.7	3.5	2.1	0.76	1.2	0.1	0.4	1100	0.14	3.94	3.91	6.5	680	73	11	20
M core 2	2-4B	7.4	1.7	3.4	2.2	0.75	1.3	0.09	0.4	750	0.13	3.72	3.72	4.9	690	74	11	20
M core 2	4-6B	7.3	1.6	3.3	2.1	0.75	1.3	0.07	0.4	560	0.13	3.82	3.82	8.3	680	75	10	20
M core 2	6-8B	7.5	1.6	3.1	2.2	0.71	1.4	0.07	0.38	460	0.13	3.58	3.58	8.8	710	75	11	18
M core 2	8-10B	7.6	1.5	3.3	2.2	0.73	1.4	0.07	0.39	420	0.1	3.3	3.3	6.9	700	77	10	20
M core 2	10-12B	7.8	1.5	3.2	2.4	0.69	1.5	0.06	0.37	400	0.09	2.38	2.38	6.4	740	76	9	18
M core 2	12-14B	7.7	1.5	3.2	2.3	0.71	1.4	0.06	0.4	410	0.08	2.51	2.51	3.8	730	78	10	19
M core 2	14-19B	7.8	1.4	2.9	2.8	0.56	1.8	0.05	0.34	350	0.06	1.33	1.33	4.6	820	79	8	14
M core 2	19-24B	8.1	1.5	3.1	2.9	0.53	1.9	0.05	0.36	380	<0.05	0.8	0.8	4	870	85	9	14

Site	Depth cm	Cu ppm	Ga ppm	Hg ppm	La ppm	Li ppm	Nb ppm	Nd ppm	Ni ppm	Pb ppm	Sc ppm	Se ppm	Sr ppm	Th ppm	V ppm	Y ppm	Yb ppm	Zn ppm
M core 1	0-2A	12	17	<0.02	42	17	15	31	4	46	8	0.1	440	12	55	20	2	84
M core 1	0-2B	13	18	<0.02	41	17	14	32	4	49	8	0.1	450	11	59	20	2	90
M core 1	2-4A	11	16	<0.02	42	17	15	32	3	45	8	0.1	440	11	54	20	2	82
M core 1	2-4B	12	16	<0.02	41	17	17	32	3	45	8	0.1	460	11	56	20	2	87
M core 1	4-6A	12	17	<0.02	44	17	15	33	4	45	7	0.1	430	13	55	21	2	83
M core 1	4-6B	12	15	<0.02	48	14	9	36	3	34	8	<0.1	420	16	43	21	2	65
M core 1	6-11A	10	15	<0.02	46	14	14	35	3	34	7	<0.1	410	14	42	20	2	60
M core 1	6-11B	10	14	<0.02	44	13	8	38	2	28	8	<0.1	390	18	36	19	2	50
M core 1	11-16A	16	18	<0.02	47	20	16	37	5	24	11	0.2	370	13	82	25	3	79
M core 1	11-16B	14	17	<0.02	46	20	16	35	5	29	10	0.1	380	11	73	24	3	76
M core 1	16-21A	18	18	<0.02	46	19	17	36	4	26	10	0.2	370	13	76	24	3	74
M core 1	16-21A s	15	18	<0.02	47	20	16	37	4	27	10	0.2	370	12	75	24	2	75
M core 1	16-21B	15	18	<0.02	46	20	16	36	5	27	10	0.2	390	12	77	25	3	76
M core 2	0-2B	25	15	<0.02	39	23	16	32	8	61	12	0.3	310	10	86	23	2	150
M core 2	2-4B	23	16	<0.02	40	23	16	32	7	62	12	0.3	330	11	86	23	2	150
M core 2	4-6B	23	17	<0.02	40	23	16	32	7	68	12	0.3	330	9	90	24	2	150
M core 2	6-8B	24	16	<0.02	41	22	17	32	7	68	12	0.3	340	10	87	25	2	150
M core 2	8-10B	23	17	<0.02	42	23	16	35	7	69	13	0.3	330	10	89	25	2	150
M core 2	10-12B	22	18	<0.02	42	22	16	33	6	66	12	0.2	340	10	81	23	2	140
M core 2	12-14B	25	17	<0.02	43	23	17	35	6	66	13	0.2	330	11	86	25	3	150
M core 2	14-19B	16	18	<0.02	45	19	16	33	5	32	10	0.2	350	12	70	23	2	92
M core 2	19-24B	16	18	<0.02	48	19	17	38	5	27	10	0.2	380	13	74	25	2	78

All samples below detection limits for the following elements:

Ag	<2 ppm	Ho	<4 ppm
Au	<8 ppm	Mo	<2 ppm
Bi	<10 ppm	Sn	<5 ppm
Cd	<2 ppm	Ta	<40 ppm
Eu	<2 ppm	U	<100 ppm

Table 8. Composition of wetland sediments at site N in June 1993. (Based on dry weights)
s = laboratory split

Site	Depth cm	Al wt%	Ca wt%	Fe wt%	K wt%	Mg wt%	Na wt%	P wt%	Ti wt%	Mn ppm	S wt%	tot C wt%	org C wt%	As ppm	Ba ppm	Ce ppm	Co ppm	Cr ppm
N core 1	0-2	8	2.8	2.3	2.8	0.57	2.5	0.09	0.33	560	0.13	1.3	1.14	4.7	980	73	9	13
N core 1	2-4	8	2.6	2.5	3	0.53	2.5	0.08	0.3	610	0.14	0.82	0.69	4.3	1000	77	10	10
N core 1	4-6	8.2	2.3	2.7	3.2	0.53	2.6	0.08	0.33	570	0.13	0.89	0.84	8.6	1000	84	12	12
N core 1	6-8	8.1	2.2	2.9	2.8	0.59	2.4	0.08	0.35	630	0.08	0.75	0.73	3.8	960	80	12	14
N core 1	8-10	8	2.3	2.7	2.9	0.55	2.5	0.07	0.34	680	0.05	0.54	0.52	3.5	980	79	12	13
N core 1	10-12	8.2	2.1	2.9	2.9	0.6	2.4	0.08	0.35	850	<0.05	0.43	0.42	3.5	980	80	13	15
N core 1	12-14	8.1	2	4	2.4	0.85	2	0.1	0.45	1300	<0.05	0.65	0.63	7.3	880	82	16	18
N core 1	14-19	8.2	2	3.1	2.9	0.6	2.3	0.08	0.36	1000	<0.05	0.38	0.36	5.3	970	86	14	13
N core 1	14-19 s	8.2	2.1	3.2	2.9	0.6	2.4	0.08	0.36	1000	<0.05	0.31	0.3	5.1	990	88	14	14
N core 1	19-24	8	1.9	2.6	3.3	0.43	2.5	0.08	0.32	650	<0.05	0.17	0.17	7.9	1000	89	9	10
N core 2	0-2	8.1	2.7	2.7	2.8	0.64	2.5	0.09	0.35	650	0.08	0.72	0.6	5.6	980	77	11	14
N core 2	2-4	8.1	2.6	3.3	2.6	0.77	2.3	0.1	0.38	880	0.07	0.64	0.52	4.6	910	79	13	16
N core 2	4-6	8.3	2.8	3	2.6	0.71	2.4	0.09	0.38	760	0.06	0.6	0.48	4	970	76	12	15
N core 2	6-11	8.4	2.8	3.1	2.6	0.73	2.4	0.09	0.39	800	0.06	0.5	0.4	5.5	950	76	12	14
N core 2	11-16	8.2	2.6	3.1	2.7	0.67	2.3	0.09	0.37	820	0.06	0.48	0.36	3.4	950	80	11	14
N core 2	16-21	8.3	2.7	3.3	2.7	0.72	2.3	0.09	0.39	850	0.06	0.53	0.4	4.3	950	79	13	14

Site	Depth cm	Cu ppm	Ga ppm	Hg ppm	La ppm	Li ppm	Nb ppm	Nd ppm	Ni ppm	Pb ppm	Sc ppm	Se ppm	Sr ppm	Th ppm	V ppm	Y ppm	Yb ppm	Zn ppm
N core 1	0-2	12	17	<0.02	42	16	16	33	4	22	7	0.1	570	10	57	20	2	53
N core 1	2-4	10	18	<0.02	45	16	16	34	3	25	7	<0.1	540	12	52	20	2	56
N core 1	4-6	9	19	<0.02	45	17	15	35	5	23	7	0.1	520	13	59	21	2	58
N core 1	6-8	11	19	<0.02	45	18	16	35	5	24	8	0.1	520	14	62	22	3	63
N core 1	8-10	9	18	<0.02	42	16	16	35	5	24	8	<0.1	520	12	58	20	3	58
N core 1	10-12	11	19	<0.02	46	18	15	37	6	17	8	<0.1	510	13	62	22	2	63
N core 1	12-14	16	19	<0.02	44	23	16	36	9	24	12	0.1	460	12	81	25	3	89
N core 1	14-19	12	21	<0.02	48	19	16	36	7	21	9	0.1	470	13	65	23	2	67
N core 1	14-19 s	10	20	<0.02	48	18	17	37	6	24	9	<0.1	480	14	66	23	2	67
N core 1	19-24	9	19	<0.02	51	15	17	38	4	26	7	0.2	460	14	51	23	2	53
N core 2	0-2	11	18	<0.02	43	18	17	32	5	20	8	0.1	570	10	60	21	2	60
N core 2	2-4	13	18	<0.02	44	21	17	35	6	21	9	0.1	530	12	73	22	2	76
N core 2	4-6	10	19	<0.02	42	19	14	33	6	21	9	<0.1	580	11	67	21	2	68
N core 2	6-11	11	19	<0.02	42	19	14	33	5	21	9	<0.1	580	11	70	21	3	70
N core 2	11-16	9	19	<0.02	44	19	15	34	5	21	9	0.1	530	12	66	21	2	70
N core 2	16-21	13	19	<0.02	44	20	18	35	6	23	9	0.1	540	12	73	22	2	73

All samples below detection limits for the following elements:

Ag	<2 ppm	Ho	<4 ppm
Au	<8 ppm	Mo	<2 ppm
Bi	<10 ppm	Sn	<5 ppm
Cd	<2 ppm	Ta	<40 ppm
Eu	<2 ppm	U	<100 ppm

Table 9. Composition of wetland sediments at site O in June 1993. (Based on dry weights)
B = field split; s = laboratory split

Site	Depth cm	Al wt%	Ca wt%	Fe wt%	K wt%	Mg wt%	Na wt%	P wt%	Ti wt%	Mn ppm	S wt%	tot C wt%	org C wt%	As ppm	Ba ppm	Ce ppm	Co ppm	Cr ppm
O core 1	0-2B	7.8	1.5	4.9	2	0.86	0.98	0.18	0.37	1600	0.16	3.24	3.19	6.3	680	67	27	20
O core 1	2-4B	8.1	1.3	4.8	2.2	0.88	1	0.16	0.39	900	0.12	2.66	2.66	3.4	690	73	20	22
O core 1	4-6B	8	1.3	4.6	2.1	0.87	0.98	0.16	0.39	660	0.13	3.22	3.21	3.3	660	70	17	20
O core 1	6-8B	8.1	1.3	4.7	2.2	0.89	1	0.16	0.39	610	0.13	3.17	3.17	5.5	670	69	17	21
O core 1	8-10B	8	1.3	5	2.1	0.86	0.98	0.18	0.39	780	0.13	2.8	2.8	4.8	660	70	20	21
O core 1	10-12B	8.1	1.3	4.8	2.1	0.86	1	0.17	0.41	630	0.12	2.68	2.68	6.4	680	72	17	21
O core 1	10-12B s	8	1.3	4.7	2.1	0.85	0.99	0.17	0.39	620	0.12	2.65	2.65	4.6	670	70	16	22
O core 1	12-14B	8.1	1.3	4.8	2.1	0.86	1	0.17	0.38	830	0.11	2.28	2.27	8.3	680	69	18	20
O core 1	14-19B	8.6	1.2	5.1	2.2	0.88	0.99	0.18	0.38	710	0.11	1.89	1.89	7.3	700	71	15	21
O core 1	19-24B	8.4	1.2	5.3	2.1	0.86	0.99	0.19	0.4	770	0.11	1.66	1.66	9.9	660	73	20	20
O core 2	0-2	8	1.4	6.2	2	0.83	0.99	0.22	0.38	670	0.11	1.72	1.67	11	620	70	18	20
O core 2	2-4	7.7	1.1	6.1	2	0.8	0.97	0.21	0.37	820	0.11	1.38	1.36	6.9	660	74	18	19
O core 2	4-6	8.2	1.3	5.8	2.1	0.86	1	0.2	0.38	670	0.11	1.95	1.93	4.6	650	70	20	20
O core 2	6-11	8.1	1.2	5.3	2	0.85	0.99	0.19	0.39	640	0.11	2	2	4.7	650	71	18	20
O core 2	6-11 s	8.1	1.2	5.3	2.1	0.85	1	0.19	0.4	630	0.12	2.14	2.12	5.3	650	70	17	22
O core 2	11-16	8.3	1.2	5.8	2.1	0.84	0.98	0.21	0.38	700	0.11	1.66	1.66	9.9	650	70	20	19
O core 2	16-21	8.4	1.2	5.8	2.1	0.84	1	0.21	0.4	640	0.11	1.36	1.36	7.1	650	73	18	20
O core 2	33-42	7.8	1.1	5.2	2.1	0.8	1.1	0.17	0.39	870	0.1	0.96	0.96	5.5	700	74	20	20

Site	Depth cm	Cu ppm	Ga ppm	Hg ppm	La ppm	Li ppm	Nb ppm	Nd ppm	Ni ppm	Pb ppm	Sc ppm	Se ppm	Sr ppm	Th ppm	V ppm	Y ppm	Yb ppm	Zn ppm
O core 1	0-2B	43	18	<0.02	35	16	11	30	13	30	12	0.9	400	9	110	19	2	130
O core 1	2-4B	44	19	<0.02	37	17	10	34	11	29	13	0.8	410	9	120	20	2	130
O core 1	4-6B	44	17	0.02	36	16	12	30	11	32	12	0.9	400	8	120	20	2	130
O core 1	6-8B	44	19	0.02	37	17	13	33	11	27	13	1	400	10	120	20	2	130
O core 1	8-10B	44	18	0.02	36	16	11	33	12	30	12	1.1	400	10	120	20	2	130
O core 1	10-12B	43	18	0.02	37	16	13	30	11	33	12	1.2	410	10	120	21	2	130
O core 1	10-12B s	44	18	0.02	37	16	11	33	12	31	12	1	400	10	110	20	2	130
O core 1	12-14B	44	18	0.02	36	16	12	32	12	32	12	1	400	10	120	20	2	130
O core 1	14-19B	44	20	0.02	38	17	12	34	12	27	13	1.3	400	11	120	20	2	140
O core 1	19-24B	43	20	<0.02	38	17	12	35	12	29	13	1.6	400	10	130	22	2	140
O core 2	0-2	39	17	<0.02	36	15	12	32	11	27	13	1.4	400	9	120	20	2	140
O core 2	2-4	40	16	<0.02	39	16	11	34	11	27	12	1.5	400	10	130	18	1	130
O core 2	4-6	42	17	<0.02	37	16	12	32	11	30	13	1.3	400	10	120	20	2	140
O core 2	6-11	42	18	<0.02	37	16	11	33	11	30	13	1.3	400	9	120	20	2	130
O core 2	6-11 s	41	17	<0.02	37	16	11	32	12	31	13	1.3	400	9	120	20	2	130
O core 2	11-16	42	18	<0.02	38	16	13	34	12	31	13	1.7	400	11	130	20	2	140
O core 2	16-21	42	18	<0.02	38	16	11	32	12	30	13	1.6	400	10	130	21	2	140
O core 2	33-42	44	18	<0.02	38	15	11	30	13	28	12	0.7	410	9	120	16	1	120

All samples below detection limits for the following elements:

Ag	<2 ppm	Ho	<4 ppm
Au	<8 ppm	Mo	<2 ppm
Bi	<10 ppm	Sn	<5 ppm
Cd	<2 ppm	Ta	<40 ppm
Eu	<2 ppm	U	<100 ppm

Table 10. Composition of wetland sediments at sites Q and R in June 1993. (Based on dry weights)
s = laboratory split

Site	Depth cm	Al wt%	Ca wt%	Fe wt%	K wt%	Mg wt%	Na wt%	P wt%	Ti wt%	Mn ppm	S wt%	tot C wt%	org C wt%	As ppm	Ba ppm	Ce ppm	Co ppm	Cr ppm
Q	0-5	3.1	2.3	1.3	0.98	0.51	0.54	0.17	0.12	160	1.1	28.3	28.2	0.6	270	25	5	9
Q	0-5 s	3.3	2.4	1.4	1.1	0.52	0.61	0.17	0.12	190	1.05	26.3	26.2	1	300	25	6	10
Q	10-15	7.1	1.9	3.7	2.5	0.97	1.2	0.24	0.34	400	0.16	2.5	2.34	4.1	770	59	16	17
Q	15-25	7.5	2.7	4.2	2.5	1.1	1.1	0.21	0.34	640	0.14	1.86	1.44	6.1	730	61	22	17
R	0-10	6	1.5	2.5	2	0.66	1.2	0.12	0.3	300	0.53	11.5	11.5	1.2	570	47	9	16
R	10-15	7.3	1.2	4.2	2.6	0.76	1.6	0.16	0.46	430	0.13	1.62	1.62	2.7	610	64	14	20
R	15-22	7.6	1.3	4.5	2.7	0.63	1.5	0.18	0.41	860	0.12	1.02	0.99	5	800	65	20	17
R	22-32	8	2.5	4.6	2.7	1	1.3	0.16	0.4	1100	0.11	0.9	0.52	5.2	730	64	25	15

Site	Depth cm	Cu ppm	Ga ppm	Hg ppm	La ppm	Li ppm	Nb ppm	Nd ppm	Ni ppm	Pb ppm	Sc ppm	Se ppm	Sr ppm	Th ppm	V ppm	Y ppm	Yb ppm	Zn ppm
Q	0-5	32	7	<0.02	13	7	4	12	5	19	4	0.8	260	<4	36	7	<1	99
Q	0-5 s	32	7	<0.02	13	8	5	12	6	16	4	1.3	270	<4	41	7	<1	100
Q	10-15	42	15	<0.02	30	13	11	27	13	31	9	1.5	440	7	96	15	1	110
Q	15-25	46	15	<0.02	32	15	11	30	17	29	10	1.2	430	7	110	17	1	120
R	0-10	48	13	<0.02	24	13	6	21	9	28	7	0.6	380	6	84	11	1	110
R	10-15	31	16	<0.02	34	14	13	26	11	26	9	0.6	450	9	120	15	2	110
R	15-22	38	16	<0.02	34	15	12	27	13	26	10	0.8	440	8	120	15	1	110
R	22-32	44	17	<0.02	32	17	13	29	14	26	11	0.8	430	7	120	15	1	120

All samples below detection limits for the following elements:

Ag	<2 ppm	Ho	<4 ppm
Au	<8 ppm	Mo	<2 ppm
Bi	<10 ppm	Sn	<5 ppm
Cd	<2 ppm	Ta	<40 ppm
Eu	<2 ppm	U	<100 ppm

Table 11. Pb-210 and water content of cores at wetland sites O and M in June 1993. (Based on dry weights)
s = laboratory split

Site	Depth cm	supported Pb-210 dpm/g	fraction of water	estimated date
O core 1	0-2	1.68	0.702	1988-1993
O core 1	2-4	1.55	0.627	1983-1988
O core 1	2-4 s	1.5		
O core 1	4-6	1.85	0.624	1977-1983
O core 1	6-8	1.86	0.617	1971-1977
O core 1	8-10	1.67	0.609	1966-1971
O core 1	10-12	1.29	0.589	1960-1966
O core 1	12-14	1.22	0.589	1953-1960
O core 1	12-14 s	1.26		
O core 1	14-19	0.969	0.586	1938-1953
O core 1	19-24	0.917	0.587	1923-1938
O core 2	33-42	0.819		
M core 2	0-2	2.62	0.743	1986-1993
M core 2	2-4	2.52	0.663	1977-1986
M core 2	2-4 s	2.96		
M core 2	4-6	2.32	0.652	1968-1977
M core 2	6-8	1.98	0.621	1958-1968
M core 2	8-10	1.93	0.616	1948-1958
M core 2	10-12	1.94	0.602	1938-1948
M core 2	12-14	1.44	0.593	1927-1938
M core 2	12-14 s	1.54		
M core 2	14-19	0.875	0.563	
M core 2	19-24	0.865	0.762	

Site O core 1 was compacted during collection.
Uncompacted depths = (1.36 x sampled depth), assuming uniform compaction.

Estimated dates from analysis of Pb-210 data (see text).

Table 12. Composition of aquatic plant, Persicaria amphibia (smartweed), in wetlands in June 1993. (Based on dry weight)
DUP = duplicate field sample; s = laboratory split

Site	ash wt%	Al ppm	Ca wt%	Fe ppm	K wt%	Mg wt%	Na wt%	P wt%	Ti ppm	Mn ppm	total S wt%	As ppm
L sample 1	9.67	220	1.9	270	1.4	0.36	0.57	0.35	10	780	0.163	1.2
L sample 1 DUP	9.33	210	1.9	310	1.2	0.35	0.57	0.31	9	550	0.159	1.1
L sample 2	8.33	130	1.5	270	1.4	0.34	0.49	0.34	<9	550	0.155	0.7
S sample 1	9	81	0.99	230	1.3	0.32	1	0.4	<9	4100	0.257	0.6
S sample 2	8.67	150	0.95	250	1.1	0.31	0.95	0.39	9	4500	0.19	0.7
S sample 2 DUP	9	140	0.99	250	1.3	0.32	1.1	0.41	9	4400	0.267	0.7
O sample 1	8.33	25	1.2	270	2	0.28	0.16	0.36	<9	1500	0.228	0.6
O sample 1 DUP	7.67	31	1	210	2	0.25	0.15	0.35	<9	1200	0.189	0.4
O sample 1 DUP s	7.67	77	1	210	2.1	0.25	0.15	0.38	<9	1100	0.196	0.4
O sample 2	6.67	47	1	220	1.7	0.23	0.13	0.28	<9	1100	0.166	0.5
O sample 2 DUP	7.67	23	1.1	230	1.9	0.26	0.15	0.32	<9	1200	0.189	0.4
P1	9	18	1.3	350	2.4	0.3	0.17	0.49	<9	490	0.28	0.4
P1 DUP	9	45	1.4	380	2.2	0.32	0.17	0.55	<9	410	0.314	0.3
Q	10.3	41	1.1	310	2.7	0.39	0.49	0.43	<9	1400	0.622	0.3
Q DUP	10	40	1.1	350	2.7	0.37	0.45	0.46	<9	1600	0.653	0.3
R sample 1	8	16	1	180	2.2	0.26	0.067	0.54	<9	290	0.326	0.1
R sample 2	8.67	26	1.4	180	2.2	0.33	0.087	0.43	<9	470	0.27	0.1
R sample 2 s	8.67	26	1.4	180	2.2	0.32	0.087	0.44	<9	470	0.273	0.1

Site	Ba ppm	Co ppm	Cr ppm	Cu ppm	La ppm	Li ppm	Mo ppm	Ni ppm	Pb ppm	Sr ppm	V ppm	Zn ppm
L sample 1	140	0.58	0.2	4.2	<0.4	0.8	2.5	<0.3	2.8	290	1.5	18
L sample 1 DUP	110	1.3	<0.2	2.7	<0.4	0.8	2.9	<0.3	2.1	260	1.4	13
L sample 2	92	0.67	0.2	3.2	<0.4	0.7	2.3	0.3	1.3	210	1.1	17
S semple 1	83	1.6	<0.2	4.8	0.4	0.5	0.45	<0.3	<0.8	130	0.36	18
S sample 2	76	1.6	<0.2	7.3	0.4	0.5	0.43	0.8	<0.8	120	0.52	20
S sample 2 DUP	78	1.5	<0.2	6.9	0.5	0.5	0.45	0.8	<0.8	140	0.45	21
O sample 1	29	1.9	<0.2	7.4	<0.4	<0.3	0.92	0.4	<0.8	120	1.5	21
O sample 1 DUP	23	1.7	<0.2	5.6	<0.4	<0.3	0.92	0.4	<0.8	110	1.2	18
O sample 1 DUP s	23	1.7	0.2	5.8	<0.4	<0.3	0.92	0.4	<0.8	110	1.2	19
O sample 2	23	1.3	<0.2	4.3	<0.4	<0.3	1.1	0.3	<0.8	110	1.5	15
O sample 2 DUP	25	1.5	<0.2	4.8	<0.4	<0.3	1.2	0.4	<0.8	120	1.9	17
P1	14	2.1	0.2	13	<0.4	0.5	1.6	0.5	<0.8	140	0.54	33
P1 DUP	14	2.5	0.3	12	<0.4	0.5	1.8	0.5	<0.8	130	0.81	40
Q	23	1.9	<0.2	8.4	<0.4	0.5	0.72	0.4	<0.8	140	<0.36	25
Q DUP	22	1.9	<0.2	7.3	<0.4	<0.3	0.6	<0.3	<0.8	120	<0.36	28
R sample 1	15	2.2	0.2	13	<0.4	0.3	0.88	0.6	<0.8	96	0.4	41
R sample 2	14	2.5	<0.2	9.5	<0.4	0.6	1.5	4	<0.8	110	0.43	39
R sample 2 s	14	2.5	0.2	10	<0.4	0.7	1.6	2	<0.8	110	0.52	40

Sites O, P1, Q, and R receive some surface water from the Alamosa River.
Sites L and S recaive surface water from other sources.

All samples below detection limits for the following elements:
(Assumes ash weight of 9%)

Ag	<0.4 ppm	Nb	<0.7 ppm
Au	<2 ppm	Nd	<0.7 ppm
Be	<0.2 ppm	Sc	<0.4 ppm
Bi	<2 ppm	Sn	<1 ppm
Cd	<0.4 ppm	Ta	<7 ppm
Ce	<0.7 ppm	Th	<0.06 ppm
Eu	<0.4 ppm	U	<18 ppm
Ga	<0.7 ppm	Y	<0.4 ppm
Hg	<0.02 ppm	Yb	<0.2 ppm
Ho	<0.7 ppm		

Table 13. Composition of aquatic plant, Potamogeton natans (pondweed), in wetlands in June 1993. (Based on dry weights)
DUP = duplicate field sample

Site	ash wt%	Al ppm	Ca wt%	Fe ppm	K wt%	Mg wt%	Na wt%	P wt%	Ti ppm	Mn ppm	total S wt%	As ppm
L sample 1	9	430	1.7	460	1.4	0.32	0.36	0.32	30	710	0.203	1.2
L sample 1 DUP	9.67	330	1.8	410	1.7	0.31	0.43	0.36	20	730	0.183	1.1
L sample 2	9.67	390	1.7	500	1.7	0.3	0.36	0.42	20	670	0.177	1.5
M sample 1	9	890	2.1	650	0.76	0.34	0.23	0.48	50	160	0.222	0.5
M sample 1 DUP	9.67	360	1.8	380	1.5	0.32	0.39	0.62	20	150	0.275	0.5
M sample 2	9.67	400	0.84	390	2.6	0.24	0.71	0.45	20	92	0.28	0.8
M sample 2 DUP	10	400	0.89	400	2.7	0.26	0.75	0.49	20	93	0.3	0.9
N sample 1	8	380	1.5	880	0.96	0.19	0.44	0.3	20	770	0.214	5.6
N sample 1 DUP	8.67	430	1.3	510	1.4	0.21	0.65	0.35	30	950	0.31	4.2
N sample 2	8.67	78	1.3	170	1.9	0.23	0.6	0.37	<9	290	0.3	2.7
P1	9	140	1.7	1700	1.3	0.32	0.17	0.36	<9	3000	0.292	1.4

Site	Ba ppm	Co ppm	Cr ppm	Cu ppm	La ppm	Li ppm	Mo ppm	Ni ppm	Pb ppm	Sr ppm	V ppm	Zn ppm
L sample 1	77	0.63	0.3	6.3	0.5	<0.3	2.7	0.5	4.7	220	3.7	25
L sample 1 DUP	130	0.77	0.3	6.7	0.5	0.4	3	<0.3	5	230	3.1	34
L sample 2	97	0.58	0.3	7.1	<0.4	0.4	4	0.6	4.3	200	7	30
M sample 1	83	0.72	0.5	9	0.6	0.5	1.3	0.5	1.3	200	1.6	47
M sample 1 DUP	75	0.58	0.4	6.9	<0.4	<0.3	1.2	<0.3	0.8	180	0.97	48
M sample 2	41	0.68	0.1	5.2	0.4	<0.3	0.97	2	1	97	3	36
M sample 2 DUP	42	0.6	0.4	5.5	0.5	<0.3	1.1	2	1.3	100	3.2	38
N sample 1	62	0.4	0.2	3.7	0.5	0.4	3.8	<0.3	<0.8	230	4.5	22
N sample 1 DUP	61	0.52	0.3	3.6	0.5	0.5	4.7	0.5	0.8	230	4.7	36
N sample 2	49	0.26	0.2	4.9	<0.4	<0.3	5	0.6	<0.8	210	2	28
P1	68	8.3	<0.2	14	<0.4	<0.3	1.6	<0.3	<0.8	170	1.6	38

Site P1 receives some surface water from the Alamosa River.
Sites L, M, and N receive surface water from other sources.

All samples below detection limits for the following elements:
(Assumes ash weight of 9%)

Ag	<0.4 ppm	Nb	<0.7 ppm
Au	<2 ppm	Nd	<0.7 ppm
Be	<0.2 ppm	Sc	<0.4 ppm
Bi	<2 ppm	Sn	<1 ppm
Cd	<0.4 ppm	Ta	<7 ppm
Ce	<0.7 ppm	Th	<0.06 ppm
Eu	<0.4 ppm	U	<18 ppm
Ga	<0.7 ppm	Y	<0.4 ppm
Hg	<0.02 ppm	Yb	<0.2 ppm
Ho	<0.7 ppm		

Table 14. Composition of Standard Reference Materials (SRM) for sediments. (Based on dry weight)

Element		SRM 2709 This work Ave of 3	Std. Dev.	NIST value	SRM 2710 This work Ave of 3	Std. Dev.	NIST value	SRM 2711 This work Ave of 3	Std. Dev.	NIST value
Al	wt%	7.43	0.09	7.5	6.43	0.17	6.44	6.6	0.22	6.53
Ca	wt%	2	0	1.89	1.33	0.05	1.25	3	0.08	2.88
Fe	wt%	3.6	0.08	3.5	3.47	0.12	3.38	2.97	0.12	2.89
K	wt%	1.97	0.05	2.03	2.03	0.05	2.11	2.47	0.05	2.45
Mg	wt%	1.53	0.05	1.51	0.87	0.02	0.853	1.07	0.05	1.05
Na	wt%	1.2	0	1.16	1.17	0.05	1.14	1.23	0.05	1.14
P	wt%	0.07	0	0.062	0.12	0	0.106	0.09	0	0.086
Ti	wt%	0.34	0	0.342	0.27	0	0.283	0.28	0.01	0.306
Mn	ppm	560	8		10300	497	10100	667	19	638
S	wt%	0.09	0	0.089	0.24	0.01	0.24	<0.05		0.042
total C	wt%	1.2	0.03	(1.2)	3.14	0.05	(3)	1.88	0.03	(2)
org C	wt%	0.94	0.02		3.13	0.05		1.36	0.03	
As	ppm	16.3	2.4	17.7	600	0	626	76.7	4.7	105
Ba	ppm	933	19	968	700	8	707	730	0	726
Ce	ppm	46	2.2	(42)	59.7	2.9	(57)	76.3	2.9	(69)
Co	ppm	15.7	0.5	13.4	11.7	0.9	(10)	12	0.8	(10)
Cr	ppm	126.7	4.7	130	34.3	0.9	(39)	48.7	2.1	(47)
Cu	ppm	35	0	34.6	3000	163	2950	117	5	114
Ga	ppm	16	0.8	(14)	40.3	2.4	(34)	17.3	0.5	(15)
Hg	ppm	1.4	0	1.4	26.7	0.9	32.6	5.2	0.7	6.25
La	ppm	24.3	1.2	(23)	33	2.2	(34)	41	2.2	(40)
Li	ppm	56.7	0.5		41	0.8		28	1.4	
Nb	ppm	11.7	0.5		13	0.8		17.3	0.5	
Nd	ppm	20	0.8	(19)	24	0.8	(23)	32.7	0.5	(31)
NI	ppm	87	2.2	88	12.7	0.5	14.3	20.3	0.5	20.6
Pb	ppm	21	1	18.9	4933	368	5532	1053	105	1162
Se	ppm	1.43	0.12	1.57	0.6	0		1.3	0.08	1.52
Sc	ppm	12	0	(12)	9	0	(8.7)	10	0	(9)
Sr	ppm	240	0	231	340	0	(240)	257	5	245
Th	ppm	11.3	1.7	(11)	11	0.8	(13)	14.7	2.1	13.6
V	ppm	117	5	112	75.7	1.2	76.6	85	2	81.6
Y	ppm	15.7	0.5	(18)	20.7	0.5	(23)	25.3	0.5	(25)
Yb	ppm	1.3	0.5	(1.6)	2	0	(1.3)	2.7	0.5	(2.7)
Zn	ppm	103	5	106	6767	287	6952	353	17	350.4

NIST values from Certificate of Analysis for each reference material; parentheses indicate non-certified values

Table 15. Composition of Standard Reference Material (SRM) for plants (SRM 1515, apple leaves, based on dry weight)

		SRM 1515 This study n=1	NIST value
ash	wt%	7	
Al	ppm	260	286
Ca	wt%	1.5	1.526
Fe	ppm	70	(80)
K	wt%	1.6	1.61
Mg	wt%	0.25	0.271
Na	ppm	35	24.4
P	wt%	0.17	
Ti	ppm	10	
Mn	ppm	50	54
total S	wt%	0.11	(0.18)
As	ppm	0.06	0.038
Ba	ppm	46	49
Co	ppm	0.21	(0.09)
Cr	ppm	0.42	(0.3)
Cu	ppm	5.5	5.64
Hg	ppm	0.04	0.044
La	ppm	20	(20)
Li	ppm	<4	
Mo	ppm	<4	0.094
Ni	ppm	0.91	0.91
Pb	ppm	<7	0.47
Sr	ppm	25	25
V	ppm	<4	0.26
Zn	ppm	11	12.5

NIST value from Certificate of Analysis for the reference material; parentheses indicate non-certified values

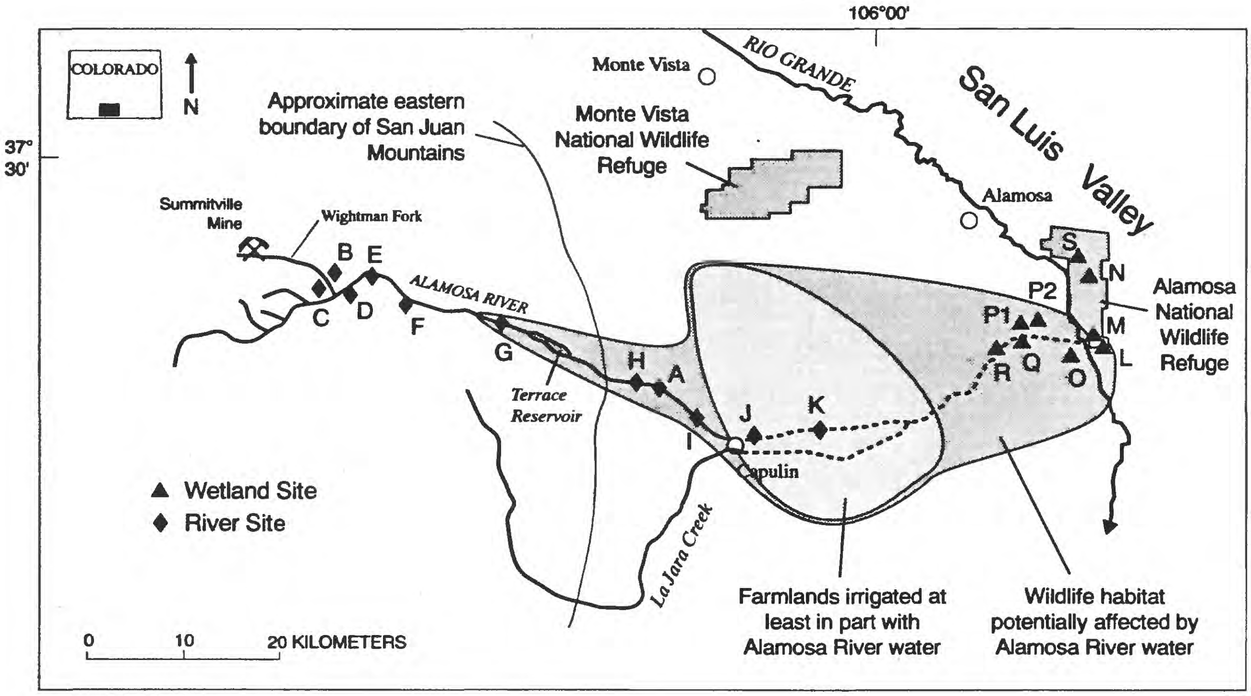

Fig. 1. Map of the study area showing river and wetland sampling locations.

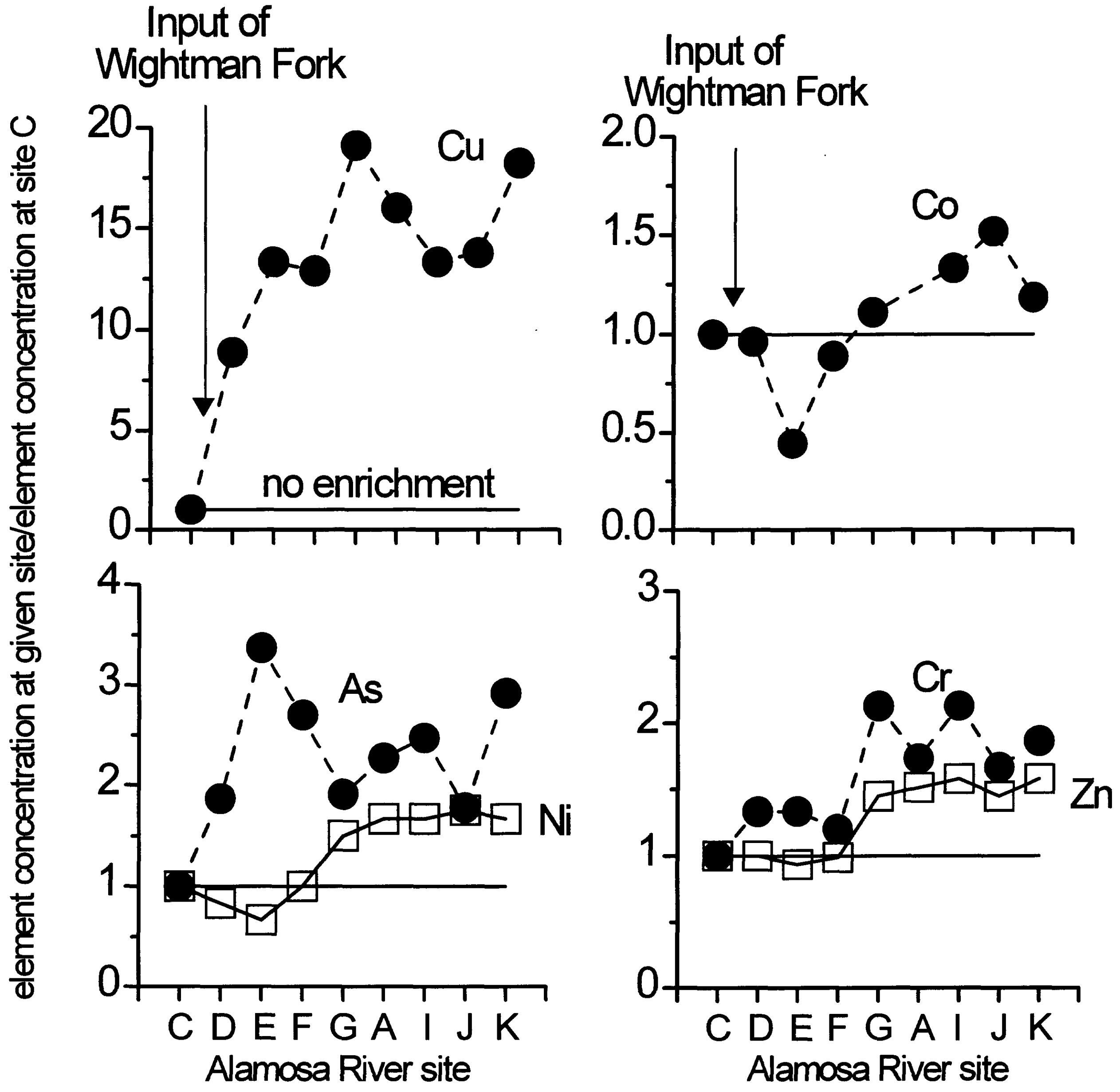

Fig. 2. Enrichment of elements in Alamosa River bed sediments at sites downstream of the confluence with the Wightman Fork relative to bed sediments at a site above the confluence (site C) during June 1993. A value of 1 indicates no enrichment relative to site C.

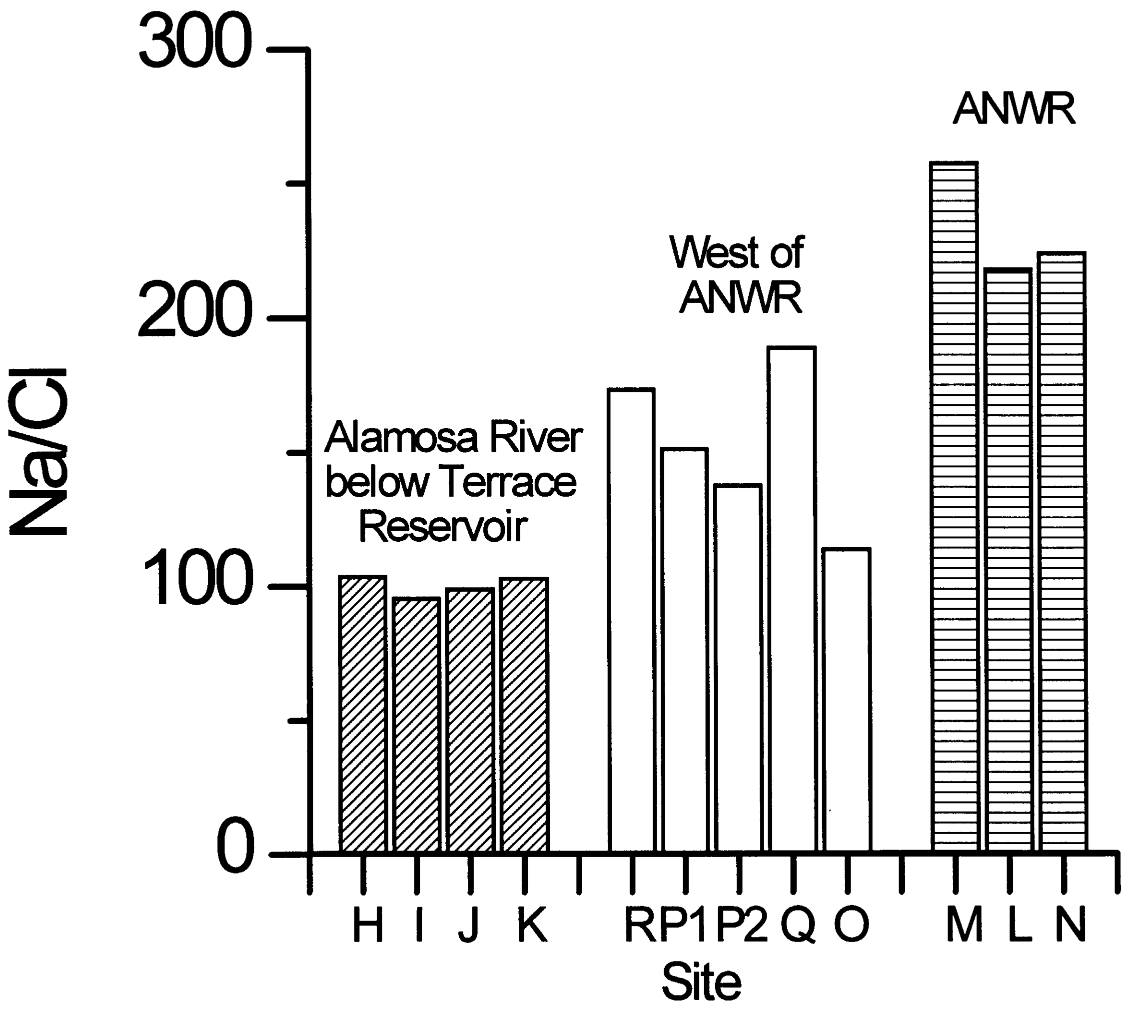

Fig. 3. Ratio of Na to Cl concentrations in Alamosa River waters below Terrace Reservoir and in wetland waters west of and within the Alamosa National Wildlife Refuge (ANWR) during June 1993.

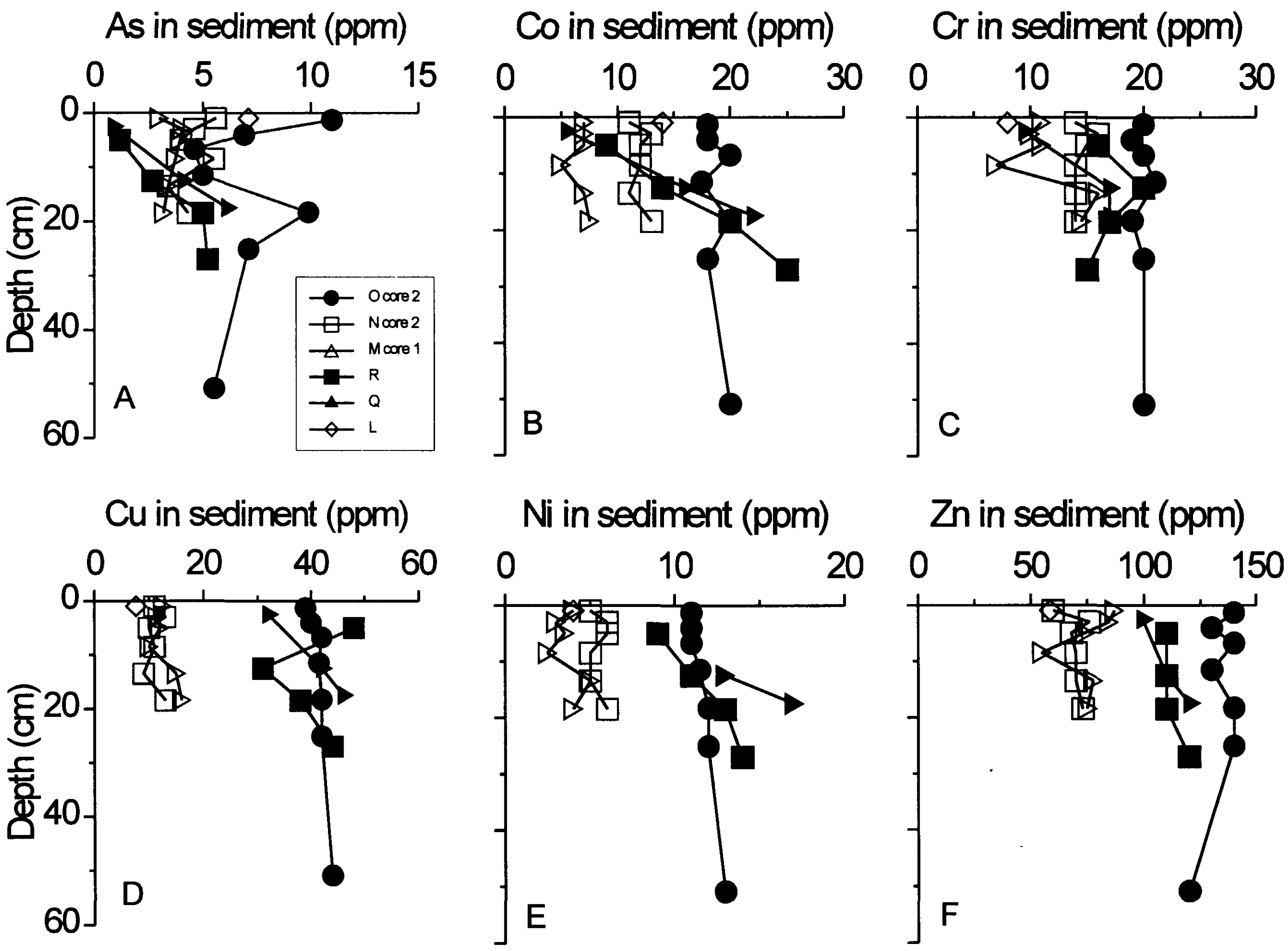

Fig. 4. Concentrations of indicator elements in selected wetland sediments during June 1993. Closed symbols indicate wetlands receiving Alamosa River water; open symbols indicate wetlands receiving water from other sources.

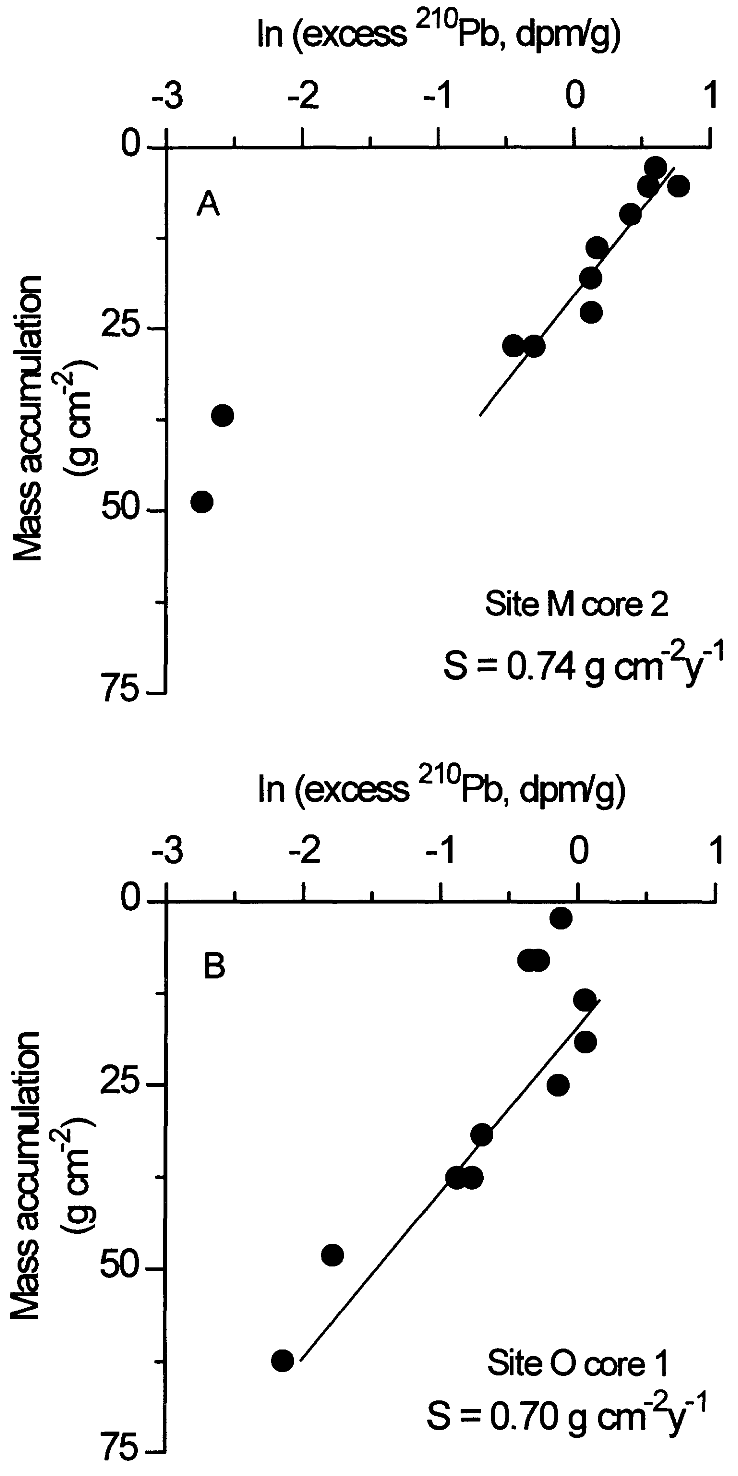

Fig. 5. Excess ^{210}Pb as a function of mass accumulation at wetland sites M and O. The slope of the solid line is used to calculate the accumulation rate (see text).

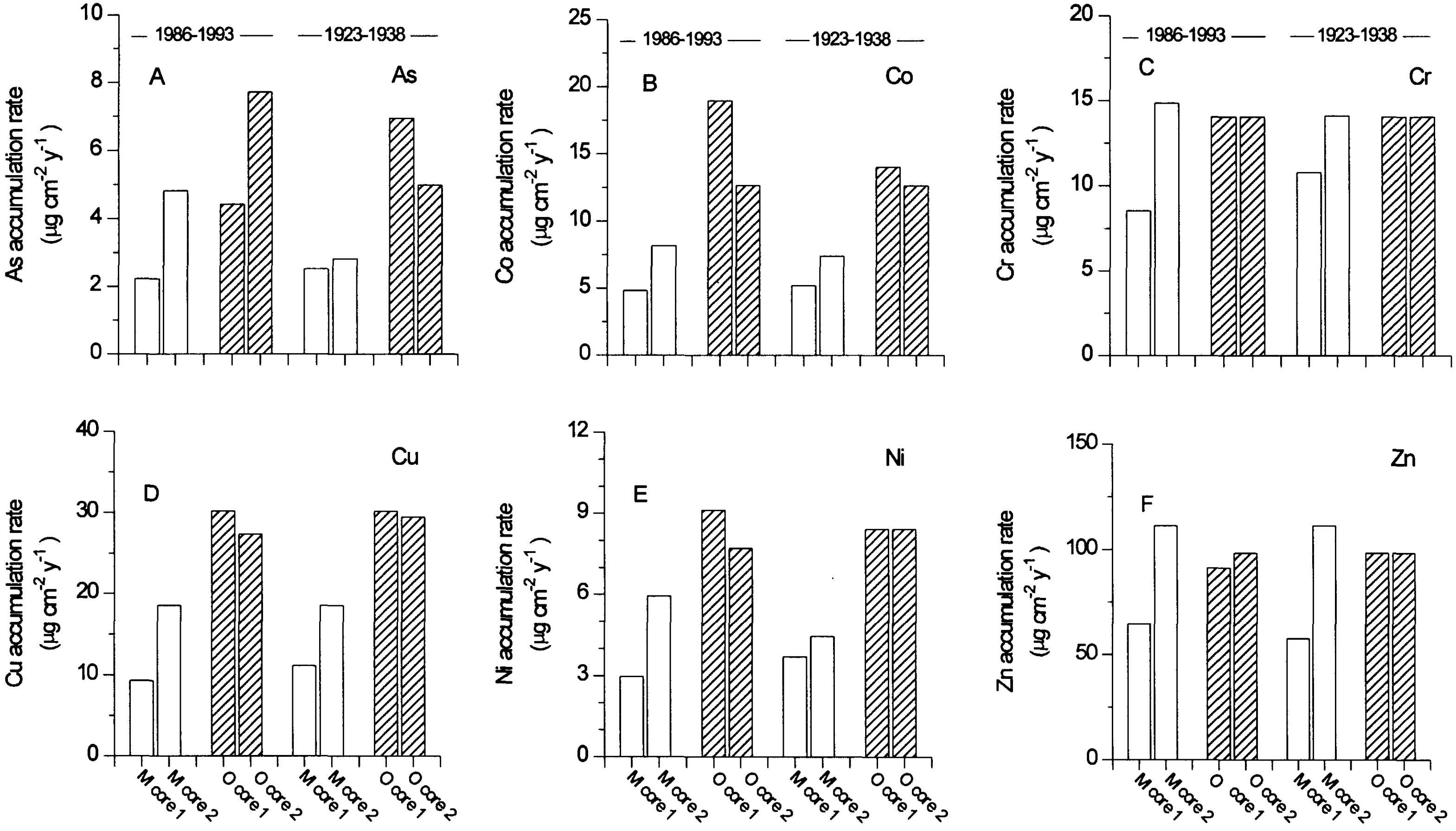

Fig. 6. Accumulation rates for indicator elements at two wetland sites for two time periods: pre (1923-1938) and post (1986-1993) open-pit mining at Summitville Mine. Site O receives Alamosa River water whereas site M receives surface water from other sources.

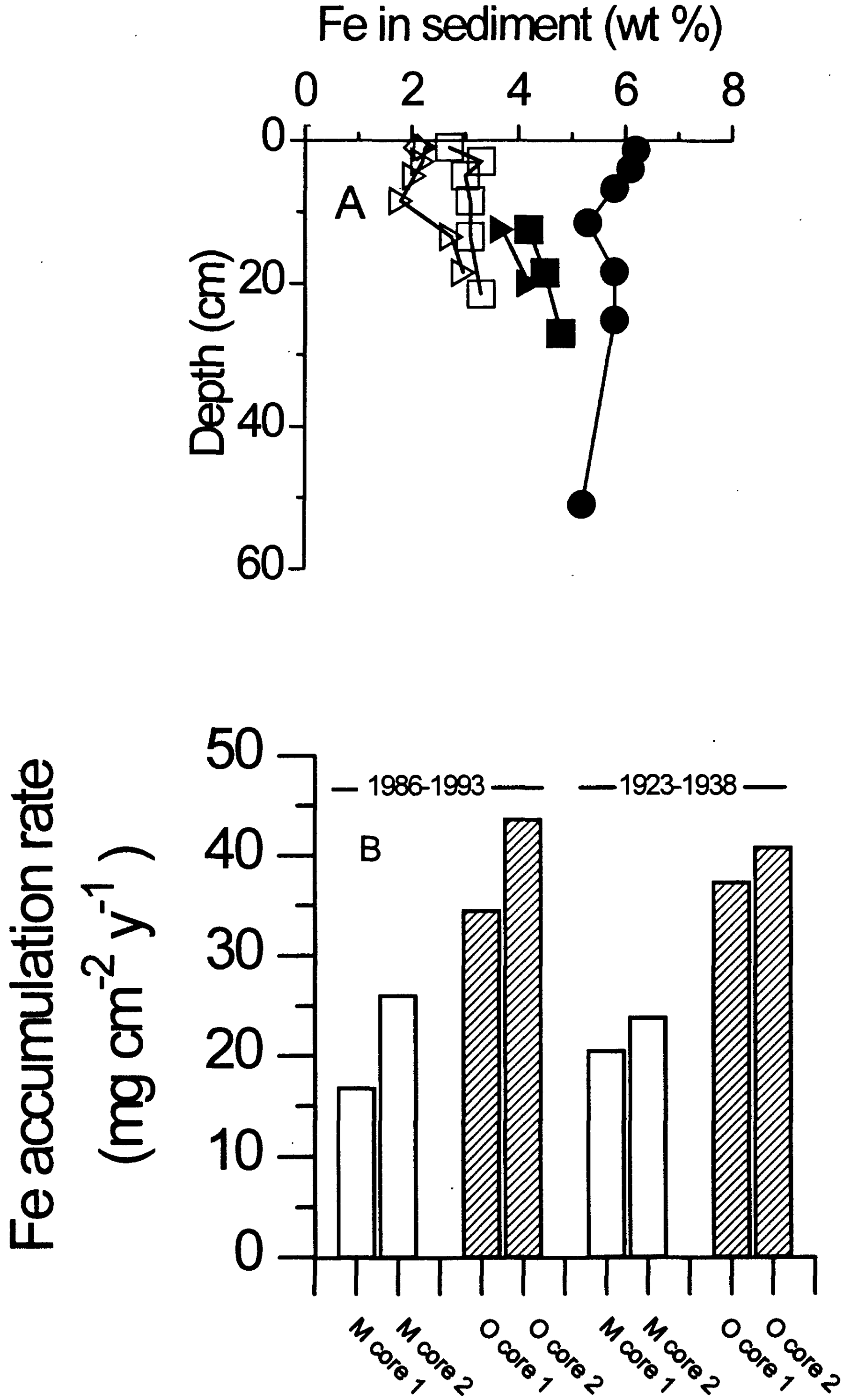

Fig. 7. a) Fe content and b) accumulation rate in selected wetlands in the San Luis Valley, Co during 1993. Site O and wetlands denoted by closed symbols receive Alamosa River water; site M and wetlands denoted by open symbols receive surface water from other sources.

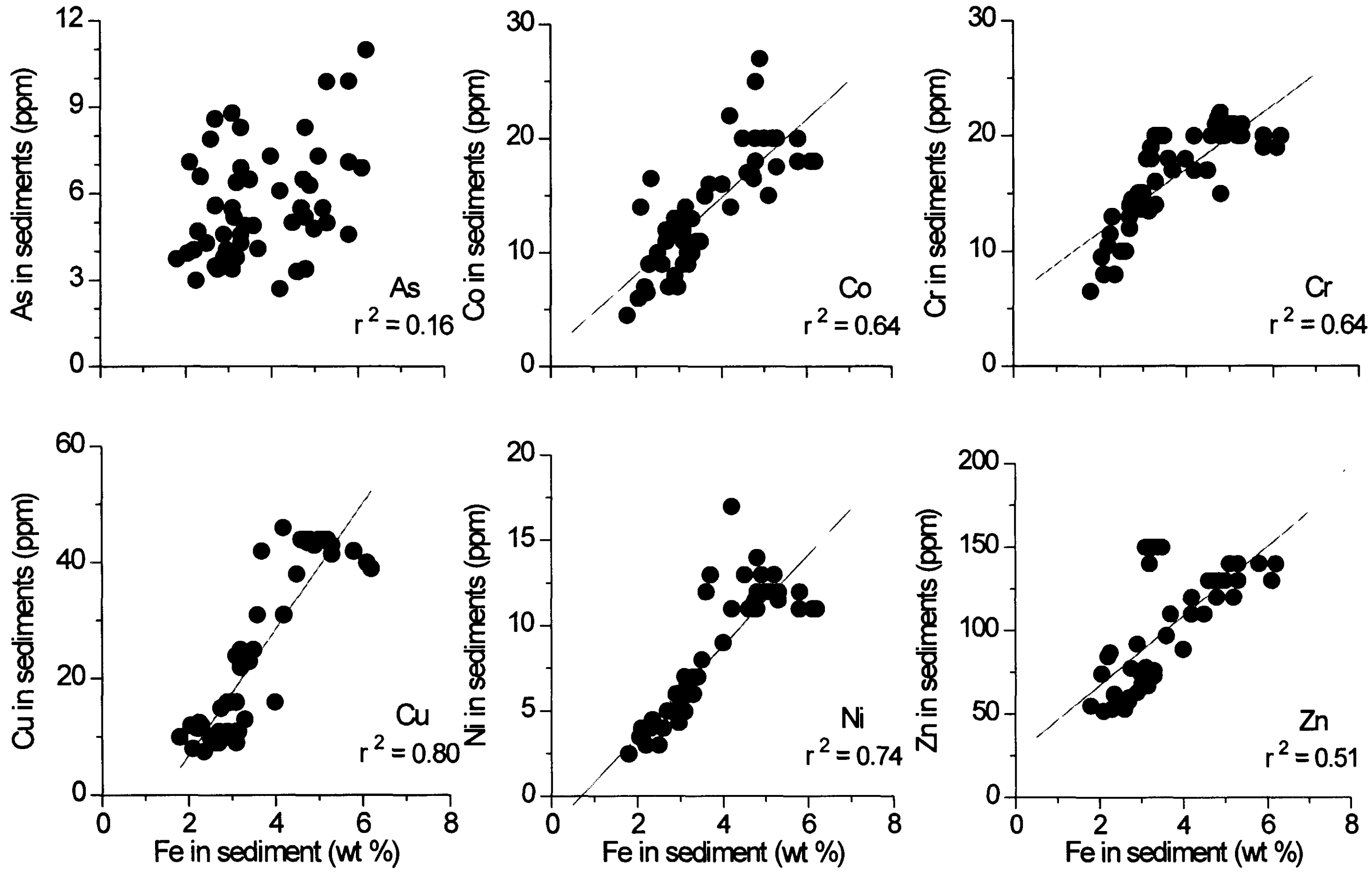

Fig. 8. Correlations between concentrations of Fe and indicator elements in all wetland sediments except those at site P2 and those having >4% organic C.

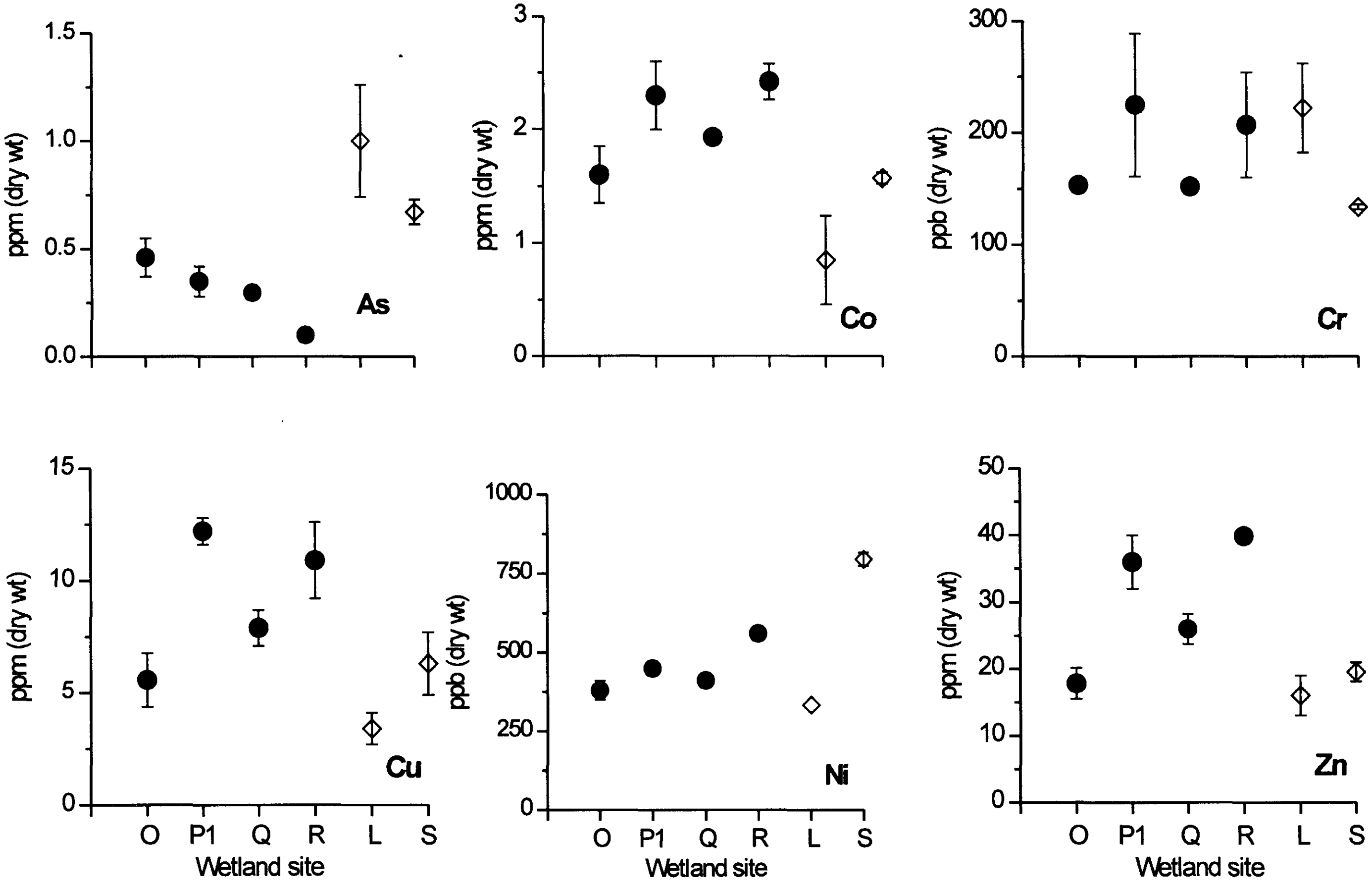

Fig. 9. Concentrations of indicator elements in the aquatic wetland plant Persicaria amphibia (smartweed) in selected wetlands in the San Luis Valley, Co during June 1993. Closed symbols denote wetlands receiving Alamosa River water; open symbols denote wetlands receiving surface water from other sources. Error bars denote standard deviation of element concentrations of all plants at a given site.

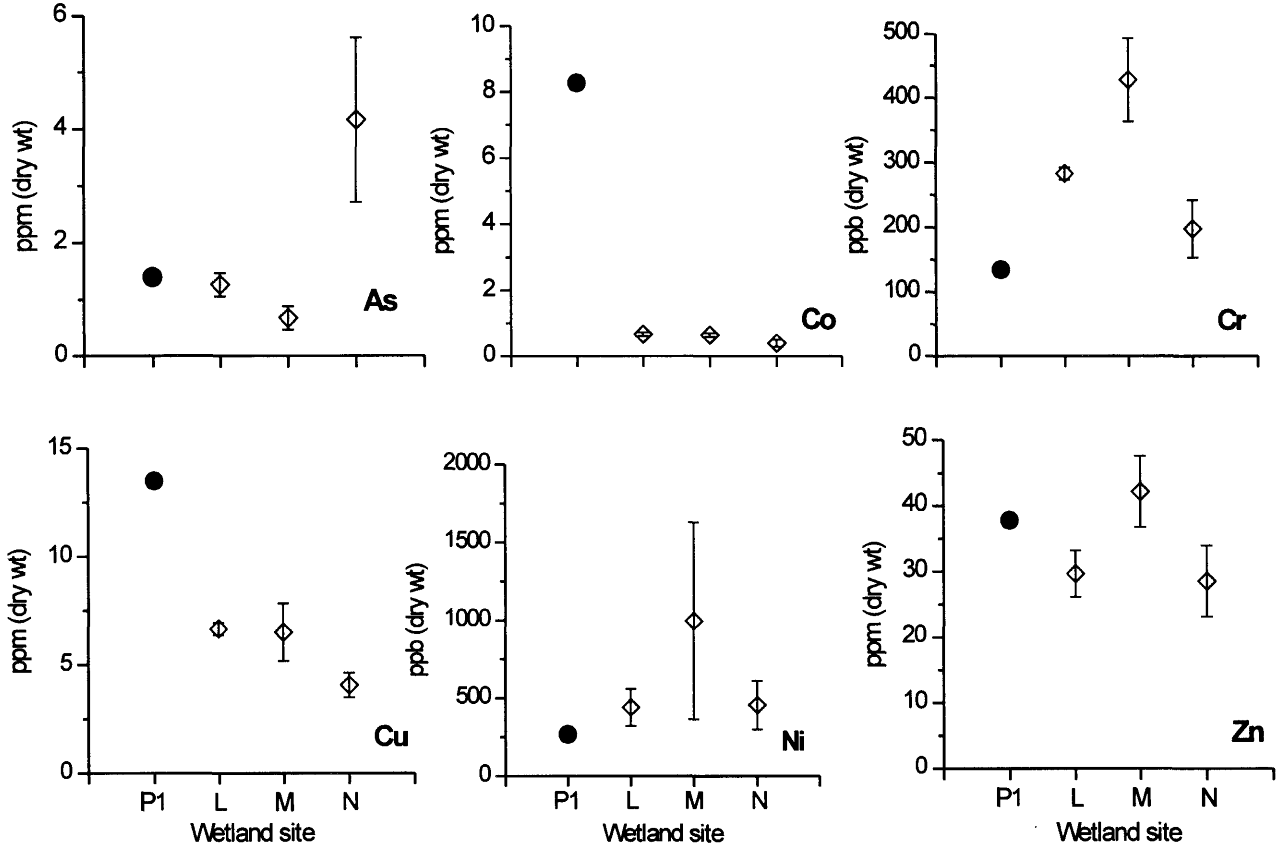

Fig. 10. Concentrations of indicator elements in the aquatic wetland plant Potamogeton natans (pondweed) in selected wetlands in the San Luis Valley, Co during June 1993. Closed symbols denote wetlands receiving Alamosa River water; open symbols denote wetlands receiving surface water from other sources. Error bars denote standard deviation of element concentrations in all plants at a given site.