# RECONNAISSANCE INVESTIGATION OF WATER QUALITY, BOTTOM SEDIMENT, AND BIOTA ASSOCIATED WITH IRRIGATION DRAINAGE IN THE VERMEJO PROJECT AREA AND THE MAXWELL NATIONAL WILDLIFE REFUGE, COLFAX COUNTY, NORTHEASTERN NEW MEXICO, 1993

by James R. Bartolino, U.S. Geological Survey;
Lynn A. Garrabrant, U.S. Geological Survey;
Mark Wilson, U.S. Fish and Wildlife Service; and
Joel D. Lusk, U.S. Fish and Wildlife Service

---

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 96-4157

U.S. GEOLOGICAL SURVEY
U.S. FISH AND WILDLIFE SERVICE
BUREAU OF RECLAMATION
BUREAU OF INDIAN AFFAIRS


Albuquerque, New Mexico
1996

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director



For additional information write to:

District Chief
U.S. Geological Survey
Water Resources Division
4501 Indian School Road NE, Suite 200
Albuquerque, NM 87110-3929

Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Denver, CO 80225-0286

## CONTENTS


Page

Abstract ..... 1
Introduction ..... 2

Purpose and scope ..... 4
Acknowledgments ..... 4

General description of the study area ..... 4

Vermejo Project ..... 6
Maxwell Wildlife Refuge ..... 6

Primary habitat types ..... 7
Fish and migratory birds ..... 8
Threatened and endangered species ..... 9

Climate ..... 9
Surface geology ..... 11
Soils ..... 11

Hydrologic setting ..... 11

Water supply ..... 13
Hydrology of the Vermejo Project ..... 14

Previous studies ..... 14

Results from the 1989 investigation ..... 17
Results from the 1991 investigation ..... 17
Results from the 1992 investigation ..... 19

Sample collection and analysis ..... 20

Sampling sites ..... 20
Sampling methods ..... 25
Analytical support ..... 27
Statistical analysis ..... 28

Water quality, bottom sediment, and biota ..... 29

Concentrations of trace elements in water ..... 29
Concentrations of trace elements in bottom sediment ..... 34
Concentrations of trace elements in biota ..... 37

Aluminum ..... 38
Arsenic ..... 40
Barium ..... 40
Beryllium ..... 40
Boron ..... 40
Cadmium ..... 41

## CONTENTS--Concluded


Page

Concentrations of trace elements in biota--Concluded

Chromium ..... 42
Copper ..... 42
Iron ..... 42
Lead ..... 42
Magnesium and manganese ..... 43
Mercury ..... 43
Nickel ..... 45
Selenium ..... 46
Strontium ..... 50
Vanadium ..... 50
Zinc ..... 50

Correlation of trace elements among water, bottom sediment, and biota ..... 51
Concentrations of pesticides in water ..... 52
Concentrations of pesticides in bottom sediment ..... 52
Concentrations of pesticides in biota ..... 52

Summary and conclusions ..... 52
References cited ..... 55
Supplemental data ..... 60


## FIGURES


1. Map showing the study area and Vermejo Irrigation Project, Maxwell National Wildlife Refuge, and major irrigation features ..... 5

2. Graph showing long-term average composite monthly and 1993 monthly precipitation in the Vermejo Irrigation Project Area for the Cimarron, Raton Filter Plant, Maxwell, and Springer weather stations ..... 10

3. Map showing geology of Colfax County, New Mexico ..... 12

4. Schematic diagram of the Vermejo Irrigation Project ..... 15

5. Map showing location of water, biota, and sediment sampling sites on the Maxwell National Wildlife Refuge where samples were collected by the U.S. Fish and Wildlife Service and the U.S. Geological Survey, 1989-92 ..... 16

6. Map showing water-quality and bottom-sediment sampling sites and fish-sampling reaches in the study area, 1993 ..... 21

7. Plots showing concentrations of selected minor elements, in micrograms per liter, in 25 water samples from 13 sites, Vermejo Irrigation Project Area, New Mexico ..... 30

8. Plots showing concentrations of selected minor trace elements, in micrograms per gram, in 26 bottom-sediment samples from 11 sites, Vermejo Irrigation Project Area, New Mexico ..... 35

9. Box plots showing the biomagnification of mercury, in micrograms per gram ..... 44

## TABLES


Page

1. Streamflow-gaging stations, period of record, average discharge, and annual mean discharge for water year 1993 in the Vermejo Project Area, New Mexico ..... 13

2. Selenium concentrations in bird eggs, embryos, livers, and liver/kidney composites collected in 1989 and 1991 from the Maxwell National Wildlife Refuge ..... 18

3. Selenium concentrations in bottom sediment collected in 1989 and 1991 from the Maxwell National Wildlife Refuge ..... 19

4. Description of sampling sites and number of samples collected for water, bottom sediment, and biota in and near the Vermejo Irrigation Project near Maxwell, New Mexico ..... 22

5. Minimum analytical reporting levels for selected constituents measured in water, bottom sediment, and biota ..... 28

6. Concentrations of selected constituents in water samples collected from surface-water and ground-water reference sites and concentrations in other samples collected during the Vermejo reconnaissance study ..... 31

7. Baseline concentrations of selected constituents in water samples collected from rivers of the United States and concentrations in samples collected from the Vermejo and Canadian Rivers and irrigation project sites ..... 31

8. U.S. Environmental Protection Agency (USEPA) and State of New Mexico water-quality standards for selected constituents ..... 32

9. Concentrations of selected trace elements in soils of the Western United States, soils from the study area, bottom sediment from 19 National Irrigation Water-Quality Program (NIWQP) study areas, and bottom sediment from sites for this study exceeding the expected upper value for Western U.S. soils ..... 36

10. Geometric mean wet weight concentrations of selected elements in fish collected from the Vermejo Project Area, summer 1993, and 85th-percentile concentrations in fish samples collected nationwide by the National Contaminant Biomonitoring Program (NCBP) ..... 37

11. Geometric mean wet weight concentrations in biota collected during the Vermejo reconnaissance study, summer 1993, and various diagnostic criteria ..... 38

12. Concentrations of aluminum in biota collected during the Vermejo reconnaissance study, summer 1993 ..... 39

13. Concentrations of cadmium in biota collected during the Vermejo reconnaissance study, summer 1993 ..... 41

14. Concentrations of mercury in biota collected during the Vermejo reconnaissance study, summer 1993 ..... 45

15. Concentrations of selenium in biota collected during the Vermejo reconnaissance study, summer 1993 ..... 46

## TABLES--Concluded

Page

16. Concentrations of zinc in biota collected during the Vermejo reconnaissance study, summer 1993 ..... 51

17. Concentrations of selected constituents in water samples collected during the Vermejo reconnaissance study, spring and late summer, 1993 ..... 62

18. Concentrations of selected major and trace elements in bottom sediment collected during the Vermejo reconnaissance study, November 1993 ..... 69

19. Concentrations of selected elements in blank quality-control water samples, April and August 1993 ..... 78

20. Mean and standard deviation percent moisture of biota collected during the Vermejo reconnaissance study, summer 1993 ..... 79

21. Dry weight concentrations of trace elements in biota collected during the Vermejo reconnaissance study, summer 1993 ..... 80

22. Concentrations of selected organic compounds in bottom sediment collected during the Vermejo reconnaissance study, September 1993 ..... 90

## CONVERSION FACTORS AND ABBREVIATED WATER-QUALITY UNITS

| Multiply | By | To obtain |
|---|---|---|
| acre (acre) | 0.4047 | hectare |
| acre-foot (acre-ft) | 0.001233 | cubic hectometer |
| cubic foot per second ($ft^3/s$) | 0.02832 | cubic meter per second |
| foot (ft) | 0.3048 | meter |
| inch (in.) | 25.40 | millimeter |
| mile (mi) | 1.609 | kilometer |
| quart (qt) | 0.9464 | liter |
| square mile ($mi^2$) | 2.590 | square kilometer |
| ton, short | 0.9072 | megagram |
| ton per acre-foot (ton/acre-ft) | 0.0007357 | megagram per cubic meter |

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) as follows:

$$°F = 1.8\ (°C) + 32.$$

Sea level: In this report sea level refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Specific conductance is reported in microsiemens per centimeter (µS/cm) at 25 degrees Celsius.

Chemical concentrations in water are reported in milligrams per liter (mg/L) or in micrograms per liter (µg/L), which are equivalent to parts per million and parts per billion, respectively, when concentrations are less than about 7,000 milligrams per liter.

Chemical concentrations in sediment are reported in micrograms per gram (µg/g) or in micrograms per kilogram (µg/kg), which are equivalent to parts per million and parts per billion, respectively.

Chemical concentrations in biota are reported in micrograms per gram (µg/g) dry weight, or micrograms per kilogram (µg/kg) dry weight, which are equivalent to parts per million and parts per billion, respectively.

Wet weight versus dry weight concentrations: the relation between wet weight and dry weight concentrations, with the percent moisture expressed on a wet weight sample basis, is:

$$\text{dry weight concentration} = \frac{(\text{wet weight concentration})}{1 - \frac{(\text{percent moisture})}{100}}$$

$$\text{wet weight concentration} = \text{dry weight concentration}\left[1 - \frac{(\text{percent moisture})}{100}\right]$$

# RECONNAISSANCE INVESTIGATION OF WATER QUALITY, BOTTOM SEDIMENT, AND BIOTA ASSOCIATED WITH IRRIGATION DRAINAGE IN THE VERMEJO PROJECT AREA AND THE MAXWELL NATIONAL WILDLIFE REFUGE, COLFAX COUNTY, NORTHEASTERN NEW MEXICO, 1993

*By James R. Bartolino, U.S. Geological Survey;*

*Lynn A. Garrabrant, U.S. Geological Survey;*

*Mark Wilson, U.S. Fish and Wildlife Service; and*

*Joel D. Lusk, U.S. Fish and Wildlife Service*

## ABSTRACT

Based on findings of limited studies during 1989-92, a reconnaissance investigation was conducted in 1993 to assess the effects of the Vermejo Irrigation Project on water quality in the area of the project, including the Maxwell National Wildlife Refuge. This project was part of a U.S. Department of the Interior National Irrigation Water-Quality Program to determine whether irrigation drainage has caused or has the potential to cause significant harmful effects on human health, fish, and wildlife and whether irrigation drainage may adversely affect the suitability of water for other beneficial uses. For this study, samples of water, sediment, and biota were collected from 16 sites in and around the Vermejo Irrigation Project prior to, during the latter part of, and after the 1993 irrigation season (April, August-September, and November, respectively).

No inorganic constituents exceeded U.S. Environmental Protection Agency drinking-water standards. The State of New Mexico standard of 750 micrograms per liter for boron in irrigation water was exceeded at three sites (five samples), though none exceeded the livestock water standard of 5,000 micrograms per liter. Selenium concentrations exceeded the State of New Mexico chronic standard of 2 micrograms per liter for wildlife and fisheries water in at least eight samples from five sites.

Bottom-sediment samples were collected and analyzed for trace elements and compared to concentrations of trace elements in soils of the Western United States. Concentrations of three trace elements at eight sites exceeded the upper values of the expected 95-percent ranges for Western U.S. soils. These included molybdenum at one site, selenium at seven sites, and uranium at four sites.

Cadmium and copper concentrations exceeded the National Contaminant Biomonitoring Program 85th percentile in fish from six sites. Average concentrations of selenium in adult brine flies (33.7 µg/g dry weight) were elevated above concentrations in other invertebrates. Concentrations of other elements were below their respective toxicity levels.

Plants, invertebrates, fish, and fish fillets were collected and analyzed. These analyses were compared to diagnostic criteria and to each other to determine the extent of bioaccumulation of trace elements. Plants contained larger dry weight concentrations of aluminum, arsenic, boron, chromium, iron, lead, magnesium, manganese, nickel, and vanadium than invertebrates and fish. Adult brine flies, gathered from playas, contained larger geometric mean dry weight concentrations of boron, magnesium, and selenium than other invertebrates. Of all samples collected, the largest mercury concentrations were found in fish fillets, although these concentrations were below levels of concern. Mercury and selenium bioaccumulation was evident in various habitats of the study area.

Biological samples from Natural playa, an endemic wetland, and Half playa, a playa that receives additional water through seepage and irrigation delivery canals, generally had elevated concentrations of boron, iron, magnesium, and selenium than samples from reservoir and river sites. Selenium concentrations were lowest in biota from the two reservoir sites, although a wetland immediately downstream from the dam impounding Lake No. 13 (created by seepage from the reservoir) had elevated concentrations of selenium in biota. The geometric mean selenium concentration of whole-fish samples, except those from Lakes No. 13 and No. 14, exceeded the 5-µg/g dry weight selenium concentration that demarcates the approximate lower limit of the threshold range of concentrations that have been associated with adverse effects on piscine reproduction. Biota collected on and in the area around Maxwell National Wildlife Refuge contained concentrations of selenium that are in the lower range of threshold values that have been associated (dietarily) with risks of avian reproductive abnormalities.

Bottom-sediment samples from two sites downstream from the irrigation project were collected and analyzed for 23 organic compounds (principally organochlorine pesticide residues). Three compounds were detected at the two sites: DDD was found at 0.2 microgram per kilogram, DDE was detected at 0.1 microgram per kilogram at both sites, and chlordane was detected at 1 microgram per kilogram. None of the 28 whole-fish and fillet samples analyzed for PCB and organochlorine pesticide residues contained any of the 23 organic compounds tested for at concentrations higher than the analytical reporting limit (less than 0.01 µg/g wet weight).

Concentrations of inorganic analytes were generally within established guidelines or expected concentrations for water, sediment, and biota. Irrigation-return flows were found to be unrelated to adverse effects in biota.

## INTRODUCTION

During the last several years, there has been increasing concern about the quality of irrigation drainage and its potential harmful effects on human health, fish, and wildlife. Concentrations of selenium greater than water-quality criteria for the protection of aquatic life (U.S. Environmental Protection Agency, 1987) have been detected in surface and subsurface drainage from irrigated land. In 1983, incidences of mortality, congenital deformities, and reproductive failures in waterfowl were discovered by the U.S. Fish and Wildlife Service (USFWS) at the Kesterson National Wildlife Refuge in the western San Joaquin Valley of California where irrigation drainage was impounded. In addition, toxic and potentially toxic trace elements and pesticide residues have been detected in other areas in Western States that receive irrigation drainage.

Because of concerns expressed by the U.S. Congress, the Department of the Interior (DOI) started a program in October 1985 to identify the nature and extent of irrigation-induced water-quality problems that might exist in the Western States. The DOI developed a management strategy and formed an interbureau group known as the "Task Group on Irrigation Drainage," which prepared a comprehensive plan for reviewing irrigation-drainage concerns for which the Interior Department may have responsibility.

Initially, the task group identified 20 areas in 13 states that warranted reconnaissance-level investigations related to three specific activities: (1) irrigation or drainage facilities constructed or managed by the DOI, (2) National Wildlife Refuges managed by the DOI, and (3) other migratory-bird or endangered-species management areas that receive water from DOI-funded projects.

Nine of the 20 areas were selected for reconnaissance investigations during 1986-87:

| | |
|---|---|
| Arizona-California: | Lower Colorado-Gila River Valley Area |
| California: | Salton Sea Area |
| | Tulare Lake Bed Area |
| Montana: | Sun River Reclamation Project Area |
| | Milk River Reclamation Project Area |
| Nevada: | Stillwater Wildlife Management Area |
| Texas: | Lower Rio Grande-Laguna Atascosa National Wildlife Refuge Area |
| Utah: | Middle Green River Basin Area |
| Wyoming: | Kendrick Reclamation Project Area. |

On the basis of results of these investigations, four detailed studies began in 1988: Salton Sea Area, Stillwater Wildlife Management Area, Middle Green River Basin Area, and the Kendrick Reclamation Project Area.

Eleven more reconnaissance investigations were initiated in 1988:

| | |
|---|---|
| California: | Sacramento Refuge Complex |
| California-Oregon: | Klamath Basin Refuge Complex |
| Colorado: | Gunnison and Uncompahgre River Basins and Sweitzer Lake Pine River Project |
| Colorado-Kansas: | Middle Arkansas River Basin |
| Idaho: | American Falls Reservoir |
| New Mexico: | Middle Rio Grande Project and Bosque del Apache National Wildlife Refuge |
| Oregon: | Malheur National Wildlife Refuge |
| South Dakota: | Angostura Reclamation Unit |
| | Belle Fourche Reclamation Unit |
| Wyoming: | Riverton Reclamation Project. |

Evaluation of results for these investigations, and a continuing evaluation of all data for the Irrigation Drainage Program, led to initiating three detailed studies early in 1990:

| | |
|---|---|
| California-Oregon: | Klamath Basin Refuge Complex |
| Colorado: | Gunnison River Basin/Grand Valley Project |
| Montana: | Sun River Reclamation Project Area. |

Four reconnaissance investigations were begun in October 1990 and another was started in October 1991. The study areas are:

| | |
|---|---|
| Colorado: | Dolores Project Area |
| Nevada: | Humboldt Wildlife Management Area |
| New Mexico: | San Juan River Area |
| Oregon-Idaho: | Owyhee-Vale Projects |
| Washington: | Middle Columbia River Basin. |

One detailed study was started in October 1993:

| | |
|---|---|
| New Mexico: | San Juan River Area. |

In October 1993 another reconnaissance investigation was initiated:

| | |
|---|---|
| New Mexico: | Vermejo Project Area. |

All reconnaissance investigations are conducted by interbureau study teams composed of a scientist from the U.S. Geological Survey (USGS) as team leader, with additional Geological Survey, U.S. Fish and Wildlife Service (USFWS), Bureau of Reclamation (BOR), and Bureau of Indian Affairs scientists representing several different disciplines. The investigations are directed toward determining whether irrigation drainage: (1) has caused or has the potential to cause significant harmful effects on human health, fish, and wildlife; or (2) may adversely affect the suitability of water for other beneficial uses.

## Purpose and Scope

The purpose of this report is to present information for determining whether irrigation drain water associated with the formerly DOI-sponsored Vermejo Irrigation Project near Maxwell, New Mexico: (1) has caused or has the potential to cause significant harmful effects to human health, fish, or wildlife; or (2) may reduce the suitability of water for beneficial uses. The Vermejo Project Area was selected for study because data from previous studies in the area indicated that concentrations of some inorganic and organic substances may be large enough to cause or have the potential to cause harmful effects or to reduce the suitability of water for beneficial uses (Lusk and others, 1991; Custer and others, 1993). Additionally, rocks of Cretaceous age--the Pierre Shale in the study area and the Raton and Vermejo Formations west of the study area--have the potential to yield significant amounts of selenium and other trace elements to water, bottom sediment, and biota.

The scope of this study included collection and analysis of water, bottom-sediment, and biota samples from the Vermejo Project Area and from sites upstream and downstream from the project area. Sample collection was conducted from April through November 1993. Samples were analyzed for concentrations of major ions, selected trace elements, and selected pesticide residues. The report describes the areal distribution of concentrations of selected constituents in various media, how these constituents relate to irrigation water associated with the formerly DOI-sponsored Vermejo Project, and their effects on fish and wildlife.

## Acknowledgments

The authors thank Jerry French, Maxwell National Wildlife Refuge Manager, for his cooperation and useful information. The authors also thank Leonard Knox of the Vermejo Conservancy District and Warren Davis of the Crow Creek Ranch for granting access to some of the sampling sites.

## GENERAL DESCRIPTION OF THE STUDY AREA

The study area is located in Colfax County in northeastern New Mexico (fig. 1). The Vermejo Project and Maxwell National Wildlife Refuge (NWR) are located near the village of Maxwell (fig. 1).

The average elevation of the project area is about 6,000 ft. The terrain is gently rolling and slopes to the southeast. Slopes are generally less than several percent. Small depressions are common in the area, and some form small playa lakes.

The Raton coal field is located about 30 mi northwest of the project. Mining wash water is discharged into the Vermejo River drainage and is in compliance with U.S. Environmental Protection Agency (USEPA) regulations (Lusk and others, 1991). Abandoned coal mines are present in the Vermejo drainage downstream from the operating mine and in the upper portions of the Chicorica Creek Basin northeast of Raton. The town of Raton (see fig. 3) operates a small coal-fired power plant about 25 mi north of the refuge. Coal mining and processing and atmospheric deposition from coal burning are possible sources of selenium because coal is enriched in selenium at about one hundred times the average abundance in crustal rocks (Herring, 1991).

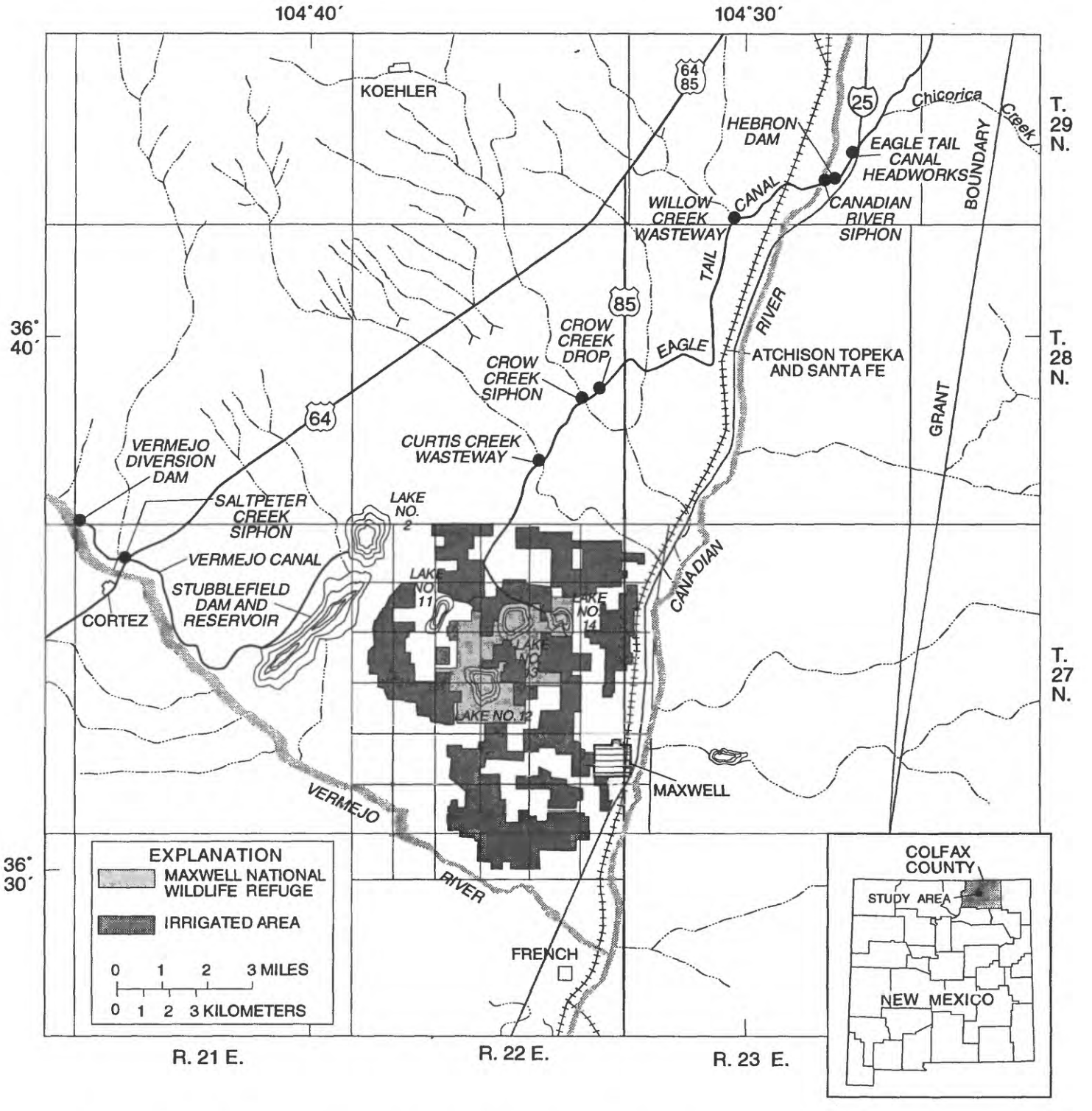


Figure 1.--Study area and Vermejo Irrigation Project, Maxwell National Wildlife Refuge, and major irrigation features.

Northeastern New Mexico has a variety of wildlife habitats ranging from mountain forests to the grasslands and farmlands of the High Plains. Popular big game animals include whitetail and mule deer, elk, and pronghorn, which are common in suitable habitat throughout the region. Large predators include black bears and mountain lions, which are associated with the variety of habitats along the Sangre de Cristo Mountains, located a few miles west of the study area. Coyotes, swift foxes, skunks, badgers, and bobcats are the primary mid-sized mammalian predators that live in the study area.

Popular species of small game living in the study area include bobwhite and scaled quail, ring-necked pheasants, lesser prairie chickens, and cottontails. Populations of wild turkeys are scattered in the forest and riparian habitats throughout the region. Prairie dogs, jackrabbits, a variety of ground squirrels, and many species of mice, voles, and rats are common and provide an ecologically important intermediate-level trophic link between primary production (vegetation) and predatory tertiary consumers (such as raptorial birds, snakes, and bobcats).

A wide variety of herptofauna (amphibians and reptiles) also live in the area. These species are prevalent in all of the major habitat types (grasslands, forests, riparian, cropland, and wetlands) of eastern New Mexico. The playas, reservoirs, streams, and various types of wetlands in the region are especially important because they provide stopover habitat for thousands of ducks, geese, and shorebirds that migrate semiannually through the region. The region provides a limited amount of nesting for these birds, especially at Maxwell NWR.

## Vermejo Project

Irrigation development in the area began in 1888, and the irrigation system was owned by various companies. In 1950, the irrigation project was approved as a Federal Reclamation Project, which provided for rehabilitation and improvement of the irrigation works. In 1952, the Vermejo Conservancy District was formed to operate and maintain the project and continues to do so today (1996). Construction of the project by the BOR began in 1953 and was completed in 1955. Title to part of the project was held by the BOR until October 1992 when full ownership was transferred to the conservancy district. The project can provide water for about 7,400 acres of irrigable land.

Principal crops grown on private lands in and around the study area are alfalfa and pasture and lesser amounts of wheat. Crops are also grown on the refuge and include alfalfa, corn, wheat, and barley. Crops on the refuge are rotated regularly; this is not necessarily true for nearby private farmland. Not all of the refuge's irrigable acres are cultivated in any given year. For the 10-year period 1968-77, the average amount of irrigated land within the Vermejo Project was about 4,425 acres (James Wilber, Bureau of Reclamation, written commun., 1992). In 1990, 5,165 acres were irrigated (Wilson, 1992).

Pesticide use in the project area generally is low. Parathion is applied aerially when needed to control serious grasshopper infestations, which may occur every 4 or 5 years (Jerry French, U.S. Fish and Wildlife Service, oral commun., 1993). In recent years, malathion insecticide and 2,4-D herbicide have been used in limited amounts on croplands in the refuge (Lusk and others, 1991).

## Maxwell National Wildlife Refuge

Maxwell NWR is located approximately in the center of the Vermejo Irrigation Project. It was established by the Migratory Bird Conservation Commission on August 24, 1965. The primary objective of the refuge is to provide a feeding and resting area for wintering migratory waterfowl. Secondary management objectives are to provide habitat for other migratory birds and nonmigratory wildlife and allow for fish- and wildlife-oriented recreation.

The refuge encompasses 2,792 acres of fee title land and 907 acres that are managed under a joint lease with the BOR and the Vermejo Conservancy District. The 907 acres include three large impoundments on the refuge: Lakes No. 12, No. 13, and No. 14. These reservoirs have a combined storage capacity of 8,000 acre-ft. The refuge owns 946.75 shares of water for cropland irrigation. A water share is based on the volume of stored irrigation water and normally equals 1 acre-ft of water per share. State law specifies that this water must be used for cropland irrigation, thereby precluding secondary storage or other uses (such as wetland development).

## Primary Habitat Types

### Cropland

In 1995, 458 acres of land within the refuge boundary were used for irrigated-crop production. The irrigated crops consisted of alfalfa, barley, corn, and wheat. Irrigation is necessary to produce crops on the refuge because rainfall is insufficient. No fertilizer is used other than what is provided by crop rotation and plowing under cover crops. In recent years, malathion and 2,4-D were used in limited amounts on croplands within the refuge (Lusk and others, 1991). Minimal applications of 2,4-D are still occasionally used to control field bindweed.

### Grasslands

Approximately 2,200 acres of shortgrass prairie are within the refuge. The predominant plant species within this grassland type include buffalo grass, blue grama, western wheatgrass, alkali sacaton, and red threeawn. In disturbed areas the predominant species are primarily foxtail barley, field bindweed, and Kochia.

Various forbs are also mixed in with the grasses. The tallest native forb is fourwing saltbush (*Atriplex canescens*), which along with *Chrysothamnus spp.* is known as chamiza (Vines, 1960). Other common plant species within the grasslands include prickly pear cactus, pincushion cactus, soapweed yucca, and winterfat. Milkvetches or locoweed (*Astragalus spp.*) are fairly common and indicative of seleniferous soils (Beath, 1964; Lakin, 1972). Scattered groups of Chinese elm, cottonwood, silver poplar, and black locust also are on the refuge. These species have been introduced into the project area and were not native plants (Jerry French, oral commun., 1993).

Chemical insecticides are not used on grasslands located within the refuge boundary. As do croplands in the area, refuge grasslands occasionally require minimal applications of 2,4-D herbicide to control field bindweed. Periodically, when grasshopper populations get very high, a biological control agent (*Nosema locustae*) is applied to grassland areas on the refuge. The use of this protozoologically based acridicide (grasshopper specific) is irregular, and no application has been necessary for several years (Jerry French, oral commun., 1993).

### Wetlands

Lakes No. 12, No. 13, and No. 14 on the refuge are irrigation storage reservoirs that provide a combined total of nearly 700 acres of lacustrine wetlands (Cowardin and others, 1979) and constitute the majority of wet surface area located within the boundaries of Maxwell NWR. Because the reservoirs are managed by the Vermejo Conservancy District for storage of irrigation water, refuge considerations do not play a role in water management of the lakes. Nonetheless, these reservoirs provide habitat beneficial for a wide variety of wildlife dependent on aquatic habitat, and are especially advantageous to migratory birds, including waterfowl, shorebirds,

and threatened species such as the bald eagle. Most fish on the refuge also live within these three reservoirs. During wet years when reservoir drawdowns are minimal, the shoreline vegetation is dense enough to aid waterfowl nesting. During dry years, the constantly changing (exposed) shoreline is beneficial to shorebirds.

Several other types of wetland habitat are on the refuge, including naturally occurring playa lakes, palustrine wetlands (marshes) created by seepage from the large reservoirs (Cowardin and others, 1979), and wet meadows in low-lying areas. These important areas are also variously used by migratory birds and other wetland-dependent wildlife (such as plains killifish, various amphibians, reptiles, and fur-bearing mammals).

## Fish and Migratory Birds

A wide variety of fauna has been cataloged at Maxwell NWR during its 30-year existence. The numbers of vertebrate species include 38 mammals, 213 birds, 13 reptiles, and 8 amphibians (Jerry French, oral commun., 1993). Although fish are vertebrates also, the exact number of fish species that exist at Maxwell NWR is unknown because a comprehensive fisheries survey has not been conducted.

### Fish

Less than 10 species of fish are known to currently exist on the refuge (Jerry French, oral commun., 1993). These include popular game fish species such as rainbow trout, channel catfish, and largemouth bass; panfish such as yellow perch, green sunfish, and black bullhead; and a few other species (such as plains killifish and carp) that are ecologically important but not highly sought for angling recreation. Because the refuge does not lie on any natural water course, it is doubtful that any fish lived in the playa lakes and wetlands on what is now the refuge prior to the completion of the irrigation canals in the early 1900's.

Fishing is the most frequent form of recreation at Maxwell NWR and accounts for 47 percent of the total refuge visitation. Most of the camping and picnicking on the refuge are also associated with fishing. The New Mexico Department of Game and Fish maintains a "put and take" fishery program in Lake No. 13 and annually stocks this reservoir with approximately 50,000 rainbow trout between 8 and 11 in. in length. To prevent unnecessary disturbance to wintering waterfowl on the refuge, anglers are permitted to fish on the refuge only from March 1 through October 31 each year.

### Migratory birds

Since 1991, the number of migratory waterfowl using Maxwell NWR has averaged around 35,000 during the spring peak and 60,000 during the fall peak (Jerry French, oral commun., 1993). Between 1991 and 1995, the refuge has averaged 5 million days of waterfowl use annually. The highest concentration of migratory waterfowl was recorded in October 1994, when approximately 88,000 ducks were counted during the refuge's autumn bird census. Summer nesting annually produces about 150 mallards, 100 gadwalls, and 50 blue-winged teal. Peak populations of wintering Canada geese average approximately 9,500 birds.

Other common migratory water birds that frequently or occasionally use the refuge include the American coot, sandhill cranes, white pelicans, four species of grebes, common loons, cormorants, great blue herons, snowy egrets, and black-crowned night herons. Of this group, American coots are by far the most abundant: in aggregate, these species accrue an average of 1.9 million days of bird use annually.

The refuge annually attracts an average of 18 species of shorebirds, primarily gulls, terns, phalaropes, and sandpipers. Most species from this group are found only during the spring and summer months. In total, this group of species accrues an average of 26,000 days of bird use each year.

Twenty-two species of raptors (birds of prey) are present in fluctuating numbers throughout the year at Maxwell NWR. Buteos, accipiters, harriers, falcons, and owls are regularly observed on the refuge, and many species are known to nest there. In combination, these species accumulate an average of 12,000 days of bird use annually.

### Threatened and Endangered Species

Five birds federally listed as either endangered or threatened are regularly observed at Maxwell NWR (Jerry French, oral commun., 1993). The bald eagle is by far the most abundant endangered raptorial bird species on the refuge. Wintering populations of bald eagles usually number about 2 dozen, although as many as 65 have been recorded. The prairie falcon, peregrine falcon, osprey, and burrowing owl are seen less frequently and in much smaller numbers. The burrowing owl nests on the refuge.

## Climate

The study area has a semiarid, continental climate characterized by hot summers and cold winters. For the period of record 1931 to 1983, the average daily maximum and minimum temperatures at Maxwell were 47 and 9.3 °F in January and 87 and 52 °F in July, the average annual temperature was 48 °F, and average annual precipitation was 13.8 in. (Kunkel, 1984). The pan-evaporation rate of the area is about 52 in. per year (Lusk and others, 1991). The average frost-free period (the growing season) varies from 151 days at Springer (approximately 14 mi south of Maxwell NWR) to 154 days at the Raton Filter Plant (approximately 20 mi north of Maxwell NWR) (Anderson and others, 1982). Most precipitation occurs as thunderstorms; Raton has an average of 75 thunderstorms a year and 90 percent occur from May through September (Anderson and others, 1982).

Four weather observation stations are in the vicinity of the study area: Cimarron 4 SW (approximately 18 mi west of Maxwell NWR), Raton Filter Plant (on the north side of Raton), Maxwell 3 NW (approximately 2 mi southeast of Maxwell NWR), and Springer (approximately 14 mi south of Maxwell NWR). Periods of record range from 90 to 41 years. A fifth station, Raton KRTN Radio, is excluded because it has been active for only 17 years. The values for these four stations were averaged to compute the following precipitation data.

The composite average annual precipitation is 16 in. in the area. In 1993, the composite average precipitation was 18 in., or 113 percent of the composite average annual precipitation. In March, April, and August, precipitation was 0.5 in. or more greater than normal. In July, September, and October, precipitation was 0.5 in. or more below normal. August precipitation was notable in that it was more than twice the average normal. Figure 2 compares the four station long-term period of record average composite monthly values of precipitation to the four station composite average monthly values of 1993 precipitation (U.S. Department of Commerce, 1993).

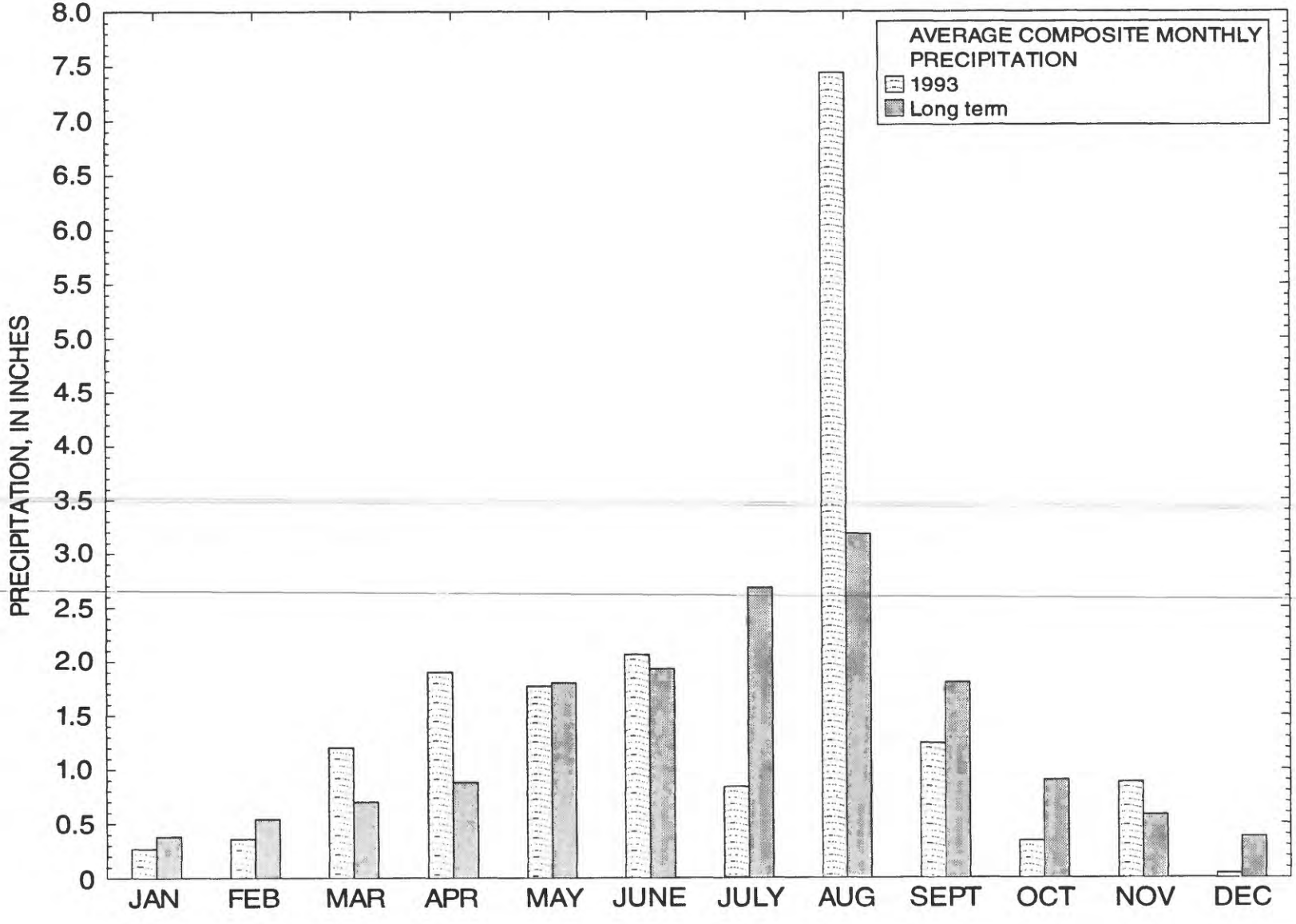


Figure 2.--Long-term average composite monthly and average 1993 monthly precipitation in the Vermejo Irrigation Project Area for the Cimarron, Raton Filter Plant, Maxwell, and Springer weather stations. Data from U.S. Department of Commerce, 1993.

## Surface Geology

The study area lies within the Great Plains physiographic province (Fenneman, 1931). The undifferentiated Upper Cretaceous Pierre Shale and upper part of the Niobrara Formation (henceforth referred to as the Pierre Shale) are the most extensively exposed geologic units in the study area, extending from Raton to Springer (fig. 3). The Pierre Shale is a silty, black marine shale about 2,500 ft thick, which erodes easily (Pillmore, 1976). In certain areas of the Western United States both the Pierre Shale and Niobrara Formation contain large concentrations of selenium, and shales in the vicinity of the refuge are reported to have areas of selenium concentrations that range from 0.2 to 160 µg/g (Anderson and others, 1982). The presence of selenium in the Pierre Shale in the study area is suggested by the presence of milkvetch or locoweed (*Astragalus spp.*), many species of which cannot reach maturity without the presence of selenium in the soil (Beath, 1964; Lakin, 1972).

In the northwestern part of the study area, the Pierre Shale is overlain by the undifferentiated Upper Cretaceous Vermejo Formation and Trinidad Sandstone, which crop out in a narrow, cliff-forming unit. The Vermejo and Trinidad are in turn overlain by the coal-bearing Cretaceous and Tertiary Raton Formation (fig. 3), which is mined west of the study area in the Raton Basin (Dane and Bachman, 1965). Locally the Pierre Shale is overlain by Cenozoic pediment gravels or volcanic rocks (Griggs, 1948). Eagle Tail Peak and other nearby volcanoes are composed of Cenozoic basalt and basaltic andesite flows.

The Canadian River, Vermejo River, and Chicorica Creek Valleys are characterized by alluvium consisting of unconsolidated silt, sand, gravel, and clay of Quaternary age. The alluvium ranges in thickness from about 0 to 50 ft, and the thickness of saturated alluvium averages about 5 ft (Griggs, 1948). Figure 3 is a geologic map of Colfax County.

## Soils

The major soils identified by Anderson and others (1982) in the study area are the Swastika, Colmor, La Brier, and Vermejo: all are 6 to 10 ft deep over bedrock. The Swastika soils are the most extensive and have well-developed A and B horizons. The dominant textures below the surface or plow layer are silty clay loam, silty clay, or clay. The Colmor soils are less well developed and have less clay in the subsoil than the Swastika soils. The La Brier soils are similar in clay content and degree of development to the Swastika soils. Swastika, Colmor, and La Brier soils are moderately well suited for irrigated-crop production. These three soils have formed from alluvial-eolian deposits derived from the Upper Cretaceous Pierre Shale. The Vermejo soils have developed in alluvium derived from shale. The substratum may contain mycelia (filamentous fungi) and crystals of salt. Vermejo soils are very slowly permeable and are less suited for irrigated crops than the other soils.

# HYDROLOGIC SETTING

The Canadian River borders the Vermejo Project on the east, and the Vermejo River borders the project on the south. The Vermejo River joins the Canadian River about 4 mi south of the village of Maxwell (fig. 1). The headwaters of the Canadian and Vermejo Rivers are in the Sangre de Cristo Mountains, which are located west and north of the area. Snowmelt from these mountains provides most of the surface water in the study area. Most runoff occurs during the spring snowmelt period from March through early June. Occasional summer thunderstorms also can produce locally large volumes of runoff. Nearly all water (98 percent) withdrawn for use in Colfax County during 1990 was from surface-water sources (Wilson, 1992).

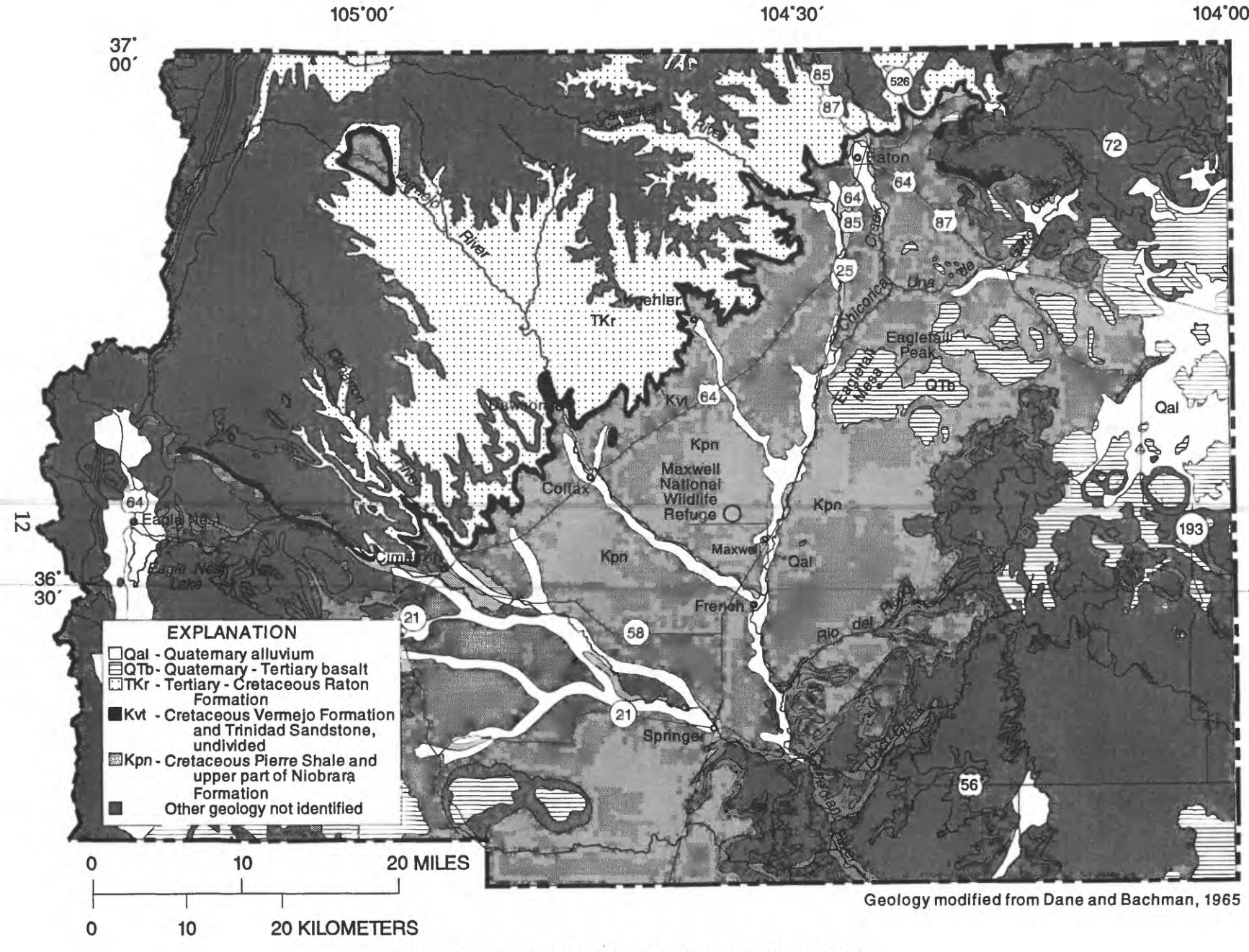


Figure 3.--Geology of Colfax County, New Mexico.

## Water Supply

About 69,100 acre-ft of water was withdrawn for use in Colfax County in 1990 (Wilson, 1992). Irrigation accounted for 84 percent of total withdrawals. About 26 percent of the total acreage irrigated in the county is in the Vermejo Conservancy District (5,165 acres). Water supplied by public or private utilities or community systems to the towns of Raton, Springer, Cimarron, Maxwell, and Eagle Nest accounted for 4 percent of total withdrawals in the county in 1990 (Wilson, 1992). About 96 percent of these withdrawals were from surface-water sources.

The USGS maintains four surface-water gages in the project area: (1) Eagle Tail Ditch (Canal) near Maxwell (07202500); (2) Vermejo River near Dawson (07203000); (3) Vermejo Ditch (Canal) near Colfax (07203505); and (4) Vermejo River near Maxwell (07203525) (table 1). Historical discharge data for the two ditches indicate that in an average year the Vermejo Ditch (Canal) supplies about 70 percent of the water to the Vermejo Project, and Eagle Tail Ditch (Canal) supplies the remainder.

Table 1.--Streamflow-gaging stations, period of record, average discharge, and annual mean discharge for water year 1993 in the Vermejo Project Area, New Mexico

[Data from U.S. Geological Survey (USGS), 1977-94. $ft^3/s$, cubic feet per second]

| USGS station number | 07202500 | 07203000 | 07203505 | 07203525 |
|---|---|---|---|---|
| Station name | Eagle Tail Ditch near Maxwell, N. Mex. | Vermejo River near Dawson, N. Mex. | Vermejo Ditch near Colfax, N. Mex. | Vermejo River near Maxwell, N. Mex. |
| Period of record (month/year) | 12/44 to 07/50, 05/75 to present | 10/15 to 07/18, 04/19 to 05/21, 01/27 to present | 12/80 to present | 11/83 to present |
| Average annual discharge ($ft^3/s$) for period of record | 6.66 (46 years) | 18.6 (77 years) | 16.1 (12 years) | 8.21 (9 years) |
| Annual mean discharge, water year 1993 ($ft^3/s$) | 16.3 | 17.8 | 13.3 | 9.22 |
| Latitude | 36°38'55" | 36°40'50" | 36°34'18" | 36°29'48" |
| Longitude | 104°33'31" | 104°47'08" | 104°41'53" | 104°34'15" |

The amount of ground water that can be obtained in the study area is limited. Wells completed in the Pierre Shale do not usually yield significant quantities of water (Griggs, 1948).

## Hydrology of the Vermejo Project

The Vermejo Project receives water from the Vermejo River and Chicorica Creek (also spelled Chico Rico Creek), a tributary of the Canadian River. Water is diverted from the Vermejo River into the Vermejo Canal at a diversion dam about 15 mi upstream from the confluence of the Vermejo and Canadian Rivers. The drainage area above the dam is 320 $mi^2$ and the average annual runoff is about 13,300 acre-ft. The water is derived from spring snowmelt and high-intensity summer thunderstorms. The entire flow of the Vermejo River may be diverted into the canal except during major floods. All water from Chicorica Creek, an ephemeral stream entering the Canadian River from the east about 12 mi north of Maxwell, is diverted into Eagle Tail Canal near the creek's confluence with the Canadian River. The creek drains about 320 $mi^2$ and provides an average annual diversion of 9,000 acre-ft (James Wilber, Bureau of Reclamation, written commun., 1992). High-intensity thunderstorms supply most of the water; the creek does not receive significant runoff from snowmelt. The features of the Vermejo Irrigation Project are shown in figure 1.

The Vermejo Canal conveys water to Stubblefield Reservoir and Laguna Madre (Lake No. 2, fig. 1) for storage. Some water from these reservoirs is delivered directly by laterals to irrigable land in the southern part of the project area. Other water from the reservoirs is carried by laterals to join the Eagle Tail Canal about 1 mi north of Lake No. 13. From this point combined flow from the Eagle Tail Canal and Vermejo drainage is directed to Lake No. 12 (through Lake No. 11), Lake No. 13, and Lake No. 14, and to a small area of irrigable land in the northeastern part of the project. Lakes No. 12, No. 13, and No. 14 are located on the Maxwell NWR; Lake No. 13 is the only one of these lakes capable of providing substantial storage. From the lakes on the refuge, water is delivered by a system of laterals to the remaining irrigable land in the project area. The project has about 65 mi of laterals that range in capacity from 5 to 80 $ft^3/s$ (James Wilber, written commun., 1992). A schematic diagram of the Vermejo Irrigation Project is shown in figure 4.

## PREVIOUS STUDIES

Three previous studies addressing concentrations of potential contaminants in water, sediment, and biota in the Vermejo River area are relevant to this reconnaissance study. The first was a contaminant investigation at Maxwell NWR conducted during the spring and summer of 1989 by personnel from the USFWS Ecological Services Field Office in Albuquerque, New Mexico. The purpose of the investigation was to screen the area for contaminant-related problems and determine baseline concentrations of trace elements and organochlorine pesticides in sediments and biota to aid in monitoring environmental conditions at the refuge. Because the investigation in 1989 revealed potentially toxic concentrations of selenium and mercury in tissue samples, further work was conducted in 1991. The findings from these two studies led to a preliminary National Irrigation Water-Quality Program (NIWQP) investigation in 1992, which in turn resulted in this reconnaissance study report. A map of the refuge and the sampling sites used during previous studies is shown in figure 5.

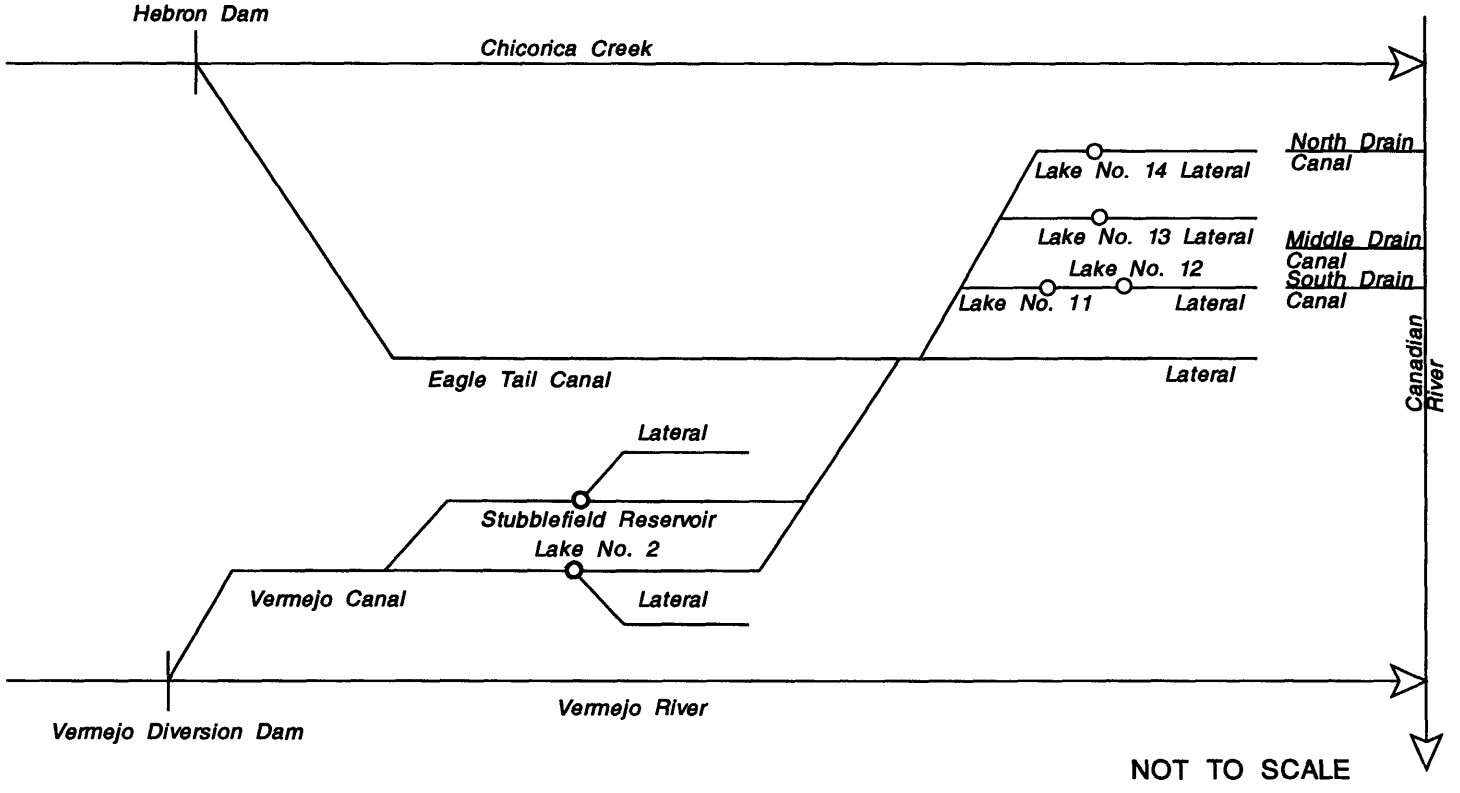


Figure 4.--Schematic diagram of the Vermejo Irrigation Project.

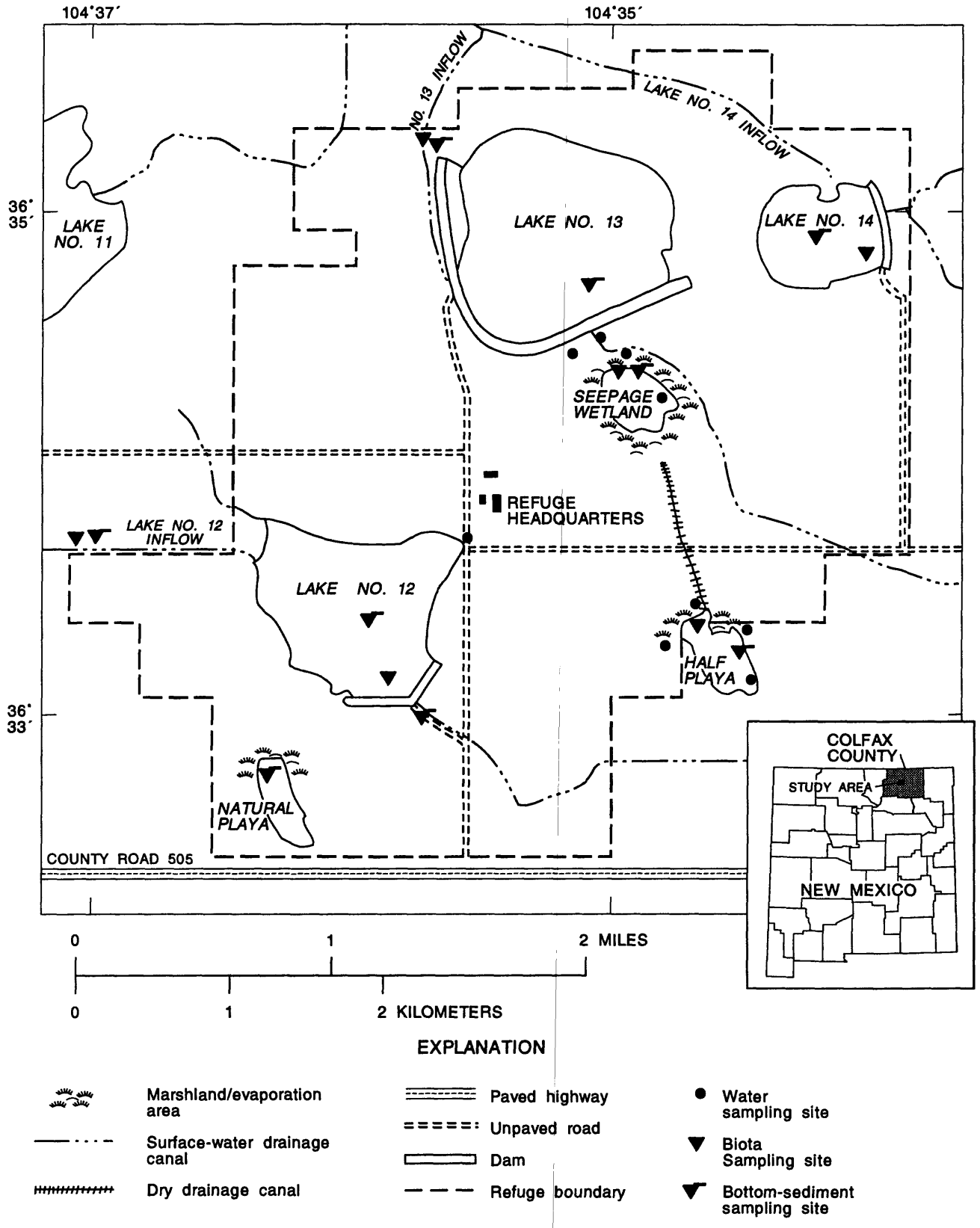


Figure 5.--Location of water, biota, and sediment sampling sites on the Maxwell National Wildlife Refuge where samples were collected by the U.S. Fish and Wildlife Service and the U.S. Geological Survey, 1989-92.

## Results from the 1989 Investigation

The 1989 investigation is described in Lusk and others (1991). During June and July 1989 10 sediment and 42 biota samples were collected from six sites on Maxwell NWR and analyzed for 23 inorganic constituents, six chlorophenoxy-acid herbicides, and 22 organochlorine compounds. Pesticide and PCB residues were detected in some bird and fish tissue samples. Cholinesterase enzyme (ChE) inhibition, indicating exposure to either organophosphate or carbamate pesticides, was detected in three of five adult mallards tested. The ChE inhibition in the three birds was 28, 50, and 52 percent of normal, free-living adult mallards, as calculated from published values (Lusk and others, 1991).

Selenium was detected in some samples of fish and bird tissues as well as in some sediment samples. Fifty percent of the fish samples collected at the refuge exceeded the National Contaminant Biomonitoring Program (NCBP) 85th-percentile selenium concentration of 0.73 µg/g wet weight (Schmitt and Brumbaugh, 1990). Lusk and others (1991) considered selenium concentrations above this value as evidence that selenium was elevated above baseline concentrations. Composite liver/kidney samples from killdeer, blue-winged teal, and gadwall had concentrations of selenium greater than 10 µg/g dry weight. On the basis of guidelines provided by Skorupa and others (1990), Lusk and others regarded selenium concentrations higher than 10 µg/g dry weight in avian liver and kidney samples as having the potential for severe abnormalities. The highest selenium concentrations (20.5 and 21.6 µg/g dry weight) were found in liver/kidney samples from killdeer. Also, killdeer eggs from the refuge had selenium concentrations as high as 5.20 µg/g dry weight. These results indicated that nesting birds, especially killdeer, were accumulating selenium to levels that may be adversely affecting reproduction (Lusk and others, 1991). Concentrations of selenium in bird eggs, embryos, livers, and liver/kidney composites from the 1989 and 1991 studies are shown in table 2. Selenium was not detected in aquatic plant samples from the refuge during the 1989 study.

Lead and mercury concentrations in all media sampled at Maxwell NWR were below levels of concern. Low concentrations of lead were detected in almost all samples of biota and sediment (Custer and others, 1993). Mercury was not detected in fillet or whole-body portions of game fish from Lake No. 13, but was detected in minute amounts in bird tissues. Mercury was not detected in any of the sediment samples.

## Results from the 1991 Investigation

The follow-up investigation conducted during the summer of 1991 is described in Custer and others (1993). The 1991 investigation was designed to (1) define more precisely the extent of selenium and mercury contamination at the refuge, and (2) estimate any risks to fish and wildlife resources by the measured concentrations of contaminants in the environment. Eighteen sediment and 59 biological samples (invertebrates, fish, and birds) were collected at six biota sampling sites (fig. 5) on the refuge. Bird samples consisted of two American avocet embryos, one composite sample of three eared grebe embryos, separate liver and kidney samples from each of three eared grebes, separate liver and kidney samples from each of three killdeer, and separate liver and kidney samples from one teal and cinnamon teal, for a total of 19 samples. Each sample was analyzed only for selenium, lead, and mercury.

The two American avocet embryos and the composite sample of eared grebe embryos had selenium concentrations of 5.56, 5.71, and 5.41 µg/g dry weight, respectively. According to Skorupa and others (1990), these concentrations of selenium do not have the potential to cause severe embryonic abnormalities in birds. Fifty percent of the livers from shorebirds and waterfowl contained concentrations of selenium that Custer and others (1993) concluded may cause some degree of adverse biological effects to nesting migratory birds based on the work of Skorupa and others.

Table 2.--Selenium concentrations in bird eggs, embryos, livers, and liver/kidney composites collected in 1989 and 1991 from the Maxwell National Wildlife Refuge

[Data from Lusk and others (1991) and Custer and others (1993). µg/g, micrograms per gram; --, not measured]

| Species / specimen | Selenium concentration | | | |
|---|---|---|---|---|
| | 1989 | | 1991 | |
| | Dry weight (µg/g) | Wet weight (µg/g) | Dry weight (µg/g) | Wet weight (µg/g) |
| Avocet embryo | -- | -- | 5.56 | 1.68 |
| Avocet embryo | -- | -- | 5.71 | 1.66 |
| Eared grebe embryos | -- | -- | 5.41 | 1.19 |
| Killdeer eggs | 5.20 | 1.50 | -- | -- |
| Cinnamon teal internal eggs | 1.59 | 0.59 | -- | -- |
| Gadwall internal eggs | 2.21 | 1.05 | -- | -- |
| Juvenile eared grebe liver | -- | -- | 5.26 | 1.50 |
| Juvenile eared grebe liver | -- | -- | 9.80 | 2.79 |
| Juvenile eared grebe liver | -- | -- | 10.1 | 2.88 |
| Juvenile teal liver | -- | -- | 10.3 | 2.81 |
| Juvenile cinnamon teal liver | -- | -- | 4.50 | 1.15 |
| Killdeer liver | -- | -- | 20.0 | 6.56 |
| Killdeer liver | -- | -- | 6.76 | 1.98 |
| Killdeer liver | -- | -- | 13.0 | 4.11 |
| Killdeer liver/kidney composite | 20.5 | 6.23 | -- | -- |
| Killdeer liver/kidney composite | 21.6 | 7.00 | -- | -- |
| Cinnamon teal liver/kidney composite | 9.58 | 2.91 | -- | -- |
| Blue-winged teal liver/kidney composite | 15.7 | 4.65 | -- | -- |
| Gadwall liver/kidney composite | 10.5 | 3.03 | -- | -- |
| Gadwall liver/kidney composite | 13.6 | 4.52 | -- | -- |
| Coot liver/kidney composite | 6.41 | 1.79 | -- | -- |

Selenium concentrations were consistently higher in all sampled media from the seepage wetland and Half playa (fig. 5) than in samples from other sites. Samples of aquatic invertebrates collected at the seepage wetland and Half playa contained mean selenium concentrations of 17.7 and 19.0 µg/g dry weight, respectively. Selenium concentrations in bottom-sediment samples collected during the 1989 and 1991 studies are shown in table 3.

Table 3.--Selenium concentrations in bottom sediment collected in 1989 and 1991 from the Maxwell National Wildlife Refuge

[Data from Lusk and others (1991) and Custer and others (1993). µg/g, micrograms per gram; --, concentration unknown or not measured; <, less than]

| Site | Selenium concentration (µg/g dry weight) | |
|---|---|---|
| | 1989 | 1991[1] |
| Lake No. 12 inflow | -- | 0.60 - 1.4 |
| Lake No. 12 | -- | 0.47 - 0.97 |
| Lake No. 12 drain | <0.40 | -- |
| Lake No. 13 inflow | 0.71 | 0.76 - 0.88 |
| Lake No. 13 | <0.40 | -- |
| Lake No. 14 | 0.40 | 0.66 - 1.4 |
| Natural playa | 0.39 | -- |
| Seepage wetland | -- | 1.2 - 3.7 |
| Half playa | -- | 2.1 - 11.0 |

[1]Range of concentrations in three samples collected in 3 different months.

Lead and mercury concentrations in all media sampled in 1991 were below levels of concern. Lead was detected at low concentrations in almost all samples. Mercury was not detected in fillet or whole-body portions of game fish from Lake No. 13 in 1991, but was detected in minute amounts in bird tissues.

## Results from the 1992 Investigation

Dissolved selenium concentrations ranging from less than 1 to 35 µg/L were found in surface-water and shallow ground-water samples collected by the USGS in June 1992 (no bottom sediment was collected). Surface-water samples from the seepage wetland and Half playa south of Lake No. 13 (fig. 5) had concentrations of 12 and 18 µg/L, respectively. Samples from two shallow wells on the east and north shoreline of Half playa had selenium concentrations of 4 and 35 µg/L, respectively. The USEPA drinking-water primary maximum contaminant level (PMCL) for selenium is 50 µg/L (U.S. Environmental Protection Agency, 1994), and the New Mexico standard for the protection of wildlife and the chronic standard for fisheries is 2 µg/L (New Mexico Water Quality Control Commission, 1995). Two other ground-water and three other surface-water samples had selenium concentrations less than 1 µg/L. The ground-water sample with a selenium concentration of 4 µg/L also contained 110 µg/L vanadium, which is slightly larger than the New Mexico standards of 100 µg/L for irrigation and livestock water (New Mexico Water Quality Control Commission, 1995). Four samples contained boron above 750 µg/L. None of the other samples contained trace metals in concentrations at or above regulatory concern.

## SAMPLE COLLECTION AND ANALYSIS

The main purposes of DOI NIWQP studies are to determine whether constituents in irrigation drainage (1) have caused or have the potential to cause significant harmful effects to human health, fish, and wildlife; or (2) may adversely affect the suitability of water for other beneficial uses. Sample collection and analysis protocols are designed to meet these objectives; trace elements and pesticides usually are of primary concern.

This reconnaissance study, initiated in 1993, was an interagency effort. The USGS and USFWS conducted the field work and prepared the reports; the BOR provided supporting information as needed. A USGS hydrologist was the study team leader. The approach of the study followed protocols developed by the NIWQP.

### Sampling Sites

From a total of 16 sites, surface water was sampled at 11 sites, ground water at 2 sites, and biota at 9 sites. Bottom-sediment samples also were collected at the 11 surface-water sites. The site locations are shown in figure 6 and are described in table 4. Site selection was based on the NIWQP protocol for conducting reconnaissance investigations (Department of the Interior, 1990), the hydrology of the area, and consideration of recent sampling by the USFWS and USGS at the Maxwell NWR. Sites were selected to observe water-quality changes along probable flow paths. Three surface-water sites (V-01, V-02, and V-03; fig. 6) are upgradient from the project and served as reference sites. Three other sites (V-06, V-07, and V-08) are on drains carrying water eastward from the project. Two sites on the Canadian River (V-04 and V-05) and one on the Vermejo River (V-09) are downstream from the project and were sampled in an attempt to identify any irrigation drain-water effect of the project on these major streams. Sites V-10 and V-11 (Natural playa and Half playa) are at playa lakes on the refuge and were sampled in previous studies by the USFWS and USGS. Although neither playa receives irrigation water directly, Natural playa receives incidental irrigation drainage from a field outside of the refuge (Lusk and others, 1991) and Half playa receives ground-water seepage as well as irrigation canal and reservoir seepage (Custer and others, 1993). One ground-water site (V-13) is upgradient from the project and served as a reference site. The other ground-water site (V-12) is a shallow well on the northern side of Half playa and is upgradient from the playa. This well was sampled once previously by the USGS in June 1992.

Water in Natural playa (V-10), Half playa (V-11), and the seepage wetland (V-16) probably undergoes significant evaporative concentration. Alkali deposits are abundant on the soils surrounding the playas and on soils in other places on the refuge. Evaporative concentration probably affects the water quality of all lakes on the refuge to some extent. Lusk and others (1991), for example, reported that specific-conductance values of water in Lakes No. 12, No. 13, and No. 14 (1,680, 906, and 532 µS/cm, respectively) are greater than in Stubblefield Reservoir and the Vermejo River (438 and 400 µS/cm, respectively).

The sampling strategy used by the USFWS for the biological part of the Vermejo reconnaissance investigation emphasized irrigation-supply water rather than irrigation-drain water, which is the main concern of the NIWQP. The refuge and its associated fish and wildlife resources are of paramount concern to USFWS investigators. Heavy public use of the refuge and the abundance (compared with other areas in the region) of natural resources under departmental trusteeship suggested that this part of the study area is the most likely source of risks to human health, fish, and wildlife. In addition, previous studies conducted on the refuge in 1989, 1991, and 1992 had indicated concerns pertaining to elevated concentrations of selenium. Therefore, the refuge became a focal point of the USFWS's biological sampling strategy. As a result, the preponderance of biological data are for areas that do not receive irrigation drainage because all of the impoundments (Lakes No. 12, No. 13, and No. 14) and wetlands on the refuge contain either irrigation-supply or naturally occurring water.

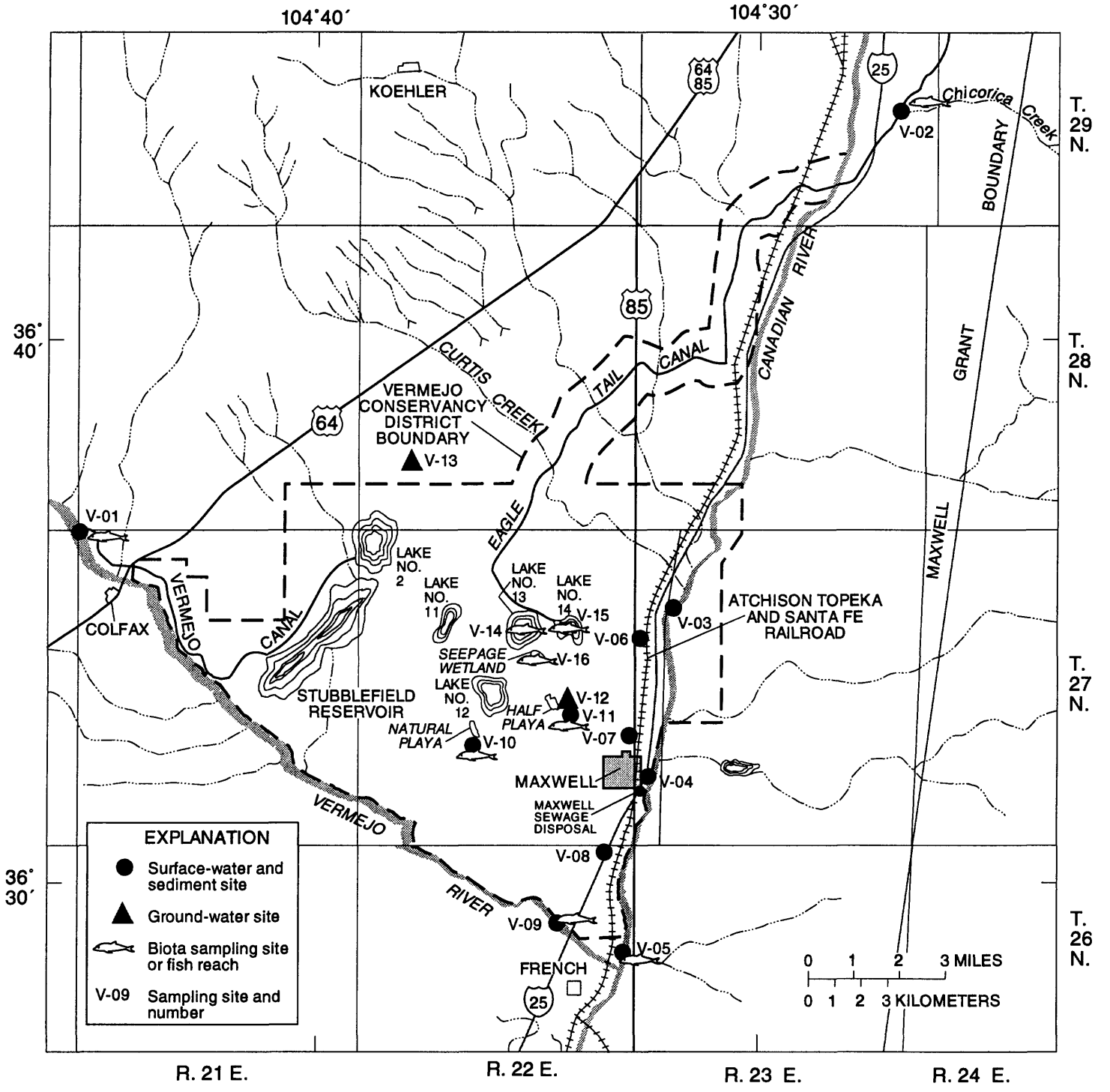


Figure 6.--Location of water-quality and bottom-sediment sampling sites and fish-sampling reaches in the study area, 1993.

Table 4.--Description of sampling sites and number of samples collected for water, bottom sediment, and biota in and near the Vermejo Irrigation Project near Maxwell, New Mexico

[I, inorganic; O, organic; R, replicate sample; S, split sample; USGS, U.S. Geological Survey; USFWS, U.S. Fish and Wildlife Service]

| Site number (fig. 6) | Site description | Elevation (feet above sea level) | Latitude/ longitude | Number of samples | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Water | Bottom sediment | | Vegetation | Invertebrates | Fish[1] |
| | | | | I | I | O | I | I | I |
| V-01 | Vermejo River upstream from the Vermejo Canal diversion dam. Irrigation source water entering project from Vermejo River Basin. Reference site. | 6,185 ± 10 | 36°36'34"N. 104°45'11"W. | 1<br>R | 1 | 0 | 1 | 1 | 1 |
| V-02 | Chicorica Creek at heading of Eagle Tail Canal. Irrigation source water entering project from Chicorica Basin. Reference site. | 6,150 ± 10 | 36°43'28"N. 104°26'39"W. | 1 | 1 | 0 | 2 | 1 | 2 |
| V-03 | Canadian River upstream from Curtis Creek and the project area. Reference site. | 6,010 ± 10 | 36°39'03"N. 104°29'15"W. | 1<br>R | 1<br>S | 0 | 0 | 0 | 0 |
| V-04 | Canadian River downstream from middle drain ditch and upstream from Maxwell sewage disposal. Receives drainage from northern part of project. | 5,865 ± 5 | 36°32'03"N. 104°31'52"W. | 1<br>S | 1 | 0 | 0 | 0 | 0 |
| V-05 | Canadian River just upstream from confluence with Vermejo River. Receives surface and subsurface drainage flowing east from project into Canadian River drainage. | 5,825 ± 5 | 36°29'12"N. 104°32'37"W. | 1 | 1 | 1 | 2 | 1 | 2 |
| V-06 | North Drain Canal west of I-25. Receives drainage from north section of project, which enters Canadian River. | 5,980 ± 5 | 36°34'52"N. 104°32'30"W. | 1 | 1<br>R | 0 | 0 | 0 | 0 |

Table 4.--Description of sampling sites and number of samples collected for water, bottom sediment, and biota in and near the Vermejo Irrigation Project near Maxwell, New Mexico--Continued

| Site number (fig. 6) | Site description | Elevation (feet above sea level) | Latitude/ longitude | Number of samples | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Water | Bottom sediment | | Vegetation | Invertebrates | Fish[1] |
| | | | | I | I | O | I | I | I |
| V-07 | Middle Drain Canal north of Maxwell. Receives drainage from the central section of the project, which enters Canadian River. | 5,918 ± 5 | 36°32'52"N. 104°32'30"W. | 1 | 1 | 0 | 0 | 0 | 0 |
| V-08 | South Drain Canal at railroad tracks. Receives drainage from south section of project, which enters Canadian River. | 5,890 ± 5 | 36°31'22"N. 104°33'03"W. | 1 | 1 | 0 | 0 | 0 | 0 |
| V-09 | Vermejo River at USGS gage just upstream from I-25. Downgradient from southerly drainage from project, which enters Vermejo River. | 5,880 ± 5 | 36°29'48"N. 104°34'15"W. | 1 | 1 | 1 | 1 | 2 | 2 |
| V-10 | Natural playa on southwest corner of refuge. Playa is not connected in irrigation distribution system. Probably receives some irrigation runoff. Sediment sampled in 1989 by USFWS. | 5,996 ± 5 | 36°33'06"N. 104°36'00"W. | 1 | 1 | 0 | 2 | 2 | 0 |
| V-11. | Half playa on southeast corner of refuge. Receives seepage from Lake No. 13 and possibly subsurface drainage from crop areas on refuge. Sediment sampled in 1991 by USFWS; water sampled in 1992 by USGS. | 5,975 ± 5 | 36°33'40"N. 104°34'15"W. | 1 | 1 | 0 | 2 | 1 | 1 |
| V-12 | Shallow well on north side of Half playa. Receives shallow subsurface drainage from central part of project. Water sampled in 1992 by USGS. | 5,978 ± 5 | 36°33'48"N. 104°34'20"W. | 1 | 0 | 0 | 0 | 0 | 0 |

Table 4.--Description of sampling sites and number of samples collected for water, bottom sediment, and biota in and near the Vermejo Irrigation Project near Maxwell, New Mexico--Concluded

| Site number (fig. 6) | Site description | Elevation (feet above sea level) | Latitude/ longitude | Number of samples: Water | Bottom sediment | | Vegetation | Invertebrates | Fish[1] |
|---|---|---|---|---|---|---|---|---|---|
| | | | | I | I | O | I | I | I |
| V-13 | Well northwest of project. Ground-water reference site upgradient from project area. | 6,157 ± 5 | 36°39'20"N. 104°35'47"W. | 1 | 0 | 0 | 0 | 0 | 0 |
| V-14 | Lake No. 13 on the refuge. Receives and stores irrigation source water; is a major wetland area and is used for recreational fishing. Sediment and biota sampled in 1989 by USFWS. | 6,046 ± 5 | 36°35'00"N. 104°35'00"W. (approximate) | 0 | 0 | 0 | 2 | 2 | 6 |
| V-15 | Lake No. 14 on the refuge. Receives irrigation source water and is a major wetland area. Sediment and biota sampled in 1989 and 1991 by USFWS. | 6,045 ± 5 | 36°34'54"N. 104°34'00"W (approximate) | 0 | 0 | 0 | 3 | 2 | 6 |
| V-16 | Seepage wetland downgradient from Lake No. 13. Discharge area for water seeping out of Lake No. 13. | 6,005 ± 5 | 36°34'30"N. 104°34'40"W. (approximate) | 0 | 0 | 0 | 3 | 2 | 0 |

[1]Includes whole fish and fillets.

Biological specimens for chemical analyses were collected at nine sites within the study area. Aquatic plant, invertebrate, amphibian, and fish samples in wetland habitats were collected in the summer of 1993 during maximum metabolic activity. If available, fish, aquatic invertebrates, and aquatic plants were collected from the sites shown in figure 6. These include Vermejo River upstream from the Vermejo Canal Diversion Dam (V-01), Chicorica Creek at the heading of the Eagle Tail Canal (V-02), Canadian River upstream from the Vermejo River (V-05), Vermejo River near Maxwell (V-09), Natural playa (V-10), Half playa (V-11), Lakes No. 13 and No. 14 (V-14, V-15), and the seepage wetland (V-16) (fig. 6). The precise locations where samples of water, bottom sediment, and biota were collected may vary slightly because some movement within a sampling area is often necessary to obtain the prerequisite amount of media, especially for biota. For example, Lake No. 13 was considered a sampling site (V-11), but it was necessary to move (by boat) to various locations around the lake to obtain the numbers and species of fish specified in the biological-sampling schedule plan.

## Sampling Methods

Sampling times for water and bottom sediment were based on seasonal irrigation practices. Surface-water samples were collected prior to and late in the irrigation season. Flow data from the USGS surface-water gages were used to estimate constituent loads for the sampled streamflow. Bottom-sediment samples collected for analyses of inorganic constituents were collected once during late fall after a period of low flow. Sediment samples collected for pesticide analysis were collected once, late in the irrigation season. The reference well also was sampled once, late in the irrigation season. The shallow well on the refuge was sampled twice on the same schedule as the surface-water sites. Sample collection and preparation of water and sediment samples followed standard USGS procedures and the guidelines developed for the NIWQP (U.S. Geological Survey, 1982; Edwards and Glysson, 1988; Severson and others, 1988).

Water samples were collected from the playas and drains by submerging a 9-qt churn splitter. Prior to collection of each sample, the churn splitter was thoroughly washed and rinsed in native water from the sampling site. Equal-width increment, depth-integrated water samples were collected from the Vermejo and Canadian Rivers and Chicorica Creek using an epoxy-coated DH-48 sampler.

Water temperature, specific conductance, pH, and dissolved oxygen were measured at the time of sample collection, and water discharge was measured where there was streamflow. Samples collected for analysis of major ions, trace elements, nitrogen species, and dissolved-uranium concentrations were filtered immediately following sample collection using a peristaltic pump and a 0.45-micrometer filter.

Except for mercury, samples collected for analysis of trace elements and uranium were preserved with nitric acid; samples collected for mercury analysis were preserved with a potassium dichromate/nitric acid solution. Samples were preserved immediately following filtration; the pH of the preserved samples was less than 2.0. Samples collected for analysis of nitrogen species were preserved with a mercuric chloride/sodium chloride solution and packed in ice immediately following filtration.

Water samples for analysis of pesticides were collected by submerging a 1-liter, baked, brown glass bottle in the centroid of flow. Prior to sample collection, the bottles were thoroughly rinsed with water from the sampling site. Samples were packed in ice immediately following collection.

All bottom-sediment sampling equipment was thoroughly washed with biodegradable detergent powder and water, rinsed with deionized water, then rinsed in native water from the sampling site immediately prior to sample collection and processing. Composite samples were collected with an unpainted BMH-53 bottom-sediment sampler. The core barrel of the sampler was stainless steel and the plunger was brass. Nine to 12 equally spaced subsample cores were collected at each site, and the top 3 to 4 in. of each core were combined in a stainless steel bucket and thoroughly mixed with a stainless steel spoon.

Bottom sediment to be analyzed for trace elements was subsampled and placed in a 500-milliliter polyethylene jar. Sample material to be analyzed for organochlorine compounds was gently worked through a 2-millimeter (mm) brass-plated sieve with a stainless steel spoon; material passing through the sieve was retained and placed in a 1-liter, baked, clear glass jar. No water was used during the sieving process. Each sample was packed in ice immediately following sieving.

Several types of quality-assurance samples were used in the study, as outlined in the program protocol. During the August-September sampling trip, replicate (two separate samples collected simultaneously) surface-water samples from each of two sites were collected and analyzed. During the same trip, one water sample was split into triplicates (three representative aliquots) and each analyzed. Replicate bottom-sediment samples collected at one site and a split sediment sample collected at another site were analyzed for trace elements. A travel blank of deionized water (produced at the New Mexico Subdistrict Office in Santa Fe) was taken on each trip during which water samples were collected; it was analyzed for the same constituents as the field samples. Laboratory quality control was in accordance with the protocols for the NIWQP. Replicate and split sample results are included with sample analytical results in tables 17 and 18; blank sample analyses are shown separately in table 19 (tables 17-22 are in the supplemental data section in the back of the report). Mean and standard deviation percent moisture of biota are shown in table 20.

Boron was detected in the April 1993 (site V-09) travel blank at 10 µg/L, and the August 1993 (site V-07) travel blank at 70 µg/L. Zinc was detected in the April 1993 (V-09) travel blank at 10 µg/L. These concentrations of boron and zinc are well below levels of concern: the boron concentrations were below or within the concentration range at the reference sites, and the single zinc travel blank detection was at the largest analytical reporting limit. It is unknown whether the presence of boron and zinc in the samples is due to contamination of the deionization system at the New Mexico Subdistrict Office or to contamination in the field.

Biota were collected according to procedures outlined by the U.S. Fish and Wildlife Service (1990) using the methods most appropriate for conditions at the collection site. Fish were collected by electrofishing, seining, or gill nets as appropriate. Attempts were made to obtain a minimum sample weight of 8 grams (g) of aquatic invertebrates using fine-mesh dip nets. Grab samples of aquatic plants were collected at the sampling sites where they grew. Table 21 lists the species, sample type, and number of biological samples collected at the nine sampling sites where biota were collected.

Fish larger than 6 centimeters (cm) were weighed, measured for total length, and composited into groups of three to five individuals (depending on the number available) of approximately the same size and weight. At sites where fish generally averaged less than 6 cm, enough small fish were collected to provide a minimum composite sample weight of at least 25 g. In some instances, USFWS biologists were unable to capture more than one fish representative of a particular ecological trophic level at a site. However, at most sites, and especially at Lakes No. 13 and No. 14 on the refuge, composite fish samples consisted of four fish of similar length and weight. Except for fish collected from Lakes No. 13 and No. 14 on the refuge, all samples were analyzed as composites of whole fish.

Because recreational fishing accounts for most public visitation to Maxwell NWR and most angling is in Lakes No. 13 and No. 14 (sites V-14 and V-15), a different fish sampling strategy was used at these two sites. Efforts were made to obtain enough fish to provide at least two composite samples of predatory (for example, largemouth bass), bottom feeder (bullhead) and forage fish (bluegill) from Lakes No. 13 and No. 14. A fillet was removed from the right side of fish collected in Lakes No. 13 and No. 14 that were judged to be of sufficient size for consumption by the angling public. These fillets generally were composited into groups of four and analyzed separately from the corresponding composite samples of four remnant whole fish (whole fish with fillet removed from the right side). The analytical data pertaining to human health (fillet data) will be provided to health regulatory officials in the New Mexico Environment Department and the Department of Health.

After normalization for weight and moisture content, analytical data for the fillets were recombined with data from the corresponding composite samples of remnant whole fish (whole fish with right-side fillets removed) to calculate an estimate of the concentrations of contaminants in whole fish from Lakes No. 13 and No. 14. This information was used to estimate risks to piscivorous wildlife and to compare to other whole-body fish in the data tables.

Fillet samples were placed in chemically precleansed glass jars and labeled. Composite samples of remnant whole fish (minus right-side fillets) were wrapped in aluminum foil, tagged with a waterproof label, and placed in plastic bags with a locking seal. Plant specimens were placed in labeled plastic bags, and aquatic invertebrates were placed in chemically precleansed, glass jars. All biological samples were weighed, labeled, and stored on ice while in the field. The samples were frozen upon returning to the field office. All samples were shipped frozen to the Environmental Trace Substances Research Center in Columbia, Missouri, for chemical analysis.

## Analytical Support

Water samples were analyzed for the major and minor elements listed in table 5. Field measurements of pH, specific conductance, dissolved oxygen, and temperature were made at all sites at the time of sample collection.

All water samples were analyzed by the USGS National Water Quality Laboratory in Arvada, Colorado, using procedures outlined in Wershaw and others (1987) in accordance with program protocols. Selected constituents and the applicable analytical reporting limits are shown in table 5.

Bottom-sediment samples were analyzed for inorganic constituents by the USGS, Branch of Geochemistry Laboratory in Denver, Colorado. Additionally, 2 of the 11 samples were analyzed for organic compounds by the USGS National Water Quality Laboratory. The analytical techniques and quality controls used in analyzing bottom-sediment samples are outlined in Fishman and Friedman (1989), Harms and others (1990), and Stewart and others (1992).

All biota collected (tables 4 and 21) were analyzed for 15 trace elements (table 5) using a preconcentration-enhanced inductively coupled plasma (ICP) emission spectroscopy methodology. Arsenic, mercury, and selenium, however, were analyzed using atomic absorption spectroscopy because of the lower analytical reporting limit compared to the ICP method. All fish samples were analyzed for PCB's and organochlorine pesticide residues using gas chromatography. The moisture content of biota was determined by keeping the samples at 105 °F until dry and comparing aliquot weights. Inorganic analytical chemistry for the biological samples was performed by the Environmental Trace Substances Research Center in Columbia, Missouri. Aliquots of these samples were then forwarded to Hazelton Environmental Services, Inc., located in Madison, Wisconsin, for organic-chemical analysis.

Both of the above contract laboratories were previously approved by the USFWS's analytical control facility located at the National Wildlife Research Center in Patuxent, Maryland. The Patuxent Analytical Control Facility uses a rigorous system of quality-control measures to ensure the analytical precision of USFWS contract laboratories. This includes the use of procedural blanks, duplicate analyses, test recoveries of spiked materials, reference material analyses, and round-robin tests. About 10 percent of the biota samples submitted to the two USFWS contract laboratories were quality-assurance/quality-control samples. These samples consisted of split, duplicate, and blank samples. Analytical results of the split and replicate samples are included in tables 17 and 18 for comparison purposes. Analytical results of blank samples are shown in table 19.

Table 5.--Minimum analytical reporting limits for selected constituents measured in water, bottom sediment, and biota

[For biota, values are reported as dry weight for inorganic and as wet weight for organic constituents; µg/L, micrograms per liter; µg/g, micrograms per gram; µg/kg, micrograms per kilogram; --, not applicable or unavailable]

| Constituent | Analytical reporting limit | | |
|---|---|---|---|
| | Water (µg/L) | Bottom sediment (µg/g) | Biota (µg/g dry weight) |
| | Inorganic constituents | | |
| Arsenic | 1 | 0.1 | 0.2 or 0.3 |
| Beryllium | -- | 1 | 0.2, 0.3, or 0.4 |
| Boron | 10 | 0.4 | 0.2 |
| Cadmium | 1 | 2 | 0.02 |
| Chromium | 1 | 1.0 | 0.09 |
| Copper | 1 | 1.0 | 0.9 |
| Lead | 1 or 2 | 4.0 | 0.4 |
| Mercury | 0.1 | 0.02 | 0.006 |
| Molybdenum | 1 | 2 | 1 |
| Nickel | -- | 2 | 0.1 |
| Selenium | 1 or 2 | 0.1 | 0.2 |
| Strontium | -- | 2.0 | 0.2 |
| Uranium | -- | 0.1 | -- |
| Vanadium | 1 | 2.0 | 0.3 |
| Zinc | 3 or 10 | 2.0 | 0.2 |
| | Organic constituents | | |
| Organophosphate insecticides | -- | 0.0001 | -- |
| Organochlorine insecticides: | | | |
| Toxaphene | -- | 0.01 | 0.05 |
| Chlordane | -- | 0.001 | 0.01 |
| PCB's | -- | 0.001 | 0.05 |
| PCN's | -- | 0.001 | 0.01 |
| Perthane | -- | 0.001 | 0.01 |
| Other organochlorine compounds | -- | 0.0001 | 0.01 |

## Statistical Analysis

No statistical analysis was performed on the water or bottom-sediment samples because the small number of samples would not provide statistically significant results for this reconnaissance study. Statistical analysis of the biota was performed using the software program Statistical Package for the Social Sciences (SPSS, Inc., 1993). If 50 percent of the samples contained trace-element concentrations above the analytical reporting limit, then a value of one-half the analytical reporting limit was used in statistical comparisons and to calculate geometric means. More than half of the beryllium and molybdenum samples had concentrations below the analytical reporting limit and no statistical analysis was made because the small number of

samples would not provide meaningful results. Prior to statistical analysis, all data were converted to their natural logarithms. Variations in trace-element concentrations between sites and between species were evaluated with a one-way analysis of variance test. If significant differences were found, Tukey's "honestly significant difference" test was used to determine if the means were also different. Unless otherwise stated, statistical significance refers to a 5-percent Type I error rate ($p \leq 0.05$). A Pearson correlation was performed on all variables: wet weight, dry weight, and log-transformed concentrations. Where significant correlations were found, the SPSS's CURVEFIT subroutine was used to fit selected curves to a line plot of the measured data. This nonlinear regression provided a best-fit equation that models the flow of trace elements through the food web. The coefficient of determination ($r^2$) is the proportion of the total variation of the dependent variable around its mean that is explained by the fitted model.

## WATER QUALITY, BOTTOM SEDIMENT, AND BIOTA

### Concentrations of Trace Elements in Water

A total of 22 surface-water samples were collected for chemical analysis during two sampling periods: prior to the irrigation season in April 1993 and during the late-irrigation season in August and September of 1993. Three ground-water samples were collected during mid-irrigation season in June 1993 and in August 1993. Results of these analyses are shown in table 17. The distribution of sample concentrations for selected elements is shown in figure 7.

Three surface-water sites (V-01, V-02, and V-03) upstream from the project served as reference sites to provide background concentrations of constituents in water prior to any effects of irrigation drainage from the Vermejo Project. One ground-water site (V-13) upgradient from the Vermejo Project was chosen as a reference site for ground water. Concentrations of dissolved constituents in water from each site were compared to the range of values at the reference sites to assess possible effects of the Vermejo Project. Table 6 summarizes the reference site concentrations of elements and identifies the sites that exceeded these values.

Concentrations of dissolved constituents in water were compared to National Baseline Values for rivers in the United States. Data from which these baseline values were calculated are from two National monitoring programs: the National Stream-Quality Accounting Network (NASQAN) and the National Water-Quality Surveillance System (NWQSS). Data have been collected for NASQAN and NWQSS since 1973. Baseline values, taken from Blanchard and others (1993), were calculated by determining the arithmetic mean concentration of a given water-quality property or constituent at each NASQAN and NWQSS station for which information was available, then ranking these mean values for all stations for percentile values. These percentile values are shown in table 7.

To evaluate water-quality conditions in the study area further, concentrations of selected constituents were compared to applicable USEPA drinking-water standards and with State of New Mexico water-quality standards (U.S. Environmental Protection Agency, 1994; New Mexico Water Quality Control Commission, 1995). These Federal and State standards for selected constituents are listed in table 8.

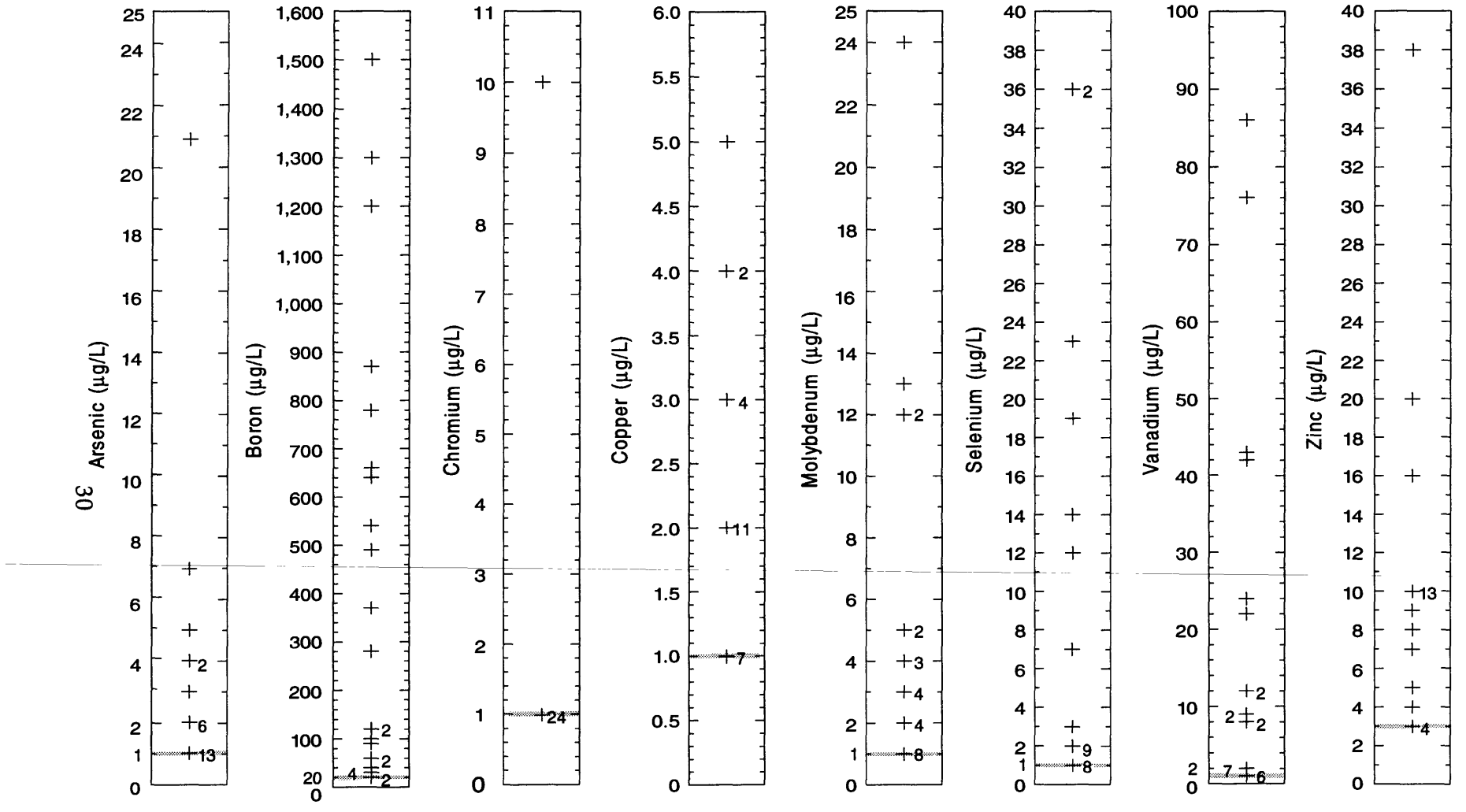


Figure 7.--Concentrations of selected minor trace elements, in micrograms per liter (µg/L), in 25 water samples from 13 sites, Vermejo Irrigation Project Area, New Mexico. Concentrations reported as less than the laboratory reporting limit are plotted as equal to the limit. Minimum laboratory reporting limits are shown in gray. The number of samples with the same value are shown next to the value.

Table 6.--Concentrations of selected constituents in water samples collected from surface-water and ground-water reference sites and concentrations in other samples collected during the Vermejo reconnaissance study

[All values are in micrograms per liter; <, less than; --, no analyses exceeded the reference site concentrations]

| Trace element | Range of concentrations at the three surface-water reference sites (V-01, V-02, V-03) | Concentrations at the ground-water reference site (V-13) | Reconnaissance study sites with concentrations exceeding those at the reference sites (fig. 6) | |
|---|---|---|---|---|
| | | | Surface-water sites | Ground-water sites |
| Arsenic | <1 - 2 | <1 | V-07, V-08, V-10, V-11 | V-12 |
| Boron | 20 - 120 | 120 | V-06, V-07, V-08, V-10, V-11 | V-12 |
| Cadmium | <1.0 | <1.0 | -- | -- |
| Chromium | <1 | <1 | V-10 | -- |
| Copper | 1 - 3 | 4 | V-07, V-11 | -- |
| Lead | <1 | <1 | -- | -- |
| Mercury | <0.1 | <0.1 | -- | -- |
| Selenium | <1 - 2 | 12 | V-06, V-08, V-11 | V-12 |
| Vanadium | <1 - 2 | <1 | V-06, V-07, V-08, V-10, V-11 | V-12 |
| Zinc | <3 - 38 | 20 | -- | -- |

Table 7.--Baseline concentrations of selected constituents in water samples collected from rivers of the United States and concentrations in samples collected from the Vermejo and Canadian Rivers and irrigation project sites

[From Blanchard and others, 1993. Baseline percentiles: determined from data in National Stream-Quality Accounting Network (NASQAN) and National Water-Quality Surveillance System (NWQSS) data bases; <, less than; --, no sites equaled or exceeded the 50th percentile]

| Trace element | NASQAN-NWQSS concentration baseline percentiles, in micrograms per liter | | | Reconnaissance study sites (fig. 6) with concentrations equal to or exceeding the 50th percentile | |
|---|---|---|---|---|---|
| | Less than or equal to | | | | |
| | 25% | 50% | 75% | Surface-water sites | Ground-water sites |
| Arsenic | <1 | 1 | 3 | V-03, V-04, V-05, V-06, V-07, V-08, V-10, V-11 | V-12 |
| Cadmium | <2 | <2 | <2 | -- | -- |
| Chromium | 9 | 10 | 10 | V-10 | -- |
| Lead | 3 | 4 | 6 | -- | -- |
| Mercury | 0.2 | 0.2 | 0.2 | -- | -- |
| Selenium | <1 | <1 | <1 | V01, V-02, V-03, V-04, V-05, V-06, V-07, V-08, V-09, V-10, V-11 | V-12, V-13 |
| Zinc | 12 | 15 | 21 | V-02, V-05 | V-13 |

Table 8.--U.S. Environmental Protection Agency (USEPA) and State of New Mexico water-quality standards for selected constituents

[USEPA drinking-water standard: Federally enforceable drinking-water standard primary maximum contaminant level, except as noted (U.S. Environmental Protection Agency, 1994); State of New Mexico standard (New Mexico Water Quality Control Commission, 1995); all values are in micrograms per liter; --, not applicable; H, hardness]

| Constituent | USEPA drinking-water standard | State of New Mexico standard | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | Fisheries | | |
| | | Domestic | Irrigation | Livestock | Acute[1] | Chronic[2] | Wildlife |
| Arsenic | 50 | 50 | 100 | 200 | -- | -- | 200 |
| Boron | -- | -- | 750 | 5,000 | -- | -- | -- |
| Cadmium | 5 | 10 | 10 | 50 | $e^{1.128[\ln(H)]-3.828}$ | $e^{0.7852[\ln(H)]-3.49}$ | -- |
| Chromium | 100 | 50 | 100 | 1,000 | $e^{0.819[\ln(H)]+3.688}$ | $e^{0.819[\ln(H)]+1.561}$ | -- |
| Copper | [3]1,300 | -- | 200 | 500 | $e^{0.9422[\ln(H)]-1.464}$ | $e^{0.8545[\ln(H)]-1.465}$ | -- |
| Lead | [3]15 | 50 | 5,000 | 100 | $e^{1.273[\ln(H)]-1.46}$ | $e^{1.273[\ln(H)]-4.705}$ | -- |
| Total mercury | [4]2 | 2 | -- | 10 | 2.4 | 0.012 | 0.012 |
| Molybdenum | -- | -- | 1,000 | -- | -- | -- | -- |
| Selenium | 50 | 50 | 130 | 50 | [5]20 | [5]2.0 | 2 |
| Selenium in presence of > 500 milligrams per liter $SO_4$ | -- | -- | 250 | -- | -- | -- | -- |
| Vanadium | -- | -- | 100 | 100 | -- | -- | -- |
| Zinc | [6]5,000 | -- | 2,000 | 25,000 | $e^{0.8473[\ln(H)]+0.8604}$ | $e^{0.8473[\ln(H)]+0.7614}$ | -- |

[1] [2] Applied to any single sample.

[3] Applied to the arithmetic mean of four samples collected on each of 4 consecutive days.

[4] Treatment techniques must be used to lower concentrations to levels no greater than this value or level.

[5] Dissolved mercury.

[6] Total recoverable selenium.

Federally nonenforceable secondary drinking-water standard maximum contaminant level.

Drinking-water standard primary maximum contaminant levels (PMCL's) established by the USEPA are federally enforceable water-quality standards. Drinking-water standard secondary maximum contaminant levels (SMCL's) are not federally enforceable, but establish recommended concentration limits above which aesthetic qualities and public acceptance of drinking water may be adversely affected. Both standards are applicable only at the point of use, such as a drinking-water tap.

Water-quality standards for various water uses (domestic, irrigation, livestock, fisheries, and wildlife) have been established for streams in New Mexico by the New Mexico Water Quality Control Commission (1995). New Mexico regulations for fisheries have separate acute and chronic standards. The acute standard is applied to any single sample. The chronic standard is applied to the arithmetic mean of four samples collected on each of 4 consecutive days. For wildlife habitat, where the natural level of a dissolved chemical constituent in streams is greater than the concentration listed in the New Mexico standards, the concentration may not be increased by more than 5 percent (by total mass) by the water user or discharger.

The largest arsenic concentration detected was 21 µg/L at Half playa (site V-11; fig. 6), in April 1993 (table 17). Upon resampling in September 1993, the concentration was below the analytical reporting limit of 1 µg/L. Water samples from Middle Drain Canal (V-07), South Drain Canal (V-08), Natural playa (V-10) and Half playa (V-11) exceeded the arsenic concentration range of <1 - 2 µg/L for the surface-water reference sites. Water from the well north of Half playa (V-12) had an arsenic concentration of 4 µg/L, which was greater than that from the ground-water reference site (<1.0 µg/L). Though the largest concentration of arsenic in water is less than half of any of the water-quality standards for arsenic listed in table 8, 14 samples from 9 sites contained arsenic concentrations that were equal to or larger than the national baseline 50th percentile of 1 µg/L.

Surface-water samples from North Drain Canal (V-06), Middle Drain Canal (V-07), South Drain Canal (V-08), Natural playa (V-10), and Half playa (V-11) contained boron concentrations above the range of reference-site concentrations (20-120 µg/L). The water sample from the well north of Half playa (V-12) had boron concentrations larger than samples from the ground-water reference site (120 µg/L). Five samples from three sites contained boron above the New Mexico irrigation water-quality standard of 750 µg/L, though none exceeded the New Mexico livestock standard of 5,000 µg/L. The boron concentrations in these five samples were: Half playa, 1,300 and 1,500 µg/L in April and September 1993, respectively; North Drain Canal, 1,200 µg/L in August 1993; and South Drain Canal, 780 and 870 µg/L in April and August 1993, respectively.

Cadmium concentrations in water were below the analytical reporting limit of 1 µg/L in all samples. This value is within the national baseline 75th percentile of less than 2 µg/L for cadmium and is smaller than any of the water-quality standards listed in table 8.

One water sample contained chromium above the analytical reporting limit of 1 µg/L: the April 1993 sample from Natural playa (V-10), which had a measured value of 10 µg/L. This value is above the surface-water reference-site chromium concentration and equal to the national baseline 50th percentile, though well below any of the water-quality standards in table 8. Upon resampling in August 1993, chromium was below the analytical reporting limit.

Concentrations of copper in water ranged from 5 µg/L at Half playa (V-11) to below the analytical reporting limit of 1 µg/L. Copper concentrations in water at Middle Drain Canal (V-07) and Half playa exceeded the surface-water background concentration range of 1 to 3 µg/L. No copper concentrations exceeded the water-quality standards shown in table 8.

Lead was not found at or above the dual analytical reporting limits of 2 µg/L (for three samples) and 1 µg/L (for the remaining 26 samples). Both limits are below the national baseline 25th percentile and all water-quality standards in table 8.

No water samples contained mercury at or above the analytical reporting limit of 0.1 µg/L. The lowest applicable State of New Mexico standard is 0.012 µg/L total mercury (fisheries chronic standard and wildlife standard). Because the samples were analyzed for dissolved mercury, the number of samples containing mercury concentrations exceeding this criterion is not known. However, all samples were less than the USEPA drinking-water PMCL of 2 µg/L.

Of the 29 water samples collected from 13 sites (including split and replicate samples), 21 contained selenium at or above the analytical reporting limits of 1 and 2 µg/L. Surface-water concentrations of selenium exceeded the concentration range at the reference sites (less than 1 to 2 µg/L) in five samples from three sites (less than 1 to 2 µg/L). The largest concentrations of selenium were measured in ground water from the well north of Half playa (V-12): 36 µg/L in June and August 1993. This selenium concentration was greater than those in samples from the ground-water reference site (12 µg/L). Because the national baseline 25th, 50th, and 75th percentiles for selenium are all less than 1 µg/L, most of the samples exceeded these concentrations. No samples exceeded USEPA drinking-water or State of New Mexico domestic or livestock standards of 50 µg/L or the State of New Mexico irrigation-water standard of 130 µg/L. The most stringent State of New Mexico water-quality standards are 2.0 µg/L total recoverable selenium for fisheries (chronic standard) and water for wildlife. Only dissolved selenium was measured in this study, and the total recoverable selenium concentration might have been larger than dissolved concentrations. Thus, selenium concentrations exceeded State of New Mexico standards for fisheries and water for wildlife in at least eight samples from five sites (two sites were wells, thus the fisheries and wildlife standards are not applicable). Samples from Half playa (V-11) contained 14 µg/L of selenium in April 1993 and 23 µg/L in September 1993. The chronic fisheries and wildlife standards are exceeded in the North Drain Canal (V-06) where dissolved concentrations of 19 and 7 µg/L were measured in April and August 1993, respectively. The remaining site to exceed the selenium-concentration range at the surface-water reference sites was the South Drain Canal (V-08). All remaining samples were less than 2 µg/L.

Vanadium concentrations ranged from 86 µg/L at Natural playa (V-10) to below the analytical reporting limit of 1.0 µg/L. Ten samples from five sites exceeded the vanadium-concentration range of less than 1 to 2 µg/L at the surface-water reference sites. The five surface-water sites that had vanadium concentrations larger than the reference-site concentrations were North Drain Canal (V-06), Middle Drain Canal (V-07), South Drain Canal (V-08), Natural playa (V-10), and Half playa (V-11. The well north of Half playa (V-12) contained vanadium concentrations larger than those in samples from the ground-water reference site (less than 1 µg/L). The only water-quality standard for vanadium is 100 µg/L for New Mexico irrigation and livestock water.

Only three samples contained zinc above the largest analytical reporting limit of 10 µg/L: 38 µg/L in Chicorica Creek at the heading of the Eagle Tail Canal (V-02), 20 µg/L in ground water from the well northwest of the project area (V-13), and 16 µg/L in the Canadian River upstream from the Vermejo River (V-05). Though these three concentrations were greater than the national baseline 50th percentile (15 µg/L), they are smaller than any of the water-quality standards listed in table 8.

## Concentrations of Trace Elements in Bottom Sediment

Bottom-sediment samples were collected after the irrigation season (November 1993) from the 11 sampled surface-water sites (sites V-01 through V-11, table 4 and fig. 6). For quality assurance, one split sample from site V-03 was collected and analyzed, and a replicate sample from site V-06 was collected.

Two size fractions of bottom sediment were analyzed for each of the 13 samples: the fraction less than 0.062 mm (fine) and the fraction less than 2 mm (coarse), which includes the fraction less than 0.062 mm as well. The larger concentration of the two fractions was used for the following interpretation because of the relatively few analyses. The results of the analysis of both size fractions of these samples are shown in table 18. Distribution of concentrations of selected elements in bottom-sediment samples is shown in figure 8.

Concentrations of selected constituents were compared to values in soils of the United States west of the 97th parallel (Shacklette and Boerngen, 1984) and to concentrations measured as part of 19 studies of the NIWQP (Severson and others, 1991) and are shown in table 9.

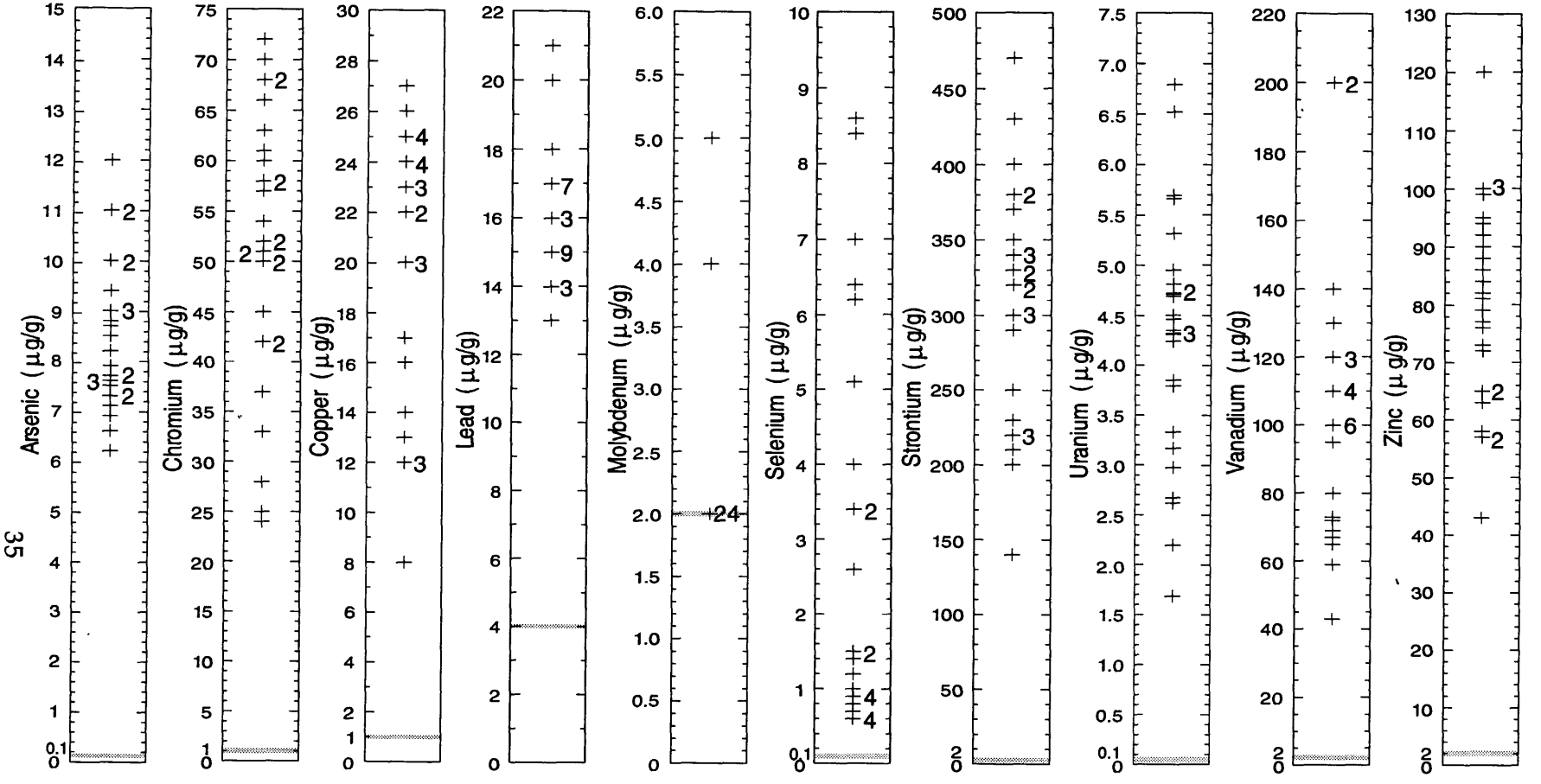


Figure 8.--Concentrations of selected minor trace elements, in micrograms per gram (µg/g), in 26 bottom-sediment samples from 11 sites, Vermejo Irrigation Project Area, New Mexico. Concentrations reported as less than the laboratory reporting limit are plotted as equal to the limit. Minimum laboratory reporting limits are shown in gray. The number of samples with the same value are shown next to the value.

Table 9.--Concentrations of selected trace elements in soils of the Western United States (Shacklette and Boerngen, 1984), bottom sediment from 19 National Irrigation Water-Quality Program (NIWQP) study areas (Severson and others, 1991), and bottom sediment from sites for this study exceeding the expected upper value for Western U.S. soils

[µg/g; micrograms per gram; --, not applicable or unavailable; <, less than]

| Trace element | Concentration range in soils of the Western U.S. (µg/g)[1] | | Concentration range in bottom sediment from 19 NIWQP study areas (µg/g)[2] | | Sites for this study exceeding the expected 95-percent range in soils of the Western U.S. (fig. 6)[1] |
|---|---|---|---|---|---|
| | Expected 95-percent range[3] | Geometric mean | <0.062 millimeter | <2.0 millimeters | |
| Arsenic | 1.2 - 22 | 5.5 | 0.6 - 59 | 0.6 - 120 | -- |
| Chromium | 8.5 - 200 | 41 | 1.0 - 300 | 20 -330 | -- |
| Copper | 4.9 - 90 | 21 | 3.0 - 180 | 5.0 - 520 | -- |
| Lead | 5.2 - 55 | 17 | <4.0 - 250 | <4.0 - 500 | -- |
| Mercury | 0.0085 - 0.25 | 0.046 | <0.02 - 20 | <0.02 - 18 | -- |
| Molybdenum | 0.18 - 4.0 | 0.85 | <2.0 - 54 | <2.0 - 73 | V-05 |
| Nickel | 3.4 - 66 | 15 | <2.0 - 160 | 8.0 - 170 | -- |
| Selenium | 0.039 - 1.4 | 0.23 | 0.1 - 120 | 0.1 - 85 | V-01, V-03, V-05, V-06, V-08, V-09, V-11 |
| Strontium | 43 - 930 | 200 | 69 - 1,400 | 59 - 110,600 | -- |
| Uranium | 1.2 - 5.3 | 2.5 | -- | -- | V-02, V-05, V-08, V-11 |
| Vanadium | 18 - 270 | 70 | 5.0 - 220 | 20 - 310 | -- |
| Zinc | 17 - 180 | 55 | 10 - 860 | 23 - 1,600 | -- |

[1]Shacklette and Boerngen (1984).
[2]Severson and others (1991).
[3]Expected 95-percent range: the concentration range within which 95 percent of the results of analyses are expected to be included.

Concentrations of three trace elements at eight sites exceeded the upper values of the expected 95-percent ranges for Western U.S. soils shown in table 9. These included molybdenum at one site, selenium at seven sites, and uranium at four sites. The Canadian River site upstream from the Vermejo River (V-05) contained 5 µg/g of molybdenum, slightly larger than the upper expected value of 4 µg/g. The values and sites at which selenium exceeded the upper expected value of 1.4 µg/g were 8.6 µg/g at the South Drain Canal site (V-08), 7.0 µg/g at the Vermejo River site upstream from I-25 (V-09), 6.4 µg/g at the North Drain Canal site (V-06), 4.0 µg/g at Half playa (V-11), 3.4 µg/g at the Canadian River site upstream from the Vermejo River (V-05), and 1.5 µg/g at both the Vermejo River upstream from the Vermejo Canal Diversion Dam (V-01) and the Canadian River site upstream from the road crossing upstream from Curtis Creek (V-03). The upper expected value for uranium is 5.3 µg/g and was slightly exceeded at Chicorica Creek at the heading of the Eagle Tail Canal (V-02) (5.31 µg/g), Half playa (V-11) (6.79 µg/g), the Canadian River site upstream from the Vermejo River (V-05) (6.52 and 5.69 µg/g), and the South Drain Canal site (V-08) (5.66 µg/g).

## Concentrations of Trace Elements in Biota

Moisture content was determined for all biological samples to facilitate the conversion between dry weight and wet weight concentrations. Table 20 presents the mean percent moisture content in each specimen and sample type. As expected, mean percent moisture content was highest in submergent aquatic plants (for example algae and elodea) and lowest in animals with calcareous shells (snails), chitinous shells (crayfish), or scales (fish).

Inorganic analytical chemistry results for analyses of biota are shown in table 21. In table 10, the concentrations of trace elements in fish can be compared to 85th-percentile concentrations in NCBP fish samples collected nationwide (Schmitt and Brumbaugh, 1990); in table 11, geometric mean concentrations of trace elements in biota can be compared to various dietary criteria for biota reported in the literature. Elemental bioaccumulation in whole fish is presumed to occur when the geometric mean concentration of any element exceeds the NCBP (Schmitt and Brumbaugh, 1990) 85th-percentile concentration of that element in fish nationwide.

Table 10.--Geometric mean wet weight concentrations of selected elements in fish collected from the Vermejo Project Area, summer 1993, and 85th-percentile concentrations in fish samples collected nationwide by the National Contaminant Biomonitoring Program (NCBP)

[From Schmitt and Brumbaugh (1990). Geometric mean wet weight concentrations were obtained from the geometric mean dry weight concentrations and the mean moisture percentage from fish overall (table 20). --, not applicable; <, less than]

| | Geometric mean concentrations (micrograms per gram wet weight) | | | | | | |
|---|---|---|---|---|---|---|---|
| Element | Vermejo River (V-01 and V-09) | Canadian River (V-05) | Chicorica Creek (V-02) | Seepage sites (V-11 and V-16) | Reservoirs (V-14 and V-15) | Study overall | NCBP 85th percentile |
| Number of samples | 3 | 2 | 2 | 1 | 12 | 20 | -- |
| Arsenic | 0.06 | 0.17 | 0.12 | 1.5 | 0.08 | 0.09 | 0.27 |
| Cadmium | 0.01 | 0.05 | 0.04 | 0.12 | 0.01 | 0.02 | 0.05 |
| Copper | 0.66 | 1.2 | 1.7 | 4.9 | 0.61 | 0.75 | 1.0 |
| Lead | <0.04 | 0.12 | 0.13 | <0.4 | <0.04 | 0.05 | 0.22 |
| Mercury | 0.04 | 0.04 | 0.03 | 0.03 | 0.07 | 0.05 | 0.17 |
| Selenium | 1.37 | 1.4 | 1.8 | 25 | 0.56 | 0.87 | 0.73 |
| Zinc | 25.7 | 33.2 | 33.2 | 171 | 15.3 | 20 | 34.2 |

Table 11.--Geometric mean wet weight concentrations in biota collected during the Vermejo reconnaissance study, summer 1993, and various diagnostic criteria

[µg/g, micrograms per gram; --, not applicable; NCBP, National Contaminant Biomonitoring Program]

| | Geometric mean concentration (µg/g wet weight) | | | | Diagnostic criteria | | |
|---|---|---|---|---|---|---|---|
| Element | Plants | Inverte-brates | Fish[1] | Fish fillets | Maximum concentration (µg/g wet weight) | Source | Reference |
| Arsenic | 0.23 | 0.21 | 0.09 | 0.02 | 26 | Avian diet | Camardese and others, 1990 |
| Boron | 4.9 | 1.2 | 0.3 | 0.2 | 30 | Poultry diet | National Research Council, 1980; Smith and Anders, 1989 |
| Cadmium | 0.03 | 0.09 | 0.01 | 0.004 | 0.1 | Avian diet | Eisler, 1985 |
| Chromium | 0.38 | 0.31 | 0.04 | 0.02 | 5.1 | Avian diet | Eisler, 1986 |
| Copper | 1.10 | 5.23 | 0.75 | 0.21 | 1.0 | Fish residue (NCBP 85th percentile) | Schmitt and Brumbaugh, 1990 |
| Lead | 0.53 | 0.52 | 0.05 | 0.05 | -- | Unknown | Eisler, 1988 |
| Mercury | 0.001 | 0.009 | 0.046 | 0.13 | 0.1<br>1.0 | Avian diet<br>Human health | Eisler, 1987; U.S. Food and Drug Administration, 1994 |
| Nickel | 0.39 | 0.33 | 0.05 | 0.01 | 200 | Avian diet | Cain and Pafford, 1981 |
| Selenium | 0.12 | 1.08 | 0.87 | 0.31 | 1 | Avian diet[2] | Lemly, 1993 |
| Vanadium | 0.80 | 0.67 | 0.10 | 0.03 | 10 | Poultry diet | National Research Council, 1980 |
| Zinc | 2.6 | 14.8 | 20.0 | 4.7 | 50 | Avian diet[2] | Eisler, 1993 |

[1] Includes fish without fillets.
[2] Converted to wet weight by dividing by 3.6 (assumed 72-percent moisture content).

## Aluminum

Aluminum was detected in 98 percent of all plant and animal samples (tables 12 and 21). The largest concentrations were found in plants and the smallest concentrations in fish tissues. Plants collected from Natural playa (V-10) and plants and invertebrates from the Vermejo River contained the largest concentrations of aluminum, though these concentration trends were not reflected in bottom-sediment samples.

Table 12.--Concentrations of aluminum in biota collected during the Vermejo reconnaissance study, summer 1993

[--, not applicable or unavailable]

| Site description or number | Concentration (micrograms per gram dry weight) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Plants | | | Invertebrates | | | Whole fish[1] | | |
| | Number of samples | Geo-metric mean | Range | Number of samples | Geo-metric mean | Range | Number of samples | Geo-metric mean | Range |
| Vermejo River (V-01, V-09) | 2 | 3,680 | 1,720 - 7,870 | 3 | 2,640 | 1,110 - 5,580 | 3 | 376 | 100 - 1,210 |
| V-01 | 1 | 7,870 | --- | 1 | 5,580 | --- | 1 | 439 | --- |
| V-09 | 1 | 1,720 | --- | 2 | 1,820 | 1,110 - 2,970 | 2 | 348 | 100 - 1,210 |
| V-02 | 2 | 1,790 | 880 - 3,630 | 1 | 989 | --- | 2 | 977 | 508 - 1,880 |
| V-05 | 2 | 2,880 | 1,600 - 5,190 | 1 | 732 | --- | 2 | 1,470 | 1,100 - 1,970 |
| V-10 | 2 | 5,060 | 2,080 - 12,300 | 2 | 1,900 | 827 - 4,340 | 0 | --- | --- |
| V-11, V-16 | 5 | 1,390 | 270 - 7,210 | 3 | 1,360 | 525 - 3,800 | 1 | 180 | --- |
| Reservoirs (V-14, V-15) | 5 | 3,810 | 1,580 - 8,380 | 4 | 1,250 | 570 - 3,440 | 12 | 57.9 | 33 - 160 |
| Project overall | 18 | 2,640 | 270 - 12,300 | 14 | 1,500 | 525 - 5,580 | 20 | 149 | 33 - 1,970 |

[1] Includes fish without fillets.

An aluminum-rich diet (greater than 1,500 µg/g wet weight) can result in significant accumulation of aluminum in bird tissues (National Research Council, 1980). Capdevielle and Scanes (1995) reported that an aluminum-rich diet (approximately 5,000 µg/g wet weight) fed to young poultry reduced their feed intake and subsequently reduced growth by as much as 50 percent. Biota from the study area did not contain aluminum concentrations that exceeded these threshold ranges of concern. Birds that feed in this area are not expected to experience aluminum toxicosis.

Aluminum can become toxic to fish when it is dissolved in a low pH aquatic environment (Kane and Rabeni, 1987). As long as alkaline (pH greater than 7) conditions predominate at the sites studied, fish will be unlikely to experience acute aluminum toxicosis. Studies have not been conducted to determine the chronic effects of elevated aluminum in the diet of fish.

## Arsenic

Arsenic was detected in 83 percent of the biological samples (table 21). The highest concentrations were in submergent plants, including algae, and snails. In a marine food chain study, Woolson (1975) reported that filamentous algal species and gastropods were efficient accumulators of arsenic, with little bioaccumulation in other invertebrates. A similar trend was found in this study.

Camardese and others (1990) reported homeostatic effects (elevated hepatic glutathione, ATPase activity, reduced growth) in mallard ducklings fed a 26.4-µg/g wet weight diet (converted to wet weight using 12-percent moisture content as reported). Arsenic concentrations in biota from the study area do not exceed this criterion. The geometric mean arsenic concentration in fish sampled (0.09 µg/g wet weight) throughout the study area is also less than the 85th-percentile arsenic concentration in fish (0.27 µg/g wet weight) sampled nationwide for the NCBP (table 10).

## Barium

Barium was detected in all plant samples but was below the analytical reporting limit in fish tissues (table 21). The largest concentrations were in plants, snails, and odonate samples. None of the sites had consistently elevated barium concentrations in any medium. Data are limited on the toxicity of barium to plants and wildlife species or the effects of excessive barium accumulation (National Research Council, 1980). Given the distribution of barium in the study area, contamination and toxicity are not likely.

## Beryllium

Beryllium was detected in 37 percent of samples collected, and the largest concentrations were found in plants (table 21). Although beryllium in water has been determined to be carcinogenic in humans, no dose-response carcinogenicity in animal studies has been consistently associated with beryllium consumption in the diet (U.S. Environmental Protection Agency, 1980). Health risks of beryllium in the diet of fish or wildlife species cannot yet be reliably estimated.

## Boron

Boron was detected in 50 percent of biota samples collected. The largest concentrations were detected in samples of submergent plants and brine flies, whereas boron was rarely detected in fish tissue. Boron was elevated in plants from the playas (V-10, V-11) and the seepage wetland site (V-16) compared to riverine and reservoir sites, suggesting that evaporative concentration of boron in these environments may be responsible. Adult brine flies, gathered from playas, contained larger geometric mean dry weight concentrations of boron than other invertebrates. The geometric mean boron concentrations in plants (4.9 µg/g wet weight) and invertebrates (1.2 µg/g wet weight) for all sites were substantially less than the dietary concentration (30 µg/g wet weight) that Smith and Anders (1989) reported as causing reduced growth in ducklings (table 11). Therefore, boron concentrations in biota from the study area are not expected to reduce avian growth.

## Cadmium

Eighty-five percent of the biota samples contained detectable cadmium concentrations. Larger concentrations of cadmium were found in invertebrates and submergent plants than in fish (tables 13 and 21). Concentrations of cadmium in plants and invertebrates did not vary substantially among sites. However, all fish collected from riverine sites (V-01, V-02, V-05, and V-09) had significantly greater geometric mean cadmium concentrations (level of significance (p) ≤ 0.008, F distribution (F) = 6.5) than fish from reservoir sites (V-14 and V-15) (table 13). Nonetheless, the geometric mean cadmium concentration for all whole fish sampled for this study (0.02 µg/g wet weight) was less than the NCBP 85th-percentile concentration (0.05 µg/g wet weight) in fish nationwide (table 10). Therefore, piscine bioaccumulation of cadmium does not appear to be of concern in the study area.

Table 13.--Concentrations of cadmium in biota collected during the Vermejo reconnaissance study, summer 1993

[<, less than; --, not applicable or unavailable]

| Site description or number | Concentration (micrograms per gram dry weight) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Plants | | | Invertebrates | | | Whole fish[1] | | |
| | Number of samples | Geo-metric mean | Range | Number of samples | Geo-metric mean | Range | Number of samples | Geo-metric mean | Range |
| Vermejo River (V-01, V-09) | 2 | 0.24 | 0.16 - 0.35 | 3 | 0.89 | 0.26 - 1.8 | 3 | 0.06 | <0.02 - 0.15 |
| V-01 | 1 | 0.35 | --- | 1 | 1.8 | --- | 1 | 0.14 | --- |
| V-09 | 1 | 0.16 | --- | 2 | 0.62 | 0.26 - 1.5 | 2 | 0.04 | <0.02 - 0.15 |
| V-02 | 2 | 0.14 | 0.11 - 0.19 | 1 | 0.27 | --- | 2 | 0.20 | 0.15 - 0.26 |
| V-05 | 2 | 0.29 | 0.2 - 0.43 | 1 | 0.36 | --- | 2 | 0.24 | 0.22 - 0.26 |
| V-10 | 2 | 0.37 | 0.21 - 0.66 | 2 | 0.82 | 0.29 - 2.4 | 0- | --- | --- |
| V-11, V-16 | 5 | 0.22 | 0.089 - 0.81 | 3 | 0.40 | 0.29 - 0.56 | 1 | 0.12 | --- |
| Reservoirs (V-14, V-15) | 5 | 0.25 | 0.16 - 0.44 | 4 | 0.26 | <0.02 - 0.46 | 12 | 0.03 | <0.02 - 0.07 |
| Project overall | 18 | 0.24 | 0.089 - 0.81 | 14 | 0.45 | <0.02 - 2.4 | 20 | 0.07 | <0.02 - 0.26 |

[1] Includes fish without fillets.

Cadmium has been shown to be a carcinogen in animals (Integrated Risk Information System, 1992). Eisler (1985) suggested a maximum dietary cadmium concentration of 0.1 µg/g wet weight for protecting avian health (table 11). Odonate samples from the Vermejo River and brine flies (0.18 and 0.26 µg/g wet weight, respectively) were the only samples of invertebrates or fish that exceeded this threshold. These data suggest that there may be some risks to wildlife whose diets include a high proportion of brine flies, and to a lesser extent, odonates and fish from particular areas in the region.

## Chromium

Chromium was detected in 93 percent of the biota samples (table 21). The largest concentrations were found in plants, snails, and brine flies; the smallest concentrations were in fish tissues. Concentrations did not vary substantially by site. Eisler (1986) suggested a protective dietary concentration of chromium in wildlife of 5.1 µg/g wet weight (table 11). This concentration was not exceeded by any samples collected in the study area. On the basis of the results of this study, the risks of chromium-related effects on wildlife appear to be slight.

## Copper

Copper, an essential nutrient, was detected in all plant and animal samples except one sample of fillets (table 21). The largest concentrations were in crayfish samples because their hemolymph is copper based, similar to iron-based hemoglobin in mammals (Anderson and Brower, 1978). Copper concentrations did not vary substantially among fish species. The geometric mean concentration of copper in whole fish (0.75 µg/g wet weight) from the study area did not exceed the 85th-percentile copper concentration of 1.0 µg/g wet weight in fish sampled nationwide (table 10). Copper toxicity occurs in domestic animals (sheep, poultry, and rabbits) at dietary concentrations above 25 µg/g wet weight (National Research Council, 1980). No samples collected for this study exceeded this threshold of concern.

## Iron

Iron is an essential element to every life form (National Research Council, 1980) and was detected in all biological samples. The largest concentrations were in plants, snails, and brine flies, and the lowest in fish fillets (table 21). Concentrations of iron in biological samples from Natural playa and Half playa were generally larger than in samples from reservoir and river sites. Though iron poisoning is rare, livestock treatment for it consists of ingestion of milk of magnesia ($MgSO_4$) or milk of lime (CaO), which precipitates iron in the gastrointestinal tract, thereby decreasing absorption (National Research Council, 1980). Concentrations of calcium in water collected for this study range from 37 to 490 mg/L and magnesium concentrations range from 12 to 3,300 mg/L. Magnesium concentrations in biota collected for this study range from 1,080 to 39,700 µg/g dry weight. Thus the effect of elevated iron concentrations in the study area is likely of little significance given the abundance of magnesium and calcium compounds in water and in the diet.

## Lead

Lead is a nonessential element to animals and was detected in 58 percent of the samples from the study area. The highest concentrations were in plants, brine flies, snails, and odonate nymphs (table 21). Lead was detected in fish fillets from one site, Lake No. 14 (V-15) (0.7 µg/g dry weight). Although lead was detected in whole fish collected from the Canadian River (V-05) (0.11 µg/g wet weight) and Chicorica Creek (V-02) (0.14 µg/g wet weight), it was below the analytical reporting limit in fish from other sites. All fish samples had lead concentrations below the 85th-percentile concentration (0.22 µg/g wet weight) in fish sampled nationwide (table 10).

Environmental lead is largely airborne, but returns to soil, water, and plants as airborne dust and thus can become a hazard. Elemental lead is more soluble in organic acids associated with decaying plants than in water (National Research Council, 1980). In this study, the geometric mean concentration of lead in plants was 0.53 µg/g wet weight and was similar to concentrations in their likely consumers: in invertebrates at 0.52 µg/g wet weight. Assessing lead-related risks to fish and wildlife is difficult because dietary and body burden criteria have not yet been proposed. However, avian mortality attributable to consumption of spent lead shot has been well documented (Eisler, 1988).

## Magnesium and Manganese

Magnesium and manganese are essential for cellular respiration and proper growth and were detected in all samples. Concentrations of magnesium in biological samples from Natural playa and Half playa were generally larger than samples from reservoir and river sites. Magnesium and manganese concentrations were highest in plants. Brine flies and longnose dace contained elevated concentrations of magnesium compared to other invertebrates and fish from the study area; however, adult brine flies, gathered from playas, contained larger geometric mean dry weight concentrations of magnesium than other invertebrates. Fish fillets had significantly lower manganese concentrations compared to other sample types. The National Research Council (1980) reported that adverse health effects did not occur in domestic animals fed dietary concentrations of manganese of as much as 1,000 μg/g wet weight. The highest manganese concentration observed in a biological sample from this study, in a bulrush collected from site V-09 (1,710 μg/g dry weight), was only about one-third of the National Research Council's criterion, and approximately 50 percent of the biological samples were two orders of magnitude less than this criterion. Toxicosis due to ingestion of plants and invertebrates that are naturally elevated in magnesium was not reported by the National Research Council (1980).

## Mercury

Mercury was detected in 80 percent of the biota samples collected for this study. The median mercury concentrations were lowest in plants and increased in higher trophic levels of the food chain (biomagnification): from plants (<0.006 μg/g dry weight), to invertebrates (0.05 μg/g dry weight), to whole fish (0.26 μg/g dry weight), and to fish fillets (0.77 μg/g dry weight) (fig. 9). The concentrations of mercury in biota from the study area exemplify the process of biomagnification within aquatic ecosystems.

By using data from the present and past studies of Maxwell NWR (Lusk and others, 1991; Custer and others, 1993) a statistically significant association (coefficient of determination ($r^2$) = 0.82, $p \leq 0.001$) exists between mercury concentrations and trophic level. Five compartments were defined, composing a food chain in an aquatic ecosystem of bottom sediment: plants (as producers), invertebrates (as intermediate consumers), fish (as tertiary consumers), and fish fillets (as food available for human consumption--the top of the food chain).

Mercury concentrations in plant and invertebrate samples were not significantly different among sites in the study area. The single sample of fish collected at Half playa (V-11) contained a lower concentration of mercury than fish from other sites (table 14). Although size varied among composite samples of fish, no significant correlation was found between average size and mercury content. The geometric mean mercury concentrations in fish from the study area were below the NCBP 85th-percentile mercury concentration of 0.17 μg/g wet weight for fish sampled nationwide (table 10).

Eisler (1985) recommended a diet incorporating less than 0.1 μg/g wet weight mercury to protect birds from deleterious effects (table 11). Although the mean concentration of mercury in fillet samples (0.14 ± 0.04 μg/g wet weight) approximated the threshold of concern proposed by Eisler, few animals consume fish muscle exclusively. Mercury concentrations in biota collected in this study are below the stated levels of concern. Mercury concentrations in fish fillets were well below the U.S. Food and Drug Administration action level (1.0 μg/g wet weight) for mercury in edible portions of fish (U.S. Food and Drug Administration, 1994). Although mercury bioaccumulation is evident, concentrations in biota collected in this study are below the stated levels of concern.

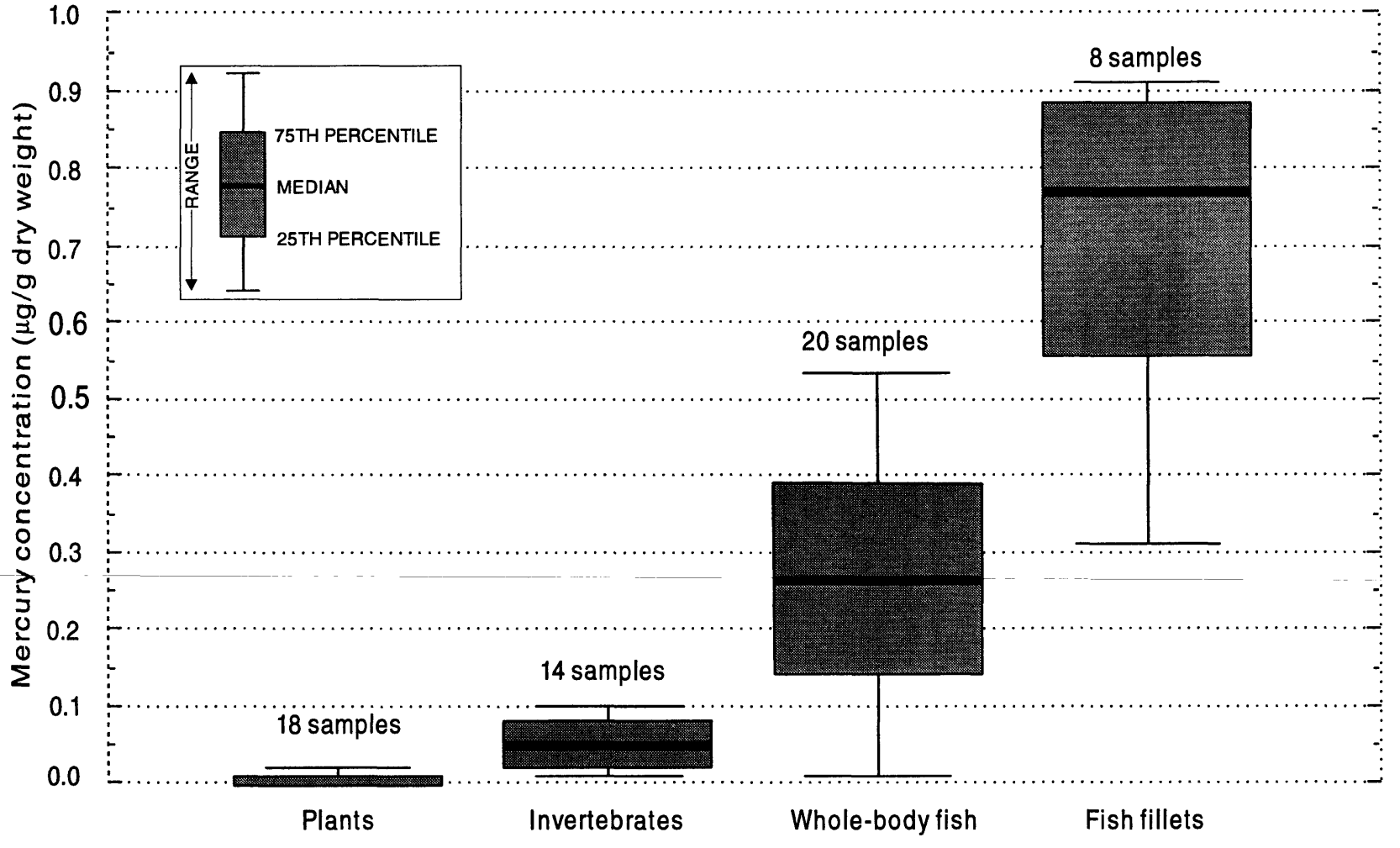


Figure 9.--Biomagnification of mercury, in micrograms per gram (µg/g).

Table 14.--Concentrations of mercury in biota collected during the Vermejo reconnaissance study, summer 1993

[<, less than; --, not applicable or unavailable]

| Site description or number | Concentration (micrograms per gram dry weight) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Plants | | | Invertebrates | | | Whole fish[1] | | |
| | Number of samples | Geo-metric mean | Range | Number of samples | Geo-metric mean | Range | Number of samples | Geo-metric mean | Range |
| Vermejo River (V-01, V-09) | 2 | 0.006 | <0.006 - 0.01 | 3 | 0.072 | 0.048 - 0.1 | 3 | 0.19 | 0.13 - 0.34 |
| V-01 | 1 | 0.01 | --- | 1 | 0.077 | --- | 1 | 0.13 | --- |
| V-09 | 1 | <0.006 | --- | 2 | 0.069 | 0.048 - 0.1 | 2 | 0.22 | 0.15 - 0.34 |
| V-02 | 2 | <0.006 | <0.006 - <0.006 | 1 | 0.065 | --- | 2 | 0.14 | 0.11 - 0.17 |
| V-05 | 2 | <0.006 | <0.006 - <0.006 | 1 | 0.048 | --- | 2 | 0.18 | 0.12 - 0.28 |
| V-10 | 2 | <0.006 | <0.006 - 0.024 | 2 | 0.026 | 0.019 - 0.036 | 0 | --- | --- |
| V-11, V-16 | 5 | <0.006 | <0.006 - <0.006 | 3 | 0.025 | 0.016 - 0.052 | 1 | 0.026 | --- |
| Reservoirs (V-14, V-15) | 5 | 0.01 | <0.006 - 0.025 | 4 | 0.038 | 0.01 - 0.093 | 12 | 0.30 | 0.054 - 0.516 |
| Project overall | 18 | 0.005 | <0.006 - 0.025 | 14 | 0.040 | 0.01 - 0.1 | 20 | 0.22 | 0.026 - 0.516 |

[1] Includes fish without fillets.

## Nickel

Measured concentrations of nickel (table 21) were highest in submergent plants and invertebrates, but below the analytical reporting limit of 0.1 µg/g dry weight in fish fillets. Variations in the concentrations of nickel were not significantly different among sites.

Three studies (National Research Council, 1980; Cain and Pafford, 1981; Eastin and O'Shea, 1981) reported no observable adverse effects to avian species that consume nickel in concentrations less than 200 µg/g wet weight. The geometric mean (wet weight) concentrations of nickel in biota collected within the study area ranged from three to four orders of magnitude below the 200-µg/g wet weight protective criterion for avian diets (table 11).

## Selenium

Selenium is an essential plant and animal micronutrient and was found at or above the analytical reporting limit of 0.2 µg/g dry weight in all but one biological sample collected for this study (bulrushes from Chicorica Creek upstream from the Vermejo Project, site V-02). The geometric mean concentration of selenium was significantly elevated ($p \leq 0.05$) in adult brine flies (33.7 ± 7.6 µg/g dry weight) compared to other invertebrates. If adult brineflies are excluded, there was no significant site-related variation in the concentration of selenium among samples of invertebrates. The geometric mean selenium concentrations were significantly larger ($p \leq 0.05$) in submergent plants from Half playa (V-11) than in similar plants from the reservoir sites (V-14 and V-15).

The single sample of whole fish (plains killifish) collected from the Half playa site (V-11) contained the highest selenium concentration (25 µg/g dry weight) of any fish sample collected for this study (table 15). If this sample (VPV11FS) is omitted, fish from the lentic sites had a significantly smaller ($p \leq 0.0001$, $F = 102.5$) geometric mean concentration of selenium (2.51 µg/g dry weight) than fish from the lotic sites (6.60 µg/g dry weight). Selenium concentrations were smallest in whole fish from the reservoir sites (V-14 and V-15); however, the seepage wetland and Half playa sites (V-16 and V-11, respectively), which are located immediately downstream and receive inflow from a reservoir (V-14), contained either no fish (V-16) or only plains killifish (V-11). Plains killifish is a species that has been documented as tolerant of highly alkaline or saline conditions that can impede other species of fish from successfully establishing a viable population (Pflieger, 1975; Sublette and others, 1990). In addition, the largest geometric mean selenium concentrations measured in other biota samples collected for this study (plants and invertebrates) also were from these locations (V-11 and V-16).

Table 15.--Concentrations of selenium in biota collected during the Vermejo reconnaissance study, summer 1993

[--, not applicable or unavailable]

| Site description or number | Concentration (micrograms per gram dry weight) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Plants | | | Invertebrates | | | Whole fish[1] | | |
| | Number of samples | Geometric mean | Range | Number of samples | Geometric mean | Range | Number of samples | Geometric mean | Range |
| Vermejo River (V-01, V-09) | 2 | 0.40 | 0.2 - 0.78 | 3 | 4.02 | 1.8 - 6.7 | 3 | 6.00 | 4.3 - 7.5 |
| V-01 | 1 | 0.78 | --- | 1 | 6.7 | --- | 1 | 6.7 | --- |
| V-09 | 1 | 0.2 | --- | 2 | 3.12 | 1.8 - 5.4 | 2 | 5.68 | 4.3 - 7.5 |
| V-02 | 2 | 0.2 | <0.2 - 0.4 | 1 | 2 | --- | 2 | 8.08 | 7.1 - 9.2 |
| V-05 | 2 | 0.87 | 0.4 - 1.9 | 1 | 2 | --- | 2 | 6.22 | 5.6 - 6.9 |
| V-10 | 2 | 0.55 | 0.2 - 1.5 | 2 | 8.80 | 3.1 - 25 | 0 | --- | --- |
| V-11, V-16 | 5 | 4.05 | 1.3 - 10 | 3 | 26.6 | 13 - 39 | 1 | 25 | --- |
| Reservoirs (V-14, V-15) | 5 | 0.78 | 0.3 - 1.3 | 4 | 2.12 | 0.99 - 4.3 | 12 | 2.51 | 2 - 3.3 |
| Project overall | 18 | 0.96 | <0.2 - 10 | 14 | 5.08 | 0.99 - 39 | 20 | 3.96 | 2 - 25 |

[1] Includes fish without fillets.

Reservoirs in the study area appear to represent a water-management regime that has lowered selenium concentrations in fish. Thus, populations of piscivorous birds that feed at multiple locations (including the reservoirs) throughout the study area are likely to receive a beneficial buffering effect from dietary exposure to potentially harmful concentrations of selenium in biota of the wetlands.

The geometric mean selenium concentration in fish from river sites (1.5 µg/g wet weight) exceeded the 85th-percentile concentration of 0.73 µg/g wet weight in NCBP fish sampled nationwide (table 10). This elevated concentration of selenium in fish probably represents a naturally occurring condition because the Canadian River and Vermejo River watersheds overlie weathered Cretaceous shales, which have been documented to contain elevated concentrations of selenium (Trelease and Beath, 1949). A comparison of data for whole fish from two riverine sample sites upstream from the influence of irrigation-return flows (V-01 and V-02) and two sites downstream from irrigation-return effluent (V-05 and V-09) indicated no significant ($p = 0.60$, $F = 0.3$) site-related differences in selenium concentrations in whole-fish samples.

Fish can accumulate selenium from water (Bertram and Brooks 1986) and perhaps sediment, but dietary uptake is the predominant route of accumulation (Lemly, 1985; Besser and others, 1993; Coyle and others, 1993). Bertram and Brooks suggested that fish accumulate selenium to concentrations approximating one-third of the concentration of selenium present in their food. Hamilton and others (1990) reported that whole-body concentrations in fish did not show bioaccumulation of selenium to concentrations greater than those in their food. By assuming that fish in the study area consume invertebrates containing selenium concentrations similar to those found in samples examined in this study, the relation suggested by Hamilton and others (1990) would be valid for the combination of all sites, but not for every individual site. The geometric mean selenium concentration for whole fish from all study sites (3.96 µg/g dry weight) is approximately 80 percent of the geometric mean selenium concentration for invertebrates from all study sites (5.08 µg/g dry weight).

The selenium-concentration thresholds for adverse reproductive effects in fish have been studied and related to whole-body concentrations. A number of these studies used cold-water or anadromous fish (Hilton and others, 1980; Hamilton and others, 1986, 1990; Hamilton and Wedemeyer, 1990) and found toxic effects associated with whole-body selenium concentrations ranging from 3 to 9.5 µg/g dry weight. In studies that used warm-water fish (Baumann and May, 1984; Ogle and Knight, 1989; Hermanutz and others, 1992; Besser and others, 1993; Coyle and others, 1993), the lowest reported concentration associated with toxic effects was 5 µg/g dry weight.

On the basis of the previously noted criteria, warm-water fish from the Half playa site (V-11) and from the river sites have a high likelihood of experiencing some adverse reproductive effects. The results of this study seem to corroborate that hypothesis. The seepage wetland (V-16), which had the highest concentrations of selenium in biota, did not appear to contain any fish during the 1993 sampling period. Half playa, which exhibited the second highest concentrations of selenium in surface water, plants, and invertebrates, contained only a single fish species: plains killifish. Pflieger (1975) and Sublette and others (1990) have indicated that plains killifish are tolerant of highly alkaline or saline conditions that can impede other species of fish from successfully establishing a viable population.

Birds that feed primarily on the same types of plants, invertebrates, and fish samples examined in this study appear to be at some risk of dietary exposure to harmful concentrations of selenium. Selenomethionine-spiked fish fed to birds in laboratory studies demonstrated similar uptake kinetics and toxicity compared to diets of wild-raised, selenium-rich fish (Hamilton and Wedemeyer, 1990). Selenomethionine has been reported as the major form of selenium in certain plants (Allaway and others, 1967; Olson and others, 1970), and was embryotoxic and teratogenic in the diet of mallards (*Anas platyrhichus*) (Heinz and others, 1987; Heinz and others, 1988; Hoffman and Heinz, 1988). In the Hoffman and Heinz study, a 6.8-percent frequency of avian embryo deformity was associated with a diet containing selenium concentrations of 8.6 µg/g dry weight (converted using 7-percent moisture content). If the selenium-concentration threshold associated with adverse reproductive effects occurs at dietary selenium concentrations of 8.6 µg/g dry weight, then birds that eat invertebrates predominantly from the playas (V-10, V-11) and seepage wetland (V-16) could have an increased risk of reproductive impairment.

The adverse-effects threshold may actually be at dietary concentrations of selenium less than 8.6 µg/g, as noted in reviews by Lemly and Smith (1987) and Lemly (1993). Their research suggests that selenium concentrations above 3 µg/g dry weight in the diet of any avian species can result in reproductive impairment (teratogenesis, decreased hatching ability). Hoffman and Heinz (1988) reported a 1.4-percent frequency of avian deformity when diets contained selenium concentrations of 4.3 µg/g dry weight (converted using 7-percent moisture content), although this percentage was not significantly different from controls.

Skorupa and others (1990) reported that a relation between the selenium concentrations in the livers of field-collected birds and teratogenic effects usually does not occur at concentrations below 10 µg/g dry weight, but usually does occur at concentrations above 30 µg/g dry weight. Further analysis is required to determine what level of risk selenium concentrations between 10 and 30 µg/g dry weight may pose to wildlife. Based on studies at the refuge, the geometric mean selenium concentration in the livers of eared grebes suggests that they are not likely to experience reproductive impairment, whereas liver and liver/kidney concentrations in puddle ducks and killdeer may be within a loosely defined (at present) threshold range of concern (Lusk and others, 1991; Custer and others, 1993).

Evaluating the risk of teratogenic effects on embryos based on concentrations of selenium in the livers of adult birds may not be a suitable method of assessment. Goede (1993) reported high selenium concentrations (more than 75 µg/g dry weight) in the livers and kidneys of shorebirds that produced eggs with "normal" levels of selenium and no apparent adverse effects. Lemly (1993) stated that selenium causes reproductive failure when excess selenium is biochemically transferred to the egg yolk where it is absorbed during early development and hatching. If this is the case, then the concentration in egg is likely more important than the concentration in adult liver as an indicator of potential teratogenic effects in embryos. In this study, elevated selenium concentrations in liver and kidney samples were assumed to reflect the elevated selenium in the diet of birds in the study area and were not used to predict avian reproductive impairment. However, avian egg data from previous USFWS studies at the refuge are compared (in the following paragraph) to selenium-related thresholds of concern to evaluate the risks of reproductive impairment in birds.

Skorupa and Ohlendorf (1991) gave the following equation relating arithmetic mean egg selenium (MES) and food chain uptake:

$$Log\,(MES) = c + d\,Log\,(D) \qquad (1)$$

where $c$ and $d$ are fitted regression parameters (here -0.142 and 1.17, respectively) and $D$ is the dietary selenium. Inserting avian egg data from previous USFWS studies at the refuge into this equation provides a comparison of predicted dietary concentrations of selenium in avian food items with the actual concentrations measured in probable dietary items. The MES value for a combination of killdeer, American avocet (*Recurvirostra americana*), and eared grebe (*Podiceps nigricollis*) eggs (and embryos) was 5.47 µg/g dry weight (table 2); the equation predicts a dietary selenium concentration of 5.65 µg/g dry weight. The measured geometric mean selenium concentration for invertebrate samples collected from the study area was 5.08 µg/g dry weight (table 15). The use of this equation demonstrates (within the limited scope of the data set) an apparently close relation between avian MES and selenium concentrations in aquatic invertebrates in the study area.

The avian MES of 4.3 ± 1.9 µg/g dry weight for the six samples collected in the study area (Lusk and others, 1991; Custer and others, 1993) is larger than the MES 90th percentile (2.9 µg/g dry weight) for birds sampled nationwide from uncontaminated nonmarine wetlands (mostly in the Western United States) as reported by Skorupa and Ohlendorf (1991). However, the avian MES for the study area is less than the approximate lower threshold of 8 µg/g dry weight (less than the 95th percentile) associated with embryo toxicity in black-necked stilts and American avocets in the Tulare Basin, California (Skorupa and Ohlendorf, 1991). Therefore, although elevated in egg samples, selenium was below the threshold concentration associated with embryo toxicity in wild shorebirds in California.

Extrapolating a level of risk posed by the measured concentrations of selenium in bird eggs from the study area needs to be done cautiously because (Heinz, 1993) the MES can vary according to the egg's sequence in the clutch (the first egg has a higher concentration than the second egg, and so forth). Because the clutch sequence of the eggs used in this evaluation is unknown, the observed MES values might be biased high or low due to a propensity of either "early" or "late-in-the-clutch" eggs collected by USFWS investigators. Nevertheless, evaluation of the data collected in this and previous investigations in the study area indicates some risk (probably at low frequency and severity) of selenium-related avian reproductive impairment occurring within the study area. However, selenium-related reductions in the fecundity of wild birds using the refuge might prove difficult to distinguish from, or be masked by the natural background occurrence of, avian reproductive anomalies.

Concentrations of selenium in biota from the seepage wetland site (V-16) and from the Half playa site (V-11) are approaching thresholds of concern. The seepage wetland site may rank equally with the Half playa site as an area of concern because the seepage wetland (1) had no water or bottom-sediment samples collected, (2) had the highest measured selenium concentrations (39 µg/g dry weight) in invertebrates, (3) had very high selenium concentrations in plant samples, and (4) had no fish at the site. Both sites are very close together; the seepage wetland is located slightly upgradient from Half playa and is hydrologically connected to Half playa through a slough-like drainage channel.

## Strontium

Although strontium was detected in all samples (table 21) it has not been shown to be an essential element for either plants or animals (National Research Council, 1980). Strontium concentrations were highest in samples of snails and crayfish (possibly because of substitution of strontium for calcium in calcareous shells and exoskeletons), and no site-related differences were apparent in the concentrations of strontium in biota.

Naturally occurring strontium is chemically and physically similar to calcium and, in its absence, will metabolically substitute for calcium in animal skeletal systems. If calcium concentrations in food in the Vermejo study area are adequate, this should not be a problem. No strontium concentrations in biota samples from the study area approached a dietary level of 2,000 µg/g wet weight, reported to be the concentration at which strontium is toxic to poultry (National Research Council, 1980).

## Vanadium

Vanadium was detected in 72 percent of the biota samples. The highest concentrations were in plants, snails, and brine flies (table 21). There were no apparent site-related differences in the concentrations of vanadium in biota. Vanadium concentrations in biota ranged from less than 0.3 to 23 µg/g dry weight.

## Zinc

Zinc is an essential mineral for all plants and animals and was detected in all biota samples (table 21). The largest concentrations were in fish and invertebrates; the smallest were in plants (tables 16 and 21). The geometric mean concentration of zinc (20 µg/g wet weight) in whole fish from the study area did not exceed the NCBP 85th-percentile zinc concentration (34.2 µg/g wet weight) in fish sampled nationwide (table 10). Zinc concentrations in biota samples from the study area are below the dietary concentration (less than 178 µg/g dry weight) associated with marginal sublethal effects in birds reported by Eisler (1993).

Table 16.--Concentrations of zinc in biota collected during the Vermejo reconnaissance study, summer 1993

[--, not applicable or unavailable]

| Site description or number | Concentration (micrograms per gram dry weight) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Plants | | | Invertebrates | | | Whole fish[1] | | |
| | Number of samples | Geo-metric mean | Range | Number of samples | Geo-metric mean | Range | Number of samples | Geo-metric mean | Range |
| Vermejo River (V-01, V-09) | 2 | 20.8 | 13 - 33.3 | 3 | 115 | 67.7 - 185 | 3 | 113 | 76 - 171 |
| V-01 | 1 | 33.3 | --- | 1 | 122 | --- | 1 | 110 | --- |
| V-09 | 1 | 13 | --- | 2 | 112 | 67.7 - 185 | 2 | 114 | 76 - 171 |
| V-02 | 2 | 22.3 | 16 - 31.1 | 1 | 69.4 | --- | 2 | 145 | 133 - 158 |
| V-05 | 2 | 25.6 | 20.1 - 32.7 | 1 | 59.2 | --- | 2 | 149 | 136 - 164 |
| V-10 | 2 | 32.7 | 27 - 39.6 | 2 | 72.7 | 69.5 - 76.2 | 0 | --- | --- |
| V-11, V-16 | 5 | 15 | 11 - 19.4 | 3 | 84.6 | 67.4 - 120 | 1 | 171 | --- |
| Reservoirs (V-14, V-15) | 5 | 23 | 10 - 41.5 | 4 | 42.4 | 21 - 71.9 | 12 | 70.1 | 46.5 - 92.7 |
| Project overall | 18 | 21.2 | 10 - 41.5 | 14 | 69.8 | 21 -185 | 20 | 91.3 | 46.5 - 171 |

[1] Includes fish without fillets.

## Correlation of Trace Elements among Water, Bottom Sediment, and Biota

The only element with elevated concentrations in more than one medium was selenium, which was detected in all but five water samples from four sites, all bottom-sediment samples, and all but one biota sample. Half playa (V-11) was the site where the largest observed concentrations of selenium were found in three media: water, sediment and fish tissue. This lends credence to the hypothesis that ground-water leaching and evaporation are concentrating selenium in the playa.

Samples of aquatic plants contained larger concentrations of aluminum, arsenic, beryllium, boron, chromium, iron, lead, magnesium, manganese, nickel, and vanadium than samples of invertebrates and fish. Several of these elements (aluminum, beryllium, chromium, iron, lead, and vanadium) were strongly correlated ($r^2 \geq 0.90$, $p < 0.01$) with each other in plant tissues. These correlations suggest that the elevated concentrations of these elements in plant tissues parallel the naturally elevated concentrations of these elements in soils of the High Plains environment, or possibly that sediment may have contaminated some of these samples.

## Concentrations of Pesticides in Water

No water samples were collected for pesticide analysis because of the limited use of pesticides in the Vermejo Project Area (Jerry French, U.S. Fish and Wildlife Service, oral commun., 1993). Instead, bottom-sediment samples were collected and analyzed as an indicator of pesticide persistence in the environment.

## Concentrations of Pesticides in Bottom Sediment

Bottom-sediment samples from two sites downstream from the irrigation project were collected and analyzed for 23 compounds: selected organophosphate and organochlorine pesticides, selected pesticide metabolites, polychlorinated biphenyls (PCB's), and polychlorinated napthalenes (PCN's) (table 22). Four detections at concentrations equal to or larger than the analytical reporting limit were found at the two sites: at the Vermejo River upstream from I-25 (site V-09), DDD was found at 0.2 µg/kg and DDE at 0.1 µg/kg; and at the Canadian River upstream from the Vermejo River (site V-05), chlordane was detected at 1.0 µg/kg and DDE at 0.1 µg/kg. DDD is an insecticide and along with DDE is a degradation product of DDT, which has been restricted for most uses in the United States since 1972 (Meister, 1995). Chlordane has been restricted for farm use in the United States since 1974 (Meister, 1995). The only applicable regulatory standard for pesticide residues in sediment is for chlordane. The USEPA tentative sediment-quality criterion for chlordane in freshwater sediment is 309 µg/kg, and the 95-percent confidence limits are 35.5 to 2,760 µg/kg (Ware, 1994).

## Concentrations of Pesticides in Biota

A total of 28 whole fish and fillet tissues were scanned for a suite of organochlorine compounds; none were detected at concentrations exceeding the analytical reporting limit (less than 0.01 µg/g wet weight). Whole fish did not contain organochlorine pesticide (DDE) concentrations above those reported to threaten fish-eating wildlife (3 µg/g wet weight; Lincer, 1975; Mendenhall and others, 1983), and these pesticide concentrations are below the geometric mean (0.2 µg/g wet weight) for NCBP fish sampled nationwide (Schmitt and others, 1985). Therefore, birds that feed in the study area are unlikely to experience any reproductive impairment related to elevated concentrations of organochlorine compounds in their prey.

# SUMMARY AND CONCLUSIONS

A reconnaissance investigation was conducted in 1993 to assess the effects of the Vermejo Irrigation Project on water quality in the area of the project, including the Maxwell NWR, though no irrigation-return flows reach the refuge. Analysis of water, bottom-sediment, and biota samples collected from 16 sites in and around the Vermejo Irrigation Project prior to, during the latter part of, and after the 1993 irrigation season (April, August-September, and November, respectively) indicated that concentrations of inorganic analytes were generally within established guidelines or expected concentrations for water, sediment, and biota. No water analyses exceeded USEPA drinking-water standards for the inorganic constituents of concern.

The State of New Mexico standard for boron in irrigation water (750 µg/L) was exceeded at three sites (five samples), though none exceeded the livestock water standard of 5,000 µg/L. These sites were Half playa (V-11), North Drain Canal (V-06), and South Drain Canal (V-08). Half playa is probably subject to evaporative concentration of nonirrigation waters, and the canals probably are affected by irrigation drainage.

Selenium exceeded the State of New Mexico wildlife water standard and fisheries water chronic standard (2.0 µg/L) in at least eight samples from five sites: the well north of Half playa (V-12), Half playa (V-11), the North Drain Canal (V-06), the South Drain Canal (V-08), and the well northwest of the project area (V-13). Both the North Drain Canal and the South Drain Canal probably are affected by irrigation drainage. The less stringent acute standard of 20 µg/L was exceeded in three samples from two sites: the well north of Half playa, and Half playa.

Bottom-sediment samples were collected and analyzed for trace elements and compared to concentrations of trace elements in soils of the Western United States. Concentrations of three trace elements at eight sites exceeded the upper values of the expected 95-percent ranges for Western U.S. soils. These included molybdenum at one site, selenium at seven sites, and uranium at four sites.

Samples of aquatic plants contained larger concentrations of aluminum, arsenic, beryllium, boron, chromium, iron, lead, magnesium, manganese, nickel, and vanadium than samples of invertebrates and fish. Several of these elements (aluminum, beryllium, chromium, iron, lead, and vanadium) were strongly correlated with each other in plant tissues. These correlations suggest that the elevated concentrations of these elements in plant tissues parallel the naturally elevated concentrations of these elements in soils of the High Plains environment, or possibly that sediment may have contaminated some of these samples.

Several types of biota collected during this study contained elevated concentrations of some elements. Adult brine flies gathered from playas contained high concentrations of boron, cadmium, chromium, iron, lead, magnesium, and selenium. Snails contained high concentrations of arsenic, barium, chromium, iron, lead, and strontium. Strontium and copper were highest in crayfish samples. Mercury concentrations were highest in fish-fillet samples.

Selenium concentrations in eggs from birds nesting in the study area (though in areas not subject to irrigation-return flow) are elevated compared with those listed in a national data base, but do not exceed the threshold value of approximately 8 µg/g dry weight that has been correlated with risks for successful avian reproduction (reduced hatching success).

The relatively high concentrations of selenium in whole fish from some aquatic habitats in the study area are probably indicative of exposure to elevated selenium concentrations in the aquatic ecosystems. This study does not project selenium-related risks for piscine reproductive impairment because fish eggs were not collected for analysis.

Natural playa (V-10), an endemic wetland, generally had elevated concentrations of aluminum, boron, iron, magnesium, selenium, and vanadium compared to reservoir and river sites. The Half playa site (V-11), a playa that now receives additional water through the seepage wetland through canals, also had elevated levels of boron, iron, magnesium, selenium, and strontium. Selenium concentrations were lowest in biota from the reservoir sites, yet the seepage wetland directly downstream and receiving water from Lake No. 14 (V-15) had elevated concentrations of selenium in biota.

The data set is insufficient to determine conclusively whether biota from aquatic habitats influenced by irrigation drainage are significantly different from aquatic biota at control sites in habitats created by irrigation-supply water. However, concentrations of arsenic, cadmium, lead, mercury, and zinc in fish tissue collected at the Canadian River upstream from the Vermejo River (V-05) were below the NCBP 85th-percentile concentrations in fish nationwide.

The data suggest that birds and possibly other wildlife that feed heavily upon invertebrates (particularly brine flies) and other biota from the seepage wetland (V-16) and Half playa (V-11) may experience some dietary-related risks of reproductive impairment. However, because these areas are influenced solely by irrigation-supply water (and natural precipitation), irrigation-return flows are unrelated to any selenium-related risks to birds using the refuge.

Bottom-sediment samples from two sites downstream from the irrigation project were collected and analyzed for 23 organic compounds. Four detections at concentrations equal to or larger than analytical reporting limits were found at the two sites: at the Vermejo River upstream from I-25 (site V-09) DDD was found at 0.2 µg/kg and DDE at 0.1 µg/kg, and at the Canadian River upstream from the Vermejo River (site V-05) chlordane was detected at 1.0 µg/kg and DDE at 0.1 µg/kg.

A total of 28 whole fish and fillet tissues were scanned for a suite of organochlorine compounds; none were detected at concentrations exceeding the analytical reporting limit (less than 0.01 µg/g wet weight). Biota collected from the study area do not contain elevated concentrations of organochlorine compounds; therefore, biota are not likely to experience any adverse biological effects associated with these compounds.

Concentrations of inorganic analytes were generally within established guidelines or expected concentrations for water, sediment, and biota. Irrigation-return flows were found to be unrelated to adverse effects in biota.

## REFERENCES CITED


Allaway, W.H., Cary, E.E., and Ehlig, C.F., 1967, The cycling of low levels of selenium in soils, plants, and animals, *in* Muth, O.H., ed., Selenium in biomedicine: Westport, Conn., Avi Publishing Co., p. 273-296.

Anderson, R.V., and Brower, J.E., 1978, Patterns of trace metal accumulation in crayfish populations: Bulletin of Environmental Contamination and Toxicology, v. 20, p. 120-127.

Anderson, G.W., Hilley, T.E., Martin, P.G., Neal, C.R., and Gomez, R.S., 1982, Soil survey of Colfax County, New Mexico: U.S. Soil Conservation Service, U.S. Forest Service, and New Mexico Agricultural Experimental Station, 190 p.

Baumann, P.C., and May, T.C., 1984, Selenium residues in fish from inland waters of the United States, workshop proceedings--The effects of trace elements on aquatic ecosystems: Electric Power Research Institute Technical Report EA-3329, p. 7-1 to 7-16.

Beath, O.A., 1964, The story of selenium in Wyoming: Laramie, University of Wyoming, Agriculture Research Chemistry, 35 p.

Bertram, P.E., and Brooks, A.S., 1986, Kinetics of accumulation of selenium from food and water by fathead minnows: Water Research, v. 20, p. 877-884.

Besser, J.M., Canfield, T.J., and La Point, T.W., 1993, Bioaccumulation of organic and inorganic selenium in a laboratory food chain: Environmental Toxicology and Chemistry, v. 12, p. 57-72.

Blanchard, P.J., Roy, R.R., and O'Brien, T.F., 1993, Reconnaissance investigation of water quality, bottom sediment, and biota associated with irrigation drainage in the San Juan River area, San Juan County, northwestern New Mexico, 1990-91: U.S. Geological Survey Water-Resources Investigations Report 93-4065, 141 p.

Cain, B.W., and Pafford, E.A., 1981, Effects of dietary nickel on survival and growth of mallard ducklings: Archives of Environmental Contamination and Toxicology, v. 10, p. 737-745.

Camardese, M.B., Hoffman, D.J., LeCaptain, L.J., and Pendleton, G.W., 1990, Effects of arsenate on growth and physiology in mallard ducklings: Environmental Toxicology and Chemistry, v. 9, p. 785-795.

Capdevielle, M.C., and Scanes, C.G., 1995, Effect of dietary acid or aluminum on growth and growth-related hormones in young chickens: Toxicology and Applied Pharmacology, v. 133, p. 164-171.

Cowardin, L., Carter, V., Golet, F., and LaRoe, E., 1979, Classification of wetlands and deepwater habitats of the United States: U.S. Fish and Wildlife Service, FWS/OBS Publication 79-31, 131 p.

Coyle, J.J., Buckler, D.R., Ingersoll, C.G., Fairchild, J.F., and May, T.W., 1993, Effect of dietary selenium on the reproductive success of bluegill sunfish (*Lepomis macrochirus*): Environmental Toxicology and Chemistry, v. 12, p. 551-565.

Custer, M., Roy, R., Wilson, M., Adornato, T., and Winckel, J., 1993, An investigation of selenium, mercury, and lead concentrations in sediment and biota from Maxwell National Wildlife Refuge, Colfax County, New Mexico: Albuquerque, N. Mex., U.S. Fish and Wildlife Service Region 2, Environmental Contaminants Program, 29 p.

Dane, C.H., and Bachman, G.O., 1965, Geologic map of New Mexico: U.S. Geological Survey, 2 sheets, scale 1:500,000.

## REFERENCES CITED--Continued


Department of the Interior, 1990, Plan for irrigation water quality activities--Protocol for conducting reconnaissance investigations: revised January 26, 1990, variously paged.

Eastin, W.C., and O'Shea, T.J., 1981, Effects of dietary nickel on mallards: Journal of Toxicology and Environmental Health, v. 7, p. 883-892.

Edwards, T.K., and Glysson, G.D., 1988, Field methods for measurement of fluvial sediment: U.S. Geological Survey Open-File Report 86-531, 118 p.

Eisler, R., 1985, Cadmium hazards to fish, wildlife, and invertebrates--A synoptic review: U.S. Fish and Wildlife Service Biological Report 85 (1.2), 46 p.

_____1986, Chromium hazards to fish, wildlife, and invertebrates--A synoptic review: U.S. Fish and Wildlife Service Biological Report 85 (1.6), 60 p.

_____1987, Mercury hazards to fish, wildlife, and invertebrates--A synoptic review: U.S. Fish and Wildlife Service Biological Report 85 (1.10), 90 p.

_____1988, Lead hazards to fish, wildlife, and invertebrates--A synoptic review: U.S. Fish and Wildlife Service Biological Report 85 (1.14), 134 p.

_____1993, Zinc hazards to fish, wildlife, and invertebrates--A synoptic review: U.S. Fish and Wildlife Service Biological Report 10, 106 p.

Fenneman, N.M., 1931, Physiography of the western United States: New York, McGraw-Hill, 534 p.

Fishman, M.J., and Friedman, L.C., eds., 1989, Methods for determination of inorganic substances in water and fluvial sediments (3d ed.): U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A1, 545 p.

Goede, A.A., 1993, Selenium in eggs and parental blood of a Dutch marine wader: Archives of Environmental Contamination and Toxicology, v. 25, p. 79-84.

Griggs, R.L., 1948, Geology and ground-water resources of the eastern part of Colfax County, New Mexico: Socorro, New Mexico Bureau of Mines and Mineral Resources Ground-Water Report 1, 180 p.

Hamilton, S.J., Buhl, K.J., Faerber, N.L., Wedemeyer, R.H., and Bullard, F.A., 1990, Toxicity of organic selenium in the diet to chinook salmon: Environmental and Toxicological Chemistry, v. 9, p. 347-358.

Hamilton, S.J., Palmisano, A.N., Wedemeyer, R.H., and Yasutake, W.T., 1986, Impacts of selenium on early life stages and smoltification of fall chinook salmon: Transactions of the 51st North American Wildlife and Natural Resources Conference, v. 51, p. 343-356.

Hamilton, S.J., and Wedemeyer, R.H., 1990, Concentrations of boron, molybdenum, and selenium in chinook salmon: Transactions of the American Fisheries Society, v. 119, p. 500-510.

Harms, T.F., Stewart, K.C., Briggs, P.H., Hageman, P.L., and Papp, C.S.E., 1990, Chemical results for bottom material for Department of the Interior irrigation drainage task group studies, 1988-89: U.S. Geological Survey Open-File Report 90-50, 9 p.

Heinz, G.H., 1993, Selenium accumulation and loss in mallard eggs: Environmental Toxicology and Chemistry, v. 12, p. 775-778.

## REFERENCES CITED--Continued


Heinz, G.H., Hoffman, D.J., and Gold, L.G., 1988, Impaired reproduction of mallards fed an organic form of selenium: Journal of Wildlife Management, v. 53, no. 2, p. 418-428.

Heinz, G.H., Hoffman, D.J., Krynitsky, A.J., and Weller, D.M.G., 1987, Reproduction in mallards fed selenium: Environmental and Toxicological Chemistry, v. 6, p. 423-433.

Heinz, G.H., Pendleton, G.W., Krynitsky, A.J., and Gold, L.G., 1990, Selenium accumulation and elimination in mallards: Archives of Environmental Contamination and Toxicology, v. 19, p. 374-379.

Hermanutz, R.O., Allen, K.N., Roush, T.H., and Hedtke, S.F., 1992, Effects of elevated selenium concentrations on bluegills (*Lepomis macrochirus*) in outdoor experimental streams: Environmental and Toxicological Chemistry, v. 11, p. 217-224.

Herring, J.R., 1991, Selenium geochemistry--A conspectus, *in* Proceedings of the 1990 Billings Land Reclamation Symposium on Selenium in Arid and Semiarid Environments, Western United States: U.S. Geological Survey Circular 1064, p. 7-24.

Hilton, J.W., Hodson, P.V., and Sliniger, S.J., 1980, The requirement and toxicity of selenium in rainbow trout (*Salmo gairdneri*): The Journal of Nutrition, v. 110, p. 2527-2535.

Hoffman, D.J., and Heinz, G.H., 1988, Embryotoxic and teratogenic effects of selenium in the diet of mallards: Journal of Toxicology and Environmental Health, v. 24, p. 477-490.

Integrated Risk Information System (IRIS), 1992, Search conducted on line through Toxnet in 1992. Data base developed and maintained by U.S. Environmental Protection Agency.

Kane, D.A., and Rabeni, C.F., 1987, Effects of aluminum and pH on the early life stages of smallmouth bass (*Micropterus dolomieui*): Water Resources, v. 21, p. 633-639.

Kunkel, K.E., 1984, Temperature and precipitation summaries for selected New Mexico locations: New Mexico Department of Agriculture, Office of State Climatologist, 185 p.

Lakin, H.W., 1972, Selenium accumulation in soils and its absorption by plants and animals: Geological Society of America Bulletin, v. 83, no. 1, p. 181-190.

Lemly, A.D., 1985, Ecological basis for regulating aquatic emissions from the power industry--The case with selenium: Regulatory Toxicology and Pharmacology, v. 5, p. 465-486.

_____1993, Guidelines for evaluating selenium data from aquatic monitoring and assessment studies: Environmental Monitoring and Assessment, v. 28, p. 83-100.

Lemly, A.D., and Smith, G.J., 1987, Aquatic cycling of selenium--Implications for fish and wildlife: U.S. Fish and Wildlife Service Leaflet 12, 10 p.

Lincer, J.L., 1975, DDE-induced eggshell thinning in the American kestrel--A comparison of the field situation and laboratory results: Journal of Applied Ecology, v. 12, p. 781-793.

Lusk, J.D., O'Brien, T.F., and Roy, R.R., 1991, Contaminants investigation of the Maxwell National Wildlife Refuge, New Mexico, 1989: Albuquerque, N. Mex., U.S. Fish and Wildlife Service, Ecological Services Contaminants Report, 33 p.

Meister, R.T., ed., 1995, Farm chemicals handbook, volume 81: Willoughby, Ohio, Meister Publishing, variously paged.

Mendenhall, V.M., Klaas, E.E., and McLane, M.A.R., 1983, Breeding success of barn owls (*Tyto alba*) fed low levels of DDE and dieldrin: Archives of Environmental Contamination and Toxicology, v. 12, p. 235-240.

## REFERENCES CITED--Continued

National Research Council, Subcommittee on Mineral Toxicity in Animals, 1980, Mineral tolerance of domestic animals: Washington, D.C., National Academy Press, 577 p.

New Mexico Water Quality Control Commission, 1995, Standards for interstate and intrastate streams: New Mexico Administrative Code 20 NMAC 6.1, p. 44-50.

Ogle, R.S., and Knight, A.W., 1989, Effects of elevated foodborne selenium on growth and reproduction of the fathead minnow (*Pimephales promelas*): Archives of Environmental Contamination and Toxicology, v. 18, p. 795-803.

Olson, O.E., Novacek, E.J., Whitehead, E.I., and Palmer, I.S., 1970, Investigations on selenium in wheat: Phytochemistry, v. 9, p. 1181-1188.

Pflieger, W.L., 1975, The Fishes of Missouri: Jefferson City, Missouri Department of Conservation, 343 p.

Pillmore, C.L., 1976, Commercial coal beds of the Raton coal field, Colfax County, New Mexico, *in* Guidebook of Vermejo Park, northeastern New Mexico: New Mexico Geological Society, 27th Field Conference, p. 227.

Schmitt, C.J., and Brumbaugh, W.G., 1990, National Contaminant Biomonitoring Program--Concentrations of arsenic, cadmium, copper, lead, mercury, selenium, and zinc in U.S. freshwater fish, 1976-84: Archives of Environmental Contaminant Toxicology, v. 19, p. 731-747.

Schmitt, C.J., Zajicek, J.L., and Ribick, M.A., 1985, National Pesticide Monitoring Program--Residues of organochlorine chemicals in freshwater fish, 1980-1981: Archives of Environmental Contamination and Toxicology, v. 14, p. 225-260.

Severson, R.C., Stewart, K.C., and Harms, T.F., 1991, Partitioning of elements between two size sediment fractions in samples from nineteen areas of the Western United States: U.S. Geological Survey Open-File Report 91-381, 18 p.

Severson, R.C., Wilson, S.A., and McNeal, J.M., 1988, Analysis of bottom material collected at nine areas in the Western United States for the DOI irrigation drainage task group: U.S. Geological Survey Open-File Report 87-490, 24 p.

Shacklette, H.T., and Boerngen, J.G., 1984, Element concentrations in soils and other surficial materials of the conterminous United States: U.S. Geological Survey Professional Paper 1270, 10 p.

Skorupa, J.P., and Ohlendorf, H.M., 1991, Contaminants in drainwater and avian risk thresholds, *in* Dinar, Ariel, and Zilberman, D., eds., The economics and management of water and drainage in agriculture: Kluwer Academic Publishers, p. 345-368.

Skorupa, J.P., Ohlendorf, H.M., and Hothem, R.L., 1990, Selenium bioaccumulation and biological risk--Some interpretive guidelines for waterbirds derived from field sampling: Conference of the Western Section and Northwest Section of the Wildlife Society, February 22-25, 1990, Reno, Nev.

Smith, G.J., and Anders, V.P., 1989, Toxic effects of boron on mallard reproduction: Environmental and Toxicological Chemistry, v. 8, p. 943-950.

SPSS, Inc., 1993, Statistical package for the social sciences for Windows, release 6.0: Chicago, Ill.

## REFERENCES CITED--Concluded


Stewart, K.C., Fey, D.L., Hageman, P.L., Kennedy, K.R., Love, A.H., McGregor, R.E., Papp, C.S.E., Peacock, T.R., Sharkey, J.D., Vaughn, R.B., and Welsch, E.P., 1992, Results of chemical analysis for sediments from Department of the Interior National Irrigation Water Quality Program studies, 1988-90: U.S. Geological Survey Open-File Report 92-443, 9 p.

Sublette, J.E., Hatch, M.D., and Sublette, M., 1990, The Fishes of New Mexico: Albuquerque, University of New Mexico Press, 393 p.

Trelease, S.F., and Beath, O.A., 1949, Selenium--Its geological occurrence and its biological effects in relation to botany, chemistry, agriculture, nutrition, and medicine: New York, published by the authors, 290 p.

U.S. Department of Commerce, 1993, Climatological data annual summary, New Mexico, 1993: National Oceanic and Atmospheric Administration, v. 97, no. 13.

U.S. Environmental Protection Agency, 1980, Ambient water-quality criteria for beryllium: Office of Water, Criteria and Standards Division, U.S. Environmental Protection Agency Report 440/5-80-024, 59 p.

_____1987, Ambient water-quality criteria for selenium--1987: U.S. Environmental Protection Agency Report 440/5-87-006, 121 p.

_____1994, National primary drinking water standards: U.S. Environmental Protection Agency, Office of Water, EPA 810-F-94-001A, 4 p.

U.S. Fish and Wildlife Service, 1990, Patuxent Analytical Control Facility reference manual: U.S. Fish and Wildlife Service, Laurel, Md., 120 p.

U.S. Food and Drug Administration, 1994, Guidance documents for chemicals in fish and shellfish: U.S. Department of Agriculture Center for Food Safety and Applied Nutrition, data base search.

U.S. Geological Survey, 1977-94, Water resources data, New Mexico, water years 1976-93: U.S. Geological Survey Water-Data Reports NM-76-1 to NM-93-1 (published annually).

_____1982, Chemical and physical quality of water and sediment, *in* National handbook of recommended methods for water-data acquisition: Office of Water Data Coordination, Reston, Va., chap. 5, 194 p.

Vines, R.A., 1960, Trees, shrubs, and woody vines of the southwest: Austin, University of Texas Press, 1104 p.

Ware, G.W., ed., 1994, Reviews of environmental contamination and toxicology, volume 140--Continuation of residue reviews: New York, Springer-Verlag, 221 p.

Wershaw, R.L., Fishman, M.J., Grabbe, R.R., and Lowe, L.E., eds., 1987, Methods for determination of organic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A3, 80 p.

Wilson, B., 1992, Water use in New Mexico counties and river basins, and irrigated acreage in 1990: New Mexico State Engineer Office Technical Report 47, 141 p.

Woolson, E.A., 1975, Arsenical pesticides: American Chemical Society Serials, v. 7, p. 1-176.

# SUPPLEMENTAL DATA

Table 17.--Concentrations of selected constituents in water samples collected during the Vermejo reconnaissance study, spring and late summer, 1993

[Site numbers in parentheses designate wells; rep, replicate sample; splt, split sample; --, parameter not measured; $ft^3/s$, cubic feet per second; µS/cm, microsiemens per centimeter at 25 °C (degrees Celsius); mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than]

| Site number (fig. 6) | Station number | Date | Discharge, instantaneous ($ft^3/s$) | Specific conductance, field (µS/cm) | Specific conductance, lab (µS/cm) | pH, field (standard units) |
|---|---|---|---|---|---|---|
| V-01 | 363634104451110 | 04-07-93 | 29 | 479 | 504 | 8.0 |
| V-01 | | 09-07-93 | 17 | 462 | 466 | 8.0 |
| V-01-rep | | 09-07-93 | -- | -- | 466 | -- |
| V-02 | 364328104263910 | 04-06-93 | 25 | 429 | 453 | 7.7 |
| V-02 | | 09-08-93 | 12 | 1,650 | 1,670 | 8.0 |
| V-03 | 363903104291510 | 04-06-93 | 400 (estimate) | 457 | 527 | 7.7 |
| V-03 | | 08-30-93 | 22 | 648 | 645 | 8.1 |
| V-03-rep | | 08-30-93 | -- | -- | 648 | -- |
| V-04 | 363203104315210 | 04-05-93 | 140 | 627 | 659 | 8.0 |
| V-04 | | 08-30-93 | 29 | 905 | 936 | 8.1 |
| V-04-splt | | 08-30-93 | -- | -- | 895 | -- |
| V-04-splt | | 08-30-93 | -- | -- | 897 | -- |
| V-05 | 362912104323710 | 04-05-93 | 160 | 690 | 718 | 8.0 |
| V-05 | | 09-07-93 | 15 | 1,500 | 1,490 | 8.1 |
| V-06 | 363452104323010 | 04-07-93 | -- | 5,810 | 6,070 | 8.1 |
| V-06 | | 08-31-93 | -- | 6,140 | 6,320 | 7.8 |
| V-07 | 363252104323010 | 04-07-93 | -- | -- | 8,540 | 7.8 |
| V-07 | | 08-31-93 | -- | 4,560 | 4,640 | 7.9 |
| V-08 | 363122104330310 | 04-08-93 | 0.68 | 6,300 | 6,510 | 8.1 |
| V-08 | | 08-31-93 | 0.14 | 5,110 | 5,570 | 8.3 |
| V-09 | 07203525 | 04-05-93 | 5.8 | -- | 2,040 | 7.8 |
| V-09 | | 09-07-93 | 20 | 1,130 | 1,110 | 8.0 |
| V-10 | 363306104360010 | 04-06-93 | -- | 20,000 | 20,400 | 8.5 |
| V-10 | | 08-30-93 | -- | 15,000 | 14,600 | 9.9 |
| V-11 | 363340104341510 | 04-08-93 | -- | 22,800 | 23,300 | 8.4 |
| V-11 | | 09-08-93 | -- | 25,700 | 26,300 | 9.4 |
| (V-12) | 363348104342001 | 06-04-93 | -- | 5,880 | 5,900 | 7.5 |
| (V-12) | | 08-31-93 | -- | 5,940 | 6,000 | 7.3 |
| (V-13) | 363920104354701 | 08-30-93 | -- | 2,550 | 2,480 | 7.1 |

Table 17.--Concentrations of selected constituents in water samples collected during the Vermejo reconnaissance study, spring and late summer, 1993--Continued

| Site number (fig. 6) | Date | pH, lab (standard units) | Temperature, water (°C) | Oxygen, dissolved (mg/L) | Oxygen, dissolved (percent saturation) | Hardness, total (mg/L as $CaCO_3$) |
|---|---|---|---|---|---|---|
| V-01 | 04-07-93 | 8.0 | 8.0 | 9.6 | 102 | 180 |
| V-01 | 09-07-93 | 8.3 | 19.5 | 7.8 | 106 | 160 |
| V-01-rep | 09-07-93 | 8.4 | -- | -- | -- | 160 |
| V-02 | 04-06-93 | 7.9 | 10.5 | 9.5 | 106 | 170 |
| V-02 | 09-08-93 | 8.3 | 15.0 | 8.6 | 107 | 640 |
| V-03 | 04-06-93 | 7.8 | 8.0 | 8.9 | 94 | 160 |
| V-03 | 08-30-93 | 8.0 | 19.5 | 7.1 | 96 | 220 |
| V-03-rep | 08-30-93 | 8.0 | -- | -- | -- | 230 |
| V-04 | 04-05-93 | 7.9 | 10.5 | 9.0 | 101 | 260 |
| V-04 | 08-30-93 | 8.0 | 21.5 | 6.8 | 97 | 210 |
| V-04-splt | 08-30-93 | 7.9 | -- | -- | -- | 300 |
| V-04-splt | 08-30-93 | 7.9 | -- | -- | -- | 300 |
| V-05 | 04-05-93 | 7.9 | 11.0 | 8.7 | 99 | 290 |
| V-05 | 09-07-93 | 8.2 | 20.5 | 8.1 | 114 | 530 |
| V-06 | 04-07-93 | 8.0 | 11.5 | 10.5 | 124 | 2,000 |
| V-06 | 08-31-93 | 7.9 | 14.0 | 6.6 | 82 | 2,500 |
| V-07 | 04-07-93 | 7.9 | 14.5 | 10.2 | -- | 4,700 |
| V-07 | 08-31-93 | 7.9 | 16.5 | 8.3 | 108 | 1,900 |
| V-08 | 04-08-93 | 8.0 | 15.5 | 9.5 | 122 | 2,500 |
| V-08 | 08-31-93 | 8.4 | 19.5 | 9.5 | 132 | 2,300 |
| V-09 | 04-05-93 | 7.9 | 11.0 | 8.8 | -- | 930 |
| V-09 | 09-07-93 | 8.3 | 20.0 | 8.0 | 111 | 460 |
| V-10 | 04-06-93 | 8.4 | 13.0 | 8.4 | 107 | 6,600 |
| V-10 | 08-30-93 | 9.3 | 21.0 | 10.2 | 151 | 4,700 |
| V-11 | 04-08-93 | 8.2 | 10.0 | 8.4 | 101 | 12,000 |
| V-11 | 09-08-93 | 9.6 | 17.5 | 6.8 | 98 | 15,000 |
| (V-12) | 06-04-93 | 7.6 | 10.5 | -- | -- | 3,600 |
| (V-12) | 08-31-93 | 7.7 | 14.0 | -- | -- | 3,500 |
| (V-13) | 08-30-93 | 7.5 | 13.5 | -- | -- | 990 |

Table 17.--Concentrations of selected constituents in water samples collected during the Vermejo reconnaissance study, spring and late summer, 1993--Continued

| Site number (fig. 6) | Date | Calcium, dissolved (mg/L as Ca) | Magnesium, dissolved (mg/L as Mg) | Sodium, dissolved (mg/L as Na) | Sodium, (percent) | Sodium adsorption ratio |
|---|---|---|---|---|---|---|
| V-01 | 04-07-93 | 50 | 14 | 41 | 33 | 1 |
| V-01 | 09-07-93 | 46 | 12 | 38 | 33 | 1 |
| V-01-rep | 09-07-93 | 44 | 13 | 37 | 33 | 1 |
| V-02 | 04-06-93 | 41 | 17 | 28 | 26 | 0.9 |
| V-02 | 09-08-93 | 130 | 77 | 150 | 34 | 3 |
| V-03 | 04-06-93 | 37 | 17 | 33 | 30 | 1 |
| V-03 | 08-30-93 | 53 | 22 | 54 | 34 | 2 |
| V-03-rep | 08-30-93 | 54 | 22 | 52 | 33 | 2 |
| V-04 | 04-05-93 | 57 | 29 | 42 | 26 | 1 |
| V-04 | 08-30-93 | 46 | 24 | 57 | 36 | 2 |
| V-04-splt | 08-30-93 | 63 | 34 | 82 | 37 | 2 |
| V-04-splt | 08-30-93 | 62 | 35 | 84 | 38 | 2 |
| V-05 | 04-05-93 | 60 | 33 | 49 | 27 | 1 |
| V-05 | 09-07-93 | 100 | 68 | 140 | 36 | 3 |
| V-06 | 04-07-93 | 260 | 340 | 800 | 46 | 8 |
| V-06 | 08-31-93 | 370 | 380 | 870 | 43 | 8 |
| V-07 | 04-07-93 | 400 | 910 | 930 | 30 | 6 |
| V-07 | 08-31-93 | 200 | 350 | 520 | 37 | 5 |
| V-08 | 04-08-93 | 240 | 460 | 820 | 42 | 7 |
| V-08 | 08-31-93 | 250 | 400 | 680 | 39 | 6 |
| V-09 | 04-05-93 | 190 | 110 | 160 | 27 | 2 |
| V-09 | 09-07-93 | 110 | 45 | 81 | 28 | 2 |
| V-10 | 04-06-93 | 330 | 1,400 | 3,700 | 55 | 20 |
| V-10 | 08-30-93 | 280 | 980 | 2,600 | 54 | 16 |
| V-11 | 04-08-93 | 350 | 2,600 | 3,900 | 42 | 16 |
| V-11 | 09-08-93 | 440 | 3,300 | 4,900 | 42 | 18 |
| (V-12) | 06-04-93 | 490 | 580 | 500 | 23 | 4 |
| (V-12) | 08-31-93 | 470 | 570 | 500 | 24 | 4 |
| (V-13) | 08-30-93 | 240 | 94 | 250 | 35 | 3 |

Table 17.--Concentrations of selected constituents in water samples collected during the Vermejo reconnaissance study, spring and late summer, 1993--Continued

| Site number (fig. 6) | Date | Potassium, dissolved (mg/L as K) | Alkalinity, total, lab (mg/L as $CaCO_3$) | Sulfate, dissolved (mg/L as $SO_4$) | Chloride, dissolved (mg/L as Cl) | Fluoride, dissolved (mg/L as F) |
|---|---|---|---|---|---|---|
| V-01 | 04-07-93 | 2.0 | 174 | 74 | 6.6 | 0.50 |
| V-01 | 09-07-93 | 2.4 | 160 | 75 | 5.0 | 0.60 |
| V-01-rep | 09-07-93 | 2.5 | 164 | 75 | 5.0 | 0.60 |
| V-02 | 04-06-93 | 2.8 | 108 | 100 | 7.7 | 0.20 |
| V-02 | 09-08-93 | 4.9 | 224 | 760 | 18 | 0.30 |
| V-03 | 04-06-93 | 2.6 | 134 | 110 | 6.1 | 0.20 |
| V-03 | 08-30-93 | 3.1 | 175 | 160 | 5.9 | 0.30 |
| V-03-rep | 08-30-93 | 3.0 | 177 | 160 | 5.8 | 0.30 |
| V-04 | 04-05-93 | 3.2 | 139 | 190 | 6.2 | 0.20 |
| V-04 | 08-30-93 | 3.2 | 155 | 310 | 11 | 0.30 |
| V-04-splt | 08-30-93 | 4.2 | 156 | 310 | 10 | 0.30 |
| V-04-splt | 08-30-93 | 4.3 | 155 | 310 | 10 | 0.30 |
| V-05 | 04-05-93 | 3.3 | 141 | 220 | 7.9 | 0.20 |
| V-05 | 09-07-93 | 4.1 | 210 | 620 | 21 | 0.30 |
| V-06 | 04-07-93 | 8.3 | 489 | 3,300 | 180 | 0.70 |
| V-06 | 08-31-93 | 9.3 | 625 | 3,500 | 220 | 1.1 |
| V-07 | 04-07-93 | 2.3 | 462 | 5,800 | 160 | 0.30 |
| V-07 | 08-31-93 | 17 | 234 | 2,800 | 94 | 0.20 |
| V-08 | 04-08-93 | 10 | 316 | 3,100 | 220 | 0.50 |
| V-08 | 08-31-93 | 11 | 333 | 3,200 | 210 | 0.90 |
| V-09 | 04-05-93 | 3.0 | 245 | 940 | 24 | 0.50 |
| V-09 | 09-07-93 | 3.1 | 228 | 380 | 9.9 | 0.60 |
| V-10 | 04-06-93 | 70 | 272 | 11,000 | 2,500 | 0.80 |
| V-10 | 08-30-93 | 43 | 117 | 7,300 | 1,900 | 0.40 |
| V-11 | 04-08-93 | 38 | 453 | 18,000 | 1,100 | 0.80 |
| V-11 | 09-08-93 | 42 | 257 | 22,000 | 1,200 | 0.90 |
| (V-12) | 06-04-93 | 1.6 | 452 | 3,800 | 51 | 1.1 |
| (V-12) | 08-31-93 | 1.7 | 463 | 4,100 | 53 | 0.80 |
| (V-13) | 08-30-93 | 1.9 | 308 | 1,200 | 35 | 0.60 |

Table 17.--Concentrations of selected constituents in water samples collected during the Vermejo reconnaissance study, spring and late summer, 1993--Continued

| Site number (fig. 6) | Date | Dissolved solids, residue at 180°C (mg/L) | Dissolved solids, sum of constituents (mg/L) | Dissolved solids (tons/day) | Dissolved solids (tons/acre-feet) | Arsenic, dissolved (µg/L as As) |
|---|---|---|---|---|---|---|
| V-01 | 04-07-93 | 304 | 292 | 23.8 | 0.41 | <1 |
| V-01 | 09-07-93 | 292 | 275 | 13.0 | 0.40 | <1 |
| V-01-rep | 09-07-93 | 292 | 275 | -- | 0.40 | <1 |
| V-02 | 04-06-93 | 276 | 262 | 18.5 | 0.38 | <1 |
| V-02 | 09-08-93 | 1,290 | 1,270 | 43.5 | 1.75 | <1 |
| V-03 | 04-06-93 | 316 | 286 | -- | 0.43 | 2 |
| V-03 | 08-30-93 | 424 | 403 | 24.6 | 0.58 | <1 |
| V-03-rep | 08-30-93 | 395 | 403 | -- | 0.54 | <1 |
| V-04 | 04-05-93 | 399 | 411 | 153 | 0.54 | 2 |
| V-04 | 08-30-93 | 641 | 545 | 50.7 | 0.87 | <1 |
| V-04-splt | 08-30-93 | 620 | 597 | -- | 0.84 | <1 |
| V-04-splt | 08-30-93 | 620 | 599 | -- | 0.84 | <1 |
| V-05 | 04-05-93 | 487 | 458 | 214 | 0.66 | 1 |
| V-05 | 09-07-93 | 1,120 | 1,080 | 45.4 | 1.52 | <1 |
| V-06 | 04-07-93 | 5,970 | 5,180 | -- | 8.12 | 2 |
| V-06 | 08-31-93 | 6,100 | 5,730 | -- | 8.30 | 2 |
| V-07 | 04-07-93 | 10,100 | 8,480 | -- | 13.7 | 1 |
| V-07 | 08-31-93 | 4,510 | 4,120 | -- | 6.13 | 3 |
| V-08 | 04-08-93 | 6,720 | 5,040 | 12.3 | 9.14 | 2 |
| V-08 | 08-31-93 | 5,160 | 4,950 | 1.95 | 7.02 | 5 |
| V-09 | 04-05-93 | 1,670 | 1,570 | 26.3 | 2.27 | <1 |
| V-09 | 09-07-93 | 820 | 766 | 44.5 | 1.12 | <1 |
| V-10 | 04-06-93 | 22,300 | 19,200 | -- | 30.3 | 7 |
| V-10 | 08-30-93 | 14,400 | 13,200 | -- | 19.6 | 2 |
| V-11 | 04-08-93 | 32,100 | 26,300 | -- | 43.7 | 21 |
| V-11 | 09-08-93 | 37,400 | 32,000 | -- | 50.9 | <1 |
| (V-12) | 06-04-93 | 6,120 | 5,700 | -- | 8.32 | 4 |
| (V-12) | 08-31-93 | 6,270 | 5,970 | -- | 8.53 | 4 |
| (V-13) | 08-30-93 | 2,020 | 2,010 | -- | 2.75 | <1 |

Table 17.--Concentrations of selected constituents in water samples collected during the Vermejo reconnaissance study, spring and late summer, 1993--Continued

| Site number (fig. 6) | Date | Boron, dissolved (µg/L as B) | Cadmium, dissolved (µg/L as Cd) | Chromium, dissolved (µg/L as Cr) | Copper, dissolved (µg/L as Cu) | Lead, dissolved (µg/L as Pb) |
|---|---|---|---|---|---|---|
| V-01 | 04-07-93 | 20 | <1.0 | <1 | 2 | <1 |
| V-01 | 09-07-93 | 30 | <1.0 | <1 | 1 | <1 |
| V-01-rep | 09-07-93 | 30 | <1.0 | <1 | 2 | <1 |
| V-02 | 04-06-93 | 20 | <1.0 | <1 | 2 | <1 |
| V-02 | 09-08-93 | 120 | <1.0 | <1 | 2 | <1 |
| V-03 | 04-06-93 | 30 | <1.0 | <1 | 2 | <1 |
| V-03 | 08-30-93 | 40 | <1.0 | <1 | 3 | <1 |
| V-03-rep | 08-30-93 | 40 | <1.0 | <1 | 2 | <1 |
| V-04 | 04-05-93 | 30 | <1.0 | <1 | 2 | <1 |
| V-04 | 08-30-93 | 60 | <1.0 | <1 | 3 | <1 |
| V-04-splt | 08-30-93 | 60 | <1.0 | <1 | 3 | <1 |
| V-04-splt | 08-30-93 | 60 | <1.0 | <1 | 4 | <1 |
| V-05 | 04-05-93 | 30 | <1.0 | <1 | 3 | <1 |
| V-05 | 09-07-93 | 100 | <1.0 | <1 | 2 | <1 |
| V-06 | 04-07-93 | 90 | <1.0 | <1 | 1 | <1 |
| V-06 | 08-31-93 | 1,200 | <1.0 | <1 | 2 | <1 |
| V-07 | 04-07-93 | 370 | <1.0 | <1 | 3 | <2 |
| V-07 | 08-31-93 | 280 | <1.0 | <1 | 4 | <1 |
| V-08 | 04-08-93 | 780 | <1.0 | <1 | 2 | <1 |
| V-08 | 08-31-93 | 870 | <1.0 | <1 | 2 | <1 |
| V-09 | 04-05-93 | 100 | <1.0 | <1 | 1 | <1 |
| V-09 | 09-07-93 | 60 | <1.0 | <1 | 1 | <1 |
| V-10 | 04-06-93 | 640 | <1.0 | 10 | <1 | <2 |
| V-10 | 08-30-93 | 490 | <1.0 | <1 | 2 | <1 |
| V-11 | 04-08-93 | 1,300 | <1.0 | <1 | <1 | <2 |
| V-11 | 09-08-93 | 1,500 | <1.0 | <1 | 5 | <1 |
| (V-12) | 06-04-93 | 540 | <1.0 | <1 | 2 | <1 |
| (V-12) | 08-31-93 | 660 | <1.0 | <1 | 1 | <1 |
| (V-13) | 08-30-93 | 120 | <1.0 | <1 | 4 | <1 |

Table 17.--Concentrations of selected constituents in water samples collected during the Vermejo reconnaissance study, spring and late summer, 1993--Concluded

| Site number (fig. 6) | Date | Mercury, dissolved (µg/L as Hg) | Molybdenum, dissolved (µg/L as Mo) | Selenium, dissolved (µg/L as Se) | Vanadium, dissolved (µg/L as V) | Zinc, dissolved (µg/L as Zn) |
|---|---|---|---|---|---|---|
| V-01 | 04-07-93 | <0.1 | 1 | 1 | <1 | 3 |
| V-01 | 09-07-93 | <0.1 | 1 | <1 | <1 | 4 |
| V-01-rep | 09-07-93 | <0.1 | 1 | <1 | <1 | 3 |
| V-02 | 04-06-93 | <0.1 | 1 | 1 | 2 | 38 |
| V-02 | 09-08-93 | <0.1 | 3 | 2 | 2 | 9 |
| V-03 | 04-06-93 | <0.1 | 2 | 2 | 2 | 5 |
| V-03 | 08-30-93 | <0.1 | <1 | 1 | 2 | <3 |
| V-03-rep | 08-30-93 | <0.1 | <1 | 1 | 2 | <3 |
| V-04 | 04-05-93 | <0.1 | 2 | 1 | 2 | 8 |
| V-04 | 08-30-93 | <0.1 | 1 | <2 | 2 | 3 |
| V-04-splt | 08-30-93 | <0.1 | 1 | 1 | 2 | <3 |
| V-04-splt | 08-30-93 | <0.1 | 1 | 1 | 2 | <3 |
| V-05 | 04-05-93 | <0.1 | 3 | 2 | 2 | 7 |
| V-05 | 09-07-93 | <0.1 | 4 | 2 | 1 | 16 |
| V-06 | 04-07-93 | <0.1 | 4 | 19 | 9 | <10 |
| V-06 | 08-31-93 | <0.1 | 3 | 7 | 12 | <10 |
| V-07 | 04-07-93 | <0.1 | 24 | 2 | 8 | <10 |
| V-07 | 08-31-93 | <0.1 | 13 | 2 | 8 | <10 |
| V-08 | 04-08-93 | <0.1 | 12 | 2 | 9 | <10 |
| V-08 | 08-31-93 | <0.1 | 3 | 3 | 12 | <10 |
| V-09 | 04-05-93 | <0.1 | 1 | 2 | <1 | <10 |
| V-09 | 09-07-93 | <0.1 | 2 | <1 | <1 | <3 |
| V-10 | 04-06-93 | <0.1 | 12 | 1 | 76 | <10 |
| V-10 | 08-30-93 | <0.1 | 2 | <1 | 86 | <10 |
| V-11 | 04-08-93 | <0.1 | 5 | 14 | 43 | <10 |
| V-11 | 09-08-93 | <0.1 | 1 | 23 | 42 | <10 |
| (V-12) | 06-04-93 | <0.1 | 5 | 36 | 22 | <10 |
| (V-12) | 08-31-93 | <0.1 | 4 | 36 | 24 | <10 |
| (V-13) | 08-30-93 | <0.1 | <1 | 12 | <1 | 20 |

Table 18.--Concentrations of selected major and trace elements in bottom sediment collected during the Vermejo reconnaissance study, November 1993

[splt, split sample; rep, replicate sample; <, less than. All values reported in micrograms per gram (μg/g) unless otherwise noted]

| Site number (fig. 6) | Sample number | Date | Size fraction | Aluminum (percent) | Arsenic | Barium |
|---|---|---|---|---|---|---|
| V-01 | VR05C93 | 11-04-93 | Coarse | 3.6 | 6.2 | 490 |
| V-01 | VR05F93 | 11-04-93 | Fine | 5.9 | 8.5 | 620 |
| V-02 | VR04C93 | 11-04-93 | Coarse | 4.9 | 7.3 | 600 |
| V-02 | VR04F93 | 11-04-93 | Fine | 6.2 | 8.2 | 660 |
| V-03 | VR09C93 | 11-03-93 | Coarse | 5.0 | 6.6 | 620 |
| V-03 | VR09F93 | 11-03-93 | Fine | 6.8 | 6.9 | 620 |
| V-03-splt | VR13C93 | 11-03-93 | Coarse | 4.7 | 8.8 | 620 |
| V-03-splt | VR13F93 | 11-03-93 | Fine | 6.8 | 9.0 | 690 |
| V-04 | VR03C93 | 11-03-93 | Coarse | 4.8 | 9.4 | 690 |
| V-04 | VR03F93 | 11-03-93 | Fine | 6.7 | 9.0 | 710 |
| V-05 | VR02C93 | 11-03-93 | Coarse | 6.6 | 11 | 520 |
| V-05 | VR02F93 | 11-03-93 | Fine | 6.8 | 12 | 530 |
| V-06 | VR01C93 | 11-04-93 | Coarse | 4.9 | 8.7 | 630 |
| V-06 | VR01F93 | 11-04-93 | Fine | 6.6 | 9.0 | 690 |
| V-06-rep | VR06C93 | 11-04-93 | Coarse | 6.8 | 7.7 | 600 |
| V-06-rep | VR06F93 | 11-04-93 | Fine | 7.4 | 7.1 | 630 |
| V-07 | VR10C93 | 11-04-93 | Coarse | 7.6 | 11 | 550 |
| V-07 | VR10F93 | 11-04-93 | Fine | 7.8 | 10 | 550 |
| V-08 | VR11C93 | 11-04-93 | Coarse | 6.6 | 7.6 | 500 |
| V-08 | VR11F93 | 11-04-93 | Fine | 7.0 | 7.9 | 520 |
| V-09 | VR12C93 | 11-04-93 | Coarse | 6.9 | 7.7 | 620 |
| V-09 | VR12F93 | 11-04-93 | Fine | 7.6 | 7.6 | 630 |
| V-10 | VR07C93 | 11-04-93 | Coarse | 5.9 | 7.3 | 660 |
| V-10 | VR07F93 | 11-04-93 | Fine | 6.7 | 7.5 | 670 |
| V-11 | VR08C93 | 11-04-93 | Coarse | 5.3 | 7.6 | 580 |
| V-11 | VR08F93 | 11-04-93 | Fine | 6.3 | 10 | 550 |

Table 18.--Concentrations of selected major and trace elements in bottom sediment collected during the Vermejo reconnaissance study, November 1993--Continued

| Site number (fig. 6) | Beryllium | Bismuth | Boron (water extractable) | Cadmium | Calcium (percent) | Cesium |
|---|---|---|---|---|---|---|
| V-01 | <1 | <10 | 0.33 | <2 | 2.7 | 27 |
| V-01 | 1 | <10 | 0.66 | <2 | 4.9 | 57 |
| V-02 | 1 | <10 | 0.45 | <2 | 4.0 | 42 |
| V-02 | 1 | <10 | 0.55 | <2 | 4.4 | 69 |
| V-03 | 1 | <10 | 0.39 | <2 | 2.9 | 44 |
| V-03 | 2 | <10 | 0.54 | <2 | 5.0 | 68 |
| V-03-splt | 1 | <10 | 0.65 | <2 | 2.6 | 43 |
| V-03-splt | 2 | <10 | 0.74 | <2 | 4.0 | 65 |
| V-04 | 1 | <10 | 0.33 | <2 | 3.0 | 42 |
| V-04 | 2 | <10 | 0.51 | <2 | 4.9 | 67 |
| V-05 | 2 | <10 | 1.8 | <2 | 6.5 | 57 |
| V-05 | 2 | <10 | 2.0 | <2 | 5.5 | 61 |
| V-06 | 1 | <10 | 0.50 | <2 | 0.94 | 40 |
| V-06 | 2 | <10 | 0.43 | <2 | 1.6 | 68 |
| V-06-rep | 2 | <10 | 5.1 | <2 | 2.4 | 57 |
| V-06-rep | 2 | <10 | 5.2 | <2 | 2.9 | 64 |
| V-07 | 2 | <10 | 2.8 | <2 | 1.9 | 59 |
| V-07 | 2 | <10 | 2.3 | <2 | 1.8 | 62 |
| V-08 | 2 | <10 | 7.8 | <2 | 3.0 | 59 |
| V-08 | 2 | <10 | 4.6 | <2 | 3.1 | 65 |
| V-09 | 2 | <10 | 6.2 | <2 | 2.5 | 60 |
| V-09 | 2 | <10 | 5.5 | <2 | 3.0 | 72 |
| V-10 | 1 | <10 | 1.0 | <2 | 1.8 | 50 |
| V-10 | 2 | <10 | 0.71 | <2 | 2.0 | 70 |
| V-11 | 1 | <10 | 1.6 | <2 | 3.8 | 45 |
| V-11 | 1 | <10 | 2.7 | <2 | 4.4 | 65 |

Table 18.--Concentrations of selected major and trace elements in bottom sediment collected during the Vermejo reconnaissance study, November 1993--Continued

| Site number (fig. 6) | Chromium | Cobalt | Copper | Europium | Gallium | Gold |
|---|---|---|---|---|---|---|
| V-01 | 24 | 8 | 8 | <2 | 7 | <8 |
| V-01 | 51 | 11 | 20 | <2 | 12 | <8 |
| V-02 | 37 | 11 | 12 | <2 | 10 | <8 |
| V-02 | 52 | 10 | 20 | <2 | 15 | <8 |
| V-03 | 28 | 10 | 13 | <2 | 11 | <8 |
| V-03 | 50 | 13 | 22 | <2 | 16 | <8 |
| V-03-splt | 45 | 12 | 14 | <2 | 10 | <8 |
| V-03-splt | 70 | 13 | 25 | <2 | 16 | <8 |
| V-04 | 42 | 11 | 12 | <2 | 9 | <8 |
| V-04 | 68 | 12 | 25 | <2 | 16 | <8 |
| V-05 | 63 | 12 | 26 | <2 | 15 | <8 |
| V-05 | 66 | 12 | 27 | <2 | 16 | <8 |
| V-06 | 25 | 10 | 16 | <2 | 10 | <8 |
| V-06 | 61 | 11 | 24 | <2 | 15 | <8 |
| V-06-rep | 50 | 11 | 23 | <2 | 15 | <8 |
| V-06-rep | 58 | 12 | 23 | <2 | 17 | <8 |
| V-07 | 68 | 11 | 25 | <2 | 18 | <8 |
| V-07 | 72 | 12 | 25 | <2 | 18 | <8 |
| V-08 | 51 | 10 | 20 | <2 | 15 | <8 |
| V-08 | 57 | 11 | 22 | <2 | 17 | <8 |
| V-09 | 52 | 11 | 24 | <2 | 16 | <8 |
| V-09 | 60 | 13 | 24 | <2 | 19 | <8 |
| V-10 | 42 | 13 | 23 | <2 | 13 | <8 |
| V-10 | 58 | 13 | 24 | <2 | 14 | <8 |
| V-11 | 33 | 9 | 12 | <2 | 11 | <8 |
| V-11 | 54 | 12 | 17 | <2 | 14 | <8 |

Table 18.--Concentrations of selected major and trace elements in bottom sediment collected during the Vermejo reconnaissance study, November 1993--Continued

| Site number (fig. 6) | Holmium | Iron (percent) | Lanthanum | Lead | Lithium | Magnesium (percent) |
|---|---|---|---|---|---|---|
| V-01 | <4 | 2.5 | 16 | 14 | 14 | 0.41 |
| V-01 | <4 | 2.7 | 31 | 15 | 29 | 1.0 |
| V-02 | <4 | 3.0 | 23 | 13 | 22 | 0.65 |
| V-02 | <4 | 2.7 | 37 | 16 | 31 | 0.95 |
| V-03 | <4 | 3.6 | 23 | 16 | 21 | 0.51 |
| V-03 | <4 | 2.9 | 35 | 15 | 32 | 0.90 |
| V-03-splt | <4 | 4.9 | 24 | 15 | 19 | 0.62 |
| V-03-splt | <4 | 3.5 | 38 | 17 | 37 | 1.1 |
| V-04 | <4 | 4.9 | 24 | 16 | 20 | 0.62 |
| V-04 | <4 | 3.4 | 37 | 17 | 36 | 1.1 |
| V-05 | <4 | 2.6 | 30 | 14 | 46 | 1.2 |
| V-05 | <4 | 2.8 | 33 | 15 | 48 | 1.3 |
| V-06 | <4 | 3.2 | 22 | 20 | 22 | 0.50 |
| V-06 | <4 | 3.1 | 36 | 17 | 35 | 0.95 |
| V-06-rep | <4 | 3.1 | 31 | 21 | 38 | 0.95 |
| V-06-rep | <4 | 3.3 | 35 | 18 | 43 | 1.1 |
| V-07 | <4 | 3.1 | 31 | 17 | 46 | 1.5 |
| V-07 | <4 | 3.2 | 33 | 17 | 49 | 1.6 |
| V-08 | <4 | 2.7 | 32 | 15 | 50 | 1.7 |
| V-08 | <4 | 3.0 | 34 | 15 | 55 | 2.0 |
| V-09 | <4 | 3.2 | 33 | 17 | 39 | 0.97 |
| V-09 | <4 | 3.3 | 39 | 17 | 43 | 1.1 |
| V-10 | <4 | 2.6 | 27 | 15 | 26 | 0.7 |
| V-10 | <4 | 2.9 | 37 | 15 | 32 | 0.94 |
| V-11 | <4 | 2.2 | 25 | 14 | 29 | 0.86 |
| V-11 | <4 | 2.6 | 34 | 15 | 37 | 1.3 |

Table 18.--Concentrations of selected major and trace elements in bottom sediment collected during the Vermejo reconnaissance study, November 1993--Continued

| Site number (fig. 6) | Manganese | Mercury | Molybdenum | Neodemium | Nickel | Niobium |
|---|---|---|---|---|---|---|
| V-01 | 330 | <0.02 | <2 | 13 | 14 | 6 |
| V-01 | 390 | <0.02 | <2 | 26 | 24 | 12 |
| V-02 | 470 | <0.02 | <2 | 19 | 20 | 8 |
| V-02 | 520 | <0.02 | <2 | 33 | 23 | 14 |
| V-03 | 620 | <0.02 | <2 | 20 | 15 | 8 |
| V-03 | 780 | <0.02 | <2 | 20 | 22 | 14 |
| V-03-splt | 730 | <0.02 | <2 | 30 | 23 | 9 |
| V-03-splt | 770 | <0.02 | <2 | 31 | 31 | 14 |
| V-04 | 750 | <0.02 | <2 | 19 | 22 | 11 |
| V-04 | 720 | <0.02 | <2 | 30 | 30 | 13 |
| V-05 | 380 | <0.02 | 4 | 25 | 32 | 12 |
| V-05 | 400 | <0.02 | 5 | 28 | 32 | 13 |
| V-06 | 400 | <0.02 | <2 | 18 | 17 | 8 |
| V-06 | 360 | <0.02 | <2 | 25 | 22 | 13 |
| V-06-rep | 320 | <0.02 | <2 | 33 | 26 | 14 |
| V-06-rep | 350 | <0.02 | <2 | 30 | 24 | 15 |
| V-07 | 340 | <0.02 | <2 | 29 | 26 | 15 |
| V-07 | 330 | <0.02 | <2 | 29 | 28 | 16 |
| V-08 | 400 | <0.02 | <2 | 26 | 21 | 14 |
| V-08 | 470 | <0.02 | <2 | 29 | 23 | 13 |
| V-09 | 340 | <0.02 | <2 | 27 | 23 | 13 |
| V-09 | 380 | <0.02 | <2 | 34 | 24 | 14 |
| V-10 | 330 | <0.02 | <2 | 24 | 23 | 11 |
| V-10 | 370 | <0.02 | <2 | 33 | 25 | 17 |
| V-11 | 310 | <0.02 | <2 | 20 | 16 | 11 |
| V-11 | 480 | <0.02 | <2 | 28 | 23 | 13 |

Table 18.--Concentrations of selected major and trace elements in bottom sediment collected during the Vermejo reconnaissance study, November 1993--Continued

| Site number (fig. 6) | Phosphorus (percent) | Potassium (percent) | Scandium | Selenium | Silver | Sodium (percent) |
|---|---|---|---|---|---|---|
| V-01 | 0.04 | 1.2 | 4 | 0.6 | <2 | 1.0 |
| V-01 | 0.08 | 1.7 | 8 | 1.5 | <2 | 1.0 |
| V-02 | 0.06 | 1.5 | 6 | 0.9 | <2 | 1.1 |
| V-02 | 0.08 | 1.8 | 9 | 1.2 | <2 | 1.0 |
| V-03 | 0.06 | 1.7 | 6 | 0.8 | <2 | 0.99 |
| V-03 | 0.07 | 1.9 | 6 | 1.5 | <2 | 0.88 |
| V-03-splt | 0.08 | 1.4 | 10 | 0.9 | <2 | 1.4 |
| V-03-splt | 0.09 | 1.8 | 10 | 1.4 | <2 | 1.0 |
| V-04 | 0.08 | 1.4 | 6 | 1.0 | <2 | 1.5 |
| V-04 | 0.09 | 1.8 | 9 | 1.4 | <2 | 1.0 |
| V-05 | 0.08 | 1.9 | 10 | 3.4 | <2 | 0.73 |
| V-05 | 0.09 | 2.0 | 10 | 3.4 | <2 | 0.75 |
| V-06 | 0.04 | 1.7 | 5 | 0.7 | <2 | 1.1 |
| V-06 | 0.08 | 1.9 | 10 | 0.6 | <2 | 1.0 |
| V-06-rep | 0.07 | 2.0 | 9 | 6.4 | <2 | 0.93 |
| V-06-rep | 0.08 | 2.2 | 11 | 6.2 | <2 | 0.91 |
| V-07 | 0.08 | 2.4 | 12 | 0.6 | <2 | 1.1 |
| V-07 | 0.09 | 2.4 | 12 | 0.6 | <2 | 1.1 |
| V-08 | 0.07 | 2.0 | 9 | 8.4 | <2 | 1.3 |
| V-08 | 0.08 | 2.1 | 11 | 8.6 | <2 | 1.3 |
| V-09 | 0.07 | 2.1 | 10 | 5.1 | <2 | 0.92 |
| V-09 | 0.09 | 2.2 | 11 | 7.0 | <2 | 0.91 |
| V-10 | 0.07 | 1.8 | 7 | 0.9 | <2 | 1.1 |
| V-10 | 0.09 | 1.9 | 9 | 0.9 | <2 | 1.0 |
| V-11 | 0.07 | 1.6 | 6 | 2.6 | <2 | 1.1 |
| V-11 | 0.09 | 1.8 | 9 | 4.0 | <2 | 0.93 |

Table 18.--Concentrations of selected major and trace elements in bottom sediment collected during the Vermejo reconnaissance study, November 1993--Continued

| Site number (fig. 6) | Strontium | Tantalum | Thorium | Tin | Titanium (percent) | Thorium |
|---|---|---|---|---|---|---|
| V-01 | 220 | <40 | <4 | <5 | 0.11 | 3.4 |
| V-01 | 340 | <40 | 10 | <5 | 0.27 | 12.9 |
| V-02 | 300 | <40 | 9 | <5 | 0.19 | 7.82 |
| V-02 | 320 | <40 | 14 | <5 | 0.31 | 12.9 |
| V-03 | 210 | <40 | 8 | <5 | 0.18 | 9.02 |
| V-03 | 300 | <40 | 11 | <5 | 0.31 | 12.6 |
| V-03-splt | 290 | <40 | 6 | <5 | 0.18 | 6.67 |
| V-03-splt | 350 | <40 | 14 | <5 | 0.33 | 16.0 |
| V-04 | 320 | <40 | 7 | <5 | 0.18 | 7.77 |
| V-04 | 340 | <40 | 12 | <5 | 0.31 | 14.0 |
| V-05 | 370 | <40 | 10 | <5 | 0.26 | 13.0 |
| V-05 | 340 | <40 | 12 | <5 | 0.29 | 10.8 |
| V-06 | 140 | <40 | 6 | <5 | 0.16 | 6.71 |
| V-06 | 330 | <40 | 14 | <5 | 0.30 | 14.5 |
| V-06-rep | 200 | <40 | 10 | <5 | 0.28 | 11.3 |
| V-06-rep | 380 | <40 | 12 | <5 | 0.31 | 12.2 |
| V-07 | 230 | <40 | 12 | <5 | 0.32 | 14.1 |
| V-07 | 230 | <40 | 13 | <5 | 0.34 | 14.3 |
| V-08 | 430 | <40 | 10 | <5 | 0.29 | 10.4 |
| V-08 | 470 | <40 | 12 | <5 | 0.32 | 12.9 |
| V-09 | 330 | <40 | 11 | <5 | 0.29 | 11.7 |
| V-09 | 400 | <40 | 13 | <5 | 0.36 | 19.7 |
| V-10 | 230 | <40 | 8 | <5 | 0.25 | 9.38 |
| V-10 | 250 | <40 | 13 | <5 | 0.36 | 9.55 |
| V-11 | 300 | <40 | 9 | <5 | 0.18 | 10.0 |
| V-11 | 380 | <40 | 12 | <5 | 0.31 | 11.1 |

Table 18.--Concentrations of selected major and trace elements in bottom sediment collected during the Vermejo reconnaissance study, November 1993--Continued

| Site number (fig. 6) | Uranium | Vanadium | Yttrium | Ytterbium | Zinc | Total carbon (percent as C) |
|---|---|---|---|---|---|---|
| V-01 | 1.69 | 43 | 9 | <1 | 43 | 0.71 |
| V-01 | 4.46 | 100 | 18 | 2 | 72 | 1.45 |
| V-02 | 2.98 | 72 | 14 | 1 | 58 | 1.04 |
| V-02 | 5.31 | 100 | 20 | 2 | 77 | 1.28 |
| V-03 | 3.17 | 69 | 15 | 1 | 57 | 0.64 |
| V-03 | 4.95 | 110 | 20 | 2 | 81 | 1.04 |
| V-03-splt | 2.62 | 65 | 14 | <1 | 65 | 0.66 |
| V-03-splt | 4.71 | 120 | 20 | 2 | 92 | 1.44 |
| V-04 | 2.67 | 67 | 14 | 1 | 65 | 0.72 |
| V-04 | 4.69 | 120 | 20 | 2 | 90 | 1.40 |
| V-05 | 5.69 | 200 | 19 | 2 | 99 | 1.78 |
| V-05 | 6.52 | 200 | 20 | 2 | 100 | 1.54 |
| V-06 | 2.20 | 59 | 12 | 1 | 63 | 0.21 |
| V-06 | 4.81 | 95 | 20 | 2 | 82 | 0.41 |
| V-06-rep | 3.79 | 100 | 18 | 2 | 86 | 0.53 |
| V-06-rep | 4.50 | 110 | 21 | 2 | 95 | 0.70 |
| V-07 | 4.32 | 130 | 20 | 2 | 94 | 0.43 |
| V-07 | 4.72 | 140 | 20 | 2 | 100 | 0.43 |
| V-08 | 4.81 | 100 | 19 | 2 | 79 | 0.45 |
| V-08 | 5.66 | 110 | 21 | 2 | 88 | 0.52 |
| V-09 | 3.85 | 100 | 19 | 2 | 100 | 0.54 |
| V-09 | 4.31 | 120 | 23 | 2 | 120 | 0.70 |
| V-10 | 3.33 | 80 | 16 | 1 | 73 | 0.35 |
| V-10 | 4.35 | 100 | 22 | 2 | 84 | 0.42 |
| V-11 | 4.24 | 73 | 14 | 1 | 57 | 1.06 |
| V-11 | 6.79 | 110 | 19 | 2 | 76 | 1.07 |

Table 18.--Concentrations of selected major and trace elements in bottom sediment collected during the Vermejo reconnaissance study, November 1993--Concluded

| Site number (fig. 6) | Organic carbon (percent) |
|---|---|
| V-01 | 0.66 |
| V-01 | 1.27 |
| V-02 | 0.70 |
| V-02 | 0.88 |
| V-03 | 0.68 |
| V-03 | 1.37 |
| V-03-splt | 0.70 |
| V-03-splt | 1.25 |
| V-04 | 0.72 |
| V-04 | 1.21 |
| V-05 | 2.08 |
| V-05 | 1.70 |
| V-06 | 0.37 |
| V-06 | 0.80 |
| V-06-rep | 1.93 |
| V-06-rep | 1.88 |
| V-07 | 0.68 |
| V-07 | 0.84 |
| V-08 | 1.12 |
| V-08 | 1.26 |
| V-09 | 1.82 |
| V-09 | 1.83 |
| V-10 | 2.95 |
| V-10 | 1.40 |
| V-11 | 1.11 |
| V-11 | 1.74 |

Table 19.--Concentrations of selected elements in blank quality-control water samples, April and August 1993

[µS/cm, microsiemens per centimeter at 25 °C (degrees Celsius); dis, dissolved; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than]

| Property or compound | Sample number | |
|---|---|---|
| | V-07 blank | V-09 blank |
| Date | 08-31-93 | 04-05-93 |
| Specific conductance, lab (µS/cm) | 2.0 | 5.0 |
| pH, lab (standard units) | 7.8 | 6.4 |
| Calcium, dis (mg/L as Ca) | 0.04 | 0.17 |
| Magnesium, dis (mg/L as Mg) | <0.01 | 0.04 |
| Sodium, dis (mg/L as Na) | <0.20 | 0.20 |
| Potassium, dis (mg/Las K) | <0.10 | 0.50 |
| Alkalinity, total, lab (mg/L as $CaCO_3$) | 1.3 | 3.4 |
| Sulfate, dis (mg/L as $SO_4$) | 0.20 | 0.70 |
| Chloride, dis (mg/L as Cl) | 0.10 | 0.20 |
| Fluoride, dis (mg/L as F) | 0.10 | <0.10 |
| Dissolved solids, residue at 180 °C (mg/L) | 6 | 7 |
| Arsenic, dis (µg/L as As) | <1 | <1 |
| Boron, dis (µg/L as B) | 70 | 10 |
| Cadmium, dis (µg/L as Cd) | <1.0 | <1.0 |
| Chromium, dis (µg/L as Cr) | <1 | <1 |
| Copper, dis (µg/L as Cu) | <1 | 1 |
| Lead, dis (µg/L as Pb) | <1 | 2 |
| Mercury, dis (µg/L as Hg) | <0.1 | 0.1 |
| Molybdenum, dis (µg/L as Mo) | <1 | <1 |
| Selenium, dis (µg/L as Se) | <1 | <1 |
| Vanadium, dis (µg/L as V) | <1 | <1 |
| Zinc, dis (µg/L as Zn) | <3 | 10 |

Table 20.--Mean and standard deviation percent moisture of biota collected during the Vermejo reconnaissance study, summer 1993

[--, not applicable]

| Sample type | Number of samples | Percent moisture by weight | |
|---|---|---|---|
| | | Mean | Standard deviation |
| Vegetation | 18 | 86.5 | 6.1 |
| Submergent vegetation | 9 | 89.5 | 4.0 |
| Emergent vegetation | 9 | 83.5 | 5.3 |
| Invertebrates | 14 | 78.2 | 5.1 |
| Brine flies | 3 | 77.6 | 3.7 |
| Crayfish | 3 | 75.3 | 3.2 |
| Odonate nymphs | 5 | 80.3 | 5.3 |
| Snails | 2 | 73.4 | 1.6 |
| Water boatmen | 1 | 87.4 | -- |
| Fish | 20 | 77.8 | 1.9 |
| Black bullhead | 4 | 80.2 | 1.3 |
| Flathead chub | 4 | 78.3 | 1.9 |
| Green sunfish | 4 | 77.9 | 1.2 |
| Largemouth bass | 3 | 75.8 | 2.3 |
| Longnose dace | 2 | 77.5 | 4.7 |
| Plains killifish | 1 | 80.8 | -- |
| White sucker | 1 | 76.8 | -- |
| Yellow perch | 2 | 75.3 | 0.7 |
| Fish fillets | 8 | 80.2 | 1.9 |
| All project samples | 60 | 80.8 | 4.0 |

Table 21.--Dry weight concentrations of trace elements in biota collected during the Vermejo reconnaissance study, summer 1993

[For fish, the fillet sample immediately precedes the corresponding whole fish without fillet sample. mg/g, micrograms per gram; >, greater than; <, less than]

| Site number (fig. 6) | Sample number | Specimen | Taxon | Sample type (and number) | Sample weight (grams) |
|---|---|---|---|---|---|
| V-01 | VPV1PA1 | Willow | *Salix sp.* | Emergent (>10) | 45.7 |
| V-01 | VPV1IB | Odonates | Odonata | Invertebrate (>10) | 6.94 |
| V-01 | VPV1FS1 | Flathead chub | *Platygobio gracilis* | Whole fish (>10) | 40.7 |
| V-02 | VPV2PA1 | Bulrush | *Scirpus sp.* | Emergent (>10) | 19.6 |
| V-02 | VPV2PA2 | Sedge | *Carex sp.* | Emergent (>10) | 29.8 |
| V-02 | VPV2IB | Crayfish | Decapoda | Invertebrate (>10) | 88.2 |
| V-02 | VPV2FS2 | Longnose dace | *Rhinichthys cataractae* | Whole fish (>10) | 29.9 |
| V-02 | VPV2FS1 | Flathead chub | *Platygobio gracilis* | Whole fish (>10) | 53.9 |
| V-05 | VPV5PA2 | Unknown | Phytae | Submergent (>10) | 30.0 |
| V-05 | VPV5PA1 | Bulrush | *Scirpus acutifolius* | Emergent (>10) | 26.1 |
| V-05 | VPV5IB | Crayfish | Decapoda | Invertebrate (>10) | 15.3 |
| V-05 | VPV5FS2 | Flathead chub | *Platygobio gracilis* | Whole fish (>10) | 33.3 |
| V-05 | VPV5FS1 | Green sunfish | *Lepomis cyanellus* | Whole fish (>10) | 14.3 |
| V-09 | VPV9PA1 | Bulrush | *Scirpus sp.* | Emergent (>10) | 33.2 |
| V-09 | VPV9IB2 | Mixed | Insecta | Invertebrate (>10) | 0.93 |
| V-09 | VPV9IB1 | Crayfish | Decapoda | Invertebrate (>10) | 28.7 |
| V-09 | VPV9FS1 | Flathead chub | *Platygobio gracilis* | Whole fish (>10) | 81.2 |
| V-09 | VPV9FS2 | Flathead chub | *Platygobio gracilis* | Whole fish (>10) | 28.7 |
| V-10 | VPV10PA1 | Filamentous algae | Chlorophyta | Submergent (>10) | 94.3 |
| V-10 | VPV10PA2 | Spikerush | *Eleocharis sp.* | Emergent (>10) | 58.8 |
| V-10 | VPV10IB | Odonates | Odonata | Invertebrate (>10) | 21.1 |
| V-10 | VPV10IN | Brine flies | Diptera | Invertebrate (>10) | 6.75 |
| V-11 | VPV11PA1 | Filamentous algae | Chlorophyta | Submergent (>10) | 54.1 |
| V-11 | VPV11PA2 | Unknown | Anthophyta | Submergent (>10) | 91.3 |
| V-11 | VPV11IN | Brine flies | Diptera | Invertebrate (>10) | 17.5 |
| V-11 | VPV11FS | Plains killifish | *Fundulus zebrinus* | Whole fish (>10) | 37.3 |
| V-14 | VPV14PA1 | Filamentous algae | Chlorophyta | Submergent (>10) | 88.4 |
| V-14 | VPV14PA2 | Elodea | *Elodea canadensis* | Submergent (>10) | 50.3 |
| V-14 | VPV14IB1 | Odonates | Odonata | Invertebrate (>10) | 15.9 |

Table 21.--Dry weight concentrations of trace elements in biota collected during the Vermejo reconnaissance study, summer 1993--Continued

| Site number (fig. 6) | Sample number | Moisture (percent) | Aluminum (µg/g) | Arsenic (µg/g) | Barium (µg/g) | Beryllium (µg/g) | Boron (µg/g) |
|---|---|---|---|---|---|---|---|
| V-01 | VPV1PA1 | 87.7 | 7,870 | 1.8 | 89.8 | 0.31 | 13 |
| V-01 | VPV1IB | 80.2 | 5,580 | 0.7 | 41.3 | 0.15 | <3.0 |
| V-01 | VPV1FS1 | 75.4 | 439 | <0.30 | 23.8 | <0.02 | <2.0 |
| V-02 | VPV2PA1 | 74.6 | 880 | 0.31 | 12.4 | 0.03 | 7.4 |
| V-02 | VPV2PA2 | 77.6 | 3,630 | 0.8 | 39.7 | 0.13 | 13 |
| V-02 | VPV2IB | 72.3 | 989 | 2.1 | 56.8 | <0.02 | 3 |
| V-02 | VPV2FS2 | 74.1 | 508 | 0.5 | 14.1 | <0.02 | <2.0 |
| V-02 | VPV2FS1 | 78.8 | 1,880 | 0.6 | 32.6 | <0.02 | <2.0 |
| V-05 | VPV5PA2 | 87.1 | 5,190 | 1.1 | 45.7 | 0.2 | 15 |
| V-05 | VPV5PA1 | 78.5 | 1,600 | 0.43 | 22.5 | 0.047 | 7.9 |
| V-05 | VPV5IB | 78.6 | 732 | 0.6 | 60.5 | <0.02 | <2.0 |
| V-05 | VPV5FS2 | 79.5 | 1,100 | 0.6 | 13 | <0.02 | <2.0 |
| V-05 | VPV5FS1 | 78.9 | 1,970 | 0.94 | 16.5 | <0.02 | <2.0 |
| V-09 | VPV9PA1 | 80.6 | 1,720 | 0.32 | 14.7 | 0.058 | 12 |
| V-09 | VPV9IB2 | 71.2 | 2,970 | 0.5 | 26 | <0.04 | <5.0 |
| V-09 | VPV9IB1 | 75 | 1,110 | 0.5 | 70.4 | <0.02 | <2.0 |
| V-09 | VPV9FS1 | 76.5 | 100 | 0.3 | 1.3 | <0.02 | <2.0 |
| V-09 | VPV9FS2 | 79.4 | 1,210 | 0.5 | 11.1 | <0.02 | <2.0 |
| V-10 | VPV10PA1 | 79.8 | 12,300 | 5.9 | 60.8 | 0.41 | 320 |
| V-10 | VPV10PA2 | 83.8 | 2,080 | 1.9 | 12.9 | 0.055 | 16 |
| V-10 | VPV10IB | 84.6 | 827 | 0.44 | 4.9 | <0.02 | 13 |
| V-10 | VPV10IN | 75.1 | 4,340 | 1 | 25.6 | 0.08 | 74 |
| V-11 | VPV11PA1 | 92.4 | 270 | 2.8 | 4.4 | 0.02 | 140 |
| V-11 | VPV11PA2 | 90.9 | 991 | 19.8 | 8.5 | 0.047 | 290 |
| V-11 | VPV11IN | 81.9 | 3,800 | 2.1 | 27.1 | 0.075 | 56 |
| V-11 | VPV11FS | 80.8 | 180 | 1.5 | 2.4 | <0.03 | 6 |
| V-14 | VPV14PA1 | 91.7 | 8,380 | 2.8 | 100 | 0.32 | 252 |
| V-14 | VPV14PA2 | 91.1 | 6,010 | 2.1 | 130 | 0.21 | 350 |
| V-14 | VPV14IB1 | 82.6 | 570 | 0.4 | 39.9 | <0.02 | 3 |

Table 21.--Dry weight concentrations of trace elements in biota collected during the Vermejo reconnaissance study, summer 1993--Continued

| Site number (fig. 6) | Sample number | Cadmium (µg/g) | Chromium (µg/g) | Copper (µg/g) | Iron (µg/g) | Lead (µg/g) | Magnesium (µg/g) |
|---|---|---|---|---|---|---|---|
| V-01 | VPV1PA1 | 0.35 | 5.7 | 14 | 5,500 | 12 | 3,650 |
| V-01 | VPV1IB | 1.8 | 4.2 | 31 | 3,810 | 9.3 | 1,450 |
| V-01 | VPV1FS1 | 0.14 | 0.46 | 4 | 292 | <0.4 | 1,080 |
| V-02 | VPV2PA1 | 0.11 | 4.9 | 9.6 | 733 | 1.6 | 1,750 |
| V-02 | VPV2PA2 | 0.19 | 4.7 | 11 | 2,300 | 5.4 | 5,360 |
| V-02 | VPV2IB | 0.27 | 1.2 | 72 | 579 | 1.6 | 2,040 |
| V-02 | VPV2FS2 | 0.15 | 0.66 | 6.3 | 310 | <0.4 | 1,340 |
| V-02 | VPV2FS1 | 0.26 | 2 | 9.8 | 1,090 | 1.7 | 1,800 |
| V-05 | VPV5PA2 | 0.43 | 4.2 | 15 | 2,880 | 7.8 | 5,470 |
| V-05 | VPV5PA1 | 0.2 | 3.7 | 8 | 1,190 | 2.7 | 2,290 |
| V-05 | VPV5IB | 0.36 | 0.91 | 82 | 403 | 1 | 2,080 |
| V-05 | VPV5FS2 | 0.22 | 1.3 | 6.1 | 620 | <0.4 | 1,820 |
| V-05 | VPV5FS1 | 0.26 | 2.3 | 4.6 | 1,040 | 1.4 | 1,950 |
| V-09 | VPV9PA1 | 0.16 | 2.4 | 8.7 | 1,030 | 2.3 | 2,640 |
| V-09 | VPV9IB2 | 1.5 | 2.1 | 23 | 1,890 | 4.8 | 1,530 |
| V-09 | VPV9IB1 | 0.26 | 0.99 | 70 | 532 | 1.3 | 2,200 |
| V-09 | VPV9FS1 | <0.02 | 0.3 | 1.1 | 90 | <0.4 | 1,380 |
| V-09 | VPV9FS2 | 0.15 | 0.88 | 5.6 | 591 | <0.4 | 1,760 |
| V-10 | VPV10PA1 | 0.66 | 11 | 7.8 | 5,690 | 18 | 19,900 |
| V-10 | VPV10PA2 | 0.21 | 2.9 | 11 | 1,410 | 3.3 | 9,770 |
| V-10 | VPV10IB | 0.29 | 0.84 | 16 | 455 | 2.1 | 5,110 |
| V-10 | VPV10IN | 2.4 | 4 | 19 | 2,300 | 7.1 | 5,980 |
| V-11 | VPV11PA1 | 0.089 | 0.41 | 7.3 | 605 | 0.6 | 32,700 |
| V-11 | VPV11PA2 | 0.22 | 1.2 | 11 | 932 | 2 | 39,700 |
| V-11 | VPV11IN | 0.39 | 3.6 | 18 | 2,470 | 6 | 11,300 |
| V-11 | VPV11FS | 0.12 | 0.2 | 4.9 | 151 | <0.4 | 5,580 |
| V-14 | VPV14PA1 | 0.44 | 8.6 | 10 | 5,080 | 14 | 8,360 |
| V-14 | VPV14PA2 | 0.4 | 4.9 | 8.6 | 3,480 | 9.6 | 7,770 |
| V-14 | VPV14IB1 | 0.3 | 0.59 | 13 | 368 | 0.8 | 1,180 |

Table 21.--Dry weight concentrations of trace elements in biota collected during the Vermejo reconnaissance study, summer 1993--Continued .

| Site number (fig. 6) | Sample number | Manganese (µg/g) | Mercury (µg/g) | Molybdenum (µg/g) | Nickel (µg/g) | Selenium (µg/g) | Strontium (µg/g) |
|---|---|---|---|---|---|---|---|
| V-01 | VPV1PA1 | 315 | 0.01 | <1 | 5.8 | 0.78 | 112 |
| V-01 | VPV1IB | 202 | 0.077 | <2 | 3.1 | 6.7 | 24.6 |
| V-01 | VPV1FS1 | 13 | 0.13 | <1 | 0.42 | 6.7 | 144 |
| V-02 | VPV2PA1 | 222 | <0.006 | <1 | 3.2 | <0.2 | 44.1 |
| V-02 | VPV2PA2 | 233 | <0.006 | <1 | 4.3 | 0.4 | 106 |
| V-02 | VPV2IB | 96.6 | 0.065 | <1 | 2.3 | 2 | 710 |
| V-02 | VPV2FS2 | 18 | 0.17 | <1 | 0.56 | 9.2 | 166 |
| V-02 | VPV2FS1 | 32.2 | 0.11 | <1 | 1.3 | 7.1 | 169 |
| V-05 | VPV5PA2 | 582 | <0.006 | <1 | 8.9 | 1.9 | 126 |
| V-05 | VPV5PA1 | 472 | <0.006 | <1 | 2.9 | 0.4 | 62.4 |
| V-05 | VPV5IB | 61.2 | 0.048 | <1 | 4 | 2 | 832 |
| V-05 | VPV5FS2 | 26.1 | 0.12 | <1 | 0.76 | 6.9 | 225 |
| V-05 | VPV5FS1 | 39.9 | 0.28 | <1 | 1.3 | 5.6 | 146 |
| V-09 | VPV9PA1 | 1,710 | <0.006 | 1 | 1.7 | 0.2 | 72.5 |
| V-09 | VPV9IB2 | 429 | 0.1 | <3 | 2.2 | 5.4 | 33.3 |
| V-09 | VPV9IB1 | 187 | 0.048 | <1 | 1.8 | 1.8 | 783 |
| V-09 | VPV9FS1 | 15 | 0.34 | <1 | 0.1 | 4.3 | 135 |
| V-09 | VPV9FS2 | 37.1 | 0.15 | <1 | 0.46 | 7.5 | 166 |
| V-10 | VPV10PA1 | 462 | 0.024 | <1 | 7.6 | 1.5 | 231 |
| V-10 | VPV10PA2 | 227 | <0.006 | <1 | 1.8 | 0.2 | 69.1 |
| V-10 | VPV10IB | 19.6 | 0.019 | <1 | 0.65 | 3.1 | 55.2 |
| V-10 | VPV10IN | 69.5 | 0.036 | <1 | 2.2 | 25 | 86.8 |
| V-11 | VPV11PA1 | 230 | <0.006 | <1 | 1.2 | 5.4 | 357 |
| V-11 | VPV11PA2 | 655 | <0.006 | 1 | 1.6 | 10 | 213 |
| V-11 | VPV11IN | 155 | 0.018 | <1 | 2 | 37 | 152 |
| V-11 | VPV11FS | 23.9 | 0.026 | <1 | <0.10 | 25 | 181 |
| V-14 | VPV14PA1 | 295 | 0.02 | <1 | 7.1 | 0.96 | 177 |
| V-14 | VPV14PA2 | 848 | 0.025 | <1 | 5.2 | 1.3 | 423 |
| V-14 | VPV14IB1 | 40.9 | 0.078 | <1 | 0.68 | 4.3 | 17.4 |

Table 21.--Dry weight concentrations of trace elements in biota collected during the Vermejo reconnaissance study, summer 1993--Continued

| Site number (fig. 6) | Sample number | Vanadium (µg/g) | Zinc (µg/g) |
|---|---|---|---|
| V-01 | VPV1PA1 | 14 | 33.3 |
| V-01 | VPV1IB | 10 | 122 |
| V-01 | VPV1FS1 | 0.8 | 110 |
| V-02 | VPV2PA1 | 2.3 | 16 |
| V-02 | VPV2PA2 | 8.2 | 31.1 |
| V-02 | VPV2IB | 2.2 | 69.4 |
| V-02 | VPV2FS2 | 1.2 | 133 |
| V-02 | VPV2FS1 | 4.1 | 158 |
| V-05 | VPV5PA2 | 13 | 32.7 |
| V-05 | VPV5PA1 | 4.2 | 20.1 |
| V-05 | VPV5IB | 1.8 | 59.2 |
| V-05 | VPV5FS2 | 2.4 | 164 |
| V-05 | VPV5FS1 | 4.3 | 136 |
| V-09 | VPV9PA1 | 2.7 | 13 |
| V-09 | VPV9IB2 | 5.4 | 185 |
| V-09 | VPV9IB1 | 1.7 | 67.7 |
| V-09 | VPV9FS1 | <0.3 | 76 |
| V-09 | VPV9FS2 | 2 | 171 |
| V-10 | VPV10PA1 | 23 | 27 |
| V-10 | VPV10PA2 | 4.5 | 39.6 |
| V-10 | VPV10IB | 1.8 | 69.5 |
| V-10 | VPV10IN | 8.9 | 76.2 |
| V-11 | VPV11PA1 | 1.5 | 11 |
| V-11 | VPV11PA2 | 5.3 | 14 |
| V-11 | VPV11IN | 7.5 | 67.4 |
| V-11 | VPV11FS | 0.4 | 171 |
| V-14 | VPV14PA1 | 16 | 22.3 |
| V-14 | VPV14PA2 | 12 | 22.1 |
| V-14 | VPV14IB1 | 1.1 | 71.9 |

Table 21.--Dry weight concentrations of trace elements in biota collected during the Vermejo reconnaissance study, summer 1993--Continued

| Site number (fig. 6) | Sample number | Specimen | Taxon | Sample type (and number) | Sample weight (grams) |
|---|---|---|---|---|---|
| V-14 | VPV14IB2 | Snails | Gastropoda | Invertebrate (>10) | 6.17 |
| V-14 | VPV14BF5 | White sucker | *Catostomus commersoni* | Whole fish (1) | 382 |
| V-14 | VPV14PF1 | Largemouth bass | *Micropterus salmoides* | Whole fish (4) | 302 |
| V-14 | VPV14BF4 | Black bullhead | *Ameiurus melas* | Fillets (4) | 43.3 |
| V-14 | VPV14BF1 | Black bullhead | *Ameiurus melas* | Fish w/o fillets (4) | 1,400 |
| V-14 | VPV14BF2 | Black bullhead | *Ameiurus melas* | Fillets (4) | 52.7 |
| V-14 | VPV14BF3 | Black bullhead | *Ameiurus melas* | Fish w/o fillets (4) | 1,140 |
| V-14 | VPV14PF4 | Yellow perch | *Perca flavescens* | Fillets (4) | 17.7 |
| V-14 | VPV14PF5 | Yellow perch | *Perca flavescens* | Fish w/o fillets (4) | 532 |
| V-14 | VPV14PF6 | Yellow perch | *Perca flavescens* | Fillets (4) | 37.4 |
| V-14 | VPV14PF3 | Yellow perch | *Perca flavescens* | Fish w/o fillets (4) | 330 |
| V-15 | VPV15PA1 | Elodea | *Elodea canadensis* | Submergent (>10) | 64.7 |
| V-15 | VPV15PA3 | Cattail | *Typha sp.* | Emergent (>10) | 46.6 |
| V-15 | VPV15PA2 | Cattail | *Typha sp.* | Emergent (>10) | 881 |
| V-15 | VPV15IB1 | Odonates | Odonata | Invertebrate (>10) | 10.3 |
| V-15 | VPV15IB2 | Snails | Gastropoda | Invertebrate (>10) | 4.67 |
| V-15 | VPV15BF1 | Black bullhead | *Ameiurus melas* | Fillets (4) | 9.56 |
| V-15 | VPV15BF2 | Black bullhead | *Ameiurus melas* | Fish w/o fillets (4) | 294 |
| V-15 | VPV15BF3 | Black bullhead | *Ameiurus melas* | Fillets (4) | 30.4 |
| V-15 | VPV15BF4 | Black bullhead | *Ameiurus melas* | Fish w/o fillets (4) | 777 |
| V-15 | VPV15PF1 | Largemouth bass | *Micropterus salmoides* | Fillets (2) | 57.3 |
| V-15 | VPV15PF6 | Largemouth bass | *Micropterus salmoides* | Fish w/o fillets (2) | 647 |
| V-15 | VPV15PF2 | Largemouth bass | *Micropterus salmoides* | Whole fish (2) | 29.0 |
| V-15 | VPV15PF3 | Green sunfish | *Lepomis cyanellus* | Fillets (4) | 21.6 |
| V-15 | VPV15PF5 | Green sunfish | *Lepomis cyanellus* | Fish w/o fillets (4) | 423 |
| V-15 | VPV15PF4 | Green sunfish | *Lepomis cyanellus* | Whole fish (4) | 122 |
| V-16 | VPV16PA2 | Filamentous algae | Chlorophyta | Submergent (>10) | 108 |
| V-16 | VPV16PA1 | Unknown | Anthophyta | Submergent (>10) | 276 |
| V-16 | VPV16PA3 | Alkali grass | Anthrophyta | Emergent (>10) | 76.8 |
| V-16 | VPV16IN1 | Water boatmen | *Hemiptera sp.* | Invertebrate (>10) | 37.8 |
| V-16 | VPV16IN2 | Brine flies | Diptera | Invertebrate (>10) | 7.5 |

Table 21.--Dry weight concentrations of trace elements in biota collected during the Vermejo reconnaissance study, summer 1993--Continued

| Site number (fig. 6) | Sample number | Moisture (percent) | Aluminum (µg/g) | Arsenic (µg/g) | Barium (µg/g) | Beryllium (µg/g) | Boron (µg/g) |
|---|---|---|---|---|---|---|---|
| V-14 | VPV14IB2 | 72.3 | 2,180 | 4.2 | 5.6 | 0.058 | 3 |
| V-14 | VPV14BF5 | 76.8 | 71 | 0.5 | 3.3 | <0.02 | <2.0 |
| V-14 | VPV14PF1 | 76.7 | 76 | 0.6 | 5.8 | <0.02 | <2.0 |
| V-14 | VPV14BF4 | 82.5 | <3 | <0.20 | 0.1 | <0.02 | <2.0 |
| V-14 | VPV14BF1 | 80.6 | 45 | 0.3 | 6 | <0.02 | <2.0 |
| V-14 | VPV14BF2 | 82.4 | 3 | <0.20 | 0.1 | <0.02 | <2.0 |
| V-14 | VPV14BF3 | 81.7 | 56 | <0.30 | 7.2 | <0.03 | <2.0 |
| V-14 | VPV14PF4 | 77.8 | 5 | <0.20 | 1.1 | <0.02 | <2.0 |
| V-14 | VPV14PF5 | 74.5 | 35 | 0.4 | 3 | <0.02 | <2.0 |
| V-14 | VPV14PF6 | 78.9 | 8 | <0.20 | 0.2 | <0.02 | <2.0 |
| V-14 | VPV14PF3 | 75.7 | 57 | 0.3 | 2.8 | <0.02 | <2.0 |
| V-15 | VPV15PA1 | 91.9 | 2,160 | 6.9 | 133 | 0.061 | 19 |
| V-15 | VPV15PA3 | 92.7 | 1,580 | 1.8 | 161 | 0.03 | 25 |
| V-15 | VPV15PA2 | 92.9 | 4,670 | 1.3 | 56.2 | 0.16 | 12 |
| V-15 | VPV15IB1 | 82.8 | 568 | 0.5 | 9.5 | <0.02 | 3 |
| V-15 | VPV15IB2 | 74.6 | 3,440 | 3.8 | 83.8 | 0.13 | 4 |
| V-15 | VPV15BF1 | 81.2 | 21 | <0.20 | 0.67 | <0.02 | <2.0 |
| V-15 | VPV15BF2 | 78.5 | 71 | 0.4 | 5.7 | <0.02 | <2.0 |
| V-15 | VPV15BF3 | 81.8 | 8 | <0.20 | 0.2 | <0.02 | <2.0 |
| V-15 | VPV15BF4 | 79.8 | 160 | 0.4 | 11 | <0.02 | 2 |
| V-15 | VPV15PF1 | 78.3 | 18 | <0.20 | 0.35 | <0.02 | <2.0 |
| V-15 | VPV15PF6 | 72.7 | 45 | 0.4 | 3.3 | <0.02 | <2.0 |
| V-15 | VPV15PF2 | 77.5 | 62 | 0.5 | 5.2 | <0.02 | <2.0 |
| V-15 | VPV15PF3 | 78.9 | 7 | <0.20 | 0.2 | <0.02 | <2.0 |
| V-15 | VPV15PF5 | 77.3 | 33 | 0.3 | 2.8 | <0.02 | <2.0 |
| V-15 | VPV15PF4 | 78.9 | 50 | 0.3 | 1.4 | <0.02 | <2.0 |
| V-16 | VPV16PA2 | 89.6 | 6,520 | 3.8 | 42.7 | 0.22 | 150 |
| V-16 | VPV16PA1 | 90.7 | 7,210 | 6.5 | 45.2 | 0.25 | 140 |
| V-16 | VPV16PA3 | 82.8 | 411 | 0.76 | 3 | <0.02 | 13 |
| V-16 | VPV16IN1 | 87.4 | 525 | 1 | 6.3 | <0.02 | 7.5 |
| V-16 | VPV16IN2 | 75.9 | 1,270 | 1.4 | 13.8 | <0.02 | 59 |

Table 21.--Dry weight concentrations of trace elements in biota collected during the Vermejo reconnaissance study, summer 1993--Continued

| Site number (fig. 6) | Sample number | Cadmium (µg/g) | Chromium (µg/g) | Copper (µg/g) | Iron (µg/g) | Lead (µg/g) | Magnesium (µg/g) |
|---|---|---|---|---|---|---|---|
| V-14 | VPV14IB2 | 0.25 | 1.9 | 20 | 1,300 | 3.5 | 1,460 |
| V-14 | VPV14BF5 | <0.02 | 0.09 | 2.6 | 97 | <0.4 | 1,100 |
| V-14 | VPV14PF1 | 0.05 | 0.1 | 4 | 96 | <0.4 | 1,250 |
| V-14 | VPV14BF4 | <0.02 | 0.1 | 1 | 39 | <0.4 | 1,380 |
| V-14 | VPV14BF1 | 0.03 | 0.1 | 2.7 | 188 | <0.4 | 1,500 |
| V-14 | VPV14BF2 | <0.02 | 0.1 | 1 | 49 | <0.4 | 1,390 |
| V-14 | VPV14BF3 | 0.05 | 0.1 | 3.3 | 186 | <0.4 | 1,630 |
| V-14 | VPV14PF4 | <0.02 | 0.2 | 1 | 13 | <0.4 | 1,400 |
| V-14 | VPV14PF5 | 0.03 | 0.09 | 1.8 | 67 | <0.4 | 1,210 |
| V-14 | VPV14PF6 | <0.02 | 0.1 | 2 | 10 | <0.4 | 1,480 |
| V-14 | VPV14PF3 | 0.05 | 0.2 | 3.1 | 80 | <0.4 | 1,140 |
| V-15 | VPV15PA1 | 0.2 | 2.1 | 5.7 | 1,230 | 3.6 | 11,800 |
| V-15 | VPV15PA3 | 0.16 | 1.8 | 5 | 855 | 2.6 | 6,530 |
| V-15 | VPV15PA2 | 0.19 | 3.7 | 6.2 | 2,720 | 7.2 | 3,460 |
| V-15 | VPV15IB1 | 0.13 | 0.63 | 14 | 333 | 1 | 1,220 |
| V-15 | VPV15IB2 | 0.46 | 4.2 | 22 | 3,380 | 6 | 2,450 |
| V-15 | VPV15BF1 | 0.04 | 0.2 | 1 | 66 | <0.4 | 1,390 |
| V-15 | VPV15BF2 | 0.067 | 0.1 | 5.3 | 164 | <0.4 | 1,100 |
| V-15 | VPV15BF3 | 0.09 | <0.09 | 1 | 45 | <0.4 | 1,410 |
| V-15 | VPV15BF4 | 0.05 | 0.1 | 3 | 225 | <0.4 | 1,420 |
| V-15 | VPV15PF1 | <0.02 | 0.1 | <0.9 | 9.4 | <0.4 | 1,450 |
| V-15 | VPV15PF6 | 0.03 | <0.09 | 2.2 | 65 | <0.4 | 1,200 |
| V-15 | VPV15PF2 | 0.03 | <0.09 | 2.1 | 63 | <0.4 | 1,370 |
| V-15 | VPV15PF3 | 0.076 | 0.4 | 2 | 13 | 0.7 | 1,480 |
| V-15 | VPV15PF5 | <0.02 | <0.09 | 2.2 | 68 | <0.4 | 1,250 |
| V-15 | VPV15PF4 | <0.02 | 0.1 | 2.7 | 74 | <0.4 | 1,110 |
| V-16 | VPV16PA2 | 0.81 | 4.7 | 11 | 3,320 | 9.8 | 27,800 |
| V-16 | VPV16PA1 | 0.32 | 4.6 | 6.9 | 3,710 | 9.8 | 28,700 |
| V-16 | VPV16PA3 | 0.098 | 0.79 | 9.8 | 350 | 0.7 | 6,310 |
| V-16 | VPV16IN1 | 0.29 | 0.55 | 14 | 393 | 0.9 | 9,130 |
| V-16 | VPV16IN2 | 0.56 | 1.3 | 17 | 951 | 2.4 | 5,350 |

Table 21.--Dry weight concentrations of trace elements in biota collected during the Vermejo reconnaissance study, summer 1993--Continued

| Site number (fig. 6) | Sample number | Manganese (µg/g) | Mercury (µg/g) | Molybdenum (µg/g) | Nickel (µg/g) | Selenium (µg/g) | Strontium (µg/g) |
|---|---|---|---|---|---|---|---|
| V-14 | VPV14IB2 | 142 | 0.028 | <1 | 2.2 | 0.99 | 634 |
| V-14 | VPV14BF5 | 7.8 | 0.054 | <1 | <0.10 | 2.9 | 64.4 |
| V-14 | VPV14PF1 | 8.2 | 0.21 | <1 | 0.2 | 3.3 | 117 |
| V-14 | VPV14BF4 | 0.3 | 0.87 | <1 | <0.10 | 0.77 | 1.94 |
| V-14 | VPV14BF1 | 14 | 0.42 | <1 | 0.1 | 2 | 225 |
| V-14 | VPV14BF2 | 0.3 | 0.833 | <1 | <0.10 | 0.91 | 2.63 |
| V-14 | VPV14BF3 | 14 | 0.501 | <1 | 0.1 | 2 | 256 |
| V-14 | VPV14PF4 | 3.4 | 0.31 | <1 | <0.10 | 2.8 | 25.2 |
| V-14 | VPV14PF5 | 12 | 0.23 | <1 | 0.2 | 2.6 | 123 |
| V-14 | VPV14PF6 | 1.5 | 0.43 | <1 | <0.10 | 3.2 | 9.27 |
| V-14 | VPV14PF3 | 9 | 0.23 | <1 | 0.1 | 2.8 | 92.6 |
| V-15 | VPV15PA1 | 140 | 0.008 | 1 | 2.6 | 0.76 | 345 |
| V-15 | VPV15PA3 | 165 | 0.02 | <1 | 2.3 | 1 | 387 |
| V-15 | VPV15PA2 | 171 | <0.006 | <1 | 2.9 | 0.3 | 111 |
| V-15 | VPV15IB1 | 21.2 | 0.093 | <1 | 0.51 | 2.8 | 62.5 |
| V-15 | VPV15IB2 | 106 | 0.01 | <1 | 3.6 | 1.7 | 951 |
| V-15 | VPV15BF1 | 1.3 | 0.684 | <1 | <0.10 | 1.2 | 8.7 |
| V-15 | VPV15BF2 | 8.9 | 0.37 | <1 | 2.1 | 2.3 | 99.6 |
| V-15 | VPV15BF3 | 0.5 | 0.902 | <1 | <0.10 | 1.1 | 2.14 |
| V-15 | VPV15BF4 | 15 | 0.516 | <1 | 0.2 | 2 | 188 |
| V-15 | VPV15PF1 | 1.4 | 0.714 | <1 | <0.10 | 2.8 | 14.8 |
| V-15 | VPV15PF6 | 10 | 0.37 | <1 | <0.10 | 2.5 | 142 |
| V-15 | VPV15PF2 | 18 | 0.29 | <1 | 0.2 | 2.4 | 171 |
| V-15 | VPV15PF3 | 1.3 | 0.914 | <1 | 0.4 | 2.5 | 7.7 |
| V-15 | VPV15PF5 | 13 | 0.509 | <1 | <0.10 | 2.9 | 149 |
| V-15 | VPV15PF4 | 5.2 | 0.36 | <1 | 0.2 | 2.9 | 55.9 |
| V-16 | VPV16PA2 | 730 | <0.006 | <1 | 4 | 2.5 | 82.6 |
| V-16 | VPV16PA1 | 981 | <0.006 | 2 | 4.2 | 6.2 | 388 |
| V-16 | VPV16PA3 | 280 | <0.006 | 1 | 0.86 | 1.3 | 29 |
| V-16 | VPV16IN1 | 81.7 | 0.016 | <1 | 0.63 | 13 | 97.4 |
| V-16 | VPV16IN2 | 154 | 0.052 | <1 | 0.99 | 39 | 47.2 |

Table 21.--Dry weight concentrations of trace elements in biota collected during the Vermejo reconnaissance study, summer 1993--Concluded

| Site number (fig. 6) | Sample number | Vanadium (µg/g) | Zinc (µg/g) |
|---|---|---|---|
| V-14 | VPV14IB2 | 4.2 | 21 |
| V-14 | VPV14BF5 | 0.4 | 46.5 |
| V-14 | VPV14PF1 | <0.3 | 68.6 |
| V-14 | VPV14BF4 | <0.3 | 20 |
| V-14 | VPV14BF1 | 0.5 | 81.5 |
| V-14 | VPV14BF2 | <0.3 | 20 |
| V-14 | VPV14BF3 | 0.7 | 83.5 |
| V-14 | VPV14PF4 | <0.3 | 29.2 |
| V-14 | VPV14PF5 | <0.3 | 67.4 |
| V-14 | VPV14PF6 | <0.3 | 25.3 |
| V-14 | VPV14PF3 | <0.3 | 60.3 |
| V-15 | VPV15PA1 | 5.4 | 41.5 |
| V-15 | VPV15PA3 | 4.3 | 10 |
| V-15 | VPV15PA2 | 11 | 31.7 |
| V-15 | VPV15IB1 | 1.2 | 68.7 |
| V-15 | VPV15IB2 | 11 | 31.1 |
| V-15 | VPV15BF1 | <0.3 | 22 |
| V-15 | VPV15BF2 | <0.3 | 70.3 |
| V-15 | VPV15BF3 | <0.3 | 19 |
| V-15 | VPV15BF4 | 0.6 | 73.6 |
| V-15 | VPV15PF1 | <0.3 | 29.3 |
| V-15 | VPV15PF6 | <0.3 | 61.8 |
| V-15 | VPV15PF2 | <0.3 | 78.2 |
| V-15 | VPV15PF3 | <0.3 | 31 |
| V-15 | VPV15PF5 | <0.3 | 92.7 |
| V-15 | VPV15PF4 | <0.3 | 69.3 |
| V-16 | VPV16PA2 | 12 | 14 |
| V-16 | VPV16PA1 | 15 | 18 |
| V-16 | VPV16PA3 | 1.3 | 19.4 |
| V-16 | VPV16IN1 | 1.2 | 120 |
| V-16 | VPV16IN2 | 2.9 | 75.6 |

Table 22.--Concentrations of selected organic compounds in bottom sediment collected during the Vermejo reconnaissance study, September 1993

[°C, degrees Celsius; $ft^3/s$, cubic feet per second; mg/kg, micrograms per kilogram; <, less than]

| Property or compound | Site number (fig. 6) | |
|---|---|---|
| | V-05 | V-09 |
| Date | 09-07-93 | 09-07-93 |
| Water temperature (°C) | 20.5 | 20.0 |
| Discharge ($ft^3/s$) | 15 | 20 |
| PCN (µg/kg) | <1.0 | <1.0 |
| Aldrin (µg/kg) | <0.1 | <0.1 |
| Lindane (µg/kg) | <0.1 | <0.1 |
| Chordane (µg/kg) | 1.0 | <1.0 |
| DDD (µg/kg) | <0.1 | 0.2 |
| DDE (µg/kg) | 0.1 | 0.1 |
| DDT (µg/kg) | <0.3 | <0.1 |
| Dieldrin (µg/kg) | <0.1 | <0.1 |
| Endosulfan (µg/kg) | <0.1 | <0.1 |
| Endrin (µg/kg) | <0.2 | <0.3 |
| Ethion (µg/kg) | <0.1 | <0.1 |
| Toxaphene (µg/kg) | <10 | <10 |
| Heptachlor (µg/kg) | <0.1 | <0.1 |
| Heptachlor epoxide (µg/kg) | <0.1 | <0.1 |
| Methoxychlor (µg/kg) | <0.1 | <0.1 |
| PCB (µg/kg) | <1 | <1 |
| Malathion (µg/kg) | <0.1 | <0.1 |
| Parathion (µg/kg) | <0.1 | <0.1 |
| Diazinon (µg/kg) | <0.1 | <0.1 |
| Methyl parathion (µg/kg) | <0.1 | <0.1 |
| Mirex (µg/kg) | <0.1 | <0.1 |
| Trithion (µg/kg) | <0.1 | <0.1 |
| Perthane (µg/kg) | <1.00 | <1.00 |



* U.S. GOVERNMENT PRINTING OFFICE: 1996-777-218