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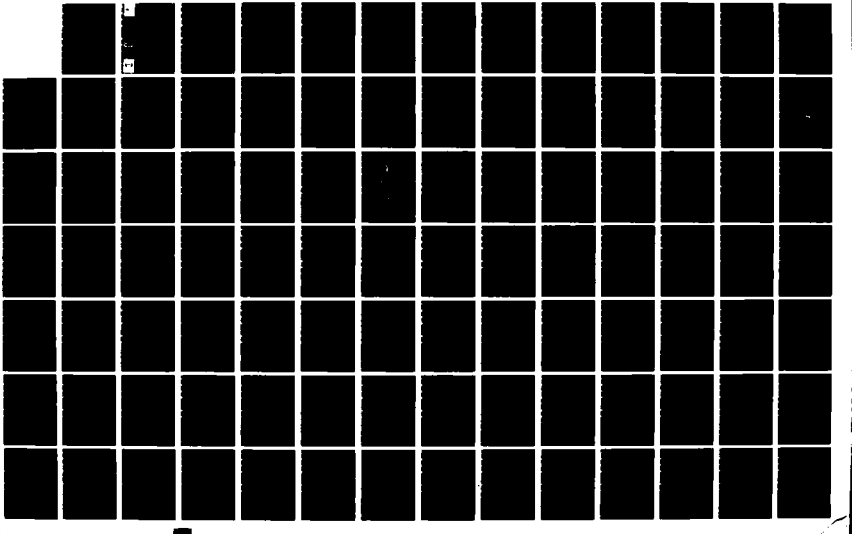

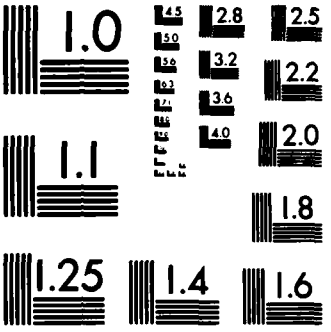

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REMEDIAL INVESTIGATION OF CONTAMINANT MOBILITY AT NAVAL WEAPONS STATION, CONCORD, CALIFORNIA

by

Charles R. Lee, L. Jean O'Neil, Ellis J. Clairain, Dennis L. Brandon, Richard G. Rhett, Dana R. Sanders, John G. Skogerboe, Stratford H. Kay, Bobby L. Folsom, Jr., James S. Wakeley, Thomas H. Roberts, Karen M. Saddler, David R. Kendall, John D. Lunz

Environmental Laboratory

DEPARTMENT OF THE ARMY
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PO Box 631, Vicksburg, Mississippi 39180-0631

January 1986
Final Report

Prepared for
DEPARTMENT OF THE NAVY
Naval Facilities Engineering
Command, Western Division
San Bruno, California 94066

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

A remedial investigation was conducted at Naval Weapons Station, Concord, California, to determine the nature and extent of contamination of wetland and terrestrial environments. The evaluation considered major pathways of contaminant migration including soil, water, air and biota. Major testing was conducted on soil and the biological components of the pathways. Chemical analysis of soil samples indicated substantial elevation in arsenic, cadmium, lead,

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20. ABSTRACT (Continued).

selenium, zinc and copper in certain contaminated areas. Field conducted clam bioassays showed a moderate potential for lead, cadmium and zinc to bioaccumulate in clams placed in surface waters of a limited number of sampling sites. Plant and earthworm bioassays indicated substantial movement of arsenic, cadmium, lead, selenium, zinc and copper into plants and soil-dwelling organisms in contaminated areas. A definite threat of these contaminants to impact wildlife, especially the endangered species that inhabit the contaminated sites, was strongly suggested by the toxicological effects of these metals on birds and mammals. A hydrological evaluation indicated substantial movement of hazardous substances into surface waters during storm events and high tides. A comprehensive evaluation of natural resources indicated that the wetland areas have moderate to high functional values for wildlife habitat, food chain support, flood storage, shoreline anchorage, sediment trapping, nutrient retention and passive recreation and heritage. A habitat evaluation for selected wildlife species indicated high to moderate potential value of upland areas and ranged from good to poor for California black rails and from moderate to poor for salt marsh harvest mice within the contaminated wetland areas. The results of this remedial investigation will be the basis for a feasibility study of remedial actions and an assessment of damage to natural resources.

EXECUTIVE SUMMARY

Contaminant presence and mobility at Naval Weapons Station (NWS), Concord, California, is the subject of this report. The US Army Engineer Waterways Experiment Station on behalf of Department of the Navy conducted a remedial investigation study to evaluate the nature and extent of contamination existing at the NWS Concord. The evaluation considered pathways of contaminant mobility including soil, water, air, and biota. Major testing was conducted on soil and the biological components of the pathways. Soil samples were collected to determine the nature and extent of the contamination present on site. Field-collected plant samples and bioassays using clams, earthworms, and plants were conducted to determine the potential for mobility of contaminants into the biological components of the food chains associated with the study area.

Chemical analysis of soil samples indicated substantial elevation in arsenic, cadmium, lead, selenium, zinc, and copper in certain contaminated areas. These areas were identified. Test results of the clam bioassay indicated that there was a moderate potential for lead, cadmium, and zinc to move into surface waters in limited sampling sites at NWS Concord. For the most part, metal movement into surface waters was restricted to the Kiln Site (KS) on Parcel 572, the Getty Oil Site (G-1, Parcel 575), Parcel 576 located between the railroad tracks and between Sites G-1 and ES, and the site adjacent to the Chemical and Pigment Company property (Site ES, Parcel 579D). Plant and earthworm bioassays indicated substantial movement of certain metals such as arsenic, cadmium, lead, selenium, zinc, and copper into plants and soil-dwelling organisms in contaminated areas. These test results indicated a high potential for the contamination of plants and soil-dwelling organisms with arsenic, cadmium, lead, and selenium. This movement of contaminants from the soil into plants and soil-dwelling organisms is the initial movement of contaminants into the food chains associated with the wetland and upland environments. The threat of these contaminants to impact wildlife, especially the endangered species that inhabit the contaminated sites, was evaluated on the basis of existing literature and knowledge of the toxicological effects of these metals on bird and mammals. Certain areas at NWS Concord are heavily contaminated compared to acceptable levels of metals in both soil and biological tissue. Evaluation of these data indicates a high potential for toxicological impacts. These areas on NWS Concord provide habitat for rare and endangered species that are being exposed to toxic heavy metals in their feeding habits. There is considerable evidence that birds and mammals that exist in environments contaminated with heavy metals generally build up elevated concentrations of these metals in their bodies. They probably do this by ingestion of these materials through the food chain, by drinking contaminated water, or by inhalation. In any case, at NWS Concord, a high potential exists for the contamination of species higher on the food chain, such as carnivorous birds and mammals, with toxic heavy metals. These toxic heavy metals, particularly lead and cadmium, are extremely persistent in animal tissues. From a toxicological perspective, the contamination present is a long-term chronic problem.

Hydrological evaluations were conducted to determine the pathways for movement of contaminants from sources, through surface waters, into wetland areas and into Suisun Bay. The soils of the tidal area at NWS Concord are generally underlain by clay silts of low permeability so that contaminant movement downward into groundwater is considered unlikely. Substantial

movement of hazardous substances occurs from sources into surface waters during storm events and high tides. Stream sediment erosion occurs in Nichols Creek at peak discharges of 94 cfs (5-year storm event) or more. A 2-year storm event will cause ponding behind a small culvert on the G-1 site (Parcel 575) and overflow across G-1 into a ditch that carries surface runoff into the culvert onto the KS site of Parcel 572. Predicted flood flows from a 25-year storm can carry suspended solids from Nichols Creek over the embankment in G-1 area into the culvert that empties into the KS site. In addition, contaminated soil is suspended in storm-water runoff from barren unvegetated sites and carried into streams and drainage ditches. Predicted 10-year high tides will completely flood the marsh plain to depths of two and one-half feet. Wave action generated from the long fetch of Suisun Bay to the west will erode surface sediments and redistribute them throughout the marsh and into Suisun Bay. These hydrologic conditions at NWS Concord indicate the potential for substantial movement of hazardous substances into the environment.

A comprehensive evaluation of natural resources was conducted to assess wetland functional values, plant and macroinvertebrate communities, and wildlife habitat. The results of this evaluation indicated that the wetland areas have moderate to high functional values for wildlife habitat, food chain support, flood storage, shoreline anchorage, sediment trapping, nutrient retention, and passive recreation and heritage. A lower potential value was determined for fishery habitat, ground-water recharge or discharge, and active recreation. The macroinvertebrate community study showed significantly lower numbers and diversity of species in the contaminated wetland site in comparison to a reference site. Plant and earthworm bioassay test results confirmed the toxic nature of the contamination. The food chains associated with the contaminated sites may include as many as eight rare or endangered species, two of which (salt marsh harvest mouse and California black rail) are confirmed year-round residents of the contaminated marsh. A habitat evaluation for selected wildlife species on the upland area indicated high to moderate potential value as wildlife habitat. Habitat quality within the contaminated marsh ranged from good to poor for California black rails and from moderate to poor for salt marsh harvest mice. Environmental features of the contaminated areas, such as plant cover, attract wildlife and consequently allow exposure to toxic metal contamination.

The results of this investigation will be the basis for a feasibility study of remedial actions for the contaminated areas and an assessment of damage to natural resources.

PREFACE

This report presents the results of a comprehensive remedial investigation of contaminant mobility at Naval Weapons Station, Concord California.

This study was conducted by the US Army Engineer Waterways Experiment Station (WES) during the period July 1984 through August 1985 by Dr. C. R. Lee, Soil Scientist, and Chief, Contaminant Mobility and Regulatory Criteria Group; Ms. L. J. O'Neil, Wildlife Biologist and Ecologist; and Mr. E. J. Clairain, Jr., Aquatic Biologist, under the general supervision of Mr. D. L. Robey, Chief, Ecosystem Research and Simulation Division; Dr. C. Kirby, Chief, Environmental Resources Division; and Dr. J. Harrison, Chief, Environmental Laboratory.

Technical contributions in the conduct of field sampling, laboratory testing, and report preparation were received from the following WES scientists: Mr. D. L. Brandon, Statistician, for experimental design, chain of custody labelling and data analysis; Dr. J. W. Simmers, Research Biologist, Mr. R. G. Rhett, Biologist, and Dr. S. H. Kay, Aquatic Biologist, for the clam and earthworm bioassay; Dr. B. L. Folsom, Jr., Soil Scientist, for the plant bioassay and field plant and soil sample collection; Mr. J. G. Skogerboe, Hydrologist, for surveying sample-site locations and map preparation; Ms. L. J. O'Neil, Ecologist, Dr. T. H. Roberts, Research Biologist, and Dr. J. S. Wakeley, Wildlife Biologist, for wildlife habitat evaluation; Dr. D. R. Sanders, Plant Physiologist, and Mr. R. F. Theriot, Biologist, for wetland characterization; Mr. E. J. Clairain, Jr., Aquatic Biologist, for the evaluation of wetland functional values; Dr. J. D. Lunz, Research Marine Biologist, Dr. D. R. Kendall, Aquatic Biologist, and Dr. T. J. Fredette, Marine Biologist, for fishery evaluation; Mr. R. W. Price, Agronomist, Mr. D. Crawley, Ecologist, and Mr. M. Richards, Biologist, for conducting field sampling and laboratory testing; Mr. J. Brandon, Biologist, Ms. C. Teeter. Biologist, and Ms. M. Barton, Chemist, for laboratory testing; and Mr. D. Brown, Chemist, and Mr. C. White, Chemist, for metal analysis of soil, plant, and animal samples. Additional assistance in manuscript preparation was received from Ms. M. N. Albritton, Ms. M. A. Tweedle, Mr. P. Pikul, Mr. D. Leflore, Mr. E. Rogers, and Ms. Ora Flagg. Assistance in special handling of reports to and from reviewers was received from Ms. R. Thurston. Captain T. Higgins assisted in compiling review comments and the preparation

of the drafts. Dr. C. R. Lee served as the overall project leader.

Technical contributions were received from Dr. C. T. Hackney, Research Estuarine Ecologist, and Dr. M. LaSalle, Estuarine Ecologist, at University of North Carolina, Wilmington, N. C., for the wetland soil invertebrate evaluation; Dr. R. J. Kendall, Environmental Toxicologist, Environmental Toxicological Services, Bellingham, Washington, for the toxicological evaluation; and Dr. P. B. Williams, Hydraulic Engineer, and Dr. R. N. Coats, Senior Associate, Philip Williams and Associates, San Francisco, California, for the hydrological evaluation.

Peer review and constructive comments on the study and draft reports were received from Dr. K. D. Jenkins, Director, Molecular Ecology Institute, California State University, Long Beach, California; Dr. W. H. Patrick, Jr., Director, Center for the Wetland Resources, Louisiana State University, Baton Rouge, La.; Dr. R. J. Kendall, Environmental Toxicological Services, Bellingham, Washington; Dr. R. K. Ringer, Professor of Physiology and Animal Science, Michigan State University, East Lansing, Michigan; Dr. S. A. Peoples, Professor Emeritus, Mammalian Toxicology, University of California, Davis, California; Dr. M. N. Josselyn, Director, Tiburon Center for Environmental Studies, San Francisco State University, Tiburon, California; Dr. H. T. Harvey, Professor Emeritus, Biology, San Jose State University, San Jose, California, and Ecologist and President, Harvey and Stanley Associates Inc., Alviso, California; Dr. E. Meyers, Chemist, Meyer Consultants Inc., Lockport, Illinois; Dr. P. B. Williams, Hydraulic Engineer, and Dr. R. N. Coats, Wildlife Resource Scientist, Philip Williams and Associates, San Francisco, California; and WES scientists: Dr. R. K. Peddicord, Research Biologist; Dr. T. M. Dillon, Aquatic Biologist; Dr. H. E. Tatem, Zoologist; Mr. V. A. McFarland, Aquatic Biologist; and Dr. R. N. Engler, Soil Scientist and Program Manager for Environmental Effects of Dredging Program.

Additional review and comments were received from Mr. R. M. Cornelius, Esq, and Mr. J. M. Robertson, Esq, Office of the General Counsel, Department of the Navy, Washington, D.C.; Mr. C. Schwab, Environmental Engineer, Western Division Naval Facilities Engineering Command, San Bruno, California; and W. K. Vizza, Public Works Officer, and Capt. G. G. Mays, Commanding Officer, Naval Weapons Station Concord, California.

Director of WES during the preparation of this report was COL Allen F. Grum, USA. Technical Director was Dr. Robert W. Whalin.

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NAVAL WEAPONS STATION, CONCORD, CALIFORNIA

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GLOSSARY

Substantial --- A real, actual amount, not imaginary.

Significant --- Statistically significant at a probability of occurring 95 percent of the time.

Potential ----- Is definitely possible, but may not have occurred yet.

Low ---------- Of little quantity, degree, value.

Moderate ------ Within reasonable limits, more than low, less than high.

High ---------- Greater in quantity, degree, value.

Excessive ----- An amount of quantity greater than desirable.

Low Potential - Little possibility of occurring, 10 percent or less probability of occurrence.

Moderate Potential --- 50 percent probability of occurrence.

High Potential --- 75 percent or more probability of occurrence.

Tidal Area ---- General term referring to wetland and transition zones that are influenced by tidal action at NWS Concord.

ANOVA --------- A statistical analysis of data to determine significant difference among data.

Mean Standing Stock ------- An average weight of plant material per area of ground.

Toxicity ------ Stress in plants and animals that can lead to death or chlorosis in plants or a 50-percent reduction in the growth and yield of plants and animals.

Mobility ------ Movement of contaminant from soil into air, water, or biological component of the environment under natural transport processes.

Distribution -- Areal extent of the presence of elevated concentrations of contaminants in surface soil.

1.0 INTRODUCTION

1.1 Site Background

The Naval Weapons Station (NWS), Concord, California, is the major ammunition transshipment port on the west coast for the Department of the Navy. It is located approximately 30 miles northeast of San Francisco on Suisun Bay (Figure 1-1). The NWS Concord encompasses 12,922 acres, including both inland areas and tidal marsh. Suisun Bay is a transition zone between saltwater and freshwater ecosystems, containing a diverse population of fish, benthic organisms, and zooplankton. The lower wetland portions of the tidal area are characterized by vegetation which tolerates frequent inundation by brackish water. The dryer upland portion of the tidal area and all of the inland area are essentially grasslands. The contaminated areas addressed in this report include portions of eight parcels of land on Concord: Parcels 571, 572, 573, 574, 575, 576, 579D, and 581. (Details of each parcel are given in 1.3). These parcels encompass approximately 210 acres and include both wetland and upland portions of the tidal plain adjacent to Suisun Bay.

The Navy acquired these parcels in 1969-1970 to create a buffer zone around its facilities. The United States purchased Parcel 571, on behalf of the Navy, from the Santa Fe Railway Foundation, Inc., on 7 November 1969. Parcel 571 contains approximately 11.314 acres of land. The United States acquired Parcel 572, on behalf of the Navy, from Allied Chemical Corporation on 13 November 1969 by declaration of taking. Parcel 572 contains approximately 121.144 acres of land. The United States purchased Parcel 573, on behalf of the Navy, from Santa Fe Railroad Foundation, Inc., on 7 November 1969. Parcel 573 contains approximately 11.533 acres of land. The United States acquired Parcel 574, on behalf of the Navy, from Elaine A. Nelson on 23 December 1968 by declaration of taking. Parcel 574 contains approximately 11.01 acres of land. The United States purchased Parcel 575, on behalf of the Navy, from Getty Oil Company on 26 January 1971. Parcel 575 contains approximately 8.96 acres of land. The United States acquired Parcel 576, on behalf of the Navy, from Marcus H. Gower, Douglas N. Griffin, and Sylvia N. Griffin on 21 June 1971 by declaration of taking. Parcel 576 contains approximately 1.50 acres of land. The United States acquired Parcel 579D, on behalf of the Navy, from Fred H. Hewins, Marguerite Tomas, Bluette Basset,

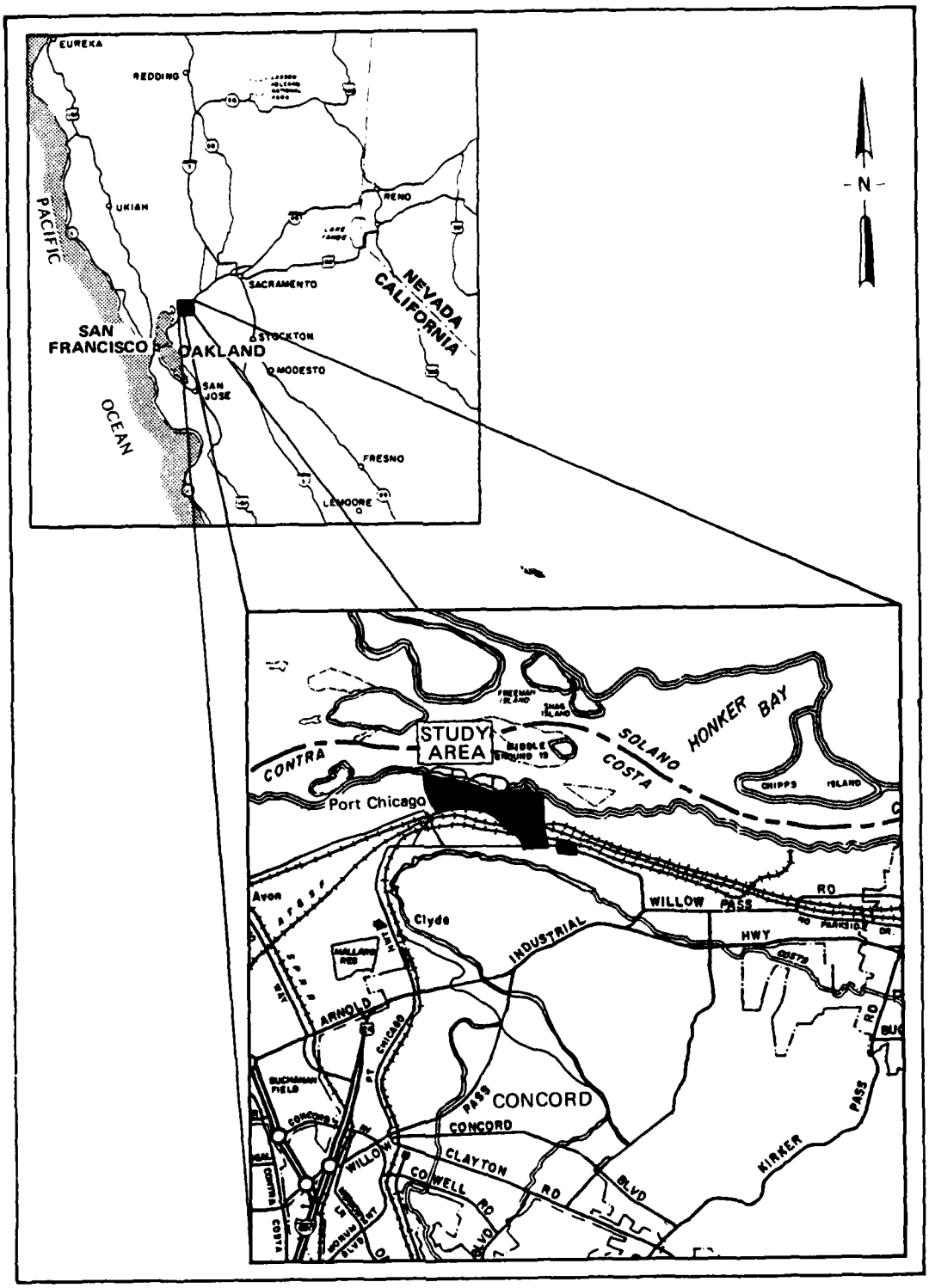


Figure 1-1. Location of study areas at NWS Concord

Robert Butzberger, Paulette Heubi, Karl Grauwiler, Rudolph Alexander Grauwiler, and Marianne Grauwiler Konig on 24 November 1975 by declaration of taking. Parcel 579D contains approximately 5.437 acres of land. The United States acquired Parcel 581, on behalf of the Navy, from Joe Sobotka and Wilda D. Sobotka on 23 December 1968 by declaration of taking. Parcel 581 contains approximately 10.27 acres of land. In 1981-1982, the State of California notified the Navy that portions of these parcels were contaminated with hazardous substances.

1.2 Naval Response to Contamination

By Executive Order 12316, the President delegated authority to respond to the release, or the threat of release, of hazardous substances on Department of Defense property under Section 104 of the Comprehensive Environmental Response, Compensation, and Liability Act to the Department of Defense. 46 Fed. Reg. 42237 (14 August 1981). On 2 November 1981, the Secretary of Defense in turn delegated such authority to respond to releases or threatened releases of hazardous substances to the Secretary of the Navy.

The Navy responds to the release or the threat of release of hazardous substances on its property through its Navy Assessment and Control of Installation Pollutants (NACIP) Program. The purpose of the program is to identify, assess, and control the contamination of Navy property by hazardous substances.

Under the NACIP Program, the Navy responds to the release or the threat of release of hazardous substances in a phased approach. In the first phase of the NACIP program, which the Navy calls Initial Assessment, all evidence which indicates that hazardous substances may have been released or may threaten to be released on Navy property must be collected and evaluated. Upon completion of its Initial Assessment Study of the contaminated sites at NWS Concord in October 1984, the Navy concluded that portions of Parcels 571, 572, 573, 574, 575, and 581 had been contaminated with hazardous substances including arsenic, lead, copper, cadmium, zinc, and selenium.

During the second phase of the NACIP Program, field studies must be conducted to confirm or deny the release or the threat of release of hazardous substances on Navy property and to define the extent or harm or threat of harm to the environment and the damage or threat of damage to the natural resources

on Navy property. The Navy calls the second phase of the NACIP Program the Confirmation phase.

From 1981-1983, the Navy had soil and water sampling and analyses conducted on Parcels 571, 572, 573, 574, 575, 576, 579D, and 581 to confirm or deny hazardous substance contamination on those parcels. The results of those sampling activities indicated that substantial releases of hazardous substances had occurred and demonstrated the need to conduct additional and more detailed investigation.

In June 1984, the Navy requested the US Army Corps of Engineers, Waterways Experiment Station (WES), to conduct additional studies to confirm or deny the release or threat of release of hazardous substances on Parcels 571, 572, 573, 574, 575, 576, 579D, and 581 of NWS Concord, and to define the extent of harm or threat of harm to the environment and the damage or threat of damage to the natural resources on these eight parcels on NWS Concord. The objectives of the study conducted by the WES were:

a. To define the nature and extent of the hazardous substance contamination
on the property.

b. To assess the bioavailability, mobility, and toxicity of the hazardous substances to plant and animal species on the property.

c. To identify the sources of the hazardous substances detected on the property.

d. To evaluate the extent of the migration of the hazardous substances on the property.

e. To evaluate the condition of the wetland and upland habitats on the property.

Federal statutes, regulations, and other authorities with which the Navy may have to comply in responding to the release or the threat of the release of hazardous substances on Parcels 571, 572, 573, 574, 575, 576, 579D, and 581 of NWS Concord include:

1. The Comprehensive Environmental Response, Compensation and Liability Act, 42 U.S.C. 9601 et seq.

2. The Resource Conservation and Recovery Act, 42 U.S.C. 9601 et. seq.

3. The Federal Water Pollution Control Act, 33 U.S.C. 1251 et. seq.

4. The River and Harbor Act, 33 U.S.C. 401 et. seq.

5. The Endangered Species Act, 16 U.S.C. 1531 et. seq.

6. The Migratory Bird Conservation Act, 16 U.S.C. 703 et. seq.

7. The Safe Drinking Water Act, 42 USC 300 f et. seq.

8. The National Oil and Hazardous Substances Contingency Plan, 40 C.F.R. Part 300.

9. Solid Waste, 40 C.F.R. Subchapter I.

10. Designation of Hazardous Substances, 40 C.F.R. Part 116.

11. Determination of Reportable Quantities for Hazardous Substances, 40 C.F.R. Part 117.

12. Regulatory Programs of the Corps of Engineers, 33 C.F.R. Parts 320-330.

13. Section 404 (b) (i) Guidelines for Specification of Disposal Sites for Dredged or Fill Material, 40 C.F.R. Part 230.

14. Endangered and Threatened Wildlife and Plants, 50 C.F.R. Part 17.

15. Responses to Environmental Damage, Executive Order 12316, 46 Fed. Reg. 42237 (14 August 1981).

16. Protection of Wetlands, Executive Order 11990, 42 Fed. Reg. 26961 (25 May 1977).

17. Memorandum of Understanding Between the Department of Defense and the Environmental Protection Agency for the Implementation of P.L. 96-510, The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (12 August 1983).

18. Memorandum of Understanding Between the Department of the Navy and The U. S. Fish and Wildlife Service Relating to Designation of Wetland Preserve on the Naval Weapons Station, Concord, California.

19. Region IV Oil and Hazardous Substance Pollution Contingency Plan.

20. Memorandum from Secretary of Defense (2 November 1981).

21. Navy Assessment and Control of Installation Pollutants Program.

State statutes and regulations which may provide guidance to the Navy in responding to the release or the threat of the release of the hazardous substances on Parcels 571, 572, 573, 574, 575, 576, 579D, and 581 include:

22. The California Solid Waste Management, Resource Recovery and Recycling Act of 1972, California Government Code, Title 7.3, Chapter 1, Section 66700, et. seq.

23. The California Hazardous Waste Control Act, California Health and Safety Code, Division 20, Chapter 6.5, Section 25100, et. seq.

24. The California Underground Storage of Hazardous Substances Act, California Health and Safety Code, Chapter 6.7, Section 25280 et. seq.

25. The California Porter-Cologne Water Quality Act, California Water Code, Division 7, Section 13000 et. seq.

26. The California Coastal Act, California Public Resources Code, Division 20, Section 30000 et. seq.

27. Migratory Birds, Article 3, Sections 355-357, Fish and Game Commission, California Fish and Game Code, Division 1, Section 101 et. seq.

28. Keene-Nejedly California Wetlands Preservation Act, California Public Resources Code, Chapter 7, Section 5810 et. seq.

29. San Francisco Bay Conservation and Development Commission, California Government Code, Title 7.2, Section 66600, et. seq.

30. Suisun Marsh Preservation Act of 1977, Public Resources Code, Division 18, Chapter 3, Section 29200 et. seq.

31. Endangered Species, Chapter 1.5, Section 2050 et. seq., California Fish and Game Commission, California Fish and Game Code, Div. 3, Section 2000 et. seq.

32. California Hazardous Waste Management Regulations, California Administrative Code 1 - Title 22, Social Security, Division 4, Environmental Health, Chapter 30 Minimum Standards for Management of Hazardous, and Extremely Hazardous Wastes.

33. California Water Regulations, California Administrative Code, Title 23, Waters, Chapter 3 - State Water Resources Control Board, Sections 1050 through 2836.

1.3 Nature and Extent of Contamination

Based on the results of its investigation, the WES defined eight areas where hazardous substances have been released or where hazardous substances threaten to be released (Figure 1-2):

1. The ES Site on Parcel 579D.

2. Parcel 576 located between the ES and G-1 Sites.

3. The G-1 Site on Parcel 575. Getty Oil Company owned and operated a pumping station known as the Nichols Pump Station on Parcel 575 before the United States acquired the property on behalf of the Navy.

4. The K-2 Site on Parcels 574 and 573. Santa Fe Railway Foundation, Inc., owned and operated part of the K-2 area; an individual landowner owned the other part of the K-2 area.

5. The Kiln Site (KS) on Parcel 572. About 1962-1964, ten large industrial kilns known as Herrshoff ovens or burners (which had been located on the Allied Chemical Corporation Bay Point Works facility adjacent to Parcel 572) were placed on and/or near Parcel 572, in an area called the Kiln Site. Allied owned and operated Parcel 572 before the United States acquired the property on behalf of the Navy.

6. Allied Site A (AA). Allied Chemical Corporation owned and operated the area on Parcel 572 known as Allied Site A until the United States acquired Parcel 572 on behalf of the Navy. This area extends beyond the tidal creek to the canal on Parcel 571.

7. Allied Site B (AB). Allied Chemical Corporation owned and operated the area on Parcel 572 known as Allied Site B until the United States acquired Parcel 572 on behalf of the Navy.

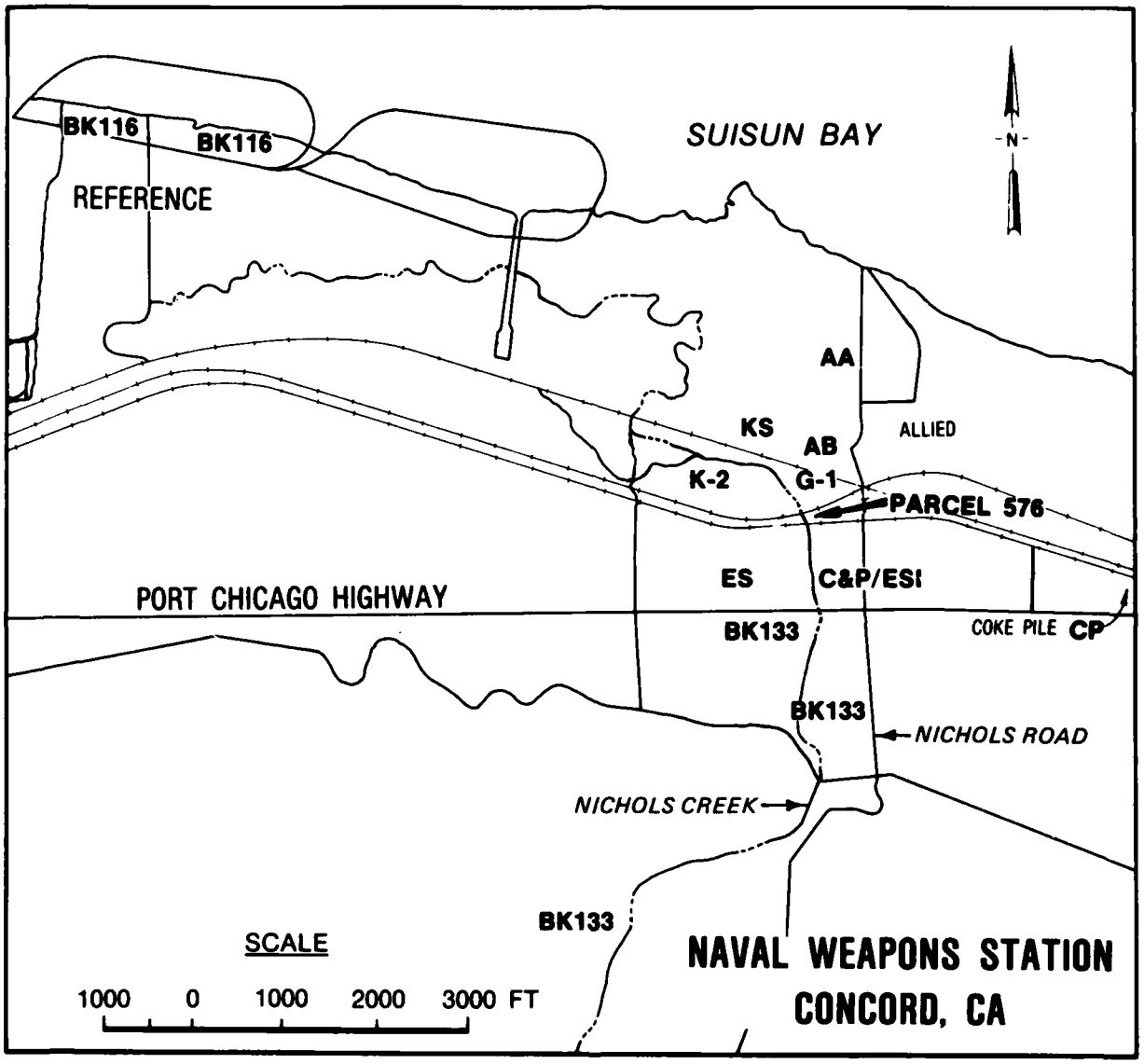


Figure 1-2. Location of sites on Naval Weapons Station Concord

8. Coke Pile Site (CP). Joe Sobotka and Wilda D. Sobotka owned and operated a dumpsite on Parcel 581 until the United States acquired Parcel 581 on behalf of the Navy.

This report presents the results of the WES' remedial investigation. Subsequent reports will present the results of the WES' Feasibility Study Report and Natural Resource Damage Assessment Report.

1.4 Pathways for Contaminant Mobility

A generalized scheme of the potential pathways for contaminant mobility at NWS Concord is illustrated in (Figure 1-3). Contaminant mobility can be assessed with essentially three major target end points: fish, ground water, and/or wildlife/human exposure.

Contaminant mobility into aquatic ecosystems commences with rainfall-initiated surface runoff or movement of detritus and suspended solids and soluble contaminants into drainage ditches and subsequently into Suisun Bay through the actions of surface drainage and tidal inundation. Fish are potentially exposed to any influx of contamination into the aquatic environment by feeding upon flora and fauna that may have accumulated contaminants introduced into the bay.

Ground-water contamination can potentially occur from soil moisture leaching down through the soil profile into the ground-water aquifier. Contaminants must be in a soluble and mobile form to leach down through the soil profile. The interactive effects of plant uptake, soil invertebrate absorption, and adsorption to soil particles and organic matter provides a rather efficient biological filter to clean leachate as it penetrates the soil profile. However, as plants and soil invertebrates die and decompose, contaminants are released and can be susceptible to leaching into the ground water.

A third major pathway of contaminant mobility at NWS Concord is related to wildlife/human exposure. Comprising the wildlife/human exposure pathway are a number of routes considered to have potential for contaminant mobility. The potential exists for the release and movement of contaminants through rainfall surface runoff and tidal flows accumulating in topographically depressed areas, creating shallow ponds and sites of concentrated contaminants. The potential also exists for the release of contaminants through plant uptake. Such release may result in an accumulation of contaminants

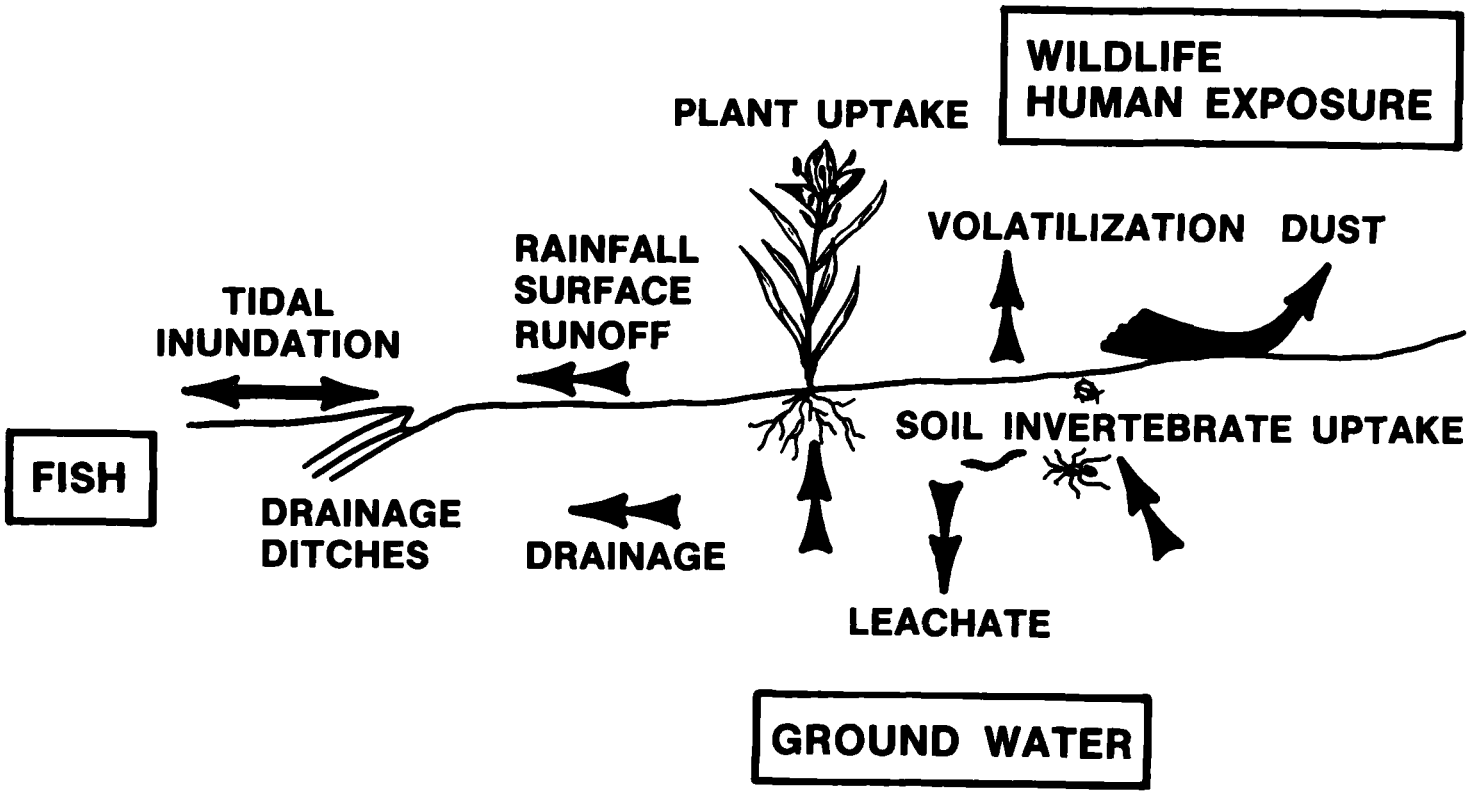


Figure 1-3. Pathways for contaminant mobility

at levels exceeding normal tissue contents. Animals feeding upon contaminated plants are at higher risk of becoming contaminated than animals feeding on uncontaminated plants in the same locale. The potential exists for the release of contaminants through uptake by soil-dwelling animals. Wildlife species whose diets consist of soil invertebrates may ingest contaminated organisms, accumulating contaminants to elevated levels that result in adverse physiological effects on these animals. Volatilization, chemical vapors or co-evaporation, has the potential of releasing contaminants into the environment and affecting human, plant, and animal life on-site as well as biological ecosystems miles from the contaminated site. Frequent breezes increase the potential for mobility of contaminants in the air. Numerous barren areas located in the study area at NWS Concord are highly susceptible to surface wind activity and movement of contaminants via contaminated dust particles. The threat posed to human health through ingestion or inhalation of contaminated dust particles would appear to far exceed the threat posed by volatilization. Personnel assigned to NWS Concord and those employed by the private companies adjacent to the study area are exposed daily to the risk of contamination from airborne soil particles.

The movement of contaminants through air, soil, water, and biota involves complex chemical and biological interactions. Consequently, biological testing is necessary to assess the potential for contamination to move from the soil into the biota of the ecosystem. Certain bioassay procedures have been developed to indicate and quantify the potential for contaminant mobility into food chains. The primary point of emphasis is: mobile contaminants not only exert their greatest influence and cause the most biological damage on site, but also may exert influence and cause damage some distance from the source.

2.0 TECHNICAL EVALUATION OF CONTAMINANT POTENTIAL

2.1 Biological Testing for Contamination

2.1.1 Field Sample Collection

2.1.1.1 Experimental Design

An experimental design for sampling each parcel was formulated based on previous soil and water sampling data and the potential pathways for contaminant mobility. The locations of sites where samples were taken by or under the direction of WES are shown in Figure 2-1. This general area map indicates the areal extent of the sampling. This experimental design was formulated to accomplish three objectives: one, to define the nature and extent of the hazardous substance contamination on Parcels 571, 572, 573, 574, 575, 576, 579D, and 581 of NWS Concord; two, to identify the most probable movement of contaminants from the parcels; and three, to assess the biological availability of the contaminants. Previous sampling data had indicated excessive amounts of contaminants in the soil (Anderson Geotechnical Consultants, 1984). The primary focus of the WES remedial investigation was to determine the potential for contaminants to move from the soil into the biota on the property.

Sample locations were established either near previously sampled sites of known contamination, or at some distance between previous samples, or beyond previous sample location to give more definition to the nature and extent of contamination. For example, a sample location of a known contamination level was collected in order to biologically test the soil to determine the effects of that contamination on biota of the ecosystem. A range of contaminant concentrations were selected from low levels to high levels. Barren areas of extremely high levels of contamination were not collected since all biota were killed on the site and there was no need to test such a site.

At some selected sites, three samples of vegetation (Typha sp) and soil were obtained from an area of approximately 4 sq ft. These triplicated samples were used to conduct statistical analyses to determine significant differences among location means for contaminant concentrations in soils, plants, and earthworms. These statistical analyses indicate where significant

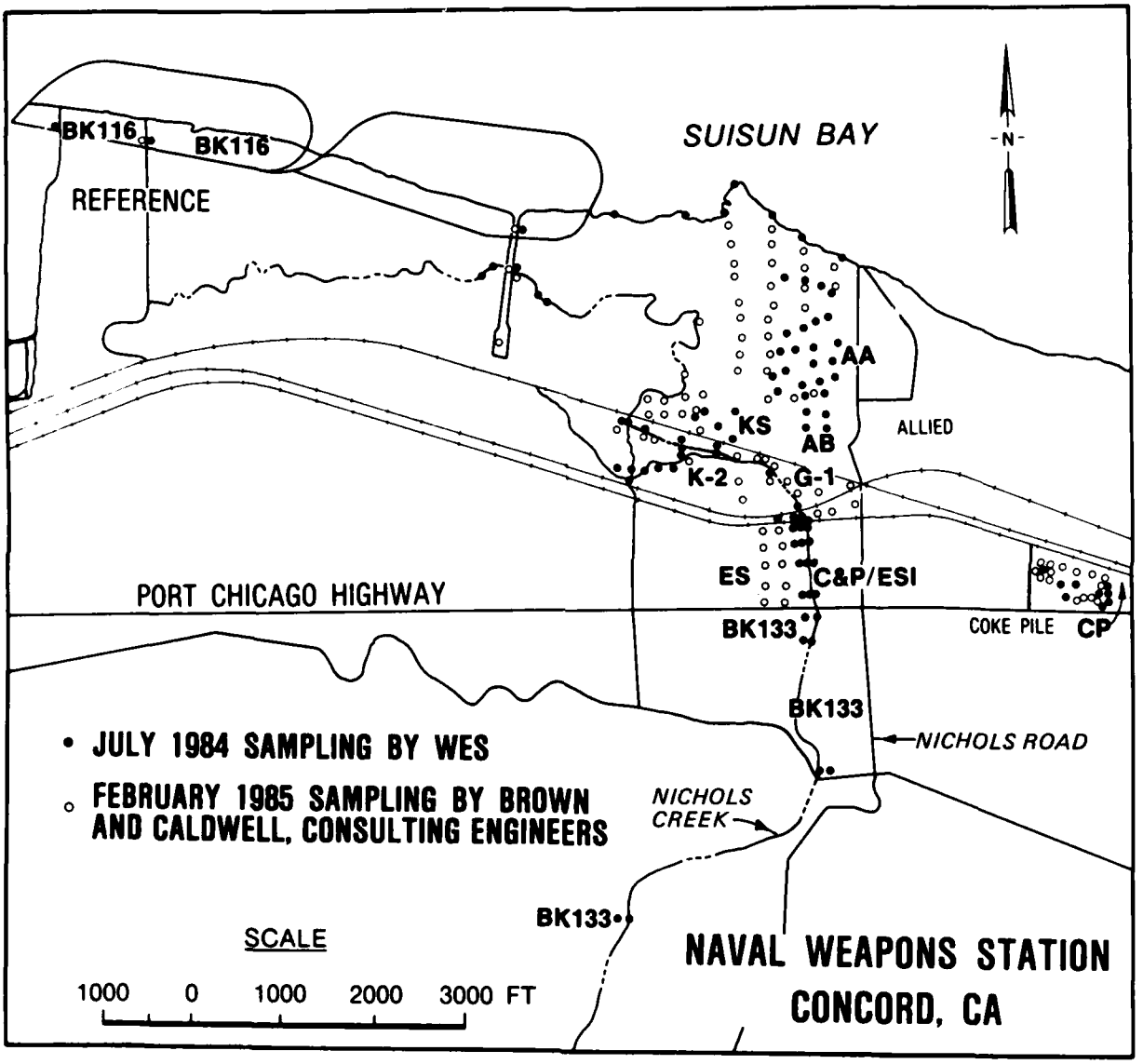


Figure 2-1. Sampling location Naval Weapons Station Concord

increases of contaminants were found in relationship to other reference sites sampled on NWS Concord. At some sample locations, only single samples of existing plant tissue and soil for the laboratory bioassay tests were collected. Regression analyses were conducted on all data obtained in the study (both triplicated samples and single samples). This sample design reduced the cost of the investigation by allowing a selected number of sample locations to be tested extensively while other sample locations would receive one-third the cost and effort. The minimum amount of data was sought to determine the seriousness of the contamination.

The seriousness of the contamination and the potential for release of contaminants into the biota can be assessed most appropriately through biological testing and the use of biological indicators to determine contaminant mobility. Because the intertidal wetland is a complex biological ecosystem, extensive testing using clams, plants, and earthworms was required to assess mobility of contaminants. Biological tests were selected instead of chemical extraction tests because chemical extraction tests have not been related to bioavailability or effects of the biota of an ecosystem. Consequently, chemical extraction test data are extremely difficult to interpret with respect to biological effects. Biological tests allow an indicator plant or animal to be used to determine the potential mobility and effects of contaminants of biota of an ecosystem. These bioassay techniques are being used quite successfully in determining contaminant mobility from contaminated dredged material, metal mining wastes, and sewage sludge amended soils (Folsom 1982; Folsom and Lee 1981a, 1981b; Folsom, Lee, and Bates 1981; Davies and Houghton 1983; Marquenie 1981; Marquenie and Simmers 1984; Simmers et al. 1984a, 1984b; Van Driel et al. 1983 and personal communication from R. L. Chaney, 1985).

2.1.1.1.1 Distribution of Contaminants in Soil

In order to assess the nature and extent of the contamination across the parcels, additional soil sample locations were selected that would supplement previous soil test data. Previous sampling by Brown and Caldwell, Inc. for Anderson Geotechnical Consultants (1984), indicated extremely large amounts of metals in the creek on ES (Parcel 579D), G-1 (Parcel 575), K-2 (Parcels 573 and 574), on the Kiln Site, KS (on Parcel 572), and AA and AB (portions of Parcel 572 adjacent to Allied Chemical waste lagoons. While these data did

show contamination to a soil depth of 18 in. on the Kiln Site, essentially all other metal contamination was observed in the 0- to 6-in. soil depth. Based on these data and available knowledge of the hydrological conditions on site, a soil sampling scheme was formulated that would better define the nature and extent of the contamination on each parcel. The scheme included soil samples from the stream as well as soil samples at some distance away from the creek. Soil samples were included in Parcel 572 that would indicate hot spot areas in KS, AA, and AB areas along wetland drainage ditches and streams.

In addition, soil samples were collected from two reference areas, BK116 and BK133 (Figure 2-1). Reference area BK116 was approximately 7,000 ft to the west of the AA contaminated area and considered far enough away from AA area to have little impact from AA contamination. Reference BK133 was across and south of Port Chicago Highway, upstream from the Chemical and Pigment Company impacted area (ES). These reference areas were used for comparison of contamination of soil and biota from Parcels 571, 572, 573, 574, 575, 576, 579D, and 581. This scheme was essentially designed to evaluate if contaminants had moved into and through the most probable pathway routes on each parcel. The scheme consisted of two groups of soil samples. One group collected by the WES scientists was used to determine contamination of biological components of the ecosystem. These data on soil metal contents and the response to and potential bioaccumulation of metals by bioassay plants and animals were used to develop relationships between soil metal content and contamination of the biota. Statistical analyses were performed on these data. The second group of soil samples were collected by Brown and Caldwell, Inc. This group of soil samples was designed to further define the real extent of soil contamination on each entire parcel. Data on soil metal content from this group of samples were compared to the relationships developed from WES group of soil samples in order to predict potential contamination of the biota. There were no statistical analyses conducted on the data from the second group of soil samples.

2.1.1.1.2 Contaminant Mobility in Surface Waters

In order to assess potential for contaminants to move in surface waters and into tidal waters, a clam bioassay was conducted at key locations in the stream that passed through the ES area on Parcel 579D, the G-1 area on

Parcel 575, and the K-2 area on Parcels 573 and 574, and across the tidal wetland adjacent to the AA, AB, and KS areas on Parcel 572 (Figure 2-2). Locations were selected based on presence of sufficient water flow to sustain clam population. Previous water sampling data indicated very low concentrations of dissolved contaminants in surface waters. These data, however, did not permit the assessment of the slow continuous release of contaminants into surface waters or tidal waters. Therefore, another technique for assessing contaminant mobility was necessary to further define the potential mobility of contaminants into surface waters. A clam biomonitoring technique was selected to meet this requirement. In previous studies, the clam bioassay has been shown to be a good indicator of dissolved contaminants in surface waters (Marquenie 1981). The clam was used as a biological integrator that would accumulate in its tissues low concentrations of contaminants dissolved in surface water and/or adsorbed to suspended particulate matter. The clam essentially filters and accumulates contaminants from surface waters. Clams were exposed to surface waters and tidal waters for a period of 28 days. During this period, the clam filtered the water surrounding it.

2.1.1.1.3 Contaminant Mobility into Plants

Existing native plants on the property were sampled to determine the nature and the degree of contamination. Little information and scientific literature are available on contaminant concentrations in local native plant species. In addition, it is extremely difficult to compare tissue contaminant contents of different plant species to confidently predict the potential for movement of contaminants into all plants on a site. Therefore, two techniques were utilized to assess the potential for movement of hazardous substance contaminants from the soil into plants on the property. Under the first technique, samples of the dominant plant species on the property were taken in the field for plant analysis. Typha angustifolia, common name cattail, was selected since it generally inhabited both the stream and tidal wetland areas. But Typha was not found in all the desired sampling locations. In addition, in the second technique, a plant bioassay was conducted under controlled greenhouse laboratory environment conditions to further assess the potential for contaminant movement from soil taken from each sample location into plants that colonize the soil. From past experience, a more thorough assessment of

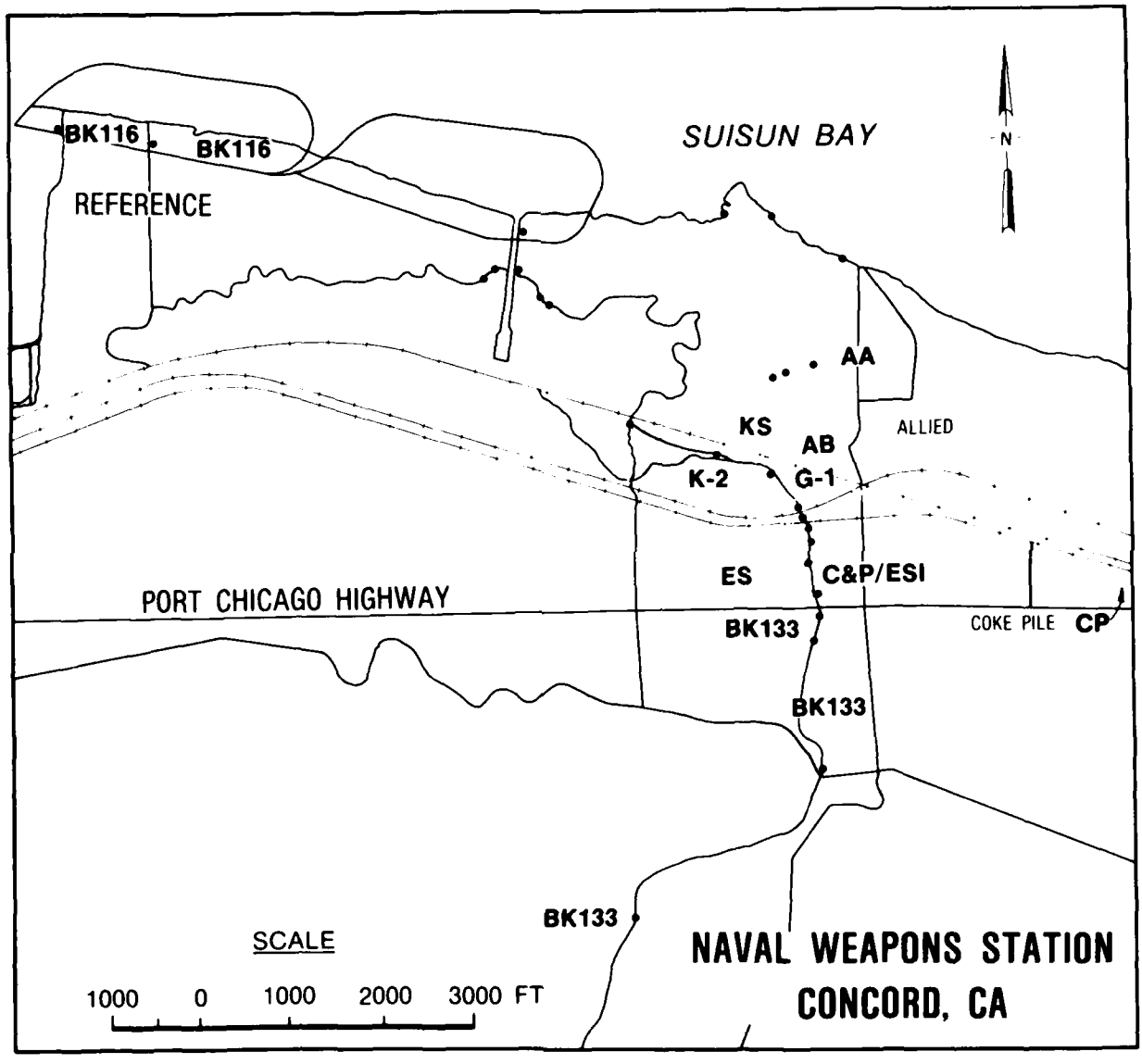


Figure 2-2. Clam bioassay locations on Naval Weapons Station Concord

plant contamination can be obtained under a controlled environment and through the use of index plant species which has a more extensive database from which to interpret test results. Cyperus esculentus has been studied from a number of years and has been tested in this country and in Europe on a variety of contaminated sediments and soils (Folsom and Lee 1981a, 1981b). The interpretation of the present plant bioassay test results can then be related to previous test results.

2.1.1.1.4 Contaminant Mobility into Soil-Dwelling Animals

Existing indigenous soil invertebrates were sampled from a heavily contaminated area in the AA site on Parcel 572 and from a remote reference site to the west of the contaminated site and far enough away from the contaminated area to show little impact from the contaminants in Parcel 572. However, when sampling existing soil invertebrates, it is extremely difficult to obtain a sufficient quantity of the same species to compare among sites. Therefore, an earthworm bioassay was utilized to assess the potential movement of contaminants from soil into soil-dwelling animals. The earthworm bioassay has been used on a number of contaminated soils and sediments in this country and in Europe to determine bioaccumulation of contaminants into soil invertebrates (Marquenie and Simmers 1984, Rhett et al. 1984, and Simmers et al. 1984).

2.1.1.1.5 Test Result Interpretation

The concentrations of hazardous substance contaminants detected in soil samples, in field collected plants and animals, and in indicator plants and animals exposed to soil samples in laboratory bioassays from Parcels 571, 572, 573, 574, 575, 576, 579D, and 581 were compared with the concentrations of such contaminants detected in soil samples, in field collected plants and animals, and in indicator plants and animals exposed to soil samples in laboratory bioassays from remote reference areas and with established criteria. These comparisons can predict the potential for contaminant mobility from the soil into food webs associated with these parcels.

2.1.1.2 Methods and Materials

Each parcel of land was sampled for surface soil to a 0-6 in. depth using a sharpshooter shovel. At each sampling location in each parcel, the procedure followed consisted of harvesting the above-ground aerial portion of the existing plants from a 1 ft × 1 ft area and collecting three soil samples, one each for a plant bioassay, an earthworm bioassay, and a soil chemical analysis from within the 1 ft × 1 ft area. The plant samples retained for chemical analysis were those of cattails, Typha angustifolia, which were predominantly in wet soil areas in the stream and scattered across the wetland areas. Plant samples from the drier upland areas were not collected because it was late in the growing season and the above-ground aerial portion of the grasses were dead, dried, and partially destroyed by wind action. Plant leaves were cut at approximately 4 in. above ground surface, placed in 30-gal plastic garbage bags, labeled, and sealed with a plastic twist-tie.

A soil sample was collected; placed in a 2-gal Bain Marie plastic bucket; and labeled for a plant bioassay. Another soil sample from the same 0-6 in. excavation was collected; placed in a 1-gal Bain Marie plastic bucket; and labeled for an earthworm bioassay. A third soil sample, large enough to fill a "ZIPLOC" plastic sandwich bag, was collected and labeled for soil chemical analysis. At selected locations across each parcel, this sampling procedure was repeated three times at each such location to give an indication of soil variability within the 0-6 in. depth within approximately a 4-sq-ft sample hole. The assignment of replicate labels were made in the sequence of sample collection. The first soil or plant sample was labelled R1, the next sample was R2, and the final sample was labelled R3. The only relationship among R1 of a soil sample, plant bioassay, animal bioassay or field-collected plant sample is that of being the first sample collected from that location. All samples were collected from the field, placed in a closed secure vehicle and transported to a secure refrigerated trailer located adjacent to the main entrance of the NWS in clear view of the security personnel on duty. After all samples were collected and placed in the refrigerated trailer, the samples were transported to WES for further testing and analysis.

Additional soil samples were collected by Brown and Caldwell Consulting Engineers to further define the extent of contamination across each parcel of

land. Soil samples were taken at 0-6 in. surface depth. Each of these soil samples were split into three separate portions.

2.1.1.3 Chain of Custody

Strict chain-of-custody procedures were implemented throughout the field sampling, during transport of samples back to the WES, and during laboratory testing. Field sampling chain-of-custody log sheets were used to record the location and time of sampling. Each plant and soil sample collected was labeled using the following procedures.

2.1.1.3.1 Vegetation

Each plant leaf sample was placed in a plastic garbage bag. The outside of the bag was labelled with a piece of adhesive tape describing the appropriate location, sample number, date, and time for each sample collected. A duplicate label was prepared on a 3 in. × 5 in. index card. This card was sealed in a "ZIPLOC" 4 in. × 6 in. plastic bag and placed with the plant leaf sample inside the garbage bag. A plastic twister was used to close the garbage bag.

2.1.1.3.2 Soil

As explained above, soil samples were collected for plant and animal bioassays and for chemical analyses, all to be conducted in the laboratory. The samples collected for plant and animal bioassays were placed in either 1- or 2-gal Bain Marie plastic buckets. After each sample of soil was placed in a bucket, a label describing the location of the sample, the sample number, and the date and time of sampling was prepared on a 3 in. × 5 in. index card and was placed on top of the soil in the bucket. In samples taken the first morning, the bucket was sealed with a labeled airtight lid and the outside of the bucket was labeled in a similar manner on adhesive tape. Water-fast ink was used to ensure the integrity of the label. After the first morning of sampling, a further precaution was implemented. After the buckets were sealed with the airtight lid, fiberglass-reinforced tape was used to tape the lid onto the bucket to further ensure that the lid would not come off in transit

or future handling of the bucket. This additional precaution eliminated the need to label the lid. Thus, after the first morning of sampling, two duplicate labels were used in the field sampling, one inside the sealed bucket and one on the outside of the sealed bucket.

The soil sample collected for chemical analysis was placed in a quartsize "ZIPLOC" plastic bag labeled on the outside on a piece of adhesive tape. A duplicate label on a 3 in. × 5 in. index card was sealed in a "ZIPLOC" 4 in. × 6 in. plastic bag to preserve the integrity of the label and was placed inside the larger quartsize plastic bag with the soil sample. The outside of the quartsize plastic bag was labeled on adhesive tape with waterfast ink.

After plant and soil samples were collected, labeled, and sealed in their respective containers (buckets or plastic bags), they were placed in boxes for transport from the field site to the WES. Samples were separated into the various components of the study (such as plant samples, soil samples for the plant bioassay, soil samples for the earthworm bioassay, and soil samples for chemical analysis) and boxed accordingly. For example, all samples of field-collected plant material were placed in four or five boxes labeled plant material. In addition, as a plastic bag of plant material was placed in a box, the identity of the sample was recorded on the outside of the box. In this way, an inventory and location of each sample in the box could be checked. After the box was filled with similar type samples, the box was sealed with fiberglass-reinforced tape and the time, date, and signatures of three members of the field party sealing the box were recorded across the tape to ensure that the boxes could not be opened without disruption of the signatures. This procedure maintained integrity of samples and chain of custody.

The boxes were loaded into a refrigerated trailer at the end of each day and maintained at 40 deg F until the laboratory testing at the WES was initiated. When all samples from the field were boxed and loaded into the trailer, the appropriate receipts and chain-of-custody forms were prepared and signed by appropriate individuals, and the samples were transported in a locked and sealed refrigerated trailer.

Upon arrival at the WES, the truck driver released the samples to WES scientists. The refrigerated trailer was placed on the WES property and samples were removed as needed to initiate the various tests to be conducted. For example, plant material boxes were released to the laboratory personnel

who processed the tissue for chemical analysis. Digested plant tissue samples were then released to the analytical chemists for chemical analysis. The appropriate chain-of-custody records were maintained throughout the study. Similar chain-of-custody procedures were followed on soil samples for the earthworm bioassays, plant bioassays, and soil chemical analyses.

2.1.1.3.3 Clams

In conducting the clam biomonitoring, ten clams and a label on a index card inside a "ZIPLOC" plastic bag were placed inside a clam basket. The basket was sealed with cable ties. If the clam basket was opened, the cables ties would have to be broken. Strict chain-of-custody was maintained in a similar manner as discussed above after the clams were harvested until they were chemically analyzed.

2.1.2 Laboratory Procedures

2.1.2.1 Soil Samples

2.1.2.1.1 Methods and Materials

Upon arrival of the refrigerated trailer at the WES, soil samples for chemical analysis were removed from the refrigerated trailer and stored in a locked cold room until processing for chemical analysis.

In processing the soil samples for chemical analysis, the soil samples were taken from the cold room and brought to the laboratory in preparation for digestion. Each bag was opened, and the contents were stirred with a teflon spatula to obtain a homogenous sample. After being thoroughly mixed, a 1-g (oven-dry weight basis) subsample (weighed to the nearest 0.001g) was weighed into a 100-ml micro-Kjeldahl flask. Fifteen ml of concentrated nitric acid (conc HNO_3) were added to the contents of the flask and allowed to set overnight for predigestion. The next morning the flasks were placed into a micro-Kjeldahl distillation apparatus and the conc HNO_3 distilled off until almost dryness. The flasks were removed from the apparatus and allowed to cool to room temperature after which 5 ml of red-fuming nitric acid (rf HNO_3) were added. The rf HNO_3 was distilled off until the contents in the flask

were almost dry. If the solution was clear, the digestion was complete; if not, another 5 ml of rf HNO_3 were added and the procedure was repeated. The procedure was repeated until the solution became clear. After the digestion was complete, the flasks were allowed to cool to room temperature. The contents of the flasks were then quantitatively filtered through Whatman No. 42 filter paper into a 50-ml volumetric flask. The filter paper was rinsed three times with 35-ml portions of 1.2N hydrocholoric acid (HCl). The flasks were diluted to volume with 1.2N HCl. The solution were transferred to 125-ml polyethylene sample bottles and chain-of-custody transferred to the WES Analytical Laboratory for chemical analysis.

The solutions were analyzed for arsenic (As), cadmium (Cd), lead (Pb), selenium (Se), zinc (Zn), copper (Cu), and nickel (Ni). The instruments and detection limits of the chemical parameters determined are listed in Table 2-1.

Table 2-1

Instruments and Detection Limits for Chemical Parameters

Chemical Species	Procedures and/or Instrumentation	Lowest Reported Concentration, µg/g
Zn*	Determined with a Spectrospan Argon Plasma Emission Spectrophotometer Model III	0.1
Cd*		0.1
Cu*		0.1
Ni*		0.1
Pb*		0.1
As	Determined by hydride generator/ Atomic Absorption Spectrophotomer, Perkin-Elmer Model 305	0.005
Se	Determined by hydride generator/ Atomic Absorption Spectrophotomer, Perkin-Elmer Model 305	0.005

* When concentrations were below 0.1 µg/g, the solutions were analyzed with a Perkin-Elmer Heated Graphite Atomic Absorption Unit to reach (all in µg/g) 0.0004 Zn, 0.0001 Cd, 0.001 Cu, 0.0003 Ni, and 0.0005 Pb.

Moisture (percent moisture on an ovendry-weight basis) and soil pH were also determined on the soil samples in addition to heavy metals. This was accomplished by the following procedure. After the sample was adequately homogenized, a subsample was removed from moisture determination and subsequent pH determination. Ten grams of soil were weighed into an aluminum dish and heated in an oven at 104 deg C until constant weight. The soil/dish was removed from the oven, placed into a vacuum desiccator, and allowed to cool to room temperature. The soil/dish was then weighed. Percent moisture on an ovendry-weight basis was calculated by the following procedure. The ovendry soil weight was subtracted from the wet weight of soil. This quantity was divided by the ovendry weight of soil and multiplied by 100 to obtain the percent of moisture on an ovendry-weight basis. Soil pH was determined by the following procedure. Ten grams of soil (ovendry-weight basis) was weighed into 50-ml glass beakers. Twenty ml of reverse osmosis (RO) water were added, and the mixture was stirred with a polyethylene rod for 1 min every 15 min for 1 hr. After 1 hr, a small magnetic stirring bar was placed into the beaker and the suspension stirred at low speed with a magnetic stirrer. During stirring, pH of the suspension was determined using a glass and reference calomel electrode on a Beckman Model Zeromatic pH meter (Beckman Instrument Co., Inc., Irving, CA).

2.1.2.1.2 Results and Discussion

2.1.2.1.2.1 Statistical Analysis of Data

Soil data from each sampling site where three samples were collected were statistically analyzed using analysis of variance (ANOVA), and mean values were compared according to Duncan's New Multiple Range Test. Significant differences were obtained at P = 0.05 and are presented in appendix Table 2-A1 by means within each column followed by different letters. The three samples were randomly collected from each sampling site and were considered to represent the variability existing in a 4-sq-ft sampling site. In some cases, there was a wide variability in values among the three samples, especially at the edge of a contaminated spill area.

In addition to the statistical analysis described above, plots of the frequency of observed contaminant concentrations in soil, plants, clams, and

earthworms were developed to indicate how many samples exceeded established values on each parcel as well as the relative magnitude of contaminant concentrations observed across parcels. These plots indicate where and how often the higher concentrations were observed.

Soil metal concentration data were compared to existing established background values for agricultural cropland (Table 2-2), the maximum allowable soil concentration values established for sewage sludge applications to agricultural land (MASSA) (Table 2-2), and the total threshold limit concentration (TTLC) established by the State of California in regulating hazardous materials (Table 2-3).

Past history of a number of parcels including the saltmarsh areas indicated that agricultural grazing was practiced. While present use of these parcels is not agricultural in nature, there is a potential for this land use in the future. Therefore, it is appropriate to consider guidelines established for agricultural cropland as a measure of the relative contamination observed on these parcels and the need for clean up to a safe level of soil contamination for permitting agricultural grazing. There are no guidelines on maximum soil concentrations allowable for wildlife habitat. However, the contamination of grazing agricultural animals can give an indication of the potential for contamination of wildlife animals that graze a contaminated area. Concern for human consumption of contaminated agricultural animals should also indicate a concern for human consumption of wildlife grazing a contaminated area as well as contamination of food webs associated with the contaminated areas. Therefore, it is appropriate to consider guidelines established for agricultural cropland in assessing the seriousness of the contamination at NWS Concord.

The State of California has established Total Threshold Limit Concentrations (TTLC) criteria for identification of hazardous and extremely hazardous wastes that can give another perspective on potential seriousness of contamination. However, the criteria were established for chemical waste materials generated from a source and not for soil contaminated with chemical waste materials per se. Consequently, direct application of the TTLC to a mixture of soil and waste material may be questionable. In addition, the biological effects or impact of TTLC values have not been clearly demonstrated for soil/waste material mixtures and consequently the interpretation of the meaning of TTLC values to the biota of an ecosystem has not been established.

Table 2-2

Background Levels and Allowable Applications of Several Heavy Metals for US Cropland Soils from Holnigren et al. (1985) and Lee et al. (1984)

Metal	Concentration in Surface Soils, mg/kg			No Effect Allowed Addition* kg/ha	Median + Allowed Application mg/kg
	5 Percentile	Median	95 Percentile		
Pb	4.0	11	27	1,000	511
Zn	7.3	54	129	500	304
Cu	3.7	19	96	250	144
Ni	3.8	19	59	125	82
Cd	0.035	0.20	0.78	5	2.7
pH	4.6	6.1	8.1	--	--

* Allowed application is mixed into the 0-15 cm (0.6 in.) surface layer of soil.

Table 2-3

Total Threshold Limit Concentration* from Anderson Geotechnical Consultants (1984)

Parameter	Total, mg/kg	Soluble, mg/ℓ
As	500	5.0
Ba	10,000	100
Cd	100	1.0
Cr	2,500	560
Cu	2,500	25
Pb	1,000	5.0
Se	100	1.0
V	2,400	24
Zn	5,000	250

* Wet-weight basis.

These comparisons were made to give some perspective to the soil concentration data obtained for each parcel. Each figure of soil data has the appropriate established values drawn across the figure. In this presentation, those soil values exceeding the established value can be seen easily. The location of the samples are presented in Section 2.2.1: Contaminant Distribution and Mobility Across the Site.

2.1.2.1.2.2 Data Presentation

Total soil concentration of heavy metals is presented in Figures 2-3 through 2-9. These figures indicate the frequency of soil concentrations found within each of the parcels. The actual location of these sites at NWS are shown and discussed in Section 2.2.1.

2.1.2.1.2.2.1 Soil Arsenic

Total soil As ranged from below detectable limits to greater than 2500 ppm (Figure 2-3.) Total soil As in the remote reference areas (BK) was generally below detectable limits. Samples from site AA on Parcel 572 had the highest total soil As (statistically significant at P = 0.05 from other sampled areas) (Appendix Table 2-A1). The locations where As was above those of other sampled areas were those from the G1 area on Parcel 575, K-2 area on Parcel 574, and the KS area on Parcel 572 as indicated by the data presented in Fig 2-3.

2.1.2.1.2.2.2 Cadmium

Total soil Cd in the sites sampled is presented in Figure 2-4. Values ranged from near detectable limits to more than 80 ppm. The remote reference areas generally had the lowest total soil Cd while the soils in the K-2 area on Parcels 573 and 574 and the AA area on Parcel 572 had elevated levels (statistically significant at P = 0.05) from other sampled areas (Appendix Table 2-A1). Total soil Cd at this site exceeded the MASSA for Cd on agricultural cropland of 2.7 ug/g (Table 2-2). Consequently, these data indicate that these areas should be restricted against an agricultural land use.

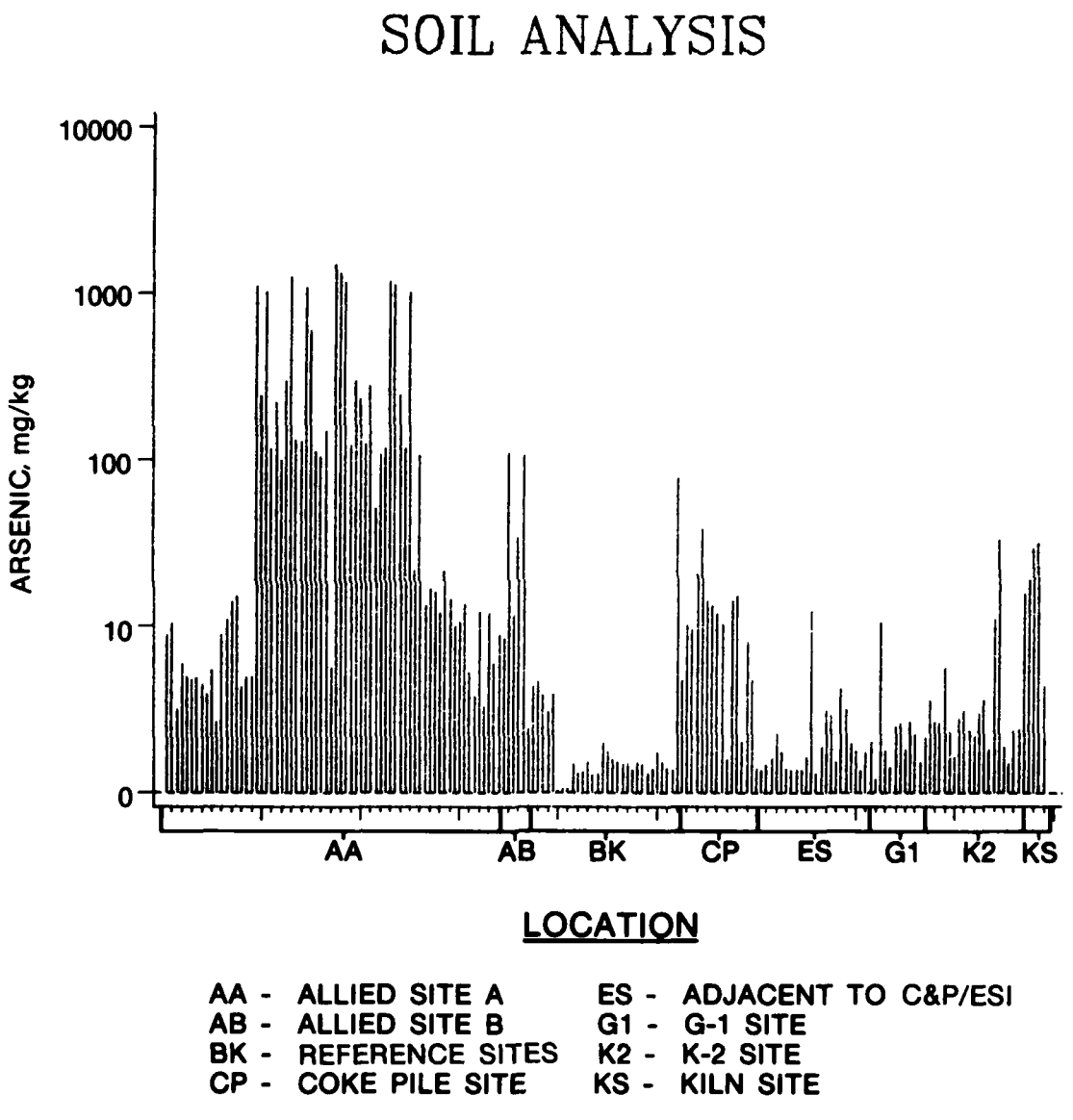
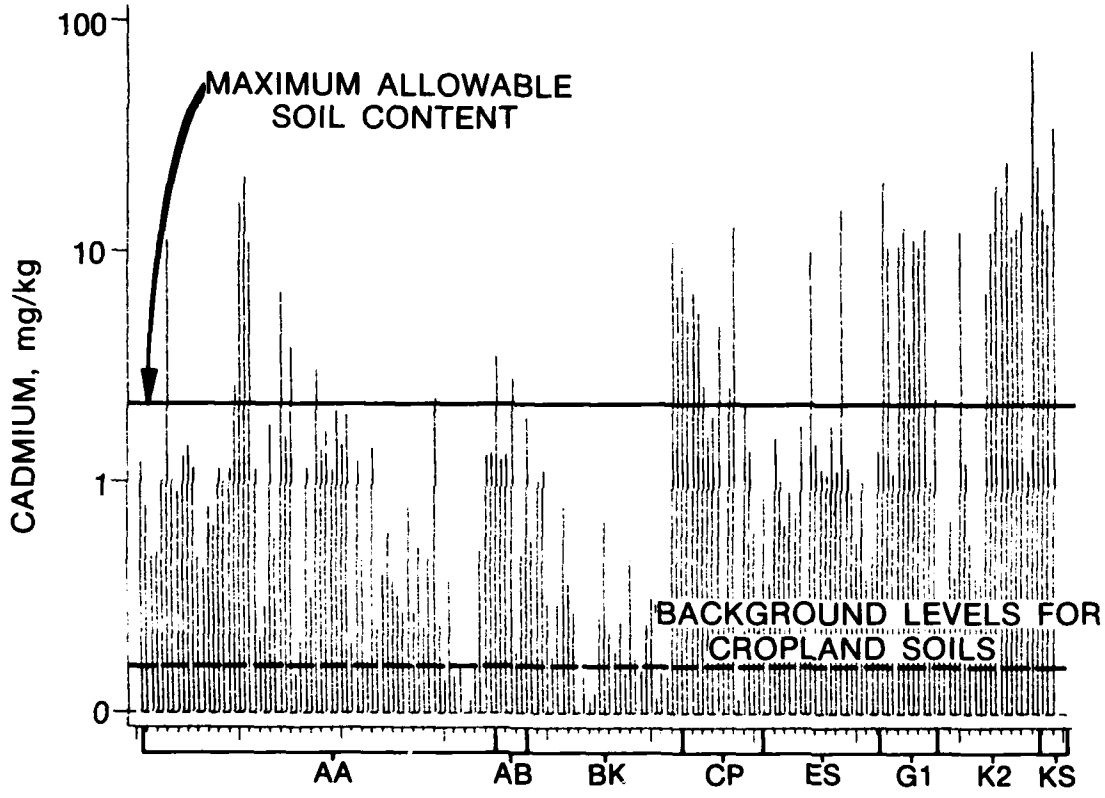


Figure 2-3. Total soil concentration of arsenic

SOIL ANALYSIS



AA - ALLIED SITE A
AB - ALLIED SITE B
BK - REFERENCE SITES
CP - COKE PILE SITE
ES - ADJACENT TO C&P/ESI
G1 - G-1 SITE
K2 - K-2 SITE
KS - KILN SITE

Figure 2-4. Total soil concentration of cadmium

SOIL ANALYSIS

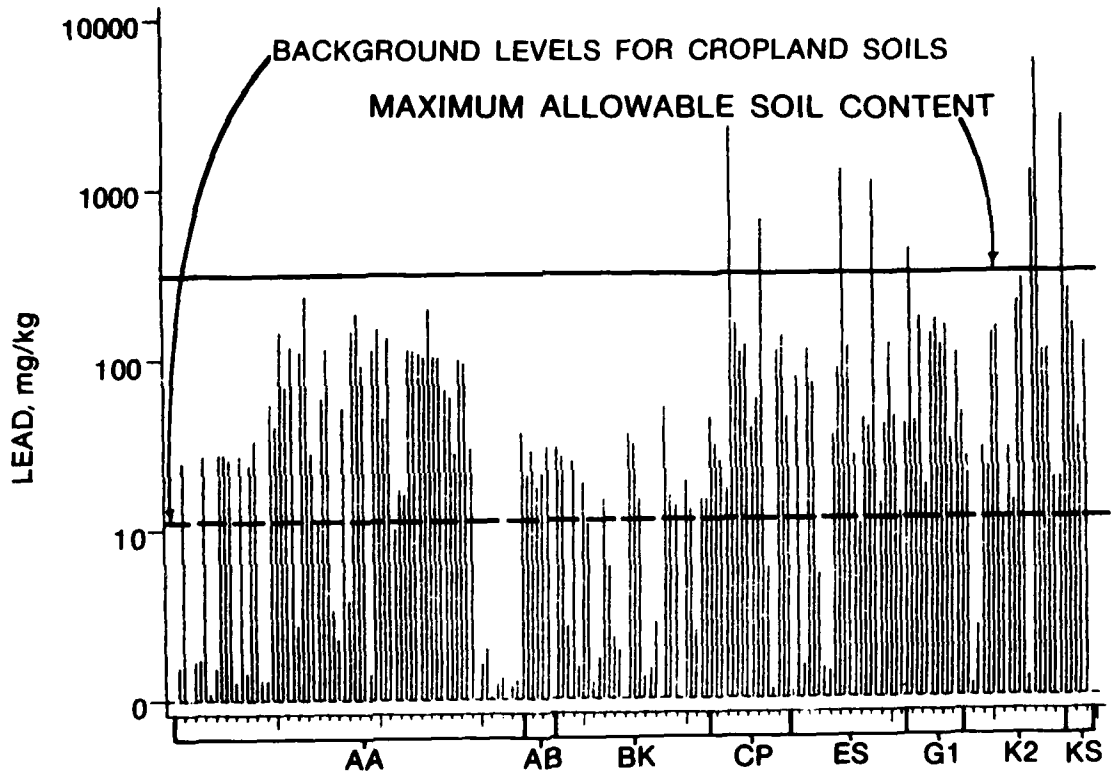


Figure 2-5. Total soil concentration of lead

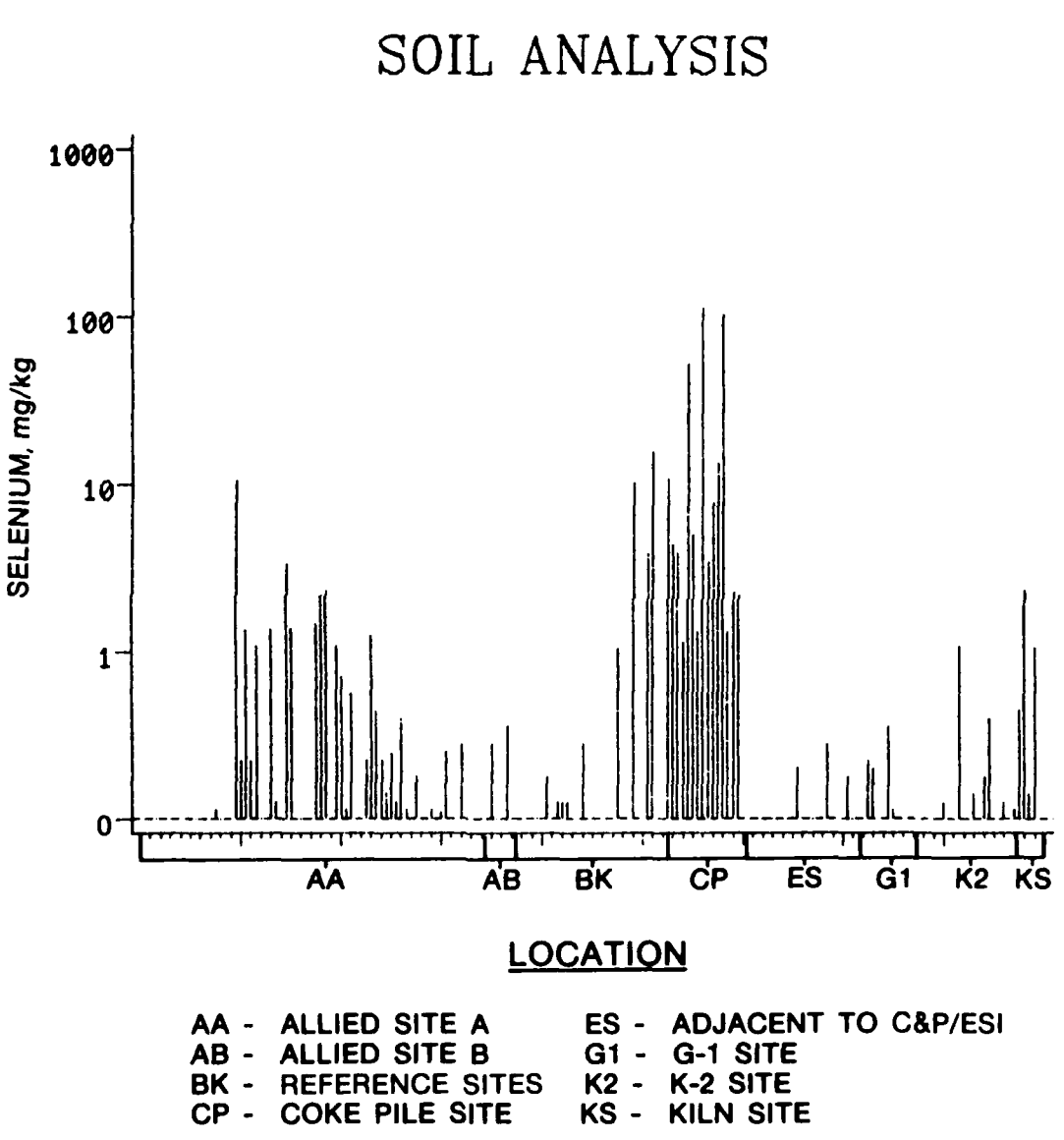


Figure 2-6. Total soil concentration of selenium

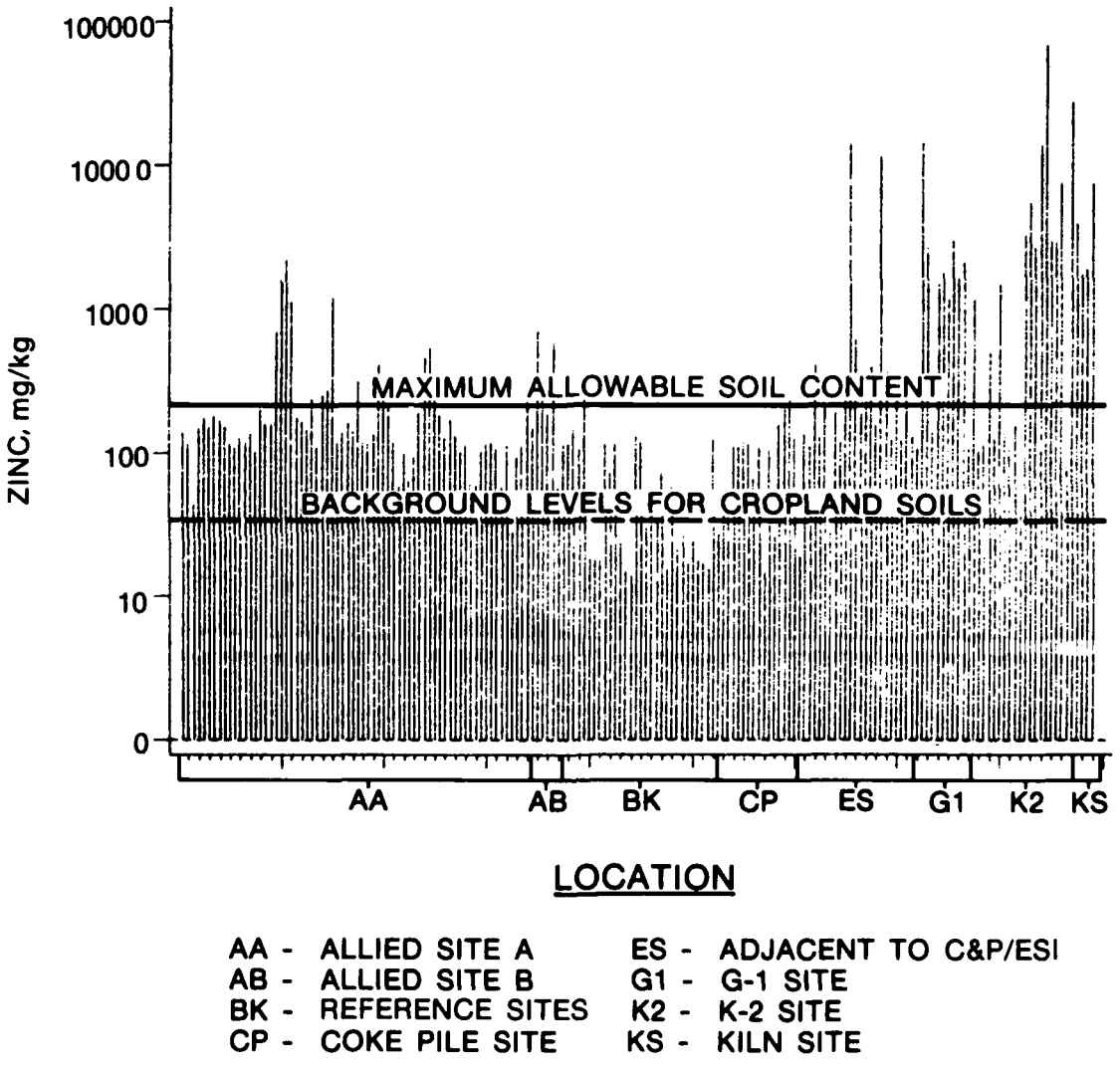
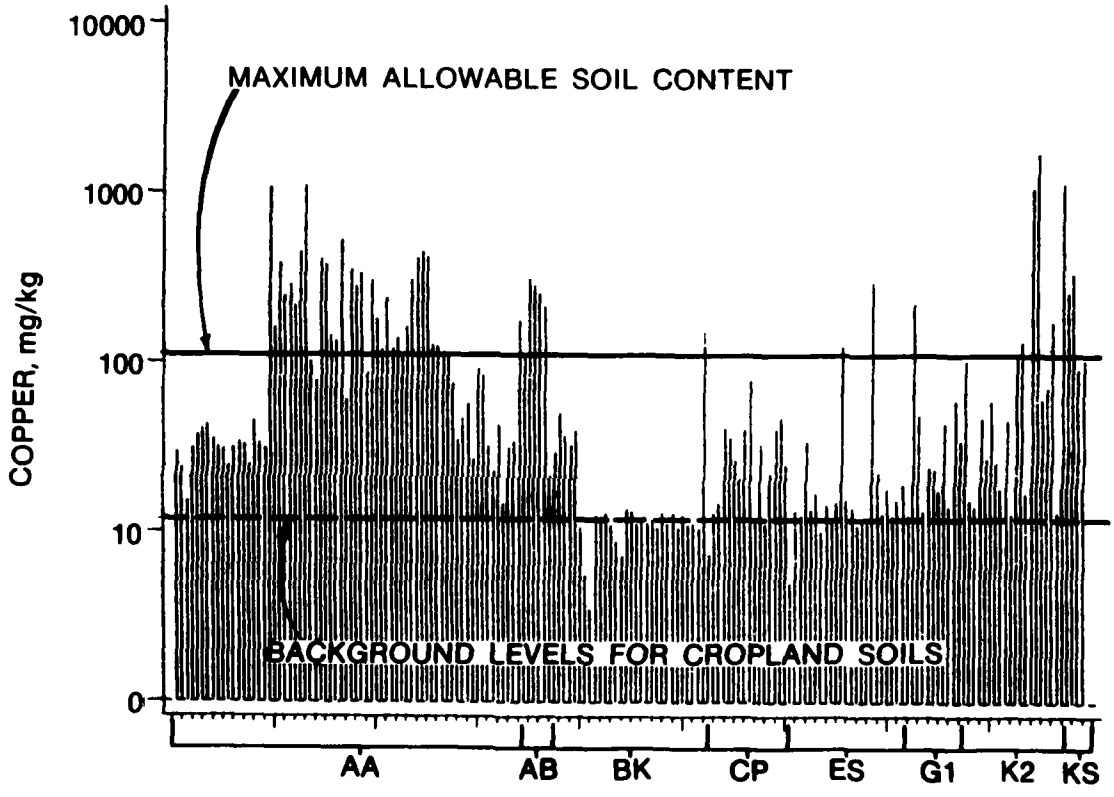


Figure 2-7. Total soil concentration of zinc

SOIL ANALYSIS

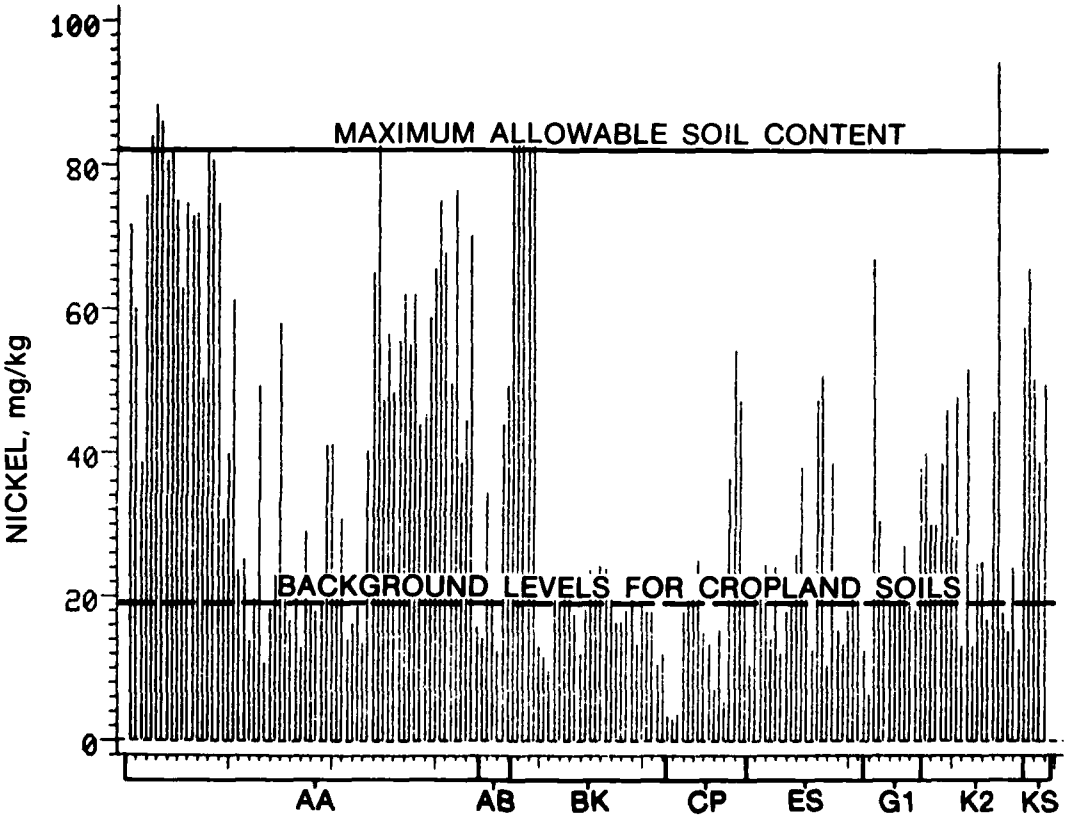


LOCATION

AA - ALLIED SITE A	ES - ADJACENT TO C&P/ESI
AB - ALLIED SITE B	G1 - G-1 SITE
BK - REFERENCE SITES	K2 - K-2 SITE
CP - COKE PILE SITE	KS - KILN SITE

Figure 2-8. Total soil concentration of copper

SOIL ANALYSIS



LOCATION

AA - ALLIED SITE A	ES - ADJACENT TO C&P/ESI
AB - ALLIED SITE B	G1 - G-1 SITE
BK - REFERENCE SITES	K2 - K-2 SITE
CP - COKE PILE SITE	KS - KILN SITE

Figure 2-9. Total soil concentration of nickel

2.1.2.1.2.2.3 Soil Lead

Values for total soil concentration of Pb ranged from near detectable limits to more than 7000 ppm (Figure 2-5). Only seven areas had total soil Pb values which exceeded the MASSA for PB on agricultural cropland. These data indicate that these seven areas should be restricted for agricultural land use. In addition, these seven areas represent a threat to human exposure through soil ingestion of dust as the soil Pb content exceeds the established soil value in Table 2-4.

Table 2-4

Recommended or Regulated Limitations on Potentially Toxic Constituents in Surface (0-15 cm) Soils from Lee et al. (1984)

Basis for Limitation	Contaminant	Soil Concentration	Reference
Soil Ingestion	Pb	500 mg/kg	EPA (1977)
	Hg	5 mg/kg	
	PCBs etc.	2.0 mg/kg	Fries (1982)
Plant Uptake	Cd	2.5 mg/kg (pH 5.5)	EPA (1979)
Phytotoxicity	Zn	250 mg/kg	Logan and Chaney (1983)
	Cu	125 mg/kg	
	Ni	62 mg/kg	
	Co	62	
Leaching	Cr (VI)	0.05 mg/ℓ	EPA Drinking Water Standard

2.1.2.1.2.2.4 Soil Selenium

Most values for total soil Se concentrations were below detectable limits (Figure 2-6). Values above detectable limits were located on the AA area of Parcel 572, CP area on Parcel 581, G-1 area on Parcel 575, and K-2

area on Parcels 573 and 574. There are no MASSA values for Se. Variation was large among the three samples collected at one sampling site, resulting in no statistical significant differences among mean values.

2.1.2.1.2.2.5 Soil Zinc

Total soil Zn is shown in Figure 2-7. Although most of the values were below the MASSA for Zn, many Zn values exceeded the 54-ppm level in normal agricultural cropland. A number of values exceeded the limit, in one case up to 80,000 ppm. Those areas exceeding the MASSA for zinc should be restricted for agricultural land use.

2.1.2.1.2.2.6 Soil Copper

Total soil concentrations of copper are illustrated in Figure 2-8. Values ranged from near detectable limits in the reference areas (BK) to more than 3000 ppm in the Kiln (KS) area on Parcel 572. Numerous locations in the AA area on Parcel 572 also had elevated soil Cu contents (Appendix Table 2-A1). Copper exceeded the MASSA (Table 2-2) at most of the locations in AA and KS areas. Consequently, these areas should be restricted for agricultural land use.

2.1.2.1.2.2.7 Soil Nickel

Total soil nickel concentration is presented in Figure 2-9. Most of the values were less than the MASSA except for four locations in Site AA on Parcel 572, four in the AB area on Parcel 572, and one in the K-2 areas on Parcel 574. These data indicate that these latter areas should be restricted for agricultural land use.

2.1.2.2 Clam Bioassay

The clam biomonitoring procedure utilized an established technique developed by The Netherlands Organization for Applied Scientific Research (TNO) (Marquenie 1981), and previously used in biomonitoring on the Rhine River by the TNO and WES.

2.1.2.2.1 Methods and Materials

Clams were caged and placed in suspected contaminated and uncontaminated aquatic areas to measure toxicity and/or bioaccumulation of waterborne contaminants during a 28-day test. All test animals were of the same origin and handled identically in the field. Locations of biomonitoring points in the stream and adjacent bay are shown in Figure 2-2.

Asiatic clams (Corbicula fluminea) were purchased from a West Coast supplier who air shipped them directly to WES. Upon arrival, the population was divided into two groups, and each group was placed in a depuration tank containing aged tap water. One group remained in aged tap water, while the other group was gradually acclimated to a salinity concentration of 5 parts per thousand (ppt) using Instant Ocean sea-water mix (Aquarium Systems, Mentor, Ohio). Both tanks were observed for one week, during which dead or moribund animals were removed. Prior to use in the study, representative collection of these animals were frozen for initial background chemical analysis.

The clams were transported to the field site in ice chests with a moist paper towel layer between them and the freezer packs. One ice chest contained those animals acclimated to saline conditions, while the other contained those individuals acclimated to the aged tap water. Within 48 hr after arrival in California, the clams were placed into biomonitoring cages and deposited at their monitoring stations. All clams were kept cool and covered with moist towels until deposition.

All biomonitoring cages were of identical two-piece construction. The base, a 9.5-in.-diameter solid circular plate, was attached to a 5-in.-high conical upper portion of the trap by using a nylon strip fastener passed through each of four 0.25-in. holes. The upper half of the cage was designed to allow free water movement through evenly spaced 0.3-in.-wide slots. Ten clams were placed in each cage and a labeled index card sealed inside a "ZIPLOC" bag was included to ensure correct sample identification.

The caged clams were placed in aquatic areas adjacent to cattails (Typha spp.). Where possible, the caged clams were placed to enhance correlations of data among water quality, plant uptake, and sediment contaminant levels. Each cage was placed so that it would remain flooded regardless of tidal fluctuations and was tied with nylon string to a marked stake. Selected water quality parameters measured during the clam biomonitoring were dissolved

oxygen, water temperature, pH, and salinity. These were measured using a USI temperature and D/O meter, a Digi-Sense portable pH meter, and an American Optical refractometer, respectively (Appendix Table 2-C1). Each instrument was properly calibrated before and during measurements.

After 28 days, the numbers of live and dead clams were recorded, as were additional water quality measurements. The surviving test animals as well as indigenous C. fluminea samples were then collected, packaged, and shipped, in precisely the same manner as described for soil and plant samples, to the WES. Upon arrival at the WES, the animals were purged for 48 hr in aged tap water or 5 ppt salt water, depending on their prior conditions, and frozen in whirl pac bags for future chemical analysis.

The following tissue digestion procedures, which were suggested by Plumb (1981), were employed for all animal tissue samples. All glassware was washed with Liquinox soap, rinsed three times with tap water, cleaned in a 20% HCL acid bath, then rinsed three times with RO water. After washing, the glassware was oven dried at 220 F for 48 hr. Animal tissue was also oven dried at 220 F for 48 hr. This temperature provided the necessary dryness for tissue grinding. Dried tissue samples were moved to a desiccator and allowed to cool to room temperature before recording the total dry weight of the tissue sample recovered. Dried tissue samples were then ground using an acid-washed glass mortar. The pestle and spatula were acid washed, rinsed, and dried between samples to prevent contamination carryover.

Approximately 0.5 g of dried and ground tissue was weighed into each 125-ml Erlenmeyer digestion flask. Weighing was performed using a Mettler PC 440 balance (Mettler Instrumente, Greifensee, CH). Weighed samples were then moistened with 1.0 ml deionized distilled water (DDW) and transferred to a fume hood where 10.0 ml concentrated nitric acid (J. T. Baker for Trace Metal Analysis) was added. The flasks were then swirled to ensure good mixing and five acid-washed glass boiling beads added to each flask. Flasks were sealed with para-film and allowed to stand overnight.

The following morning the flasks were uncovered and placed on a Thermolyne 2200 hot plate and brought slowly to boiling (203 deg F). Boiling continued until the solution was concentrated to approximately 0.5 ml. An additional 5.0 ml concentrated HNO_3 was then added per flask and boiled until the solution was again concentrated to approximately 0.5 ml. Three additions of 5.0 ml concentrated HNO_3 were added to ensure complete digestion.

After digestion, the flasks were cooled to room temperature, diluted with approximately 20.0 ml DDW, and filtered through a No. 42 Whatman filter into a 50.0 ml volumetric flask. Flasks were then rinsed with additional 5 ml portions of DDW to remove any remaining digested sample.

The collected solution was then diluted to a 50.0 ml volume with DDW and transferred to a plastic storage bottle for chemical analysis. All samples before and after digestion were stored in a locked freezer or refrigerator within a locked laboratory until transfer of custody to the WES Analytical Laboratory for metal analysis.

2.1.2.2.2 Results and Discussion

The exotic Asiatic clam (Corbicula fluminea) was used for field bioassays at sites having moving water in the stream or on tidal flow (Figure 2-2). Tissues were analyzed for seven heavy metals (As, Cd, Pb, Se, Zn, Cu, and Ni), all of which had established "action levels" for seafoods except Ni (Table 2-5 Lee et al. 1984). Because these "action levels" were originally expressed on the basis of wet weight, they were multiplied by a factor of 10 to convert metal action level concentrations to a dry-weight basis. This was based upon the general assumption that edible portions of fresh clams are about 10 percent dry matter and 90 percent water. All clam data are expressed as milligrams per kilogram dry tissue weight. The average initial concentration of metals in the clams prior to biomonitoring were 0.015 ± 0.004 mg/kg for arsenic, 0.010 ± 0.002 mg/ kg for cadmium, 0.595 ± 0.116 mg/kg for copper, 0.007 ± 0.003 mg/kg for lead, 0.014 ± 0.005 mg/kg for nickel, 0.014 ± 0.001 mg/kg for selenium, and 1.203 ± 0.080 mg/kg for zinc. The data (Figures 2-10 through 2-16) show clearly that no action-level criteria were exceeded at any station following a 28-day field exposure. There were no practical differences in the concentrations of copper, nickel, selenium, and arsenic in tissues of clams from locations near suspected contaminated areas and such tissue concentrations from the remote reference areas (Table 2-A2). However, lead, cadmium, and zinc were accumulated in clam tissues at certain locations compared to other biomonitored areas. Lead was significantly elevated in the clams at the G-1 area on Parcel 575 and the K-2 area on Parcels 573 and 574 (Table 2-A2); cadmium was significantly elevated at the K-2 area on Parcels 573 and 574, the G-1 area on Parcel 575, and the AA area on

Table 2-5

Action Levels for Contaminants in Aquatic Organisms for Human Consumption from Lee et al. 1984

Chemical	Food	Action Level* mg/kg (wet weight edible portions)	Maximum Concentration** mg/kg (wet weight edible portions)
Aldrin	Fish and shellfish	0.3	
Antimony	All nonspecified foods (including seafood)		1.5
As	Fish, crustacea, molluscs		1.0
Cd	Fish		0.2
	Molluscs		1.0
Chlordane	Fish	0.3	
Cu	Molluscs		70.0
	All nonspecified foods (including seafood)		10.0
DDT, DDE, TDE	Fish	5.0†	
Dieldrin	Fish and shellfish	0.3	
Endrin	Fish and shellfish	0.3	
Heptachlor, heptachlor epoxide	Fish and shellfish	0.3†	
Hexachlorocyclohexane (Benzene hexachloride)	Frog legs		0.5
Kepone	Fish and shellfish	0.3	
	Crabmeat	0.4	
Pb	Molluscs		2.5
	All nonspecified foods (including seafood)		1.5

(Continued)

* United States Food and Drug Administration (FDA) Action Levels for Poisonous or Deleterious Substances in Human Food.

** Australian National Health and Medical Research Council Standards for Metals in Food, May 1980

† Action level is for these chemicals individually or in combination. However, in adding concentrations, do not count any concentrations below the following levels:

Chemical	Minimum Level (mg/kg)
DDT, DDE, TDE	0.2
Heptachlor, heptachlor epoxide	0.3

Table 2-5 (Concluded)

Chemical	Food	Action Level* mg/kg (wet weight edible portions)	Maximum Concentration** mg/kg (wet weight edible portions)
Hg	Fish, crustacea, molluscs		0.5
Methylmercury	Fish, shellfish, other aquatic animals	1.0	
Mirex	Fish	0.1	
PCB (total)	Fish and shellfish	2.0††	
Se	All nonspecified foods (including seafood)		1.0
Tin	Fish		50.0
Toxaphene	Fish	5.0	
Zn	Oysters All nonspecified foods (including seafood)		1,000.0 150

†† This is not an action level but a tolerance limit established through the rulemaking process.

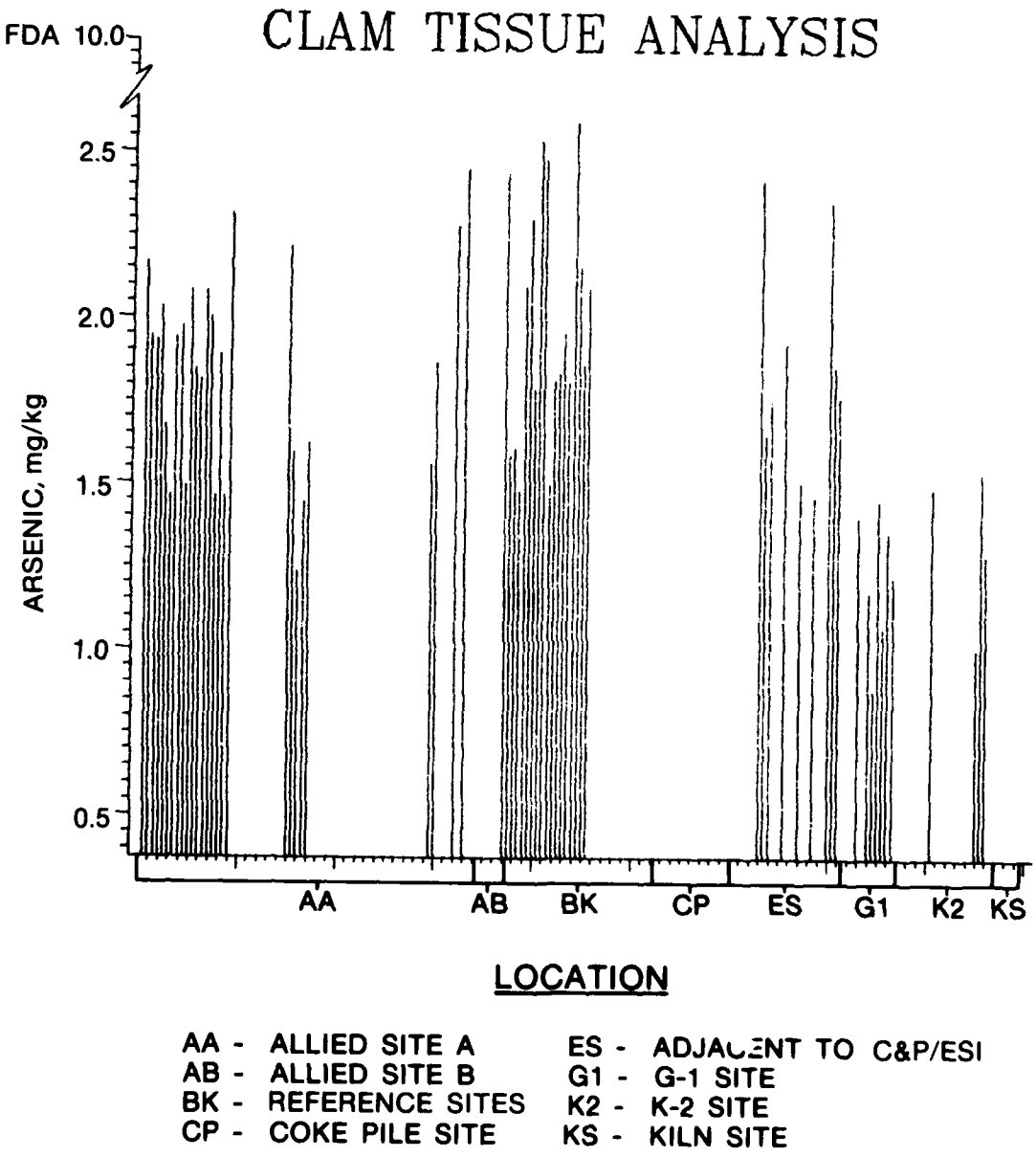


Figure 2-10. Clam tissue arsenic content

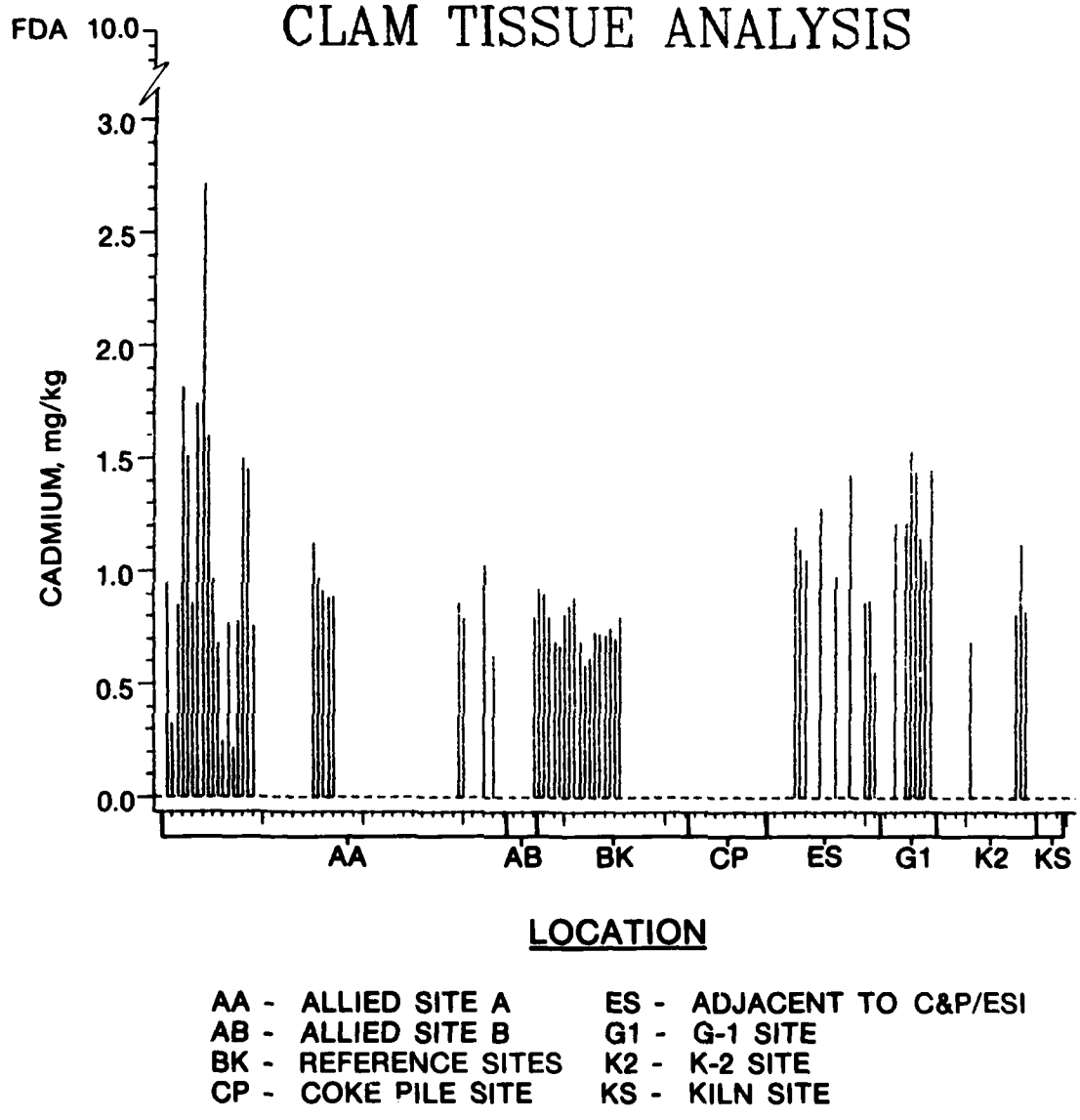


Figure 2-11. Clam tissue cadmium content

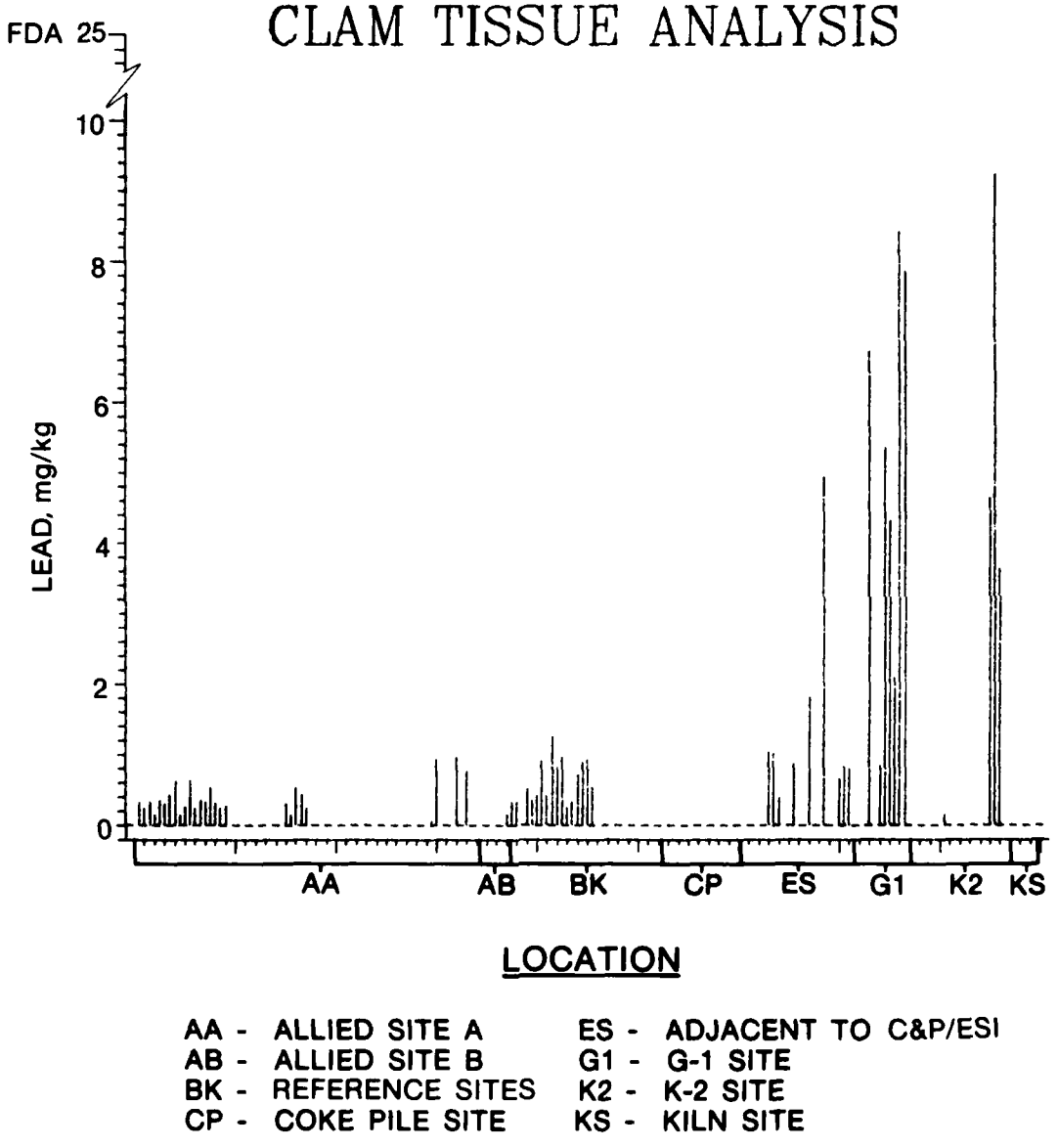


Figure 2-12. Clam tissue lead content

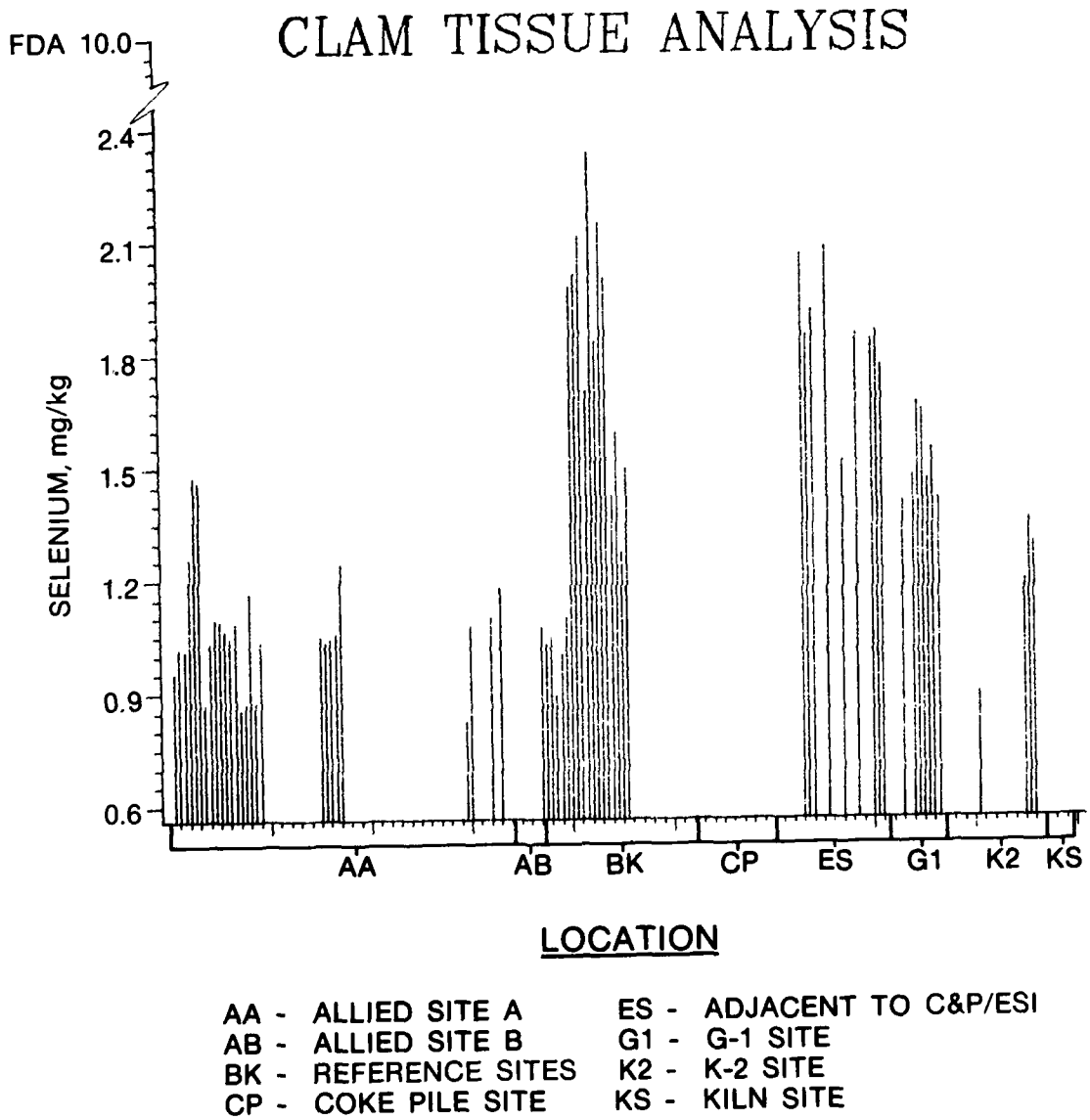


Figure 2-13. Clam tissue selenium content

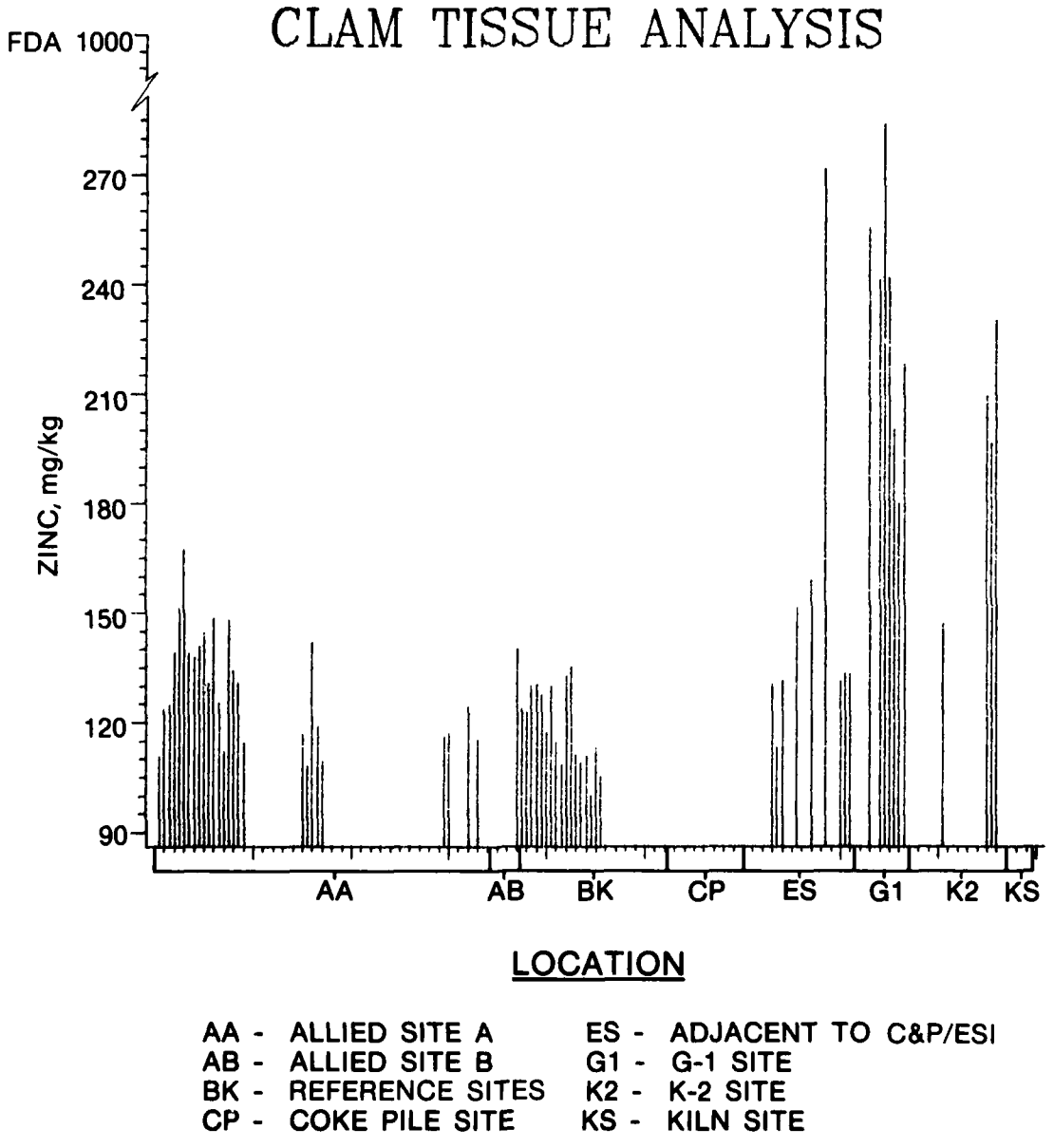


Figure 2-14. Clam tissue zinc content

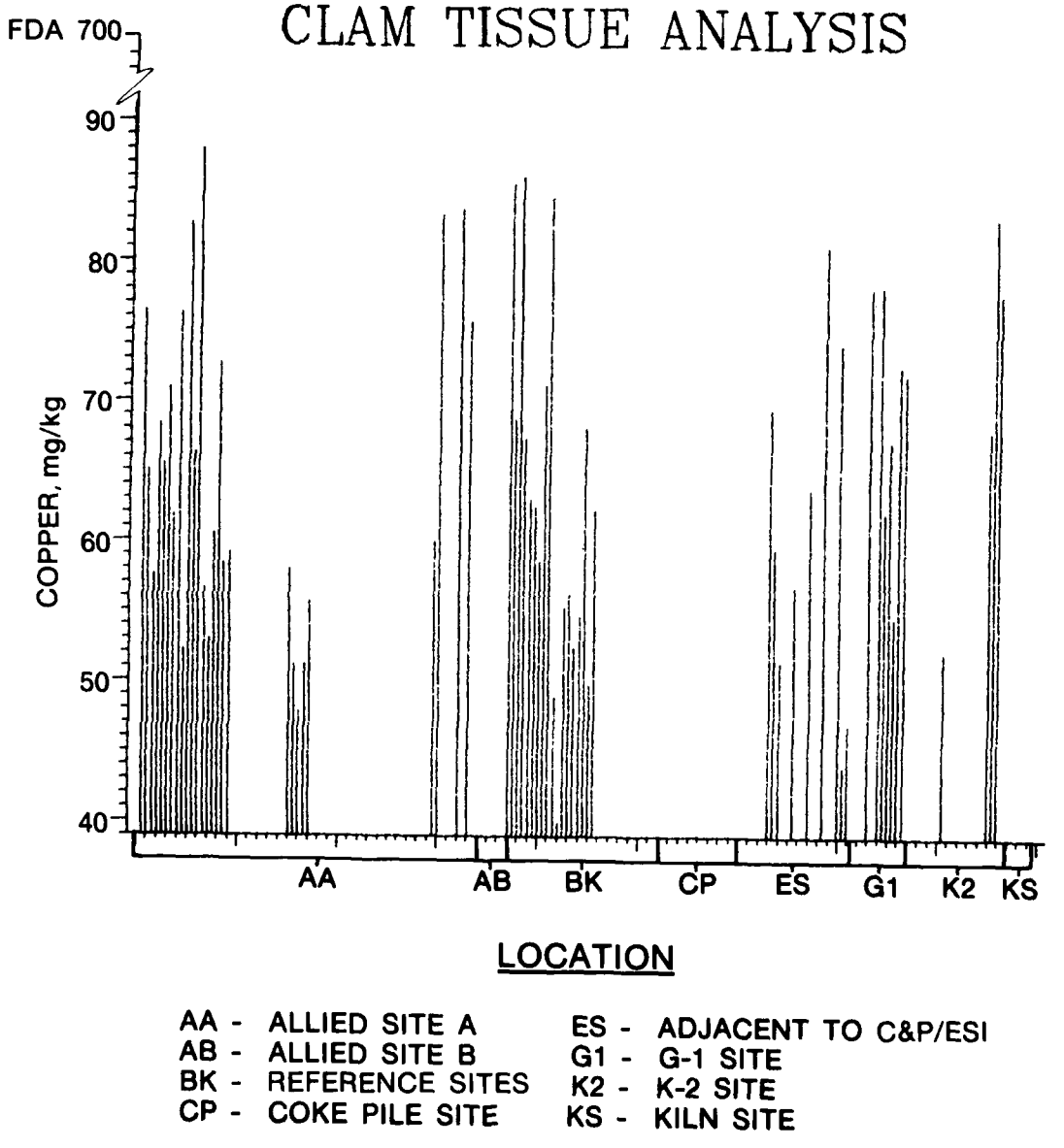
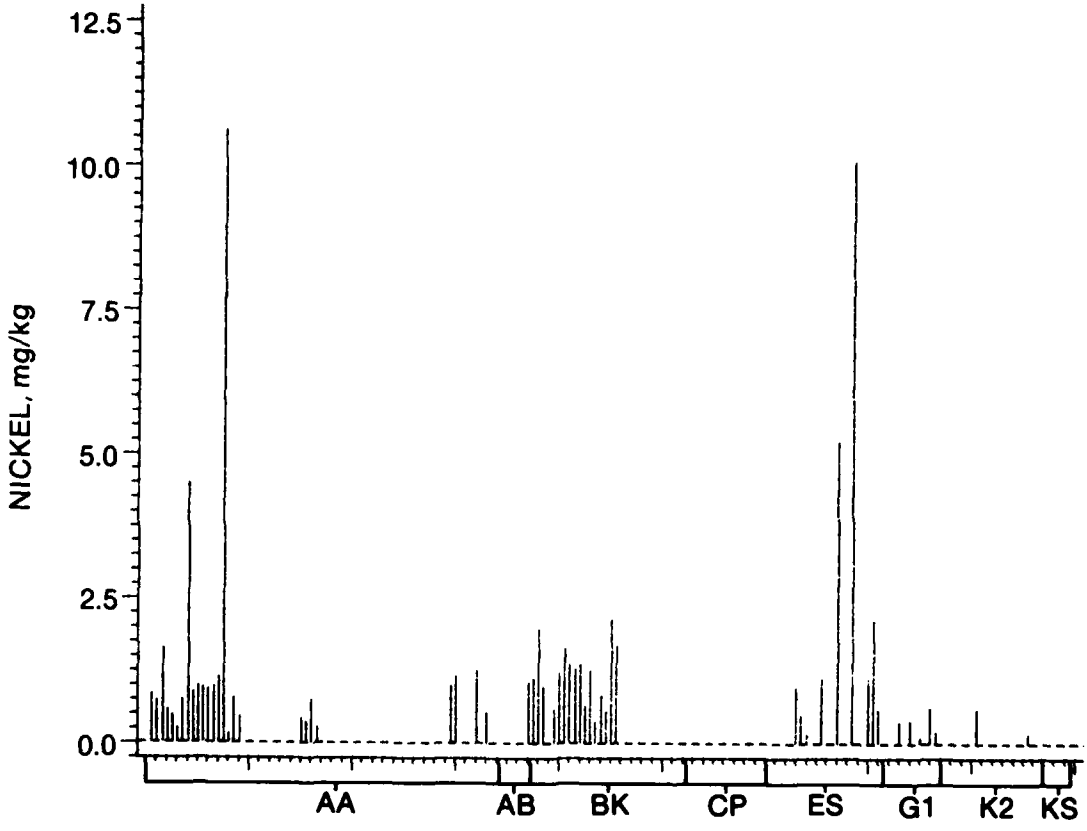


Figure 2-15. Clam tissue copper content

CLAM TISSUE ANALYSIS



LOCATION

AA - ALLIED SITE A	ES - ADJACENT TO C&P/ESI
AB - ALLIED SITE B	G1 - G-1 SITE
BK - REFERENCE SITES	K2 - K-2 SITE
CP - COKE PILE SITE	KS - KILN SITE

Figure 2-16. Clam tissue nickel content

Parcel 572; and zinc was significantly elevated at the K-2 area on Parcels 573 and 574, the G-1 area on Parcel 575, and the ES area on Parcel 579.

These data suggest that bivalve molluscs in the stream may become contaminated. These results indicate that lead and cadmium are moving into the surface water of the stream in the K-2 and G-1 areas and, to some extent, into the tidal water in the AA area. A comparison of the clam biomonitoring data with recent literature on Corbicula fluminea (Table 2-6) suggests that these data are within the expected ranges to be found elsewhere.

The use of C. fluminea for biomonitoring and laboratory bioassays for contaminant bioaccumulation has been used widely in recent years (Rodgers et al. 1980, Tatem 1982, Cairns and Cherry 1983, Graney et al. 1983, McFarland et al. 1984, McFarland et al. 1985) and has been acknowledged for its use in biomonitoring since prior to 1971 (Sinclair 1971). Previous work has indicated that C. fluminea can tolerate Cu concentrations up to 275-400 milligrams per kilogram in the tissue before gaping and cessation of filtering occurs (Rodgers et al. 1980). Cairns and Cherry (1983) reported that the LC50 for Cu and Cu + Zn were 0.59 and 2.41 mg/ℓ, respectively, for a 24-hr static bioassay and 0.04 and 0.05 mg/ℓ respectively for a 96-hr bioassay; the 96-hr LC50 for Zn alone was 6.04 mg/ℓ. They found no 24-hr LC50 for Zn exposures up to 40 mg/ℓ. Concentrations of Cu and Zn on tissues were not indicated. Recent work on C. fluminea in Suisun Bay, which borders NWS Concord, indicates that maximum Cd, Cu, and Zn bioaccumulation in the current field biomonitoring is below the maximum reported for clams collected from the bay (Luoma et al. 1984). These data suggest that the uptake of metals by C. fluminea in the present study should cause no physiological stress on the clams, and that metals in the surface water draining the study areas at NWS Concord had a minimal environmental impact on the aquatic ecosystem of Suisun Bay during the sampling period in June and July 1984.

2.1.2.3 Plant Bioassay

2.1.2.3.1 Field-Collected Plant Material

Table 2-6

A Comparison of Heavy Metals in Corbicula Fluminea from Naval Weapons Station Field Bioassays with Data from Recent Literature

Metal	Concentration in Clams, mg/kg Dry Weight	Notes and Comments	Source of Data
As	0.86-2.59	28-day NWS Field Bioassay	NWS Study
	4.60-7.10	Field Collected	Rodgers et al. (1980)
Cd	0.02-2.71	28-day NWS Field Bioassay	NWS Study
	23.45	0.003 mg/ℓ, 28-30 day aqueous exposure	Graney et al. (1983)
	101.39	0.023 mg/ℓ, in artificial stream; maximum	
	111.73	0.055 mg/ℓ, concentrations in clams	
	2.53-3.57	48-day Laboratory exposure in presence of contaminated sediments	Tatem, H. E., USACE, WES, Personal Communication, April 1985
	0.00-6.00	Field collected-Suisun Bay	Luoma et al. (1984)
	5.85-6.60	Field collected	Rodgers et al. (1980)
Cu	39.91-87.90	28-day NWS Field Bioassay	NWS Study
	316.48	0.001 mg/ℓ, 28-30 day aqueous exposure	Graney et al. (1983)
	724.90	0.016 mg/ℓ, in artificial stream; maximum	
	1431.10	0.057 mg/ℓ, concentrations in the clams	
	6.32-12.10	Field collected	Rodgers et al. (1980)
	41-155	Field collected-Suisun Bay	Luoma et al. (1984)
Pb	0.00-9.21	28-day NWS Field Bioassay	NWS Study
	1.96-2.62	48-day Laboratory exposure in presence of contaminated sediment	Tatem, H. E., USACE, WES, Personal Communication, April 1985
Ni	0.00-10.07	28 day NWS Field Bioassay	NWS Study
Se	0.68-2.33	28-day NWS Field Bioassay	NWS Study
	3.90-16.5	Field collected	Rodgers et al. (1980)
Zn	99.90-284	28-day NWS Field Bioassay	NWS Study
	114.35	0.012 mg/ℓ, 28-30 day aqueous exposure	Graney et al. (1983)
	367.47	0.218 mg/ℓ, in artificial stream; maximum	Graney et al. (1983)
	318.13	0.433 mg/ℓ, concentrations in the clams	
	530.68	0.835 mg/ℓ,	
	500-564	Field collected	Rodgers et al. (1980)
	110-349	Field collected-Suisun Bay	Luoma et al. (1984)

2.1.2.3.1.1 Methods and Materials

Upon arrival at the WES, boxes of field-collected Typha were removed from the trailer one box at a time. Each bag of plant sample was removed from the box and prepared for chemical analysis in the following manner. The plant material was removed from the bag and placed into plastic wash trays containing RO purified water. The tissue was swirled about to remove adhering airborne contamination. Each piece of tissue (leaf, stems, head) was placed into another plastic wash tray and rinsed again. The tissues were blotted dry with white paper towels; separated into leaves, stems, and heads; placed into paper bags that had several holes punched in them; and dried at 70 deg C until constant weight. All the tissue parts were weighed for total yield determination. Plant leaves were ground in a Wiley mill to pass a 40-mesh screen in preparation for chemical analysis.

The Typha leaf tissue was digested and analyzed by the same procedures as those used for digestion and subsequent heavy metal analysis in Section 2.1.2.1.1 except that 2 g of tissue were digested instead of 1 g.

2.1.2.3.1.2 Results and Discussion

Results of the plant bioassay testing were interpreted by comparing the results to existing critical tissue metal contents for demonstrated effects on plants (Table 2-7) and FDA action levels for animal feed and foodstuffs (Table 2-8 and Table 2-9) and by analyzing statistical differences among sampling site means. Statistical procedures used included Statistical Analysis System (SAS), Analysis of Variance (ANOVA), and Duncan's New Multiple Range Test.

The use of critical tissue metal contents for demonstrated effects can indicate when tissue metal contents from field-collected plant samples or laboratory bioassay test plants reach levels that have been shown to be detrimental to plant growth. These values can give an indication of the health or unhealthy condition of plants growing in contaminated soil. The use of FDA action levels indicates when plant tissue contents are approaching concentrations that might result in a hazard for consumption by humans and animals. The major consumers at NWS Concord are wildlife animals, so animal feed FDA levels are the more appropriate values to consider. Use of statistical

Table 2-7

Demonstrated Effects of Contaminants on Plants

(Taken in part from Table C-5 in Lee et al. 1984)

		Plant Growth			
Contaminant	Normal*	"Critical" Content** mg/kg leaves	10% Yield Reduction mg/kg leaves	25% Yield Reduction mg/kg leaves	Phytotoxic†
As	0.1-1	--	--	--	3-10
Cd	0.1-1	8	15	Varies	5-700
Cu	3-20	20	20	20-40	25-40
Ni	0.1-5	11	26	50-100	500-1000
Pb	2-5	--	--	--	--
Se	0.1-2	--	--	--	100
Zn	15-150	200	290	500	500-1500

* From Chaney (1983). Normal--tissue content normally observed in healthy plants.

** From Davis et al. (1978), Davis and Beckett (1978), and Beckett and Davis (1977). Tissue content above which detrimental effects have been observed in plants.

† From Chaney (1983). Phytotoxic--tissue content observed in dying or dead plants.

differences indicates that in certain areas there are plants contaminated to a higher degree than the surrounding areas. Consequently, the highly contaminated areas can be located using this method of statistical differences.

Heavy metal contents of the field collected Typha are presented in Figures 2-17 through 2-31. Generally the data show that a few samples of Typha had metal concentrations of As, Pb, Cd, and Zn above that of other sampled areas. Except for a few Typha samples downstream from the Chemical and Pigment Company plant, leaf As was below that normally found in Typha (Mudroch and Capobianco 1978). The low values of tissue As could be related to the reduced recovery of plant As obtained in the acid-digestion procedure used. Arsenic concentrations obtained for NBS standards were consistently below established values (Table 2-D4). Consequently, the values shown in Figure 2-17 are actually below true values. There were only a few plant samples with tissue contents of Zn greater than those from remote reference areas, and those plant tissue samples were from the K-2 area on Parcels 573 and 574 and the G-1 area on Parcel 575, areas that had extremely high soil As, Pb, and Zn

Table 2-8

Action Levels for Various Heavy Metals and Pesticides in Plants and Foodstuffs

Substance	Commodity	Data Source*	Action Level	Type of Limit**	Step†	Reference††
As	Non-pulpy black-currant nectar	3	0.2 mg/kg			CAC/RS 101-1978
	Fructose	3	1 mg/kg			CAC/RS 102-1978
	Cocoa powders and dry cocoa-sugar mixtures	3	1 mg/kg			CAC/RS 105-1978
Cd	Provisional weekly tolerance intake for humans	2	0.0067-0.0083 mg/kg body weight			
Pb	Non-pulpy black currant nectar	3	0.3 mg/kg	--	--	CAC/RS 101-1978
	Cocoa powders and dry cocoa-sugar mixtures		2 mg/kg	--	--	CAC/RS 105-1978 App. V, CS 5/70
	Edible acid casein		2	--	--	18th session
	Edible caseinates		2	--	--	App. VI, CS 5/70 18th session
Zn	Non-pulpy black currant nectar		5 mg/kg	--	--	CAC/RS 101-1978
Cu	Non-pulpy black-currant nectar		5 mg/kg	--	--	CAC/RS 101-1978
	Fructose		2 mg/kg	--	--	CAC/RS 102-1978
	Cocoa powders and dry cocoa-sugar mixtures		50 mg/kg	--	--	CAC/RS 105-1978
	Edible acid casein		5 mg/kg	--	--	18th sessions-1976
	Edible caseinates		5 mg/kg	--	--	App. VI, CS 5/70 18th session-1976

* Data source: 1 = FDA action levels for poisonous or deleterious substances in human food and animal feed; 2 = FAO/WHO guide to Codex Maximum Limits for Pesticide Residues; and 3 = list of maximum levels recommended for contaminants by the joint FAO/WHO Codex Alimentarius Commission. Joint FAO/WHO food standards programme Codex Alimentarius Commission CAC/FAL 4-1978.

** Type of limit: CPG = Compliance Policy Guidelines; TT = Temporary Codex Tolerance; TC = Codex Tolerance; and PRL = Practical Residue Limit.

† Step = "Step" in the procedure for the elaboration of Codex Maximum Limits for Pesticide Residue given in the FAO/WHO Guide to CODEX M.

†† Reference = Refers to CPG number.

Table 2-9

Additional Action Levels for Contaminant in Foodstuffs Used by Other Countries

Source	Contaminant	Commodity	Content, mg/kg	References
Britain	Pb	All foods	1.0 (fresh wt)	M.A.F.F. (1972)
World Health Organization (WHO)	Pb	Root vegetables	0.1 (fresh wt)	WHO (1972)
		Cereal	0.1 (fresh wt)	
		Leafy vegetables	1.2 (fresh wt)	
	Cd	Root vegetables	0.05 (fresh wt)	WHO (1972)
		Leafy vegetables	0.1 (fresh wt)	
		Potatoes, cereal	0.1 (fresh wt)	
Dutch	Cu	Animal feed	20.0 (dry wt)	DMAFCMN (1973)
Dutch (unofficial)	Cd	Single animal feet	0.5 (dry wt)	European Community (1974)
		Mixed animal feed	1.0 (dry wt)	
		Roughage	1-2 (fresh wt)	
European Economic Community	Pb	Single animal feed	10.0 (dry wt)	Van Driel et al. (1982)
		Mixed animal feed	5.0 (dry wt)	
		Roughage	40.0 (fresh wt)	
FDA (as of Sep 82)	Hg	Wheat seed	1.0 (dry wt)	FDA (1982)
	PBB	Animal feed	0.5 (dry wt)	
	Various pesticides	Vegetables, grains and feeds	0.03-0.1	

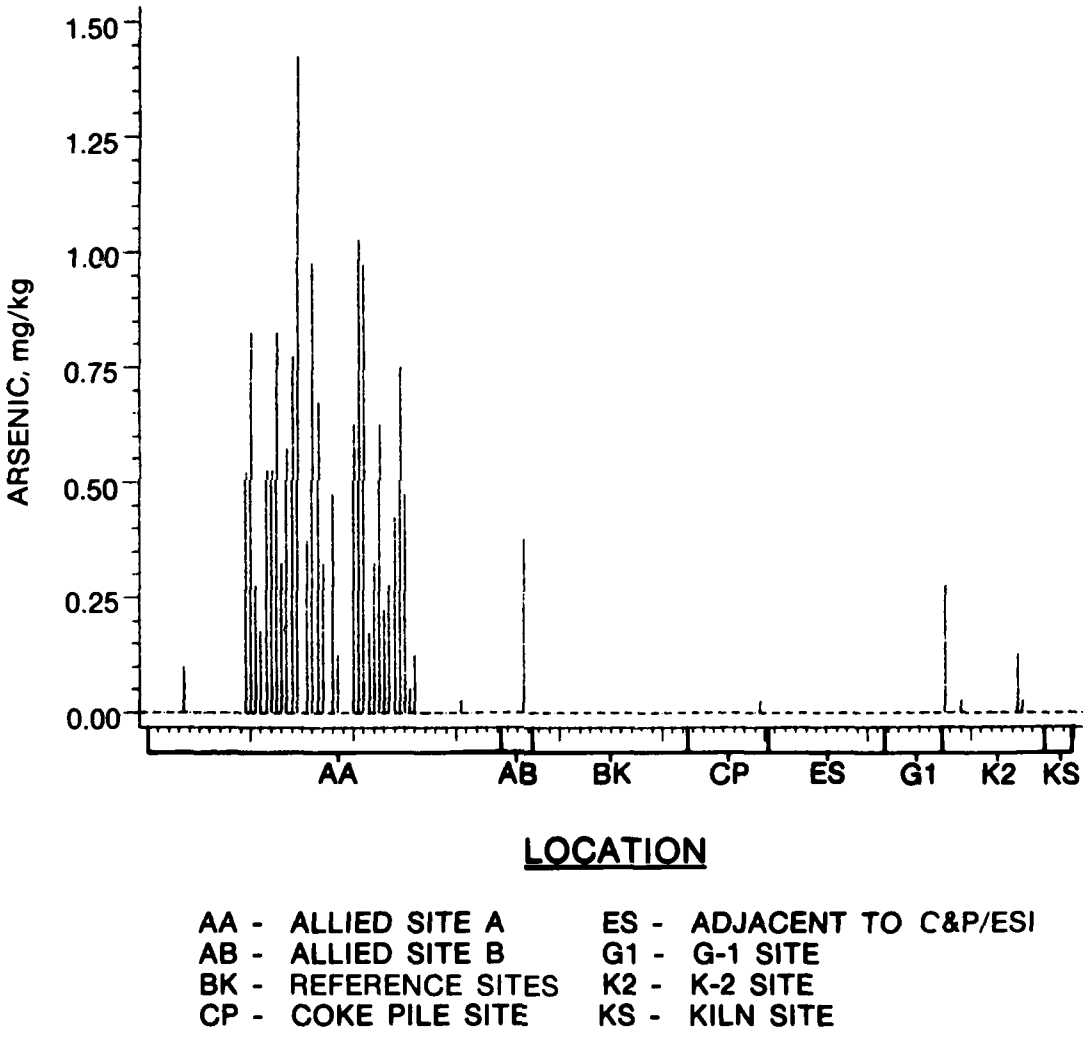


Figure 2-17. Field-collected Typha tissue content of arsenic

FIELD ANALYSIS

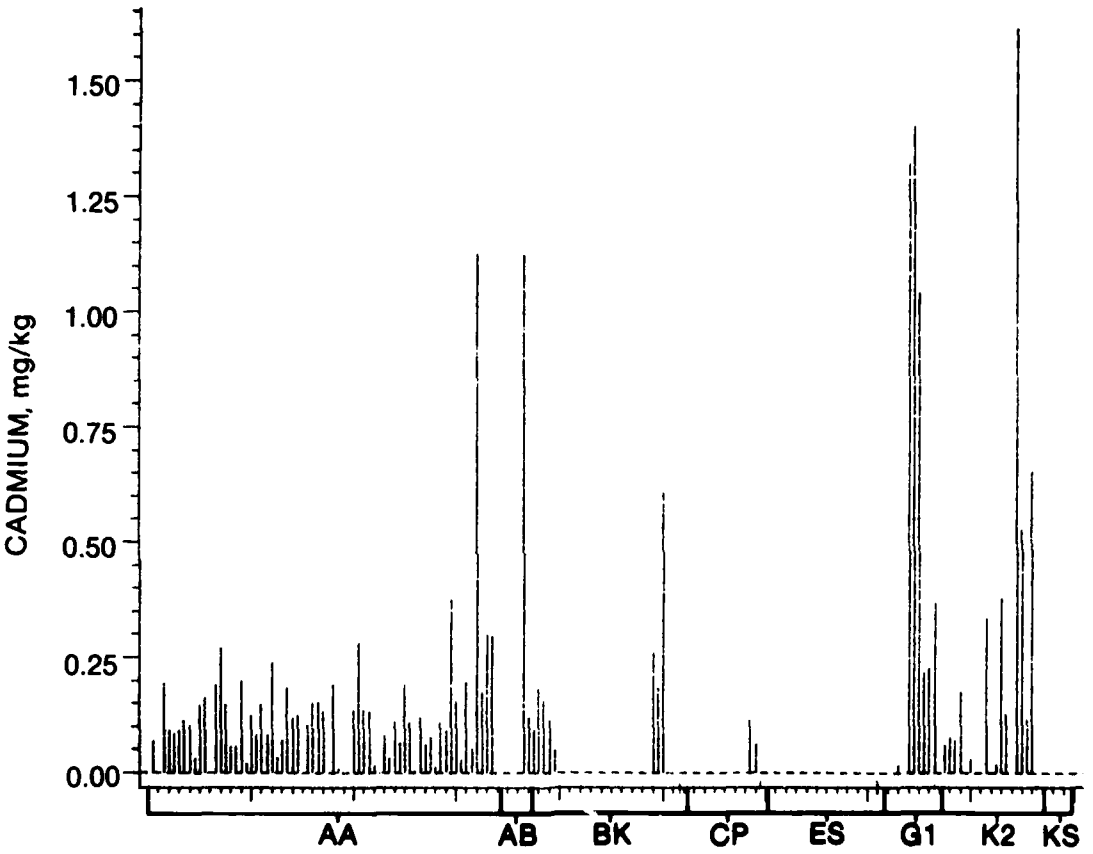


Figure 2-18. Field-collected Typha tissue content of cadmium

FIELD ANALYSIS

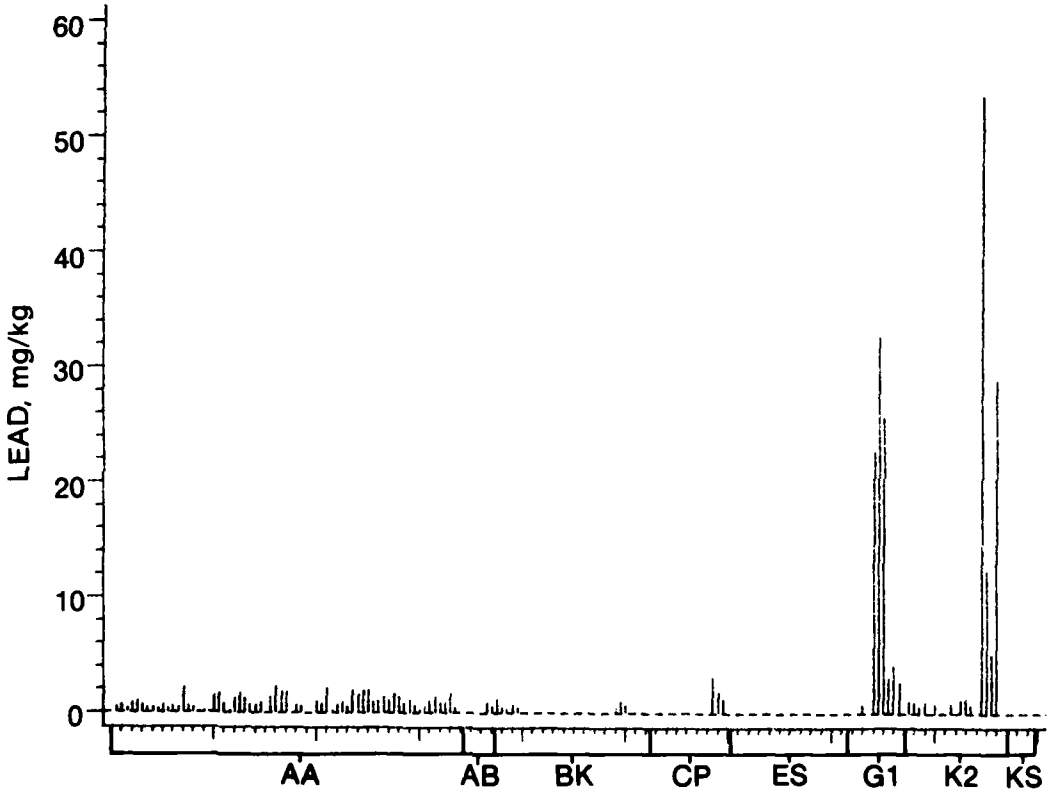


Figure 2-19. Field-collected Typha tissue content of lead

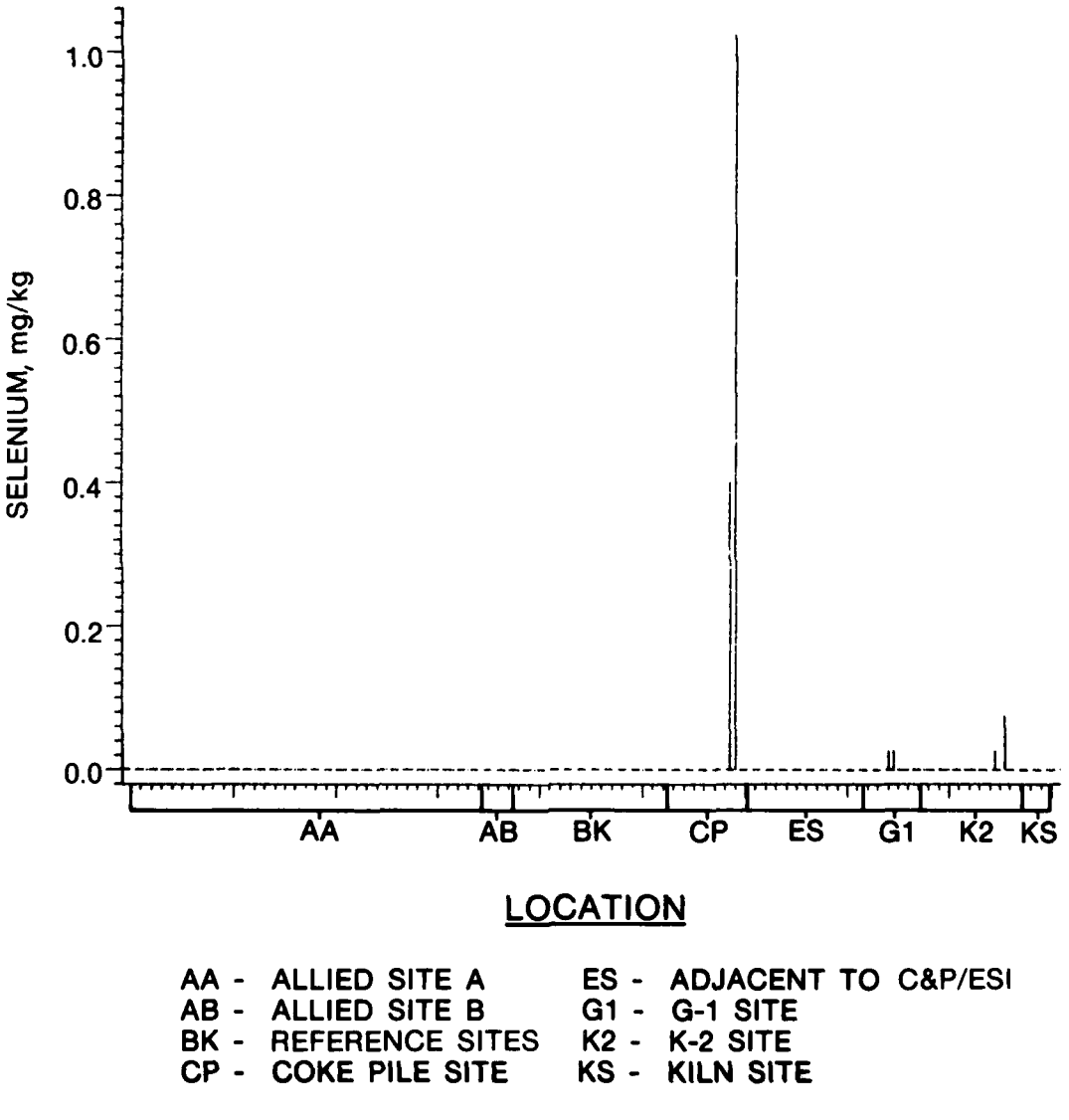
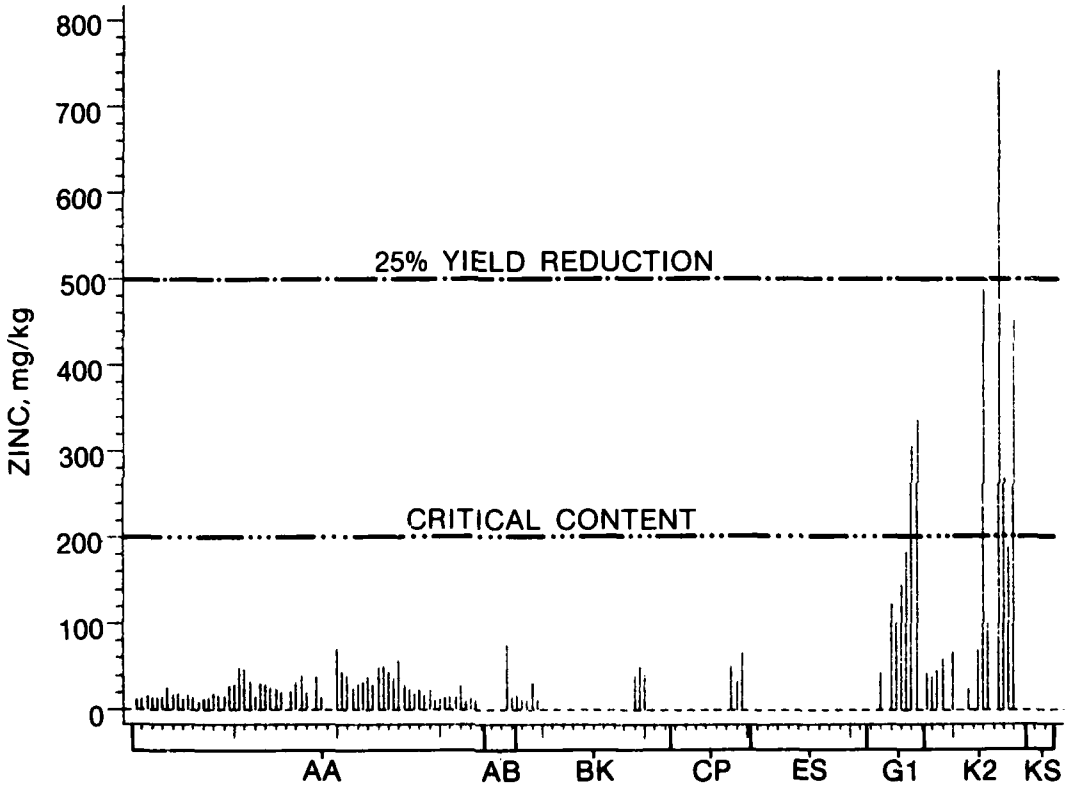


Figure 2-20. Field-collected Typha tissue content of selenium

FIELD ANALYSIS



AA - ALLIED SITE A
AB - ALLIED SITE B
BK - REFERENCE SITES
CP - COKE PILE SITE
ES - ADJACENT TO C&P/ESI
G1 - G-1 SITE
K2 - K-2 SITE
KS - KILN SITE

Figure 2-21. Field-collected Typha tissue content of zinc

FIELD ANALYSIS

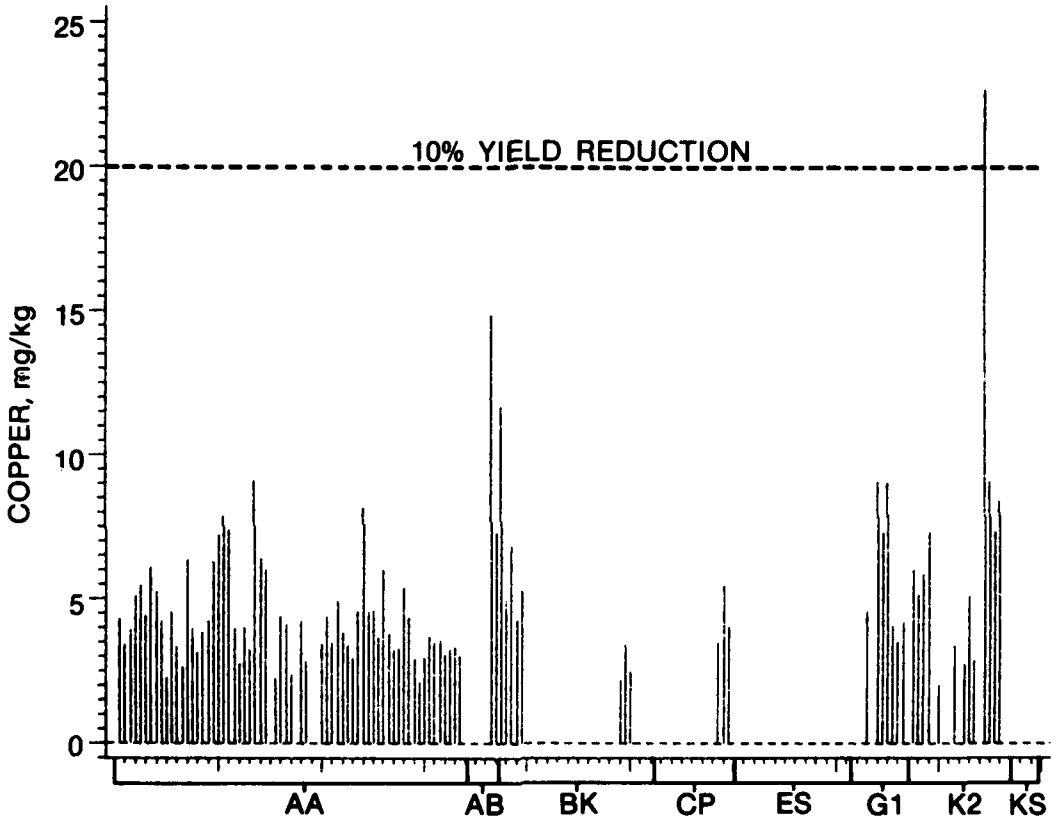


Figure 2-22. Field-collected Typha tissue content of copper

FIELD ANALYSIS

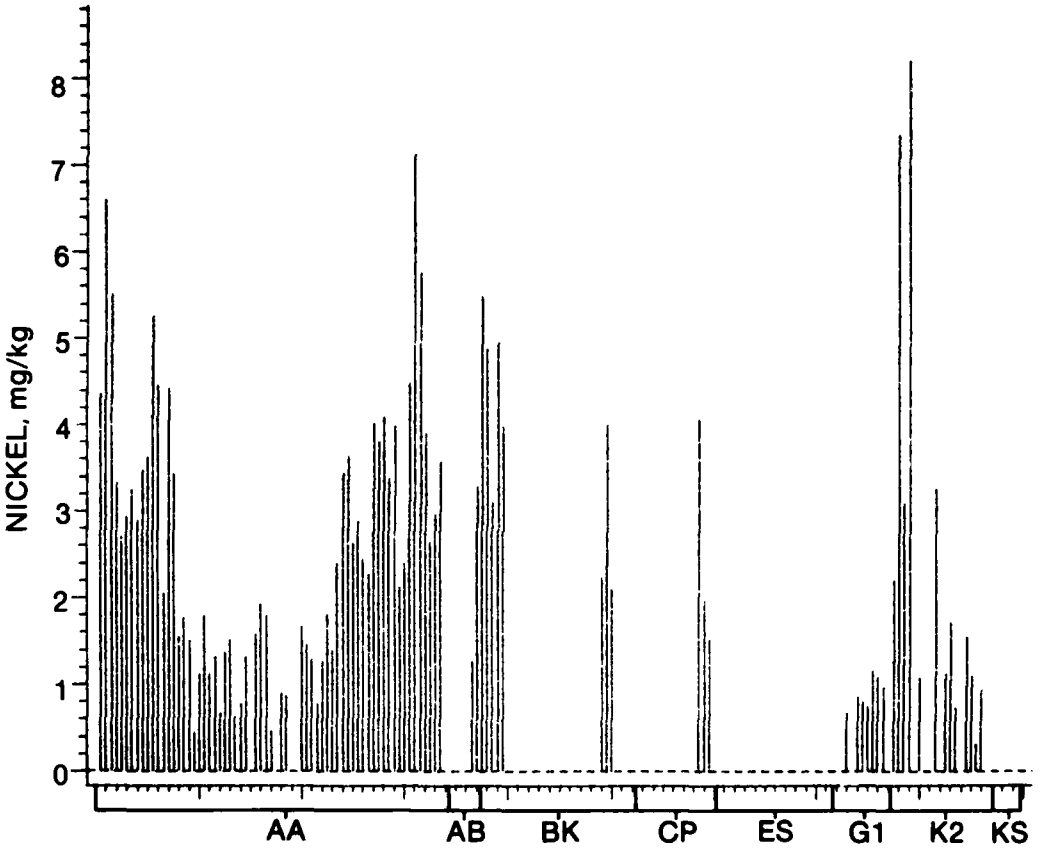


Figure 2-23. Field-collected Typha tissue content of nickel

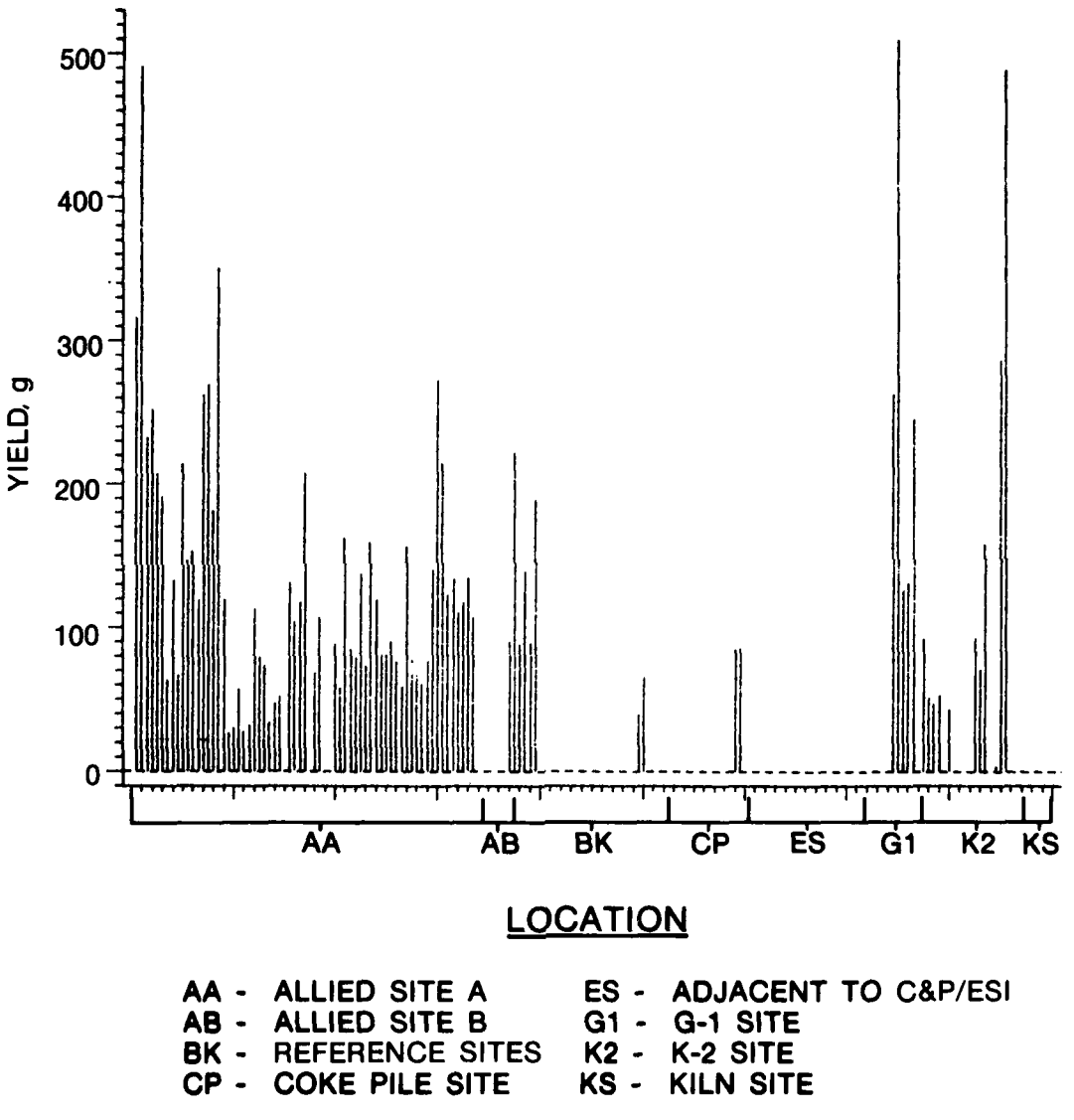


Figure 2-24. Yield of field-collected Typha angustifolia

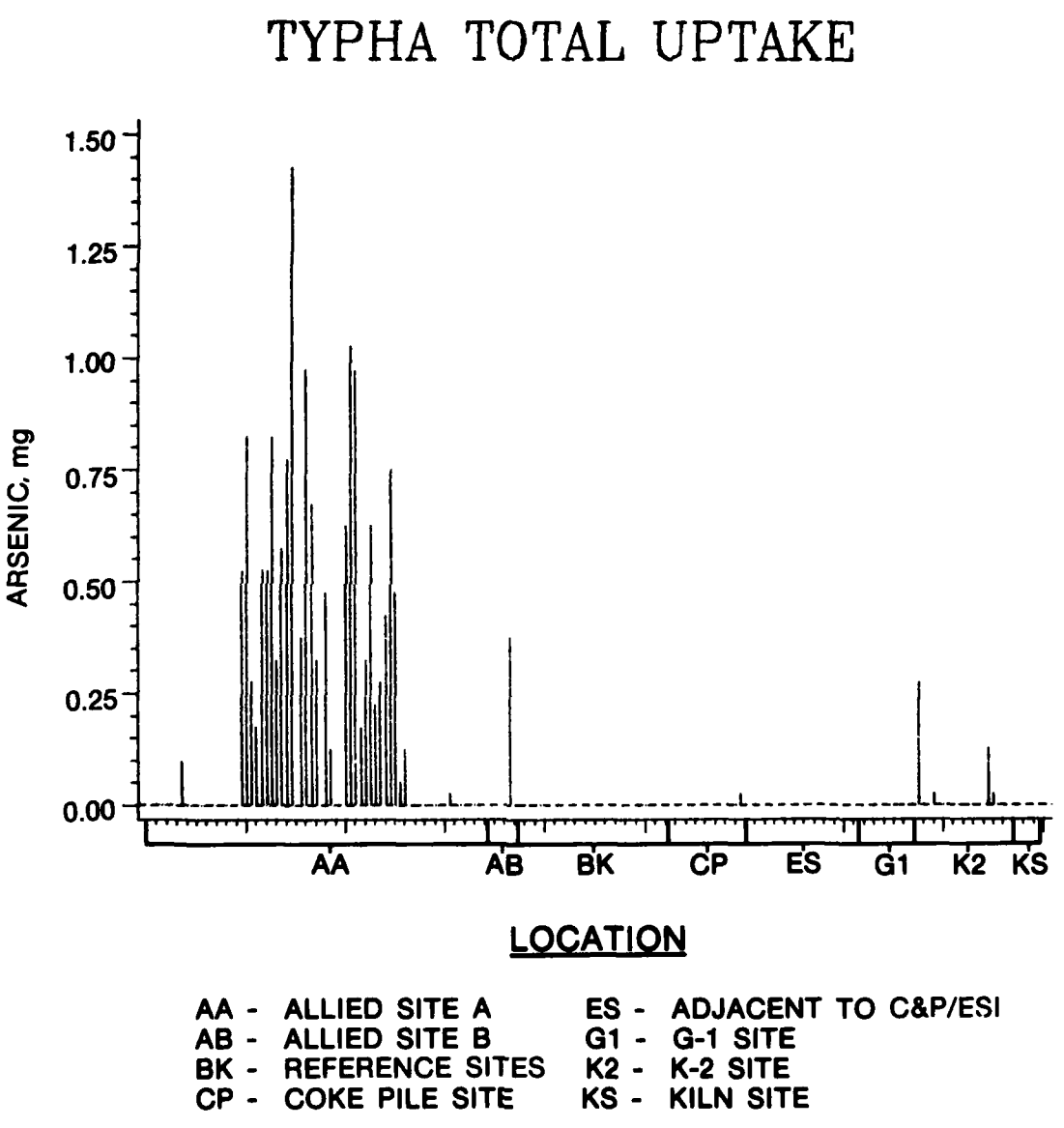


Figure 2-25. Plant uptake of arsenic by Typha

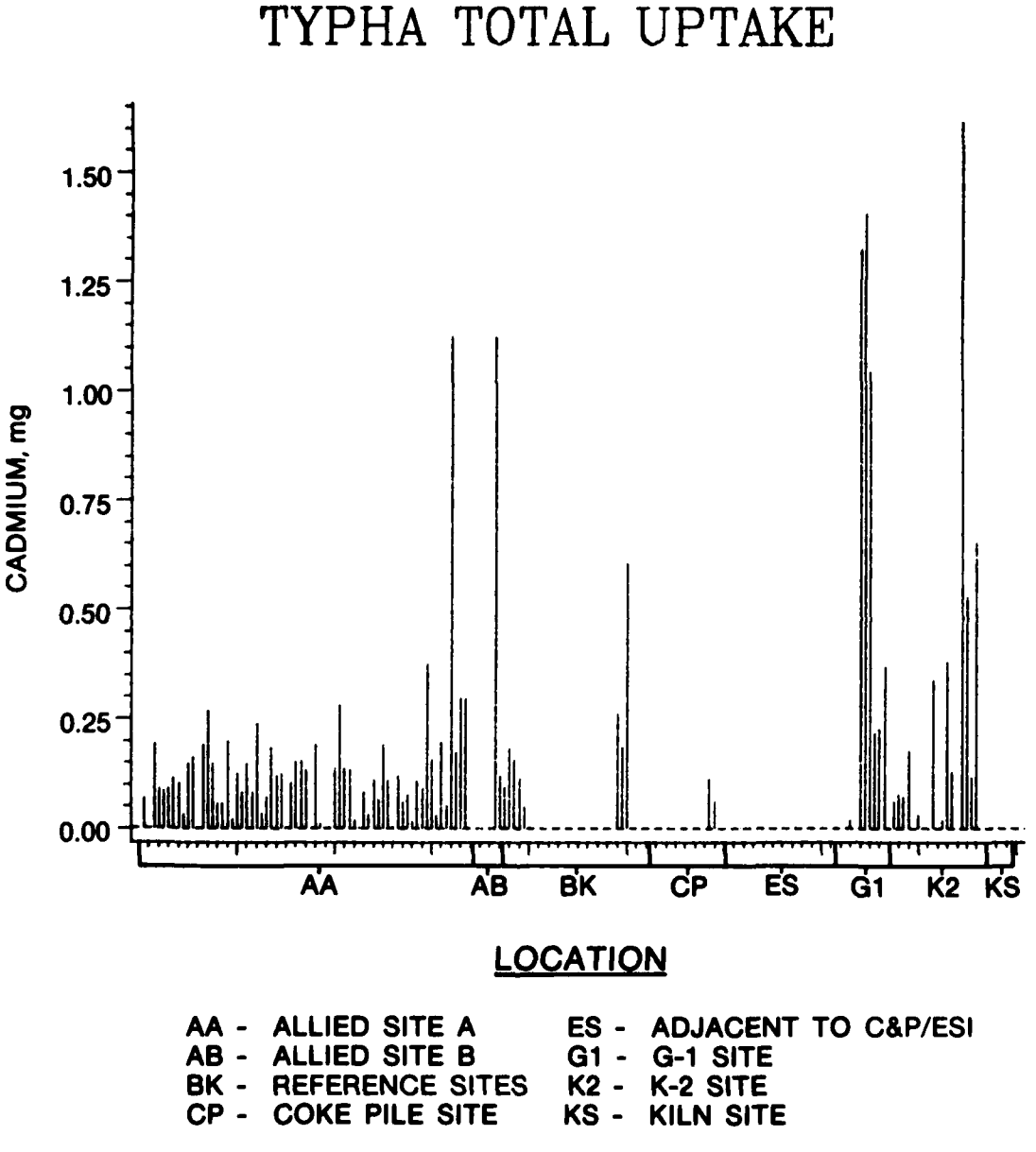


Figure 2-26. Total plant uptake of cadmium by Typha

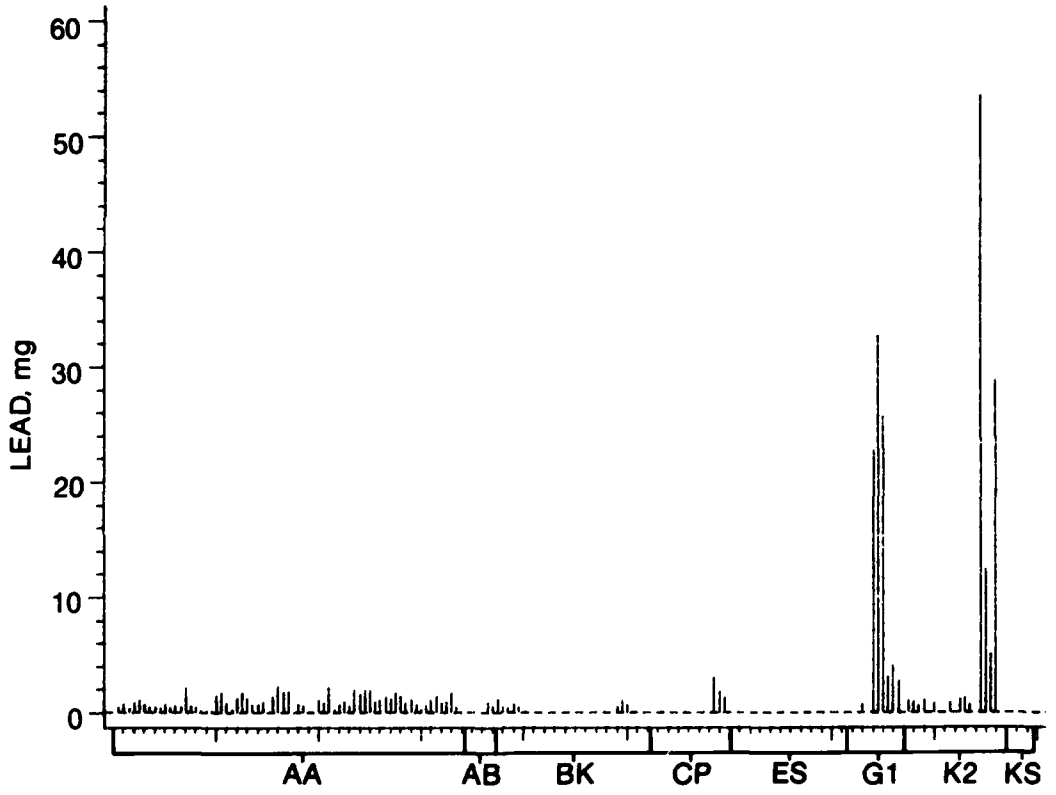


Figure 2-27. Total plant uptake of lead by Typha

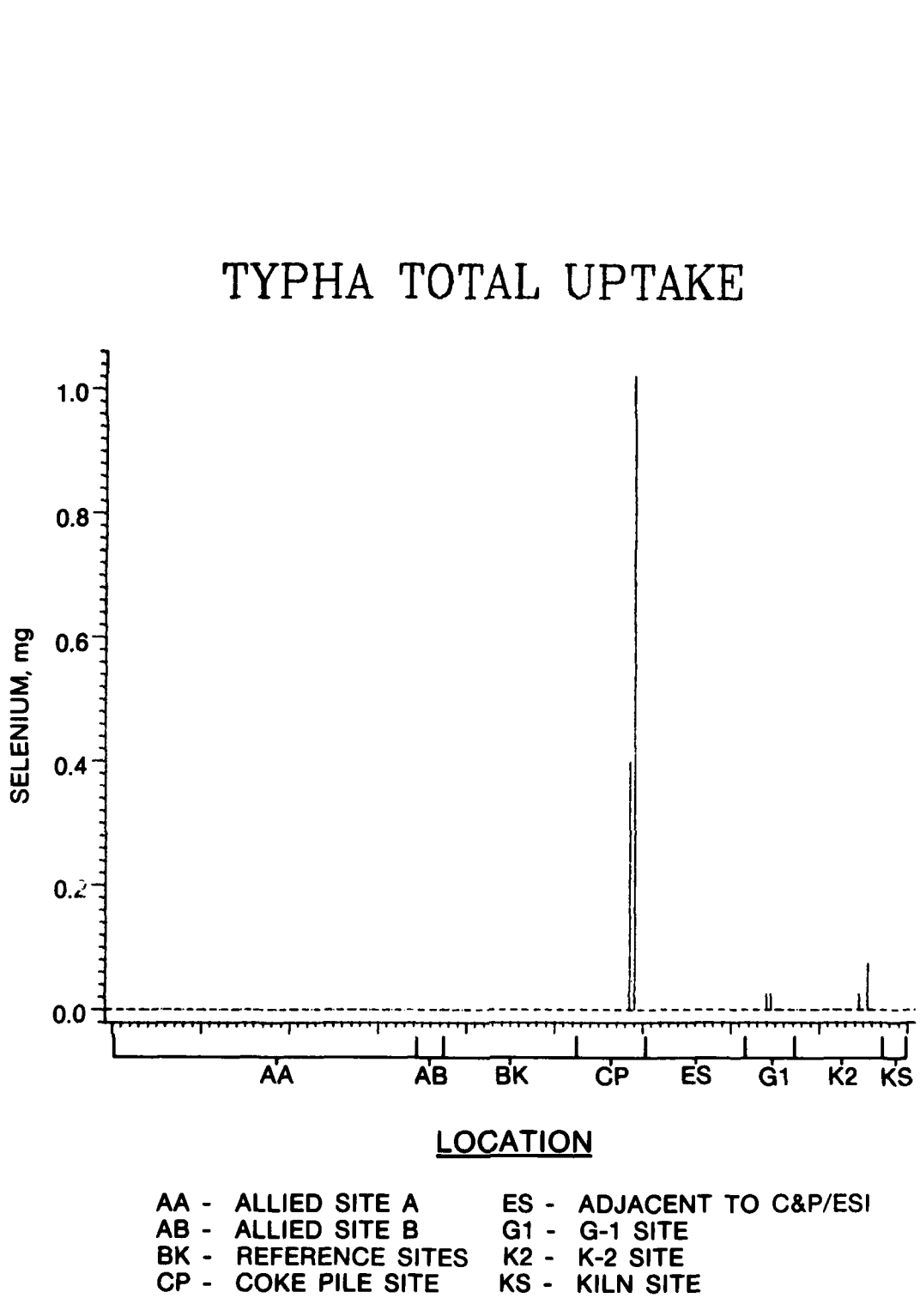
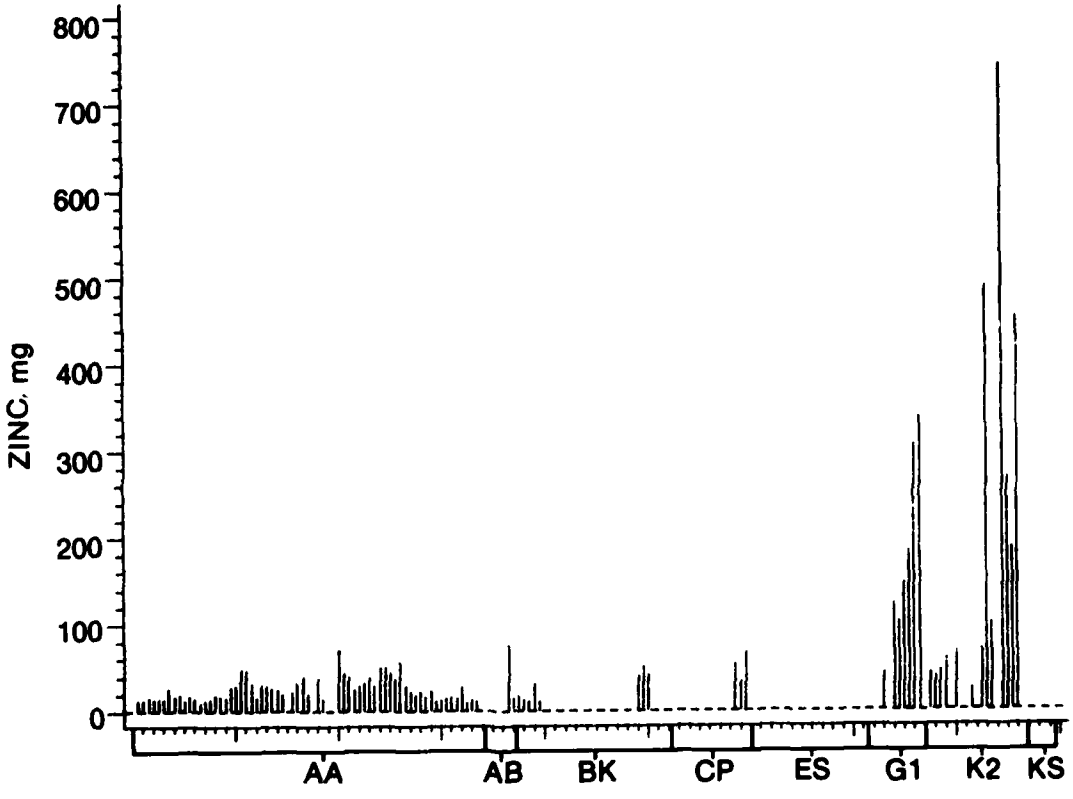


Figure 2-28. Total plant uptake of selenium by Typha

TYPHA TOTAL UPTAKE



LOCATION

AA - ALLIED SITE A	ES - ADJACENT TO C&P/ESI
AB - ALLIED SITE B	G1 - G-1 SITE
BK - REFERENCE SITES	K2 - K-2 SITE
CP - COKE PILE SITE	KS - KILN SITE

Figure 2-29. Total plant uptake of zinc by Typha

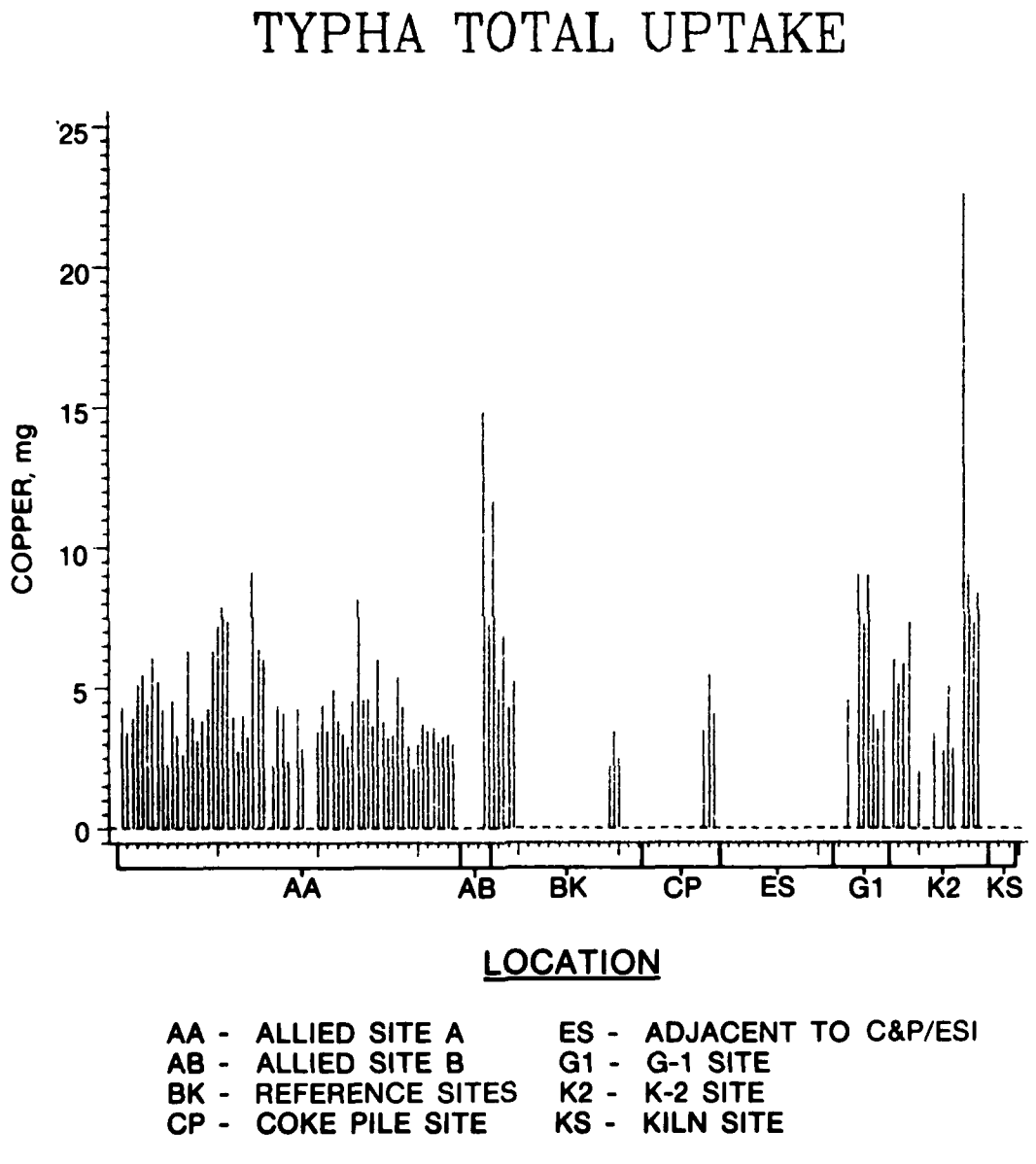


Figure 2-30. Total plant uptake of copper by Typha

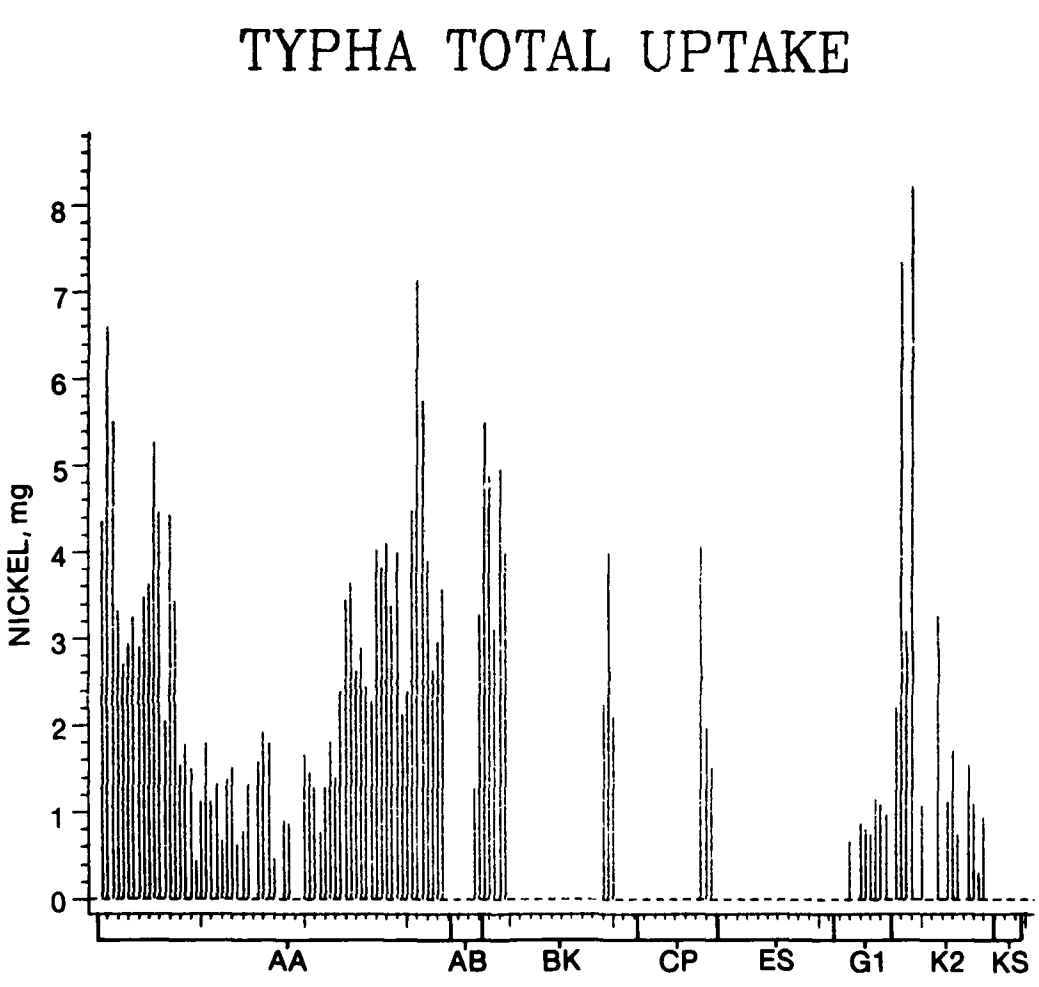


Figure 2-31. Total plant uptake of nickel by Typha

contents. The potential for total heavy metal uptake by Typha was also limited to the G-1 area on Parcel 575, the K-2 area on Parcels 573 and 574, and the AA area on Parcel 572. Locations sampled in Parcel 572 also have total plant uptake values above other sampled areas. Similar results in total plant uptake were obtained for Pb and Zn (Figures 2-27 and 2-29). This could have been expected since it has been shown by Folsom and Lee (1981a, 1981b) that heavy metal uptake by marsh plants under a flooded reduced redox potential is minor when compared to uptake from the same sediment under upland oxidized redox conditions. The reduced uptake of metals by Typha under field conditions is the result of Typha growing in wet flooded soil conditions. Metals under wet flooded soil conditions are usually less available for plant uptake because the metals are present in the form of insoluble metal compounds such as metal sulfides or organometal complexes. Even though there are some statistical differences in total heavy metals uptake, these differences do not appear to be of practical significance.

2.1.2.3.2 Greenhouse Plant Bioassay

2.1.2.3.2.1 Methods and Materials

2.1.2.3.2.1.1 Flooded Test Condition

The buckets of flooded soil samples were removed from the refrigerated trailer at the WES and brought into a secure greenhouse. The lids were removed, and the buckets were placed into a larger Bain-Marie bucket (6 gal) that had two pieces of polyvinyl chloride pipe (PVC) laying on the bottom (Figure 2-32). Water (RO purified) was added to the larger bucket to a depth 5-cm above the soil surface. Three germinated tubers of Cyperus esculentus were planted in each pot and allowed to grow 45 days according to the WES plant bioassay procedure (Folsom and Lee 1981). At the end of the 45-day growth period, the plants were individually photographed and harvested. The plants were subsequently prepared, digested, and analyzed for the same metals as described in Table 2-1.

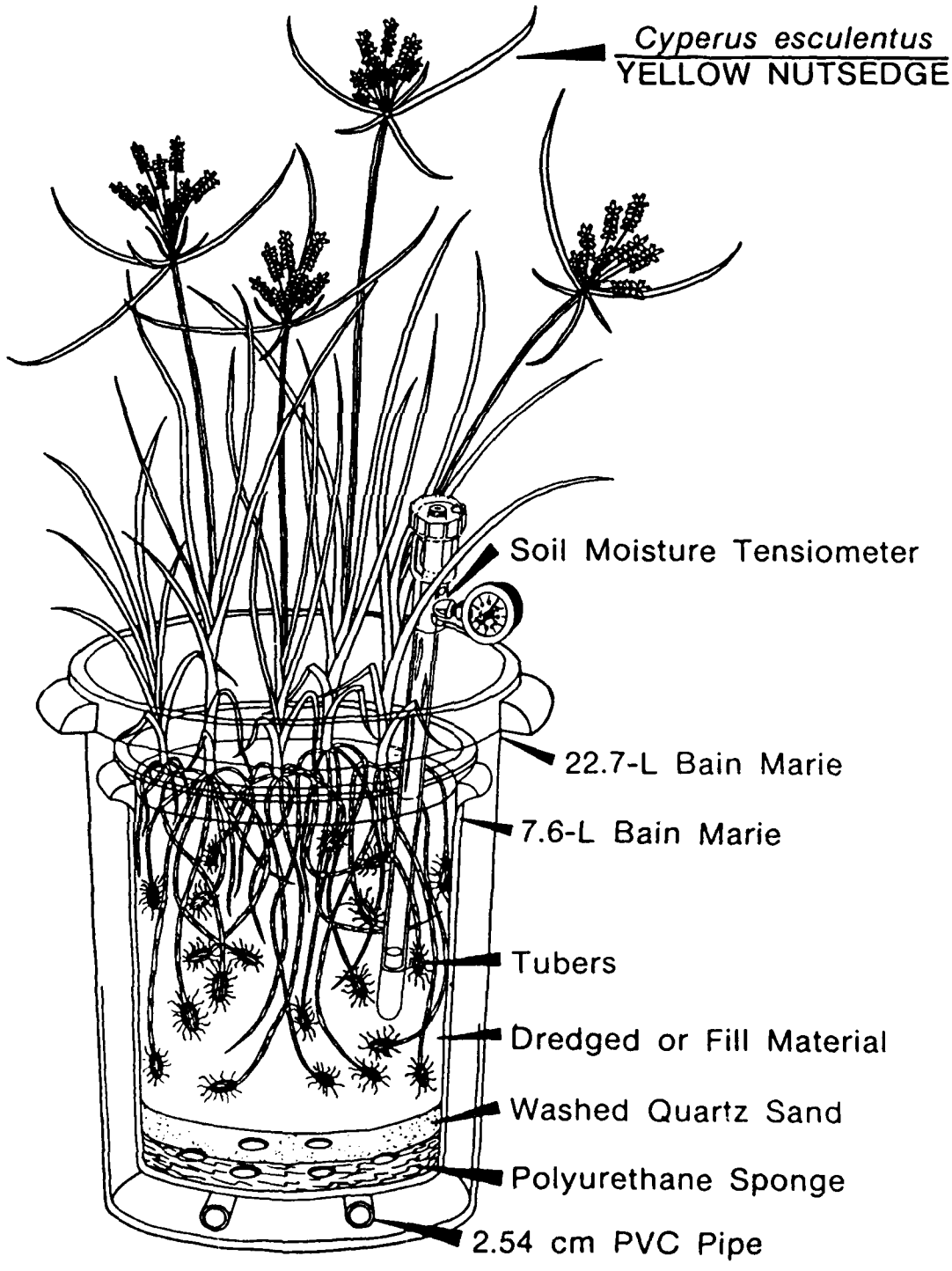


Figure 2-32. Plant bioassay apparatus

2.1.2.3.2.1.2 Upland Test Condition

The buckets of upland soil samples were placed into a larger Bain-Marie bucket as described for the flooded condition. The lids were removed and a soil tensiometer inserted. Water was added to the outer bucket up to the level of the soil surface in the inner bucket until the tensiometer read 30 percent, then the water was siphoned off. This procedure brought the soil moisture to a uniform tension of 1/3 bar throughout the entire experiment. Three germinated tubers of Cyperus esculentus were planted in each inner bucket and allowed to grow 45 days. During the growth period the moisture content was maintained between 0.3 to 0.5 bar by addition of water. The buckets of plants were individually photographed, and the plants were subsequently harvested, prepared, and analyzed as described in the flooded plant bioassay section above.

2.1.2.3.2.2 Results and Discussion

Results of the plant bioassay testing were interpreted by visually comparing levels indicated by appropriate lines drawn on figures, comparing such results to existing critical tissue metal contents for demonstrated effects on plants (Table 2-7) and FDA action levels for animal feed and foodstuffs (Table 2-8 and Table 2-9), and by analyzing statistical differences among sampling site means for which three samples were collected at a sample site. Statistical procedures used included SAS, ANOVA, and Duncan's New Multiple Range Test.

2.1.2.3.2.2.1 Flooded Test Condition

Results of the greenhouse flooded plant bioassay are presented in Figures 33-40. Plant toxicity shown in these figures indicates those soil samples in which the plant died during the bioassay test.

Generally, As was the only metal found in soils from Parcel 572 that was statistically greater in plants compared to As in plants from soils from the reference areas or from the other sites. Within Parcel 572, only sample AAW16U1 showed statistically greater concentration of As than did that from the other samples taken within that location.

GREENHOUSE FLOODED PLANT ANALYSIS

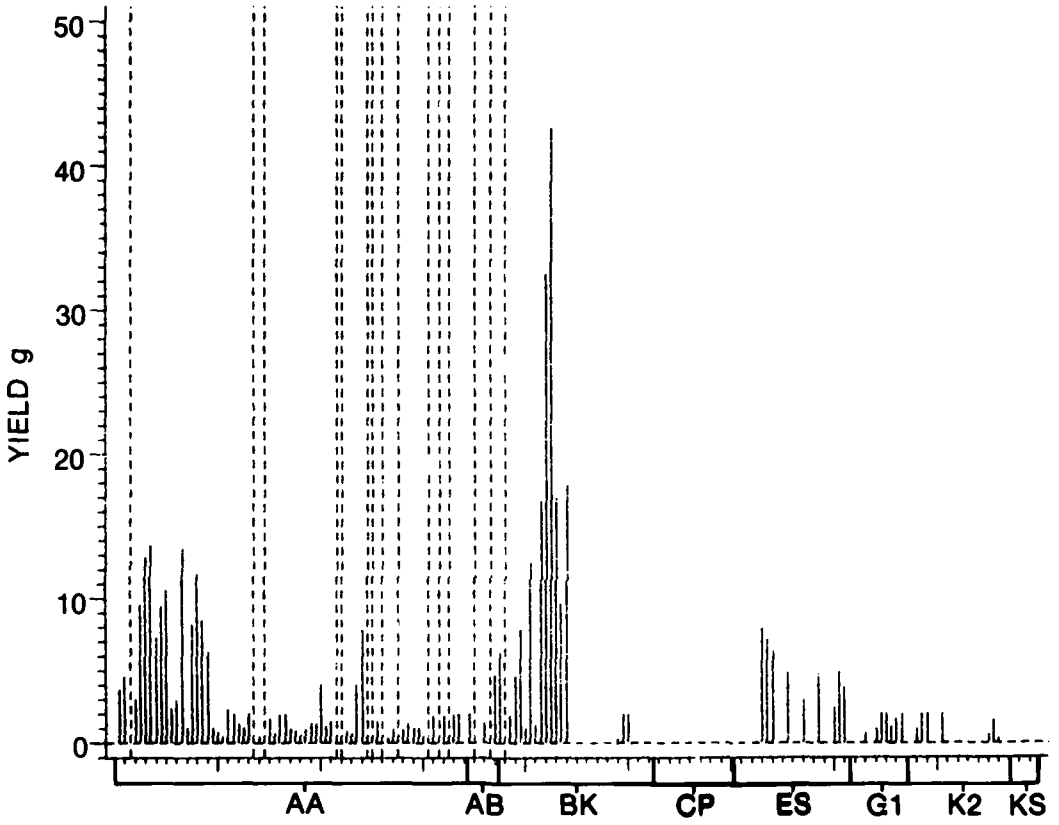
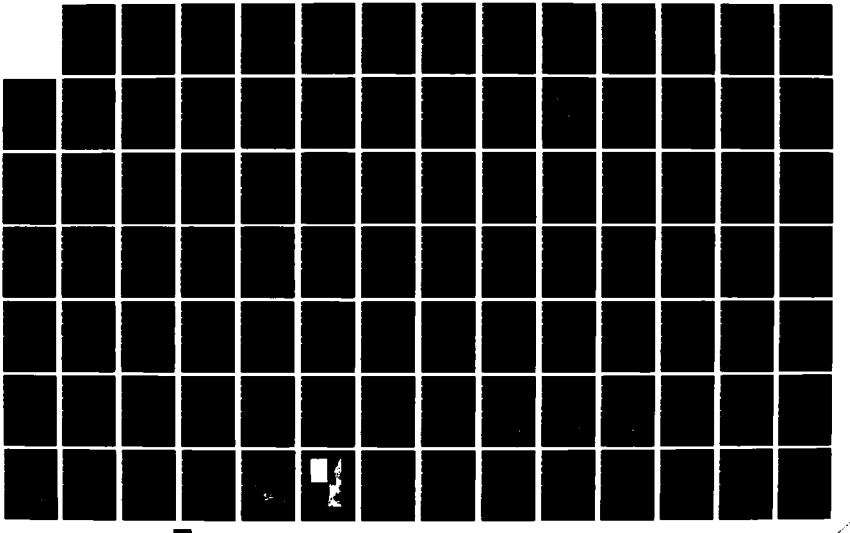
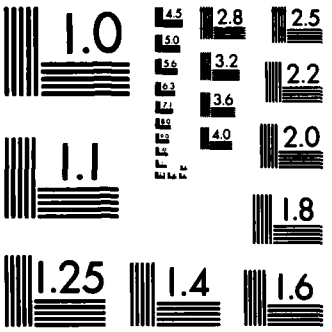


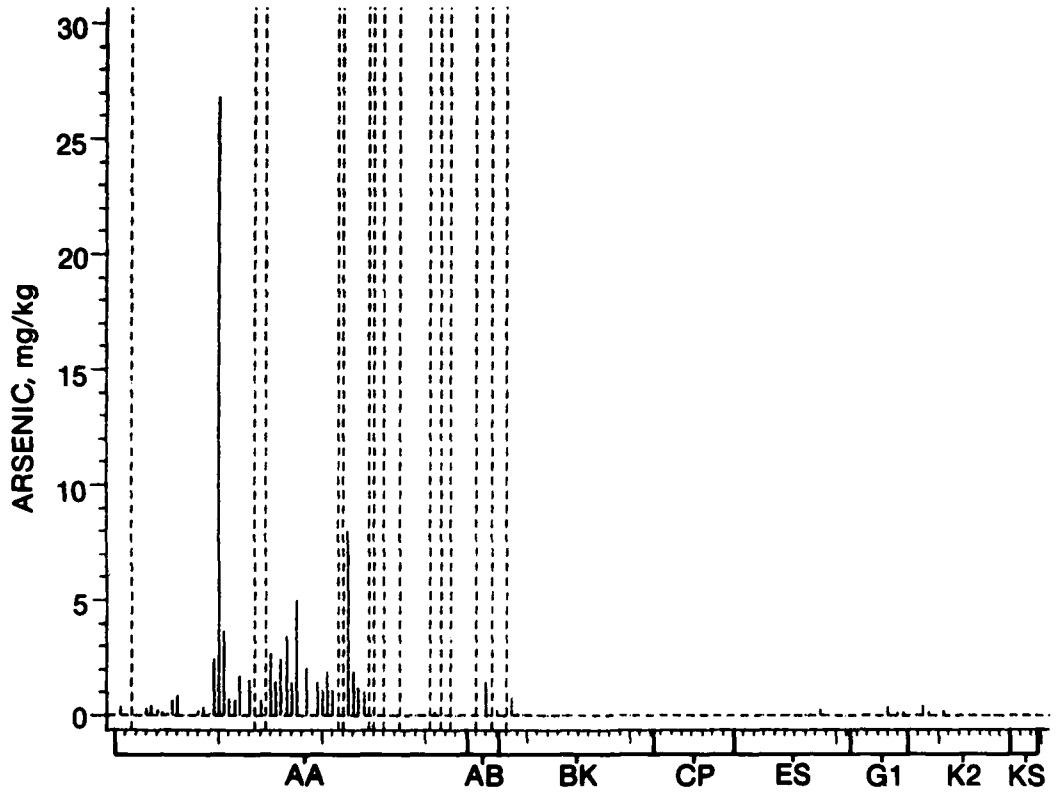
Figure 2-33. Yield of Cyperus esculentus under flooded conditions

AD-A165 127 REMEDIAL INVESTIGATION OF CONTAMINANT MOBILITY AT NAVAL 2/7
WEAPONS STATION C (U) ARMY ENGINEER WATERWAYS
EXPERIMENT STATION VICKSBURG MS ENVIR C R LEE ET AL
UNCLASSIFIED JAN 86 WES/MP/EL-86-2 F/G 6/6 NL





GREENHOUSE FLOODED PLANT ANALYSIS



LOCATION

AA - ALLIED SITE A
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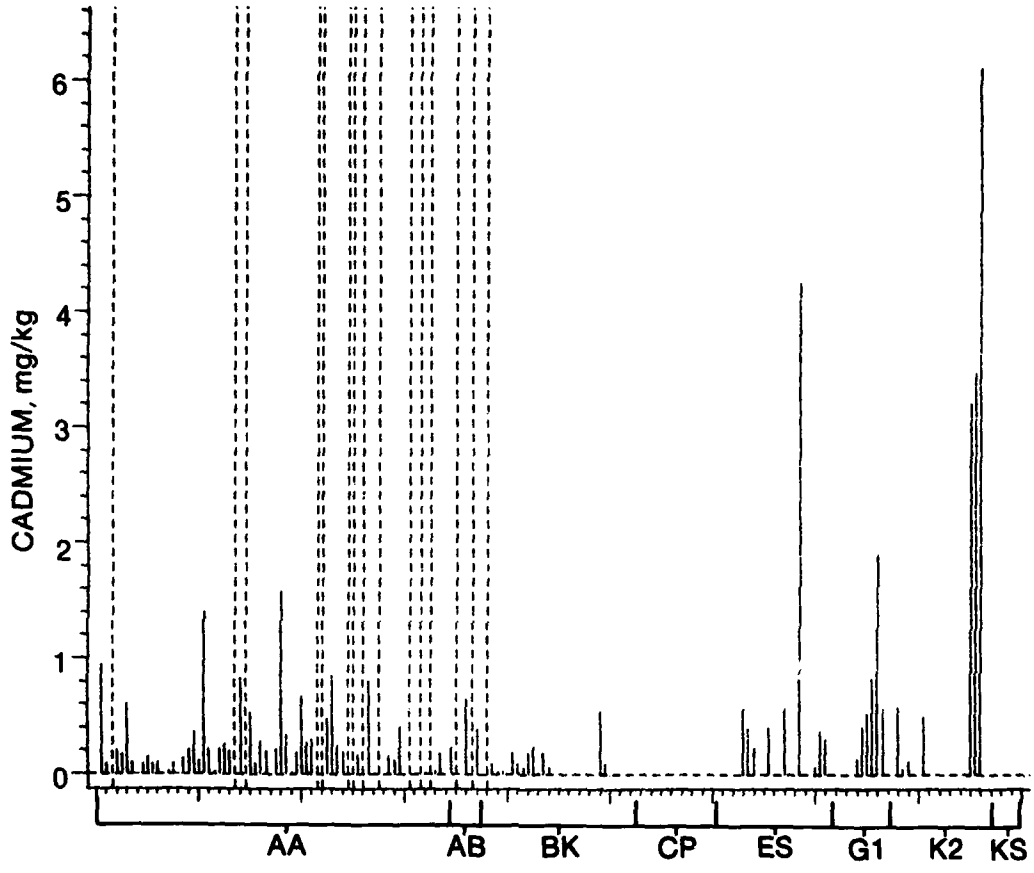
BK - REFERENCE SITES
CP - COKE PILE SITE
ES - ADJACENT TO C&P/ESI
G1 - G-1 SITE
K2 - K-2 SITE
KS - KILN SITE

----------PLANT TOXICITY

Figure 2-34. Flooded plant bioassay tissue arsenic content and plant toxicity

GREENHOUSE FLOODED PLANT ANALYSIS



LOCATION

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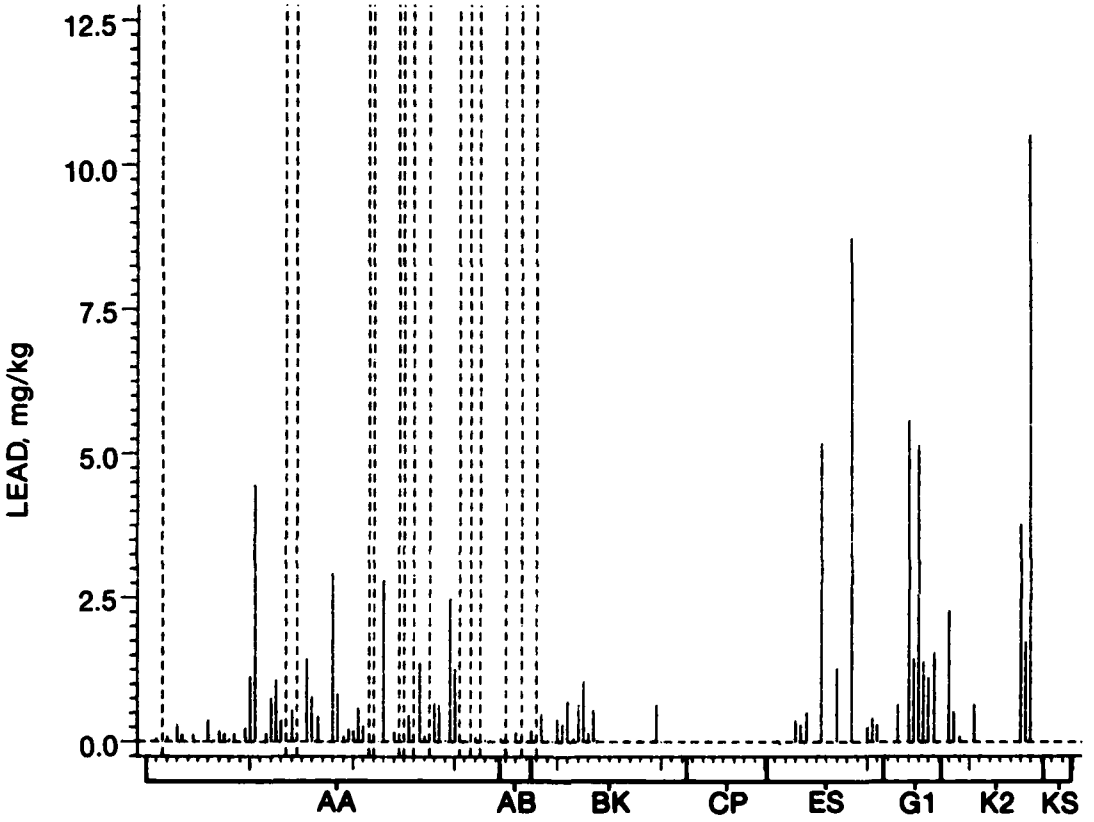
G1 - G-1 SITE
K2 - K-2 SITE
KS - KILN SITE

--------- PLANT TOXICITY

Figure 2-35. Flooded plant bioassay tissue cadmium content and plant toxicity

GREENHOUSE FLOODED PLANT ANALYSIS



LOCATION

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AB - ALLIED SITE B
BK - REFERENCE SITES
CP - COKE PILE SITE
ES - ADJACENT TO C&P/ESI
G1 - G-1 SITE
K2 - K-2 SITE
KS - KILN SITE

---------PLANT TOXICITY

Figure 2-36. Flooded plant bioassay tissue lead content and plant toxicity

GREENHOUSE FLOODED PLANT ANALYSIS

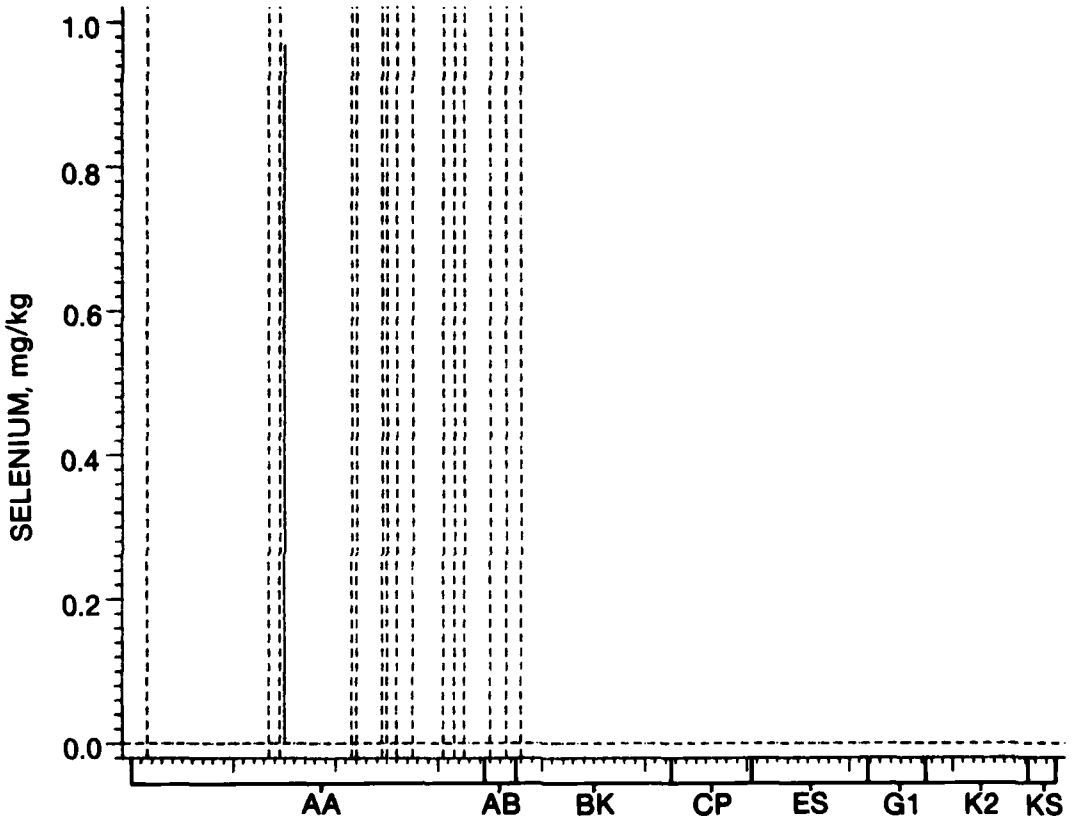


Figure 2-37. Flooded plant bioassay tissue selenium content and plant toxicity

GREENHOUSE FLOODED PLANT ANALYSIS

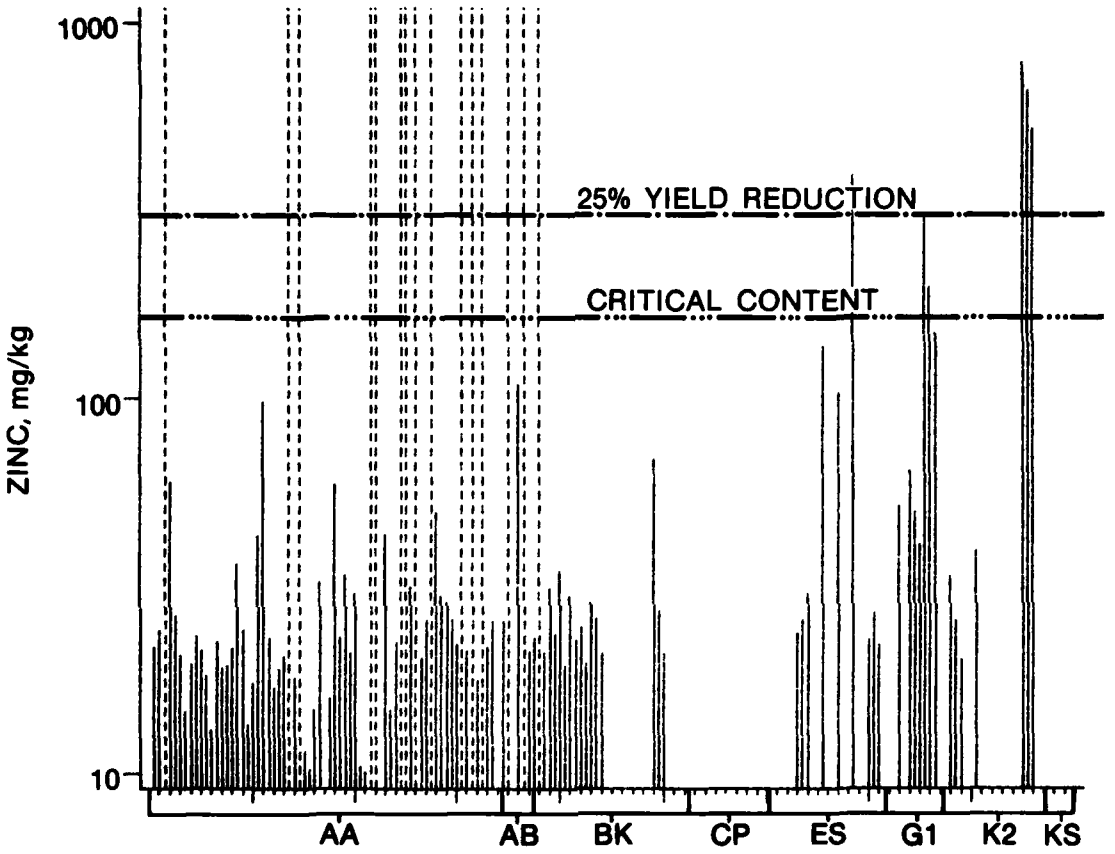
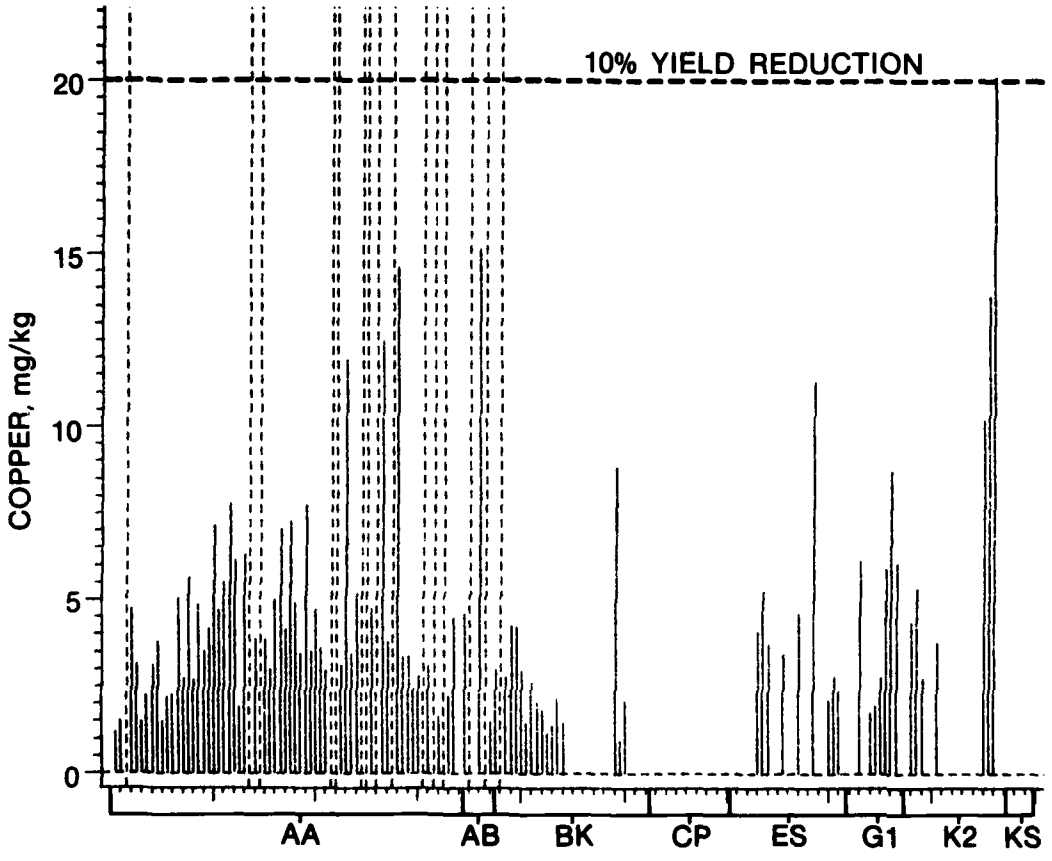


Figure 2-38. Flooded plant bioassay tissue zinc content and plant toxicity

GREENHOUSE FLOODED PLANT ANALYSIS



LOCATION

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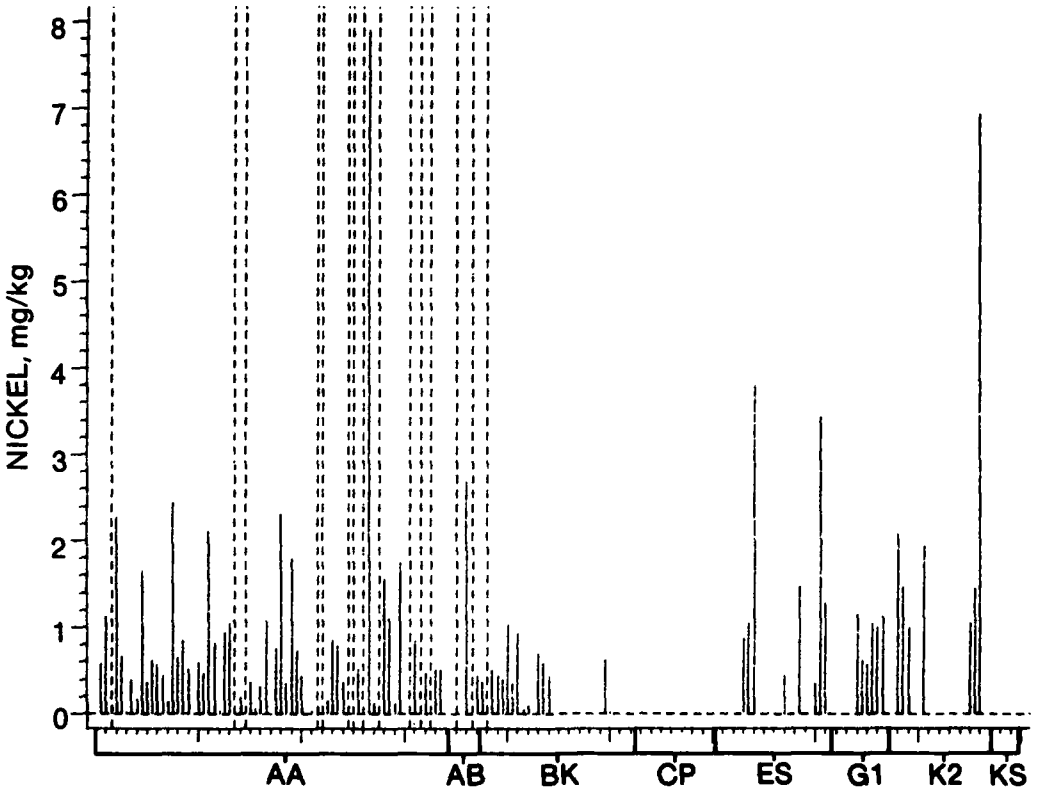
CP - COKE PILE SITE
ES - ADJACENT TO C&P/ESI
G1 - G-1 SITE
K2 - K-2 SITE
KS - KILN SITE

----------PLANT TOXICITY

Figure 2-39. Flooded plant bioassay tissue copper content and plant toxicity

GREENHOUSE FLOODED PLANT ANALYSIS



LOCATION

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AB - ALLIED SITE B
BK - REFERENCE SITES
CP - COKE PILE SITE
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G1 - G-1 SITE
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KS - KILN SITE

---------PLANT TOXICITY

Figure 2-40. Flooded plant bioassay tissue nickel content and plant toxicity

Folsom et al. (1981) have shown that arsenic was much more available under flooded reduced soil redox conditions than under oxidized soil redox conditions. This increased plant availability of As under reduced soil redox conditions is supported by the work of Woolson et al. (1971), who showed that the available As is closely associated with the same iron and aluminum compounds as phosphorus. Everett (1962) has shown that As competes with P for fixation sites in soil, as well as for plant uptake from the soil solution. Once in the plant, As competes with P for transport into cells (Needham and Pillai 1937), reacts in place of P with a number of enzymes (Needham and Pillai 1937, Sanadi et al. 1954, Singer and Slater 1967), and as an uncoupler of oxidative phosphorylation (Azzone and Ernster 1960, Crane and Lipmann 1953, Ter Welle and Slater 1967). At low As levels, As may act as a stimulant to plant growth (Woolson et al. 1971), but at higher levels it disrupts plant metabolism completely, which results in death (Woolson 1972). The same factors which affects As fixation will also influence the toxicity of soil As because these factors influence the amount of As in the soil solution (Woolson 1972).

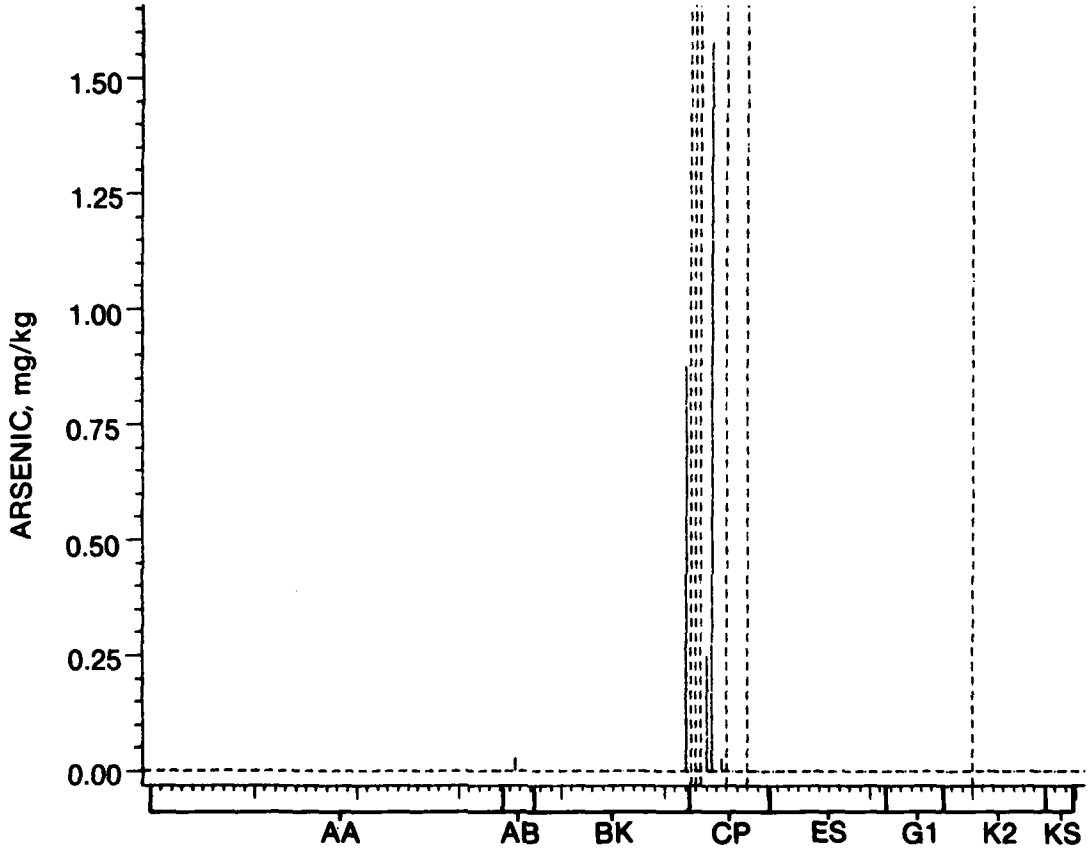
The fact that As behaves much like P is extremely important. In a flooded reduced soil like that in the AA site on Parcel 572, the P is available for plant growth and since the As level in the soil is high, its potential availability is also high and could result in As mobilization into the environment through plant uptake at site AA on Parcel 572 or could actually result in plant toxicity and death. This is readily apparent by the large number of plant deaths observed in AA (Figure 2-34). The dashed lines indicated plant death. Folsom et al. (1981) observed plant toxicity and death when this same index plant was planted and grown in dredged material containing 330 mg/kg of As under wetland flooded conditions. Not only was there a great deal of plant death in site AA on Parcel 572, but almost all plant growth (Figure 2-33) was significantly reduced compared to the reference sites. Arsenic content of the plants in sites AA and B on Parcel 572 was also much more than in plants grown on the other sites. The other metals were shown to be less available under flooded conditions. Since site AA on Parcel 572 is a wetland site, As mobilization into the environment is a major potential problem. Special attention needs to be given to the area in the form of corrective measures.

Plant cadmium, zinc, and copper from the K2w8p3r site on Parcels 573 and 574 were statistically greater than that from the Glwl3ml site on Parcel 575 (Appendix Table 2-A5). These data strongly suggest that the cadmium, zinc, and copper have migrated downstream from the Chemical and Pigment Plant site through the Glwl3ml site to the K2w8p3 site on Parcels 573 and 574. Plant Cu at site K2w8p3r on Parcel 574 was statistically greater than plant Cu in plants from the remote reference area (Appendix Table 2-A5). Plant copper content at this location approached the FDA action level of 20 ppm for animal feed and foodstuffs (Table 2-8 and Table 2-9).

2.1.2.3.2.2.2 Upland Test Condition

Results of the greenhouse upland plant bioassay are presented in Figures 2-41 through 2-49. Under upland conditions, the As taken up by the plant was undetectable (Figure 2-41). Plant uptake of Cd (Figure 2-42) indicates plants from a few sites have elevated Cd concentration. Some of the plants from these sites have tissue contents of Cd that are above those of plants from the remote reference areas. Where cadmium contents in plants are above the 10-ppm FDA allowable level (Table 2-8) as in the CP area, the K-2 area of Parcel 574, and the G1 area of Parcel 575, these areas should be restricted from agricultural grazing. Corrective measures must be implemented to minimize further vegetative contamination by Cd. Plant Pb is shown in Figure 2-43. Except for a few sites, plant Pb is no greater than in remote reference areas. The sites where plant Pb was high were site CP on Parcel 581 and site KS on Parcel 572 where the soil contents of Pb were over 4000 ppm. Hess and Blanchar (1976, 1977) have shown that in situations where metal contents are high, it is possible the chemical forms of Pb that are soluble can easily form and become available for plant uptake. Hess and Blanchar (1976) showed that for dissolution of Pb arsenate, about 200 moles of As came into solution for every mole of Pb. The ion product of 3pPb + 2pAs04 changed with changing pH, reached a minimum at final pH of 6.40 (initial pH of 6.00), and increased in both directions. This could explain the high plant Pb content in plant tissue at Site CP on Parcel 581 where the pH (Figure 2-44) was 5.1 and soil Pb was greater than 400 ppm, i.e., just such a situation as Hess and Blanchar (1976, 1977) discuss. Site KS on Parcel 572 also had a pH of 8.2 and a high soil Pb (<4600 ppm) and As (27 ppm) content. Site CP on Parcel 581

GREENHOUSE UPLAND PLANT ANALYSIS



LOCATION

AA - ALLIED SITE A
AB - ALLIED SITE B
BK - REFERENCE SITES
CP - COKE PILE SITE
ES - ADJACENT TO C&P/ESI
G1 - G-1 SITE
K2 - K-2 SITE
KS - KILN SITE

------PLANT TOXICITY

Figure 2-41. Upland plant bioassay tissue arsenic content and plant toxicity

GREENHOUSE UPLAND PLANT ANALYSIS

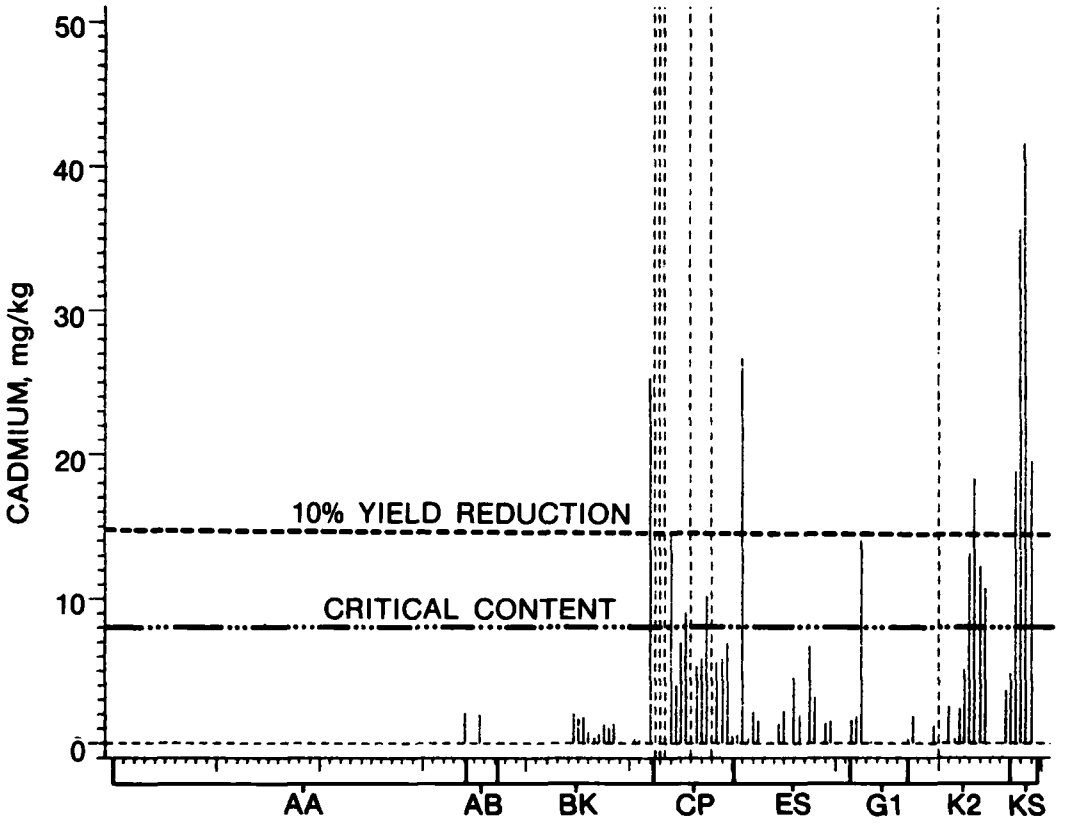
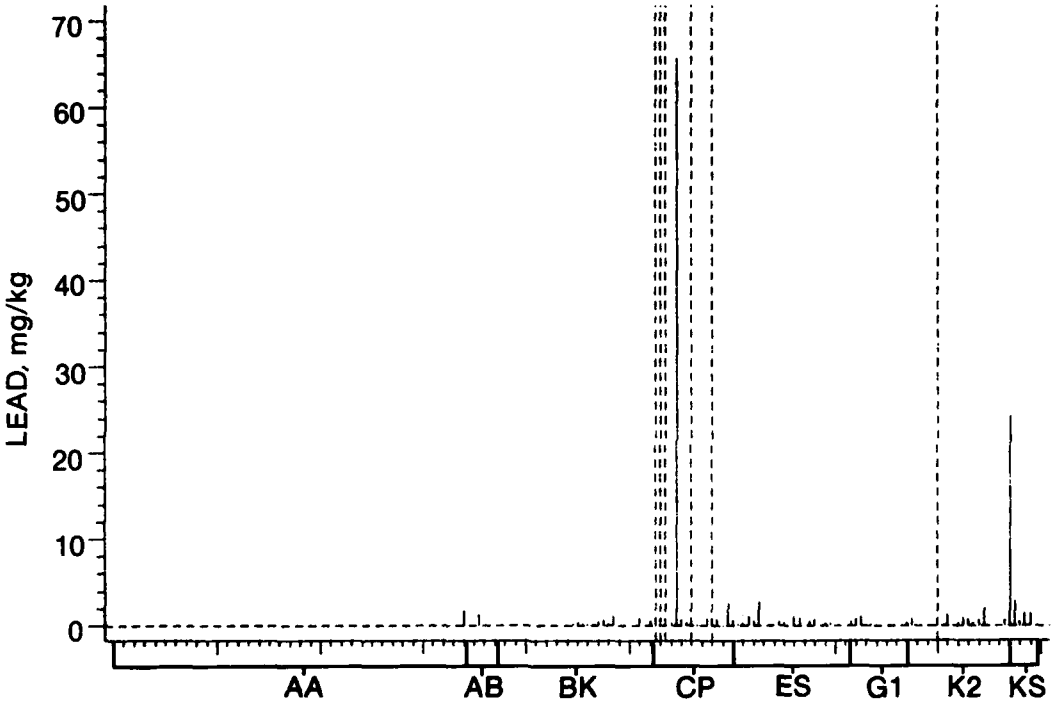


Figure 2-42. Upland plant bioassay tissue cadmium content and plant toxicity

GREENHOUSE UPLAND PLANT ANALYSIS



LOCATION

AA - ALLIED SITE A
AB - ALLIED SITE B
BK - REFERENCE SITES
CP - COKE PILE SITE
ES - ADJACENT TO C&P/ESI
G1 - G-1 SITE
K2 - K-2 SITE
KS - KILN SITE

-------- PLANT TOXICITY

Figure 2-43. Upland plant bioassay tissue lead content and plant toxicity

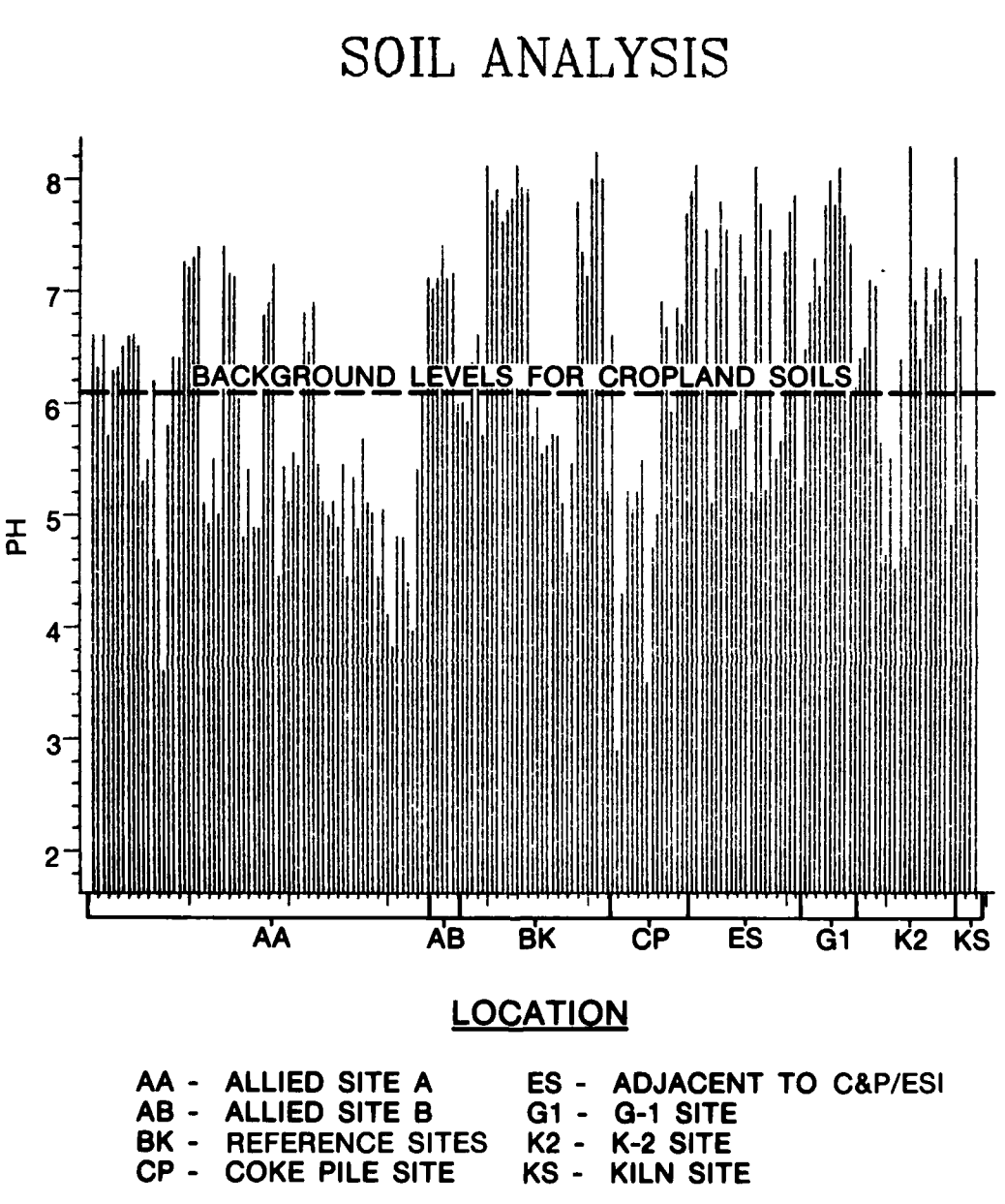


Figure 2-44. Soil pH of soil samples from NWS Concord

GREENHOUSE UPLAND PLANT ANALYSIS

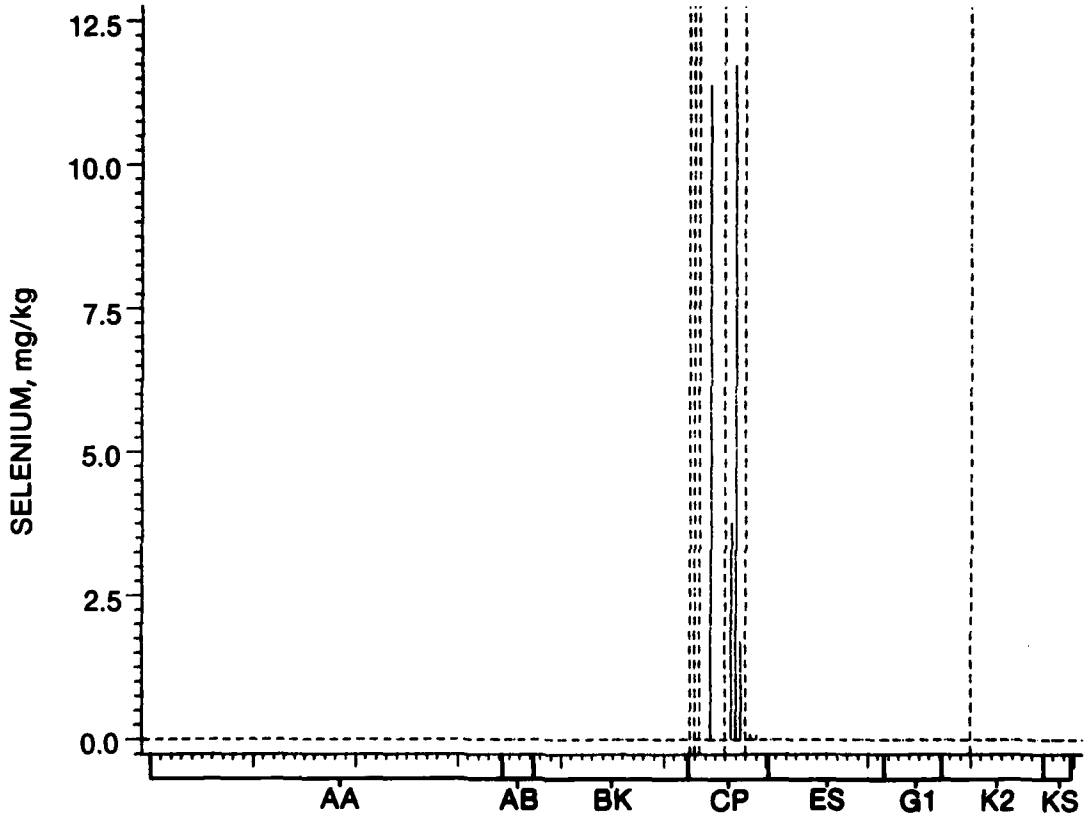
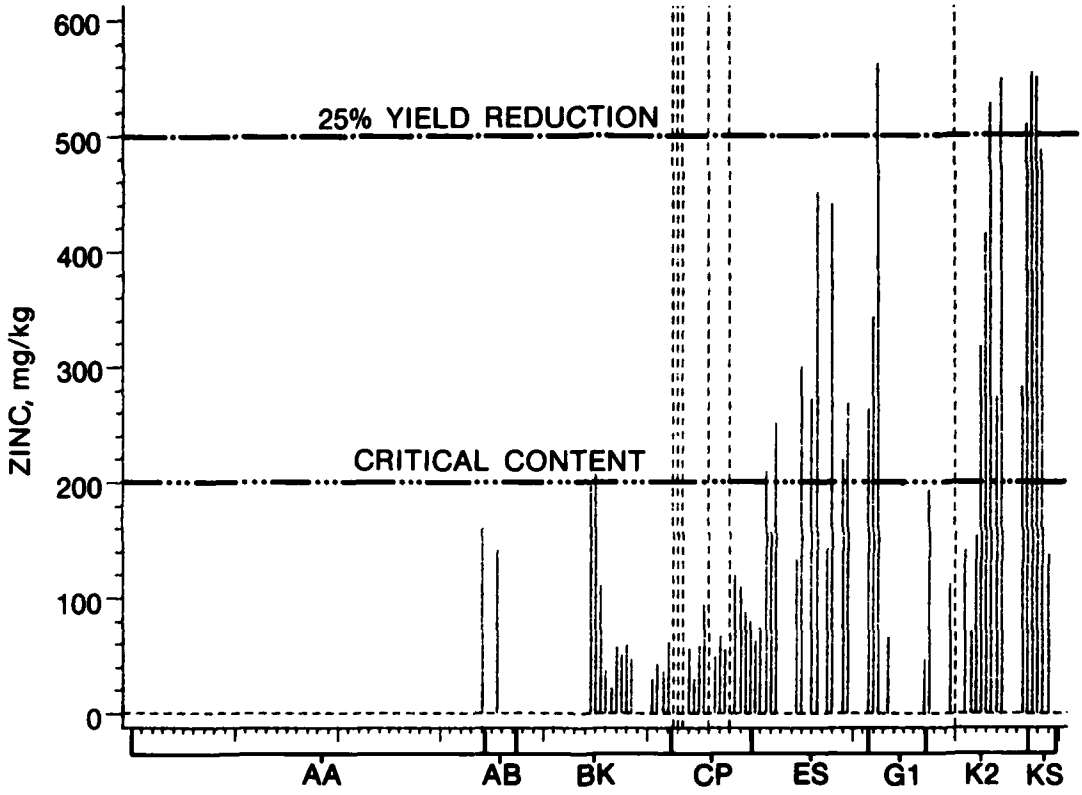


Figure 2-45. Upland plant bioassay tissue selenium content and plant toxicity

GREENHOUSE UPLAND PLANT ANALYSIS



LOCATION

AA - ALLIED SITE A
AB - ALLIED SITE B
BK - REFERENCE SITES
CP - COKE PILE SITE
ES - ADJACENT TO C&P/ESI
G1 - G-1 SITE
K2 - K-2 SITE
KS - KILN SITE

----------PLANT TOXICITY

Figure 2-46. Upland plant bioassay tissue zinc content and plant toxicity

GREENHOUSE UPLAND PLANT ANALYSIS

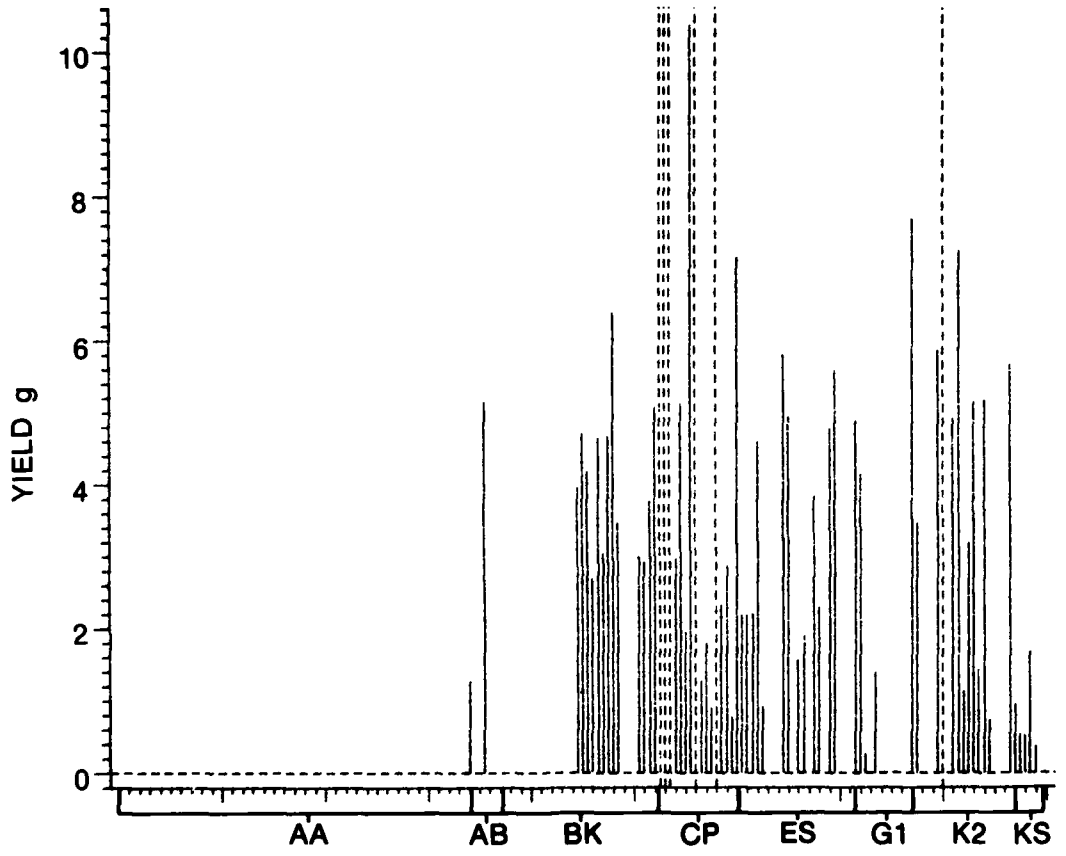
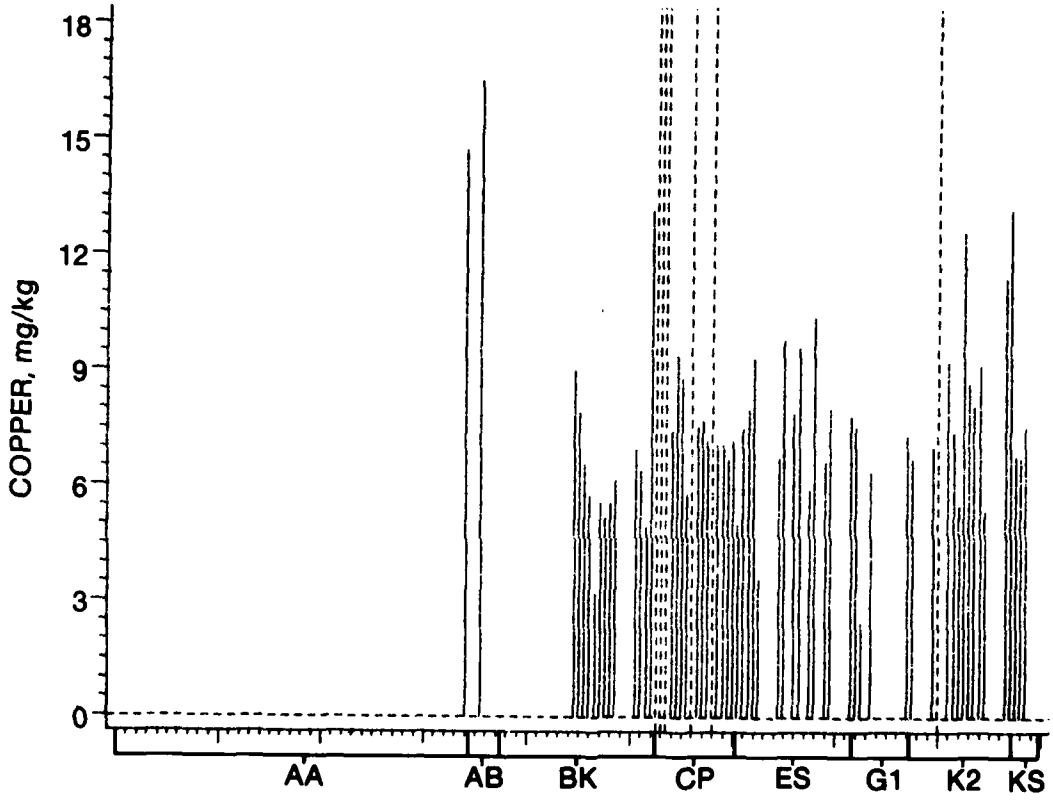


Figure 2-47. Yield of Cyperus esculentus under upland conditions

GREENHOUSE UPLAND PLANT ANALYSIS



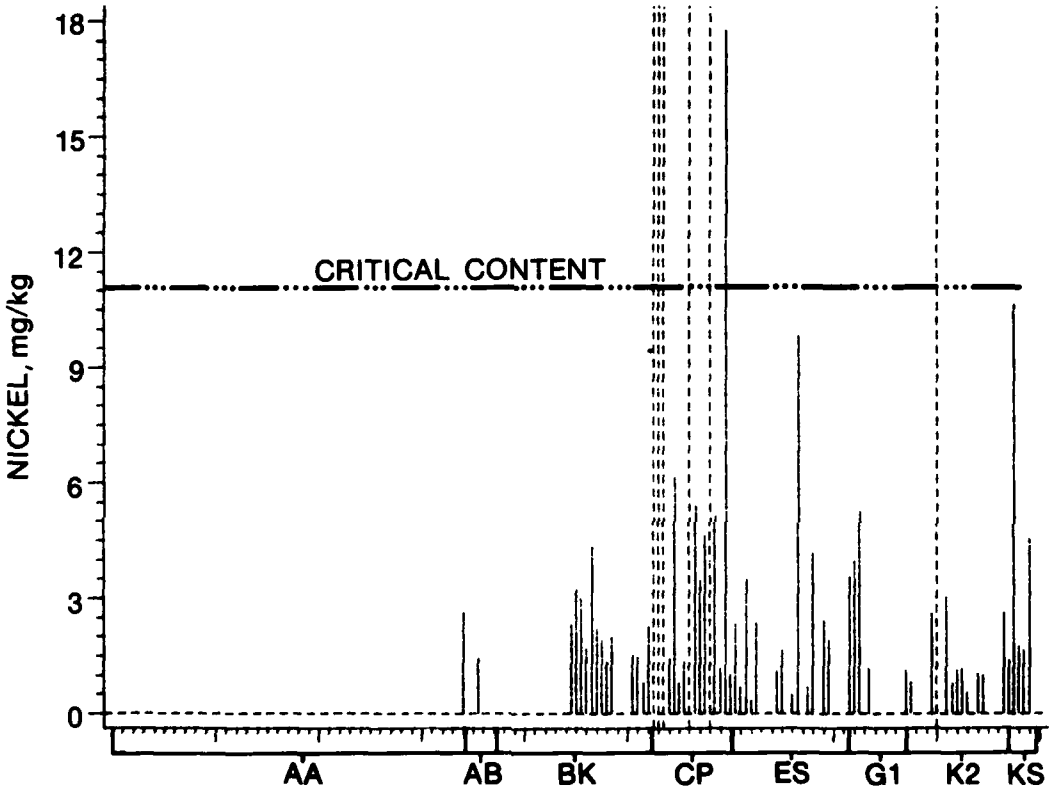
LOCATION

AA - ALLIED SITE A
AB - ALLIED SITE B
BK - REFERENCE SITES
CP - COKE PILE SITE
ES - ADJACENT TO C&P/ESI
G1 - G-1 SITE
K2 - K-2 SITE
KS - KILN SITE

----------PLANT TOXICITY

Figure 2-48. Upland plant bioassay tissue copper content and plant toxicity

GREENHOUSE UPLAND PLANT ANALYSIS



LOCATION

AA - ALLIED SITE A
AB - ALLIED SITE B
BK - REFERENCE SITES
CP - COKE PILE SITE
ES - ADJACENT TO C&P/ESI
G1 - G-1 SITE
K2 - K-2 SITE
KS - KILN SITE

----------PLANT TOXICITY

Figure 2-49. Upland plant bioassay tissue nickel content and plant toxicity

was one of the few sites where plant uptake of Se occurred (Figure 2-45). The low soil pH could also explain Se uptake in that Se is more mobile and available at low soil pH. Plant uptake of Se from the other sites approached that of plants grown in soils from the remote reference areas (i.e., no uptake, zero ppm). Plant uptake of Zn from the upland sites is presented in Figure 2-46. Plant content of Zn was higher than many encountered previously in other studies (Folsom et al. 1981; Folsom and Lee 1981a, 1981b). Some of Zn values in Site ES on Parcel 579 and Site K-2 on Parcels 573 and 574 were above that which would cause a 25-percent yield reduction (Table 2-2). There were some sites where a 25-percent yield reduction or greater occurred (Figure 2-47). These high values raise sufficient concern that corrective measures should be taken. Plant uptake of Cu is shown in Figure 2-48. Plant Cu is not elevated compared to those plants from the remote reference areas except in Site K-2.

Plant Ni is shown in Figure 2-49. Plant Ni is more uniform among the sites studied than the other metals. It is not different from that in the remote uncontaminated areas.

Results of the ANOVA for plant uptake of the heavy metals (Appendix Table 2-A8) indicated that even though some plant uptake of metals did occur in some of the sites, the extremely large variability in soil contents results in no statistical differences from that of the remote reference areas.

2.1.2.3.2.3 Summary

The results of the plant bioassay and field-collected Typha indicated certain areas at NWS have metal contamination that is potentially toxic to plants and that potentially can accumulate in plants colonizing the sites. These areas will require corrective measures to minimize plant toxicity and the spread and release of metal contaminants into food chains and the environment. The areas needing attention are described in more detail in Section 2.2.

2.1.2.4 Earthworm Bioassay

The earthworm bioassay procedure described below is a derivation of the test currently in use by the European Economic Commission (EEC) and the

Organization for European Development (OECD). In addition, this test procedure, as applied to the soil samples collected from NWS Concord, has been standardized by the WES and the TNO and has been applied to contaminated soils in the United States and Europe (Marquenie and Simmers 1984, Rhett et al. 1984, and Simmers et al. 1984).

2.1.2.4.1 Materials and Methods

Earthworms were placed in test soil materials for 28 days prior to recovery and chemical analysis. All test soil materials were allowed to absorb moisture until at approximate field capacity and were maintained under the same temperature and light conditions in a temperature-controlled growth chamber. This procedure allowed an immediate earthworm toxicity evaluation and, if survival occurred, also gave an extended bioaccumulation test. The soil samples tested in this phase of the study were collected at NWS Concord in the manner previously described in Section 2.1.1.2 from the locations indicated in Figure 2-1.

"Red wiggler" earthworms (Eisenia foetida) were removed from a manure growth media, rinsed with RO water, and then placed on paper towels to remove excess water. Worms for initial background analysis were collected at this time. Approximately 15 g wet weight of the earthworms were then weighed to the nearest thousandths of a gram before placement into test soil samples for a period of 28 days. There was a total (including triplicates within sampling stations) of 178 individual earthworm bioassay experimental units on NWS Concord soil samples, including 67 from the AA area on Parcel 572, 6 from the AB area on Parcel 572, 30 from the BK area, 16 from the CP area on Parcel 581, 23 from the ES area on Parcel 579, 11 from the GI area on Parcel 575, 20 from the K-2 area on Parcels 573 and 574, and 5 from the KS area on Parcel 572. There were an additional 30 individual or single bioassay samples in the AA area, 4 in the AB area, 2 in the Cp area, 1 in the ES area, 5 in the GI area, 1 in the K-2 area, and 3 in the KS area.

All worms used for chemical analysis were placed in sealed worm containers in a refrigerator of 50 deg F (10 deg C) and allowed to purge on moist filter paper for 24 hr to remove gut content. The filter paper was then replaced, and the worms were allowed to purge for an additional 24 hr. After purging, the earthworms were rinsed with RO water, blotted on paper, and

weighed as before. The earthworms were then placed in acid-washed glass sample jars and frozen.

Bioassay test containers were constructed using commercially available 3.5 qt (3.3 ℓ) plastic Bain Marie buckets and lids (Figure 2-50). The base of each bucket contained four 0.25-in. holes covered with a perforated 1-in. (2.5 cm) adhesive strip (Band-Aid end), which was impassable to earthworms but allowed water transfer. Each bucket was placed in a separate water reservoir 1.5 in. (3.8 cm) deep to permit the addition of RO water to prevent the drying of the soil samples (Figure 2-50). This produced a wick effect which allowed test soils to maintain suitable moisture levels for optimum earthworm growth within the physical constraints of the medium. A 16-sq-in. (103-sq-cm) section was then removed from each lid and replaced with unbleached muslin cloth to allow aeration.

The buckets were placed randomly in a temperature-controlled growth chamber 60 deg F (15.6 deg C) with continuous overhead fluorescent illumination. Each bucket was labeled with idelible ink on the inside and the outside. After 28 days, the worms were hand-sorted from the substrate, washed, weighed, counted, purged, and frozen in the same manner as the initial background tissue samples. Buckets in which there was poor earthworm survival were restocked with earthworms, and the test was conducted a second time in order to confirm the apparent poor survival.

2.1.2.4.2 Results and Discussion

Earthworms (Eisenia foetida) were used for laboratory bioassays to assess the bioavailability of metals from upland and partially dewatered wetland soils. The same action-levels criteria (Table 2-5) as discussed previously from the clam biomonitoring (Section 2.1.2.2.2) were applied to the results of the earthworm bioassays. These action levels were exceeded by earthworms at 31 sampling stations for As, 26 for Cd, 15 for Pb, and 10 for Se. The criteria for Cu and Zn were not exceeded at any sampling station, and no criterion has been established for Ni.

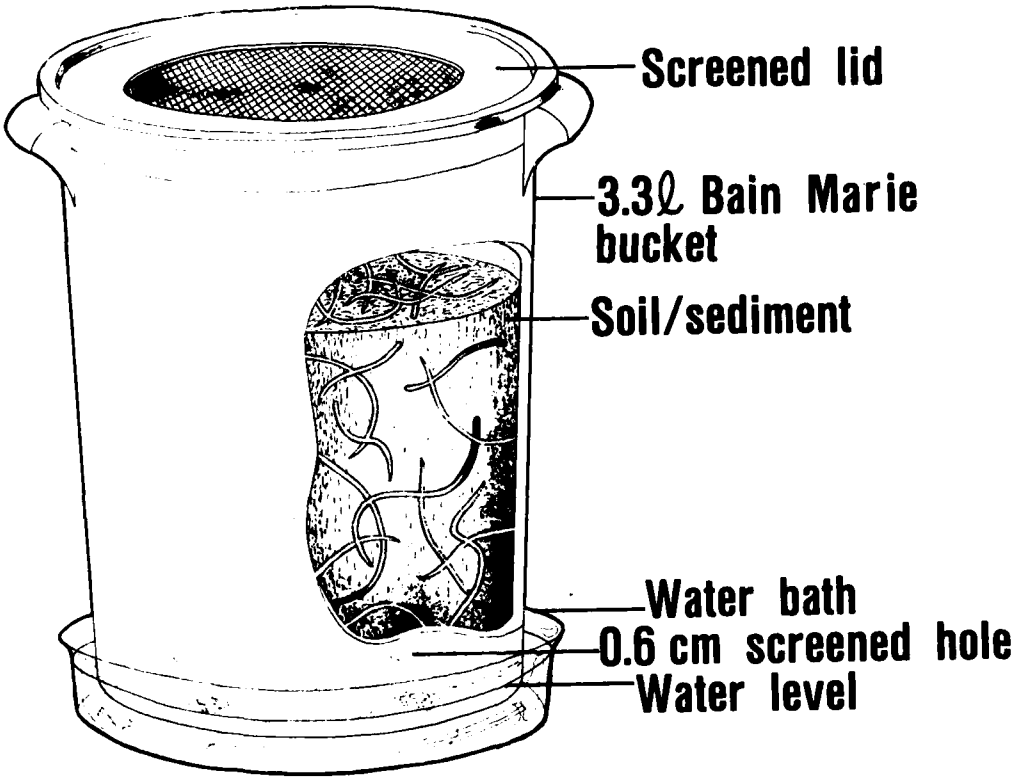


Figure 2-50. Earthworm bioassay apparatus

2.1.2.4.2.1 Earthworm Survival

There was poor earthworm survival in 1 of 67 bioassays in the AA area on Parcel 572, 2 out of 5 in the AB area on Parcel 572, and 1 out of 16 in the CP area on Parcel 581. Extremely poor survival (less than 0.75 g dry weight) was observed in 5 additional samples from the AA area on Parcel 572 and 2 from the CP area on Parcel 581 (Figure 2-51). Soil samples with survival of earthworms whose dry weight was equal or less than 50% of that in soil from the remote reference areas (BK) were considered to indicate toxicity. Therefore, the number of toxic soil samples was 11, as shown in Figure 2-51.

2.1.2.4.2.2 Bioaccumulation

2.1.2.4.2.2.1 Arsenic

The initial As concentrations (Time = 0) in bioassay worms averaged 0.016 ± 0.002 mg/kg. None of the 30 samples from the BK areas exceeded the 10 mg/kg FDA criteria for tissue As. Arsenic concentrations in earthworms are shown in Figure 2-52. The maximum As concentration in the bioassay earthworms (150.6 mg/kg) in Table 2-10 was more than 3 times concentrations reported in recently published literature (Table 2-11). There were no externally visible indications of the effects of As on the surviving earthworms. The AA area on Parcel 572, the AB area on Parcel 572, the G-1 area on Parcel 575, and the KS area on Parcel 572 may be of concern with respect to As bioaccumulation in soil invertebrates, particularly on soils from the AA area, where earthworms contained an As concentration higher than 50 mg/kg. These results indicate a definite bioaccumulation of As in earthworms and suggest a high potential for soft-bodied soil-dwelling animals to bioaccumulate As.

2.1.2.4.2.2.2 Cadmium

Earthworm Cd contents were rather variable. For example the high value (13.7 mg/kg) in the AA area on Parcel 572 was an order of magnitude greater than the other 2 replicates from the same sampling site in that area (16w1). The variation in soil contents of Cd was extreme in certain other locations.

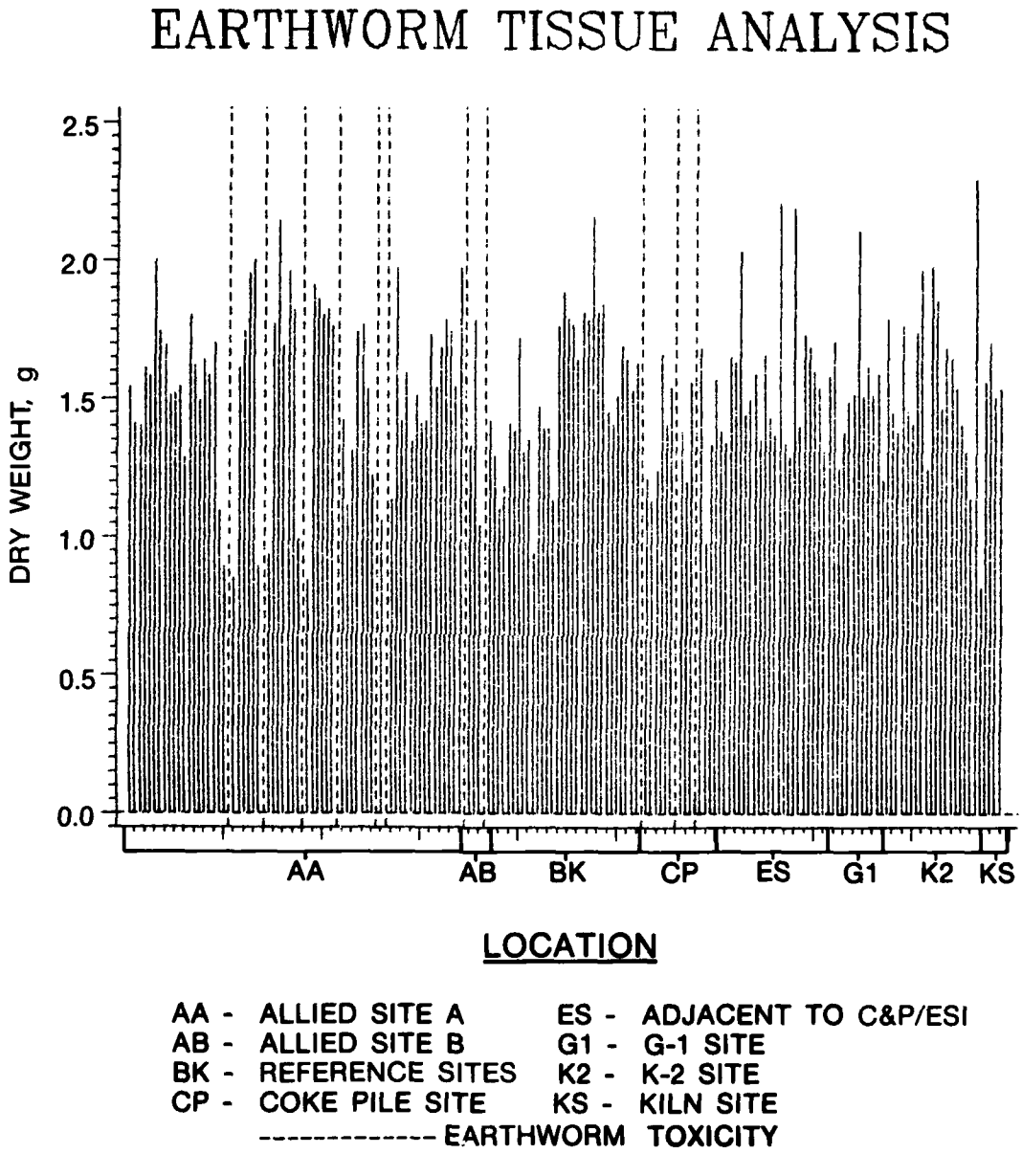


Figure 2-51. Earthworm dry-weight yield and toxicity

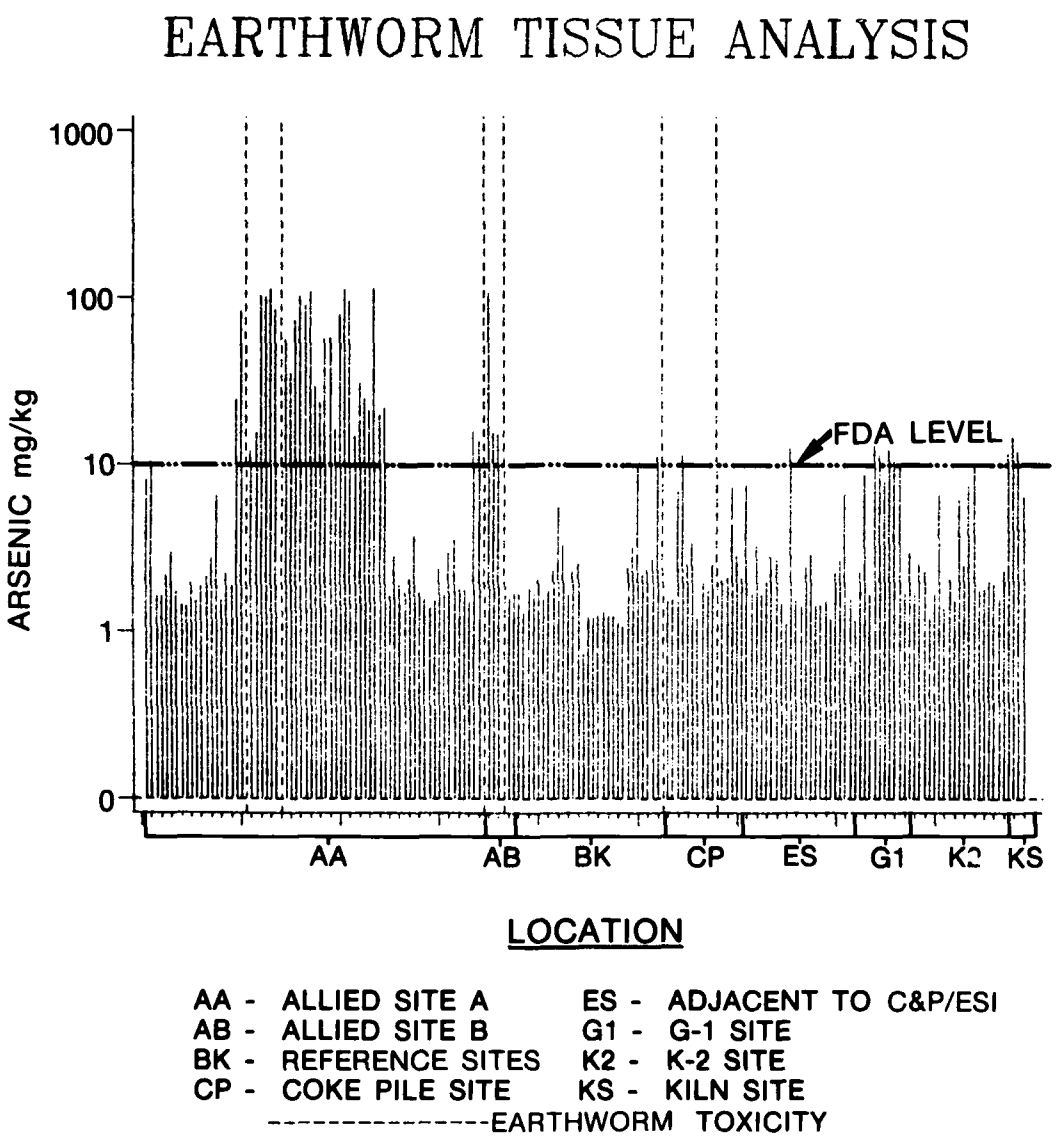


Figure 2-52. Earthworm tissue arsenic content

Table 2-10

Earthworm Tissue Metal Content

	Heavy Metal Concentration in Worms, mg/kg*																				
	Arsenic			Cadmium			Copper			Lead			Nickel			Selenium			Zinc		
Site	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
AA	36.3	2.2	150.6	3.2	0.2	13.7	17.2	6.1	69.9	2.2	0	19.9	2.7	0	14.3	3.9	1.4	8.4	138.1	99.3	400.9
AB	49.2	22.3	121.3	3.4	1.9	6.7	85.8	30.2	159.2	2.8	0.9	5.7	1.7	1.2	2.1	3.6	3.2	3.9	127.4	121.9	132.8
KS	14.7	4.3	25.6	30.7	9.0	53.7	78.1	22.9	187.7	10.7	2.3	23.6	3.6	3.0	5.8	7.3	1.2	15.4	247.4	152.7	433.2
K2	4.6	1.7	10.9	9.1	2.2	21.9	27.1	9.9	88.8	34.7	0.3	224.6	3.2	0.8	6.5	5.2	2.2	20.2	202.3	115.1	631.9
G1	9.7	1.6	20.0	7.2	3.5	11.6	12.9	7.4	27.4	12.3	0	85.2	3.4	1.6	7.1	5.8	3.9	11.4	173.0	110.4	343.5
ES	4.7	1.4	19.6	7.8	2.9	21.3	15.6	7.7	103.5	11.0	0.8	80.5	3.6	1.5	7.1	4.9	2.3	8.9	159.9	114.5	406.0
BK	3.5	0.9	9.9	5.0	1.6	11.8	10.3	7.2	14.7	1.7	0	5.8	4.1	0.2	10.3	4.4	2.1	15.8	124.5	99.2	162.4
CP	5.9	1.7	14.7	13.6	0.8	29.4	27.6	1.4	91.8	12.1	0	76.7	4.0	1.1	12.0	23.9	3.3	91.3	138.3	111.8	336.3

* Column headings defined as follows: Min - minimum value
Max - maximum value

Table 2-11

Uptake of Heavy Metals by Earthworms Reported in the Literature

Heavy Metal	Species	Exposure Route/Concentration mg · kg^{-1} Dry Weight		Concentration in Tissues mg · kg^{-1} Dry Weight	Reference
As	*E. foetida*	Sludge + plant wastes	7.00 ± 1.04	2.65 ± 1.38	Frank et al. (1983)
	Ap. tuberculata	Sludge-amended soil[a] 6.9, 7.1	(0) (15) (30) (60)	1.9 - 2.2 2.1 - 3.0 1.6 - 1.7 1.1 - 1.9	Helmke et al. (1979)
		Soil, adjacent field	6.9	1.9	
	E. foetida	Surface soil-transects from upland to flooded to upland	25.0 20.0 38.5 72.4 58.8 53.0	21.1 (upland) 17.5 (transition) 24.0 (wetland) 23.9 (wetland) 35.3 (transition) 53.8 (upland)	Simmers et al. (1984a)
		Manure controls	3.4	8.72	
Cd	*A. longa*	Sludge	NI[+]	9.2 ± 2.7	Andersen and Laursen (1982)
	S. rosea	Sludge	NI	20	
	L. terrestris	Garden soil Garden soil Garden soil Garden soil	1 ± 1.2 1 ± 1.2 1 ± 1.2 1 ± 1.2	21 ± 2.7 (whole) 9 ± 0.1 (muscle) 26 ± 6.2 (gut wall-adult) 8 ± 7.1 (gut wall-juvenile)	
	L. terrestris	Roadside soils	NI	0.55 ± -.09 to 12.10 ± 0.28	Ash and Lee (1980)
	A. chlorotica	Roadside soils	NI	0.18 ± 0.02 to 9.30 ± 0.18	

a First value is As in soil; 2nd value is level in sludge; value in ( ) is rate of sludge application as metric tons/ha.

+ NI - Not indicated

(Sheet 1 of 11)

Table 2-11 (Continued)

Heavy Metal	Species	Exposure Route/Concentration mg · kg^{-1} Dry Weight		Concentration in Tissues mg · kg^{-1} Dry Weight	Reference
Cd Cont'd	*L. rubellus*	Roadside soils	NI	4.15 ± 0.98	
		Soil	0.4 ± 0.08	6 ± 1.9 (mature adult)	Carter (1983)
	Al. chlorotica	Soil	0.4 ± 0.08	8 ± 2.4 (mature adult)	
	Ap. spp	Soil	0.4 ± 0.08	8 ± 2.5 (mature adult)	
	L. rubellus	Soil	0.4 ± 0.08	5.1 ± 1.36 (immature adult)	
	L. terrestris	Soil	1.10	17.0#	Czarnowska and Jopkiewicz (1978)
			0.30	10.5#	
			0.92	16.0#	
			0.28	9.0#	
			0.62	12.0#	
			0.29	7.0#	
			0.11	2.5#	
	E. foetida	Sludge + plant wastes	16.6 ± 6.5	1.9 ± 0.7	Frank et al. (1983)
	Ap. tuberculata	Sludge-amended soil[b]	(0)	9-18	Helmke et al. (1979)
		<0.5, 102	(15)	17-78	
			(30)	66-64	
			(60)	27-118	
		Soil, adjacent field	<0.5	7.3	
	L. rubellus	Soil	2 ± 0.1	15 ± 5	Ireland (1979)
			4 ± 0.2	4 ± 0.1	
			4 ± 0.3	25 ± 3	
	D. veneta		4 ± 0.2	7 ± 1	
	E. tetraedra		4 ± 0.2	3 ± 0.3	

b Value in soil on dry wt vasis; value in tissues on ash-free dry wt.

Table 2-11 (Continued)

Heavy Metal	Species	Exposure Route/Concentration mg · kg^{-1} Dry weight		Concentration in Tissues mg · kg^{-1} Dry Weight		Reference
Cd Cont'd	*L. rubellus*	Soil	0.1-5.7	20-202		Ma et al. (1983)
	E. foetida	Background worms		3.5[b] (initial)		Marquenie and Simmers (1984)
		Soil	5.1 ± 0.4[a]	4.2[b] (14 days)		
			5.1 ± 0.4[a]	5.5[b] (25 days)		
		(Surface 0.3m)	5.1 ± 0.4[a]	7.8[b] (42 days)		
		Soil core profile	10.0 (-0.05 m)[a]			23.5[b]
		(Times Beach) disposal area	8.5 (-0.2 m)[a]	6.0[b]		
			3.8 (-0.7 m)[a]	7.1[b]		
			6.6 (-1.1 m)[a]	0.0[b]		
		Soil core profile	0.5 (surface)[a]	7.5[b]		
			0.0 (-0.2 m)[a]	4.5[b]		
		Surface soil-transects from upland to flooded to upland	7.9[a]	15.5[b]	wooded marsh	
			2.0[a]	8.0[b]	woodland	
			10.5[a]	12.0[b]	open marsh	
			11.0[a]	11.0[b]	open marsh	
			9.5[a]	10.5[b]	open marsh	
			3.0[a]	11.5[b]	open marsh	
			6.0[a]	14.5[b]	open marsh	
			1.5[a]	8.5[b]	woodland	
	D. rubida	Soil 467 ± 29	(225 ± 9.2)[b]	1320 ± 160		Morgan and Morris (1982)
	L. rubellus	467 ± 29	(225 ± 9.2)[b]	823 ± 107		
	E. foetida	Manure Control	NI	3.1 ± 0.34 (background)		Simmers et al. (1984b)

a First value is As in soil; 2nd value is level in sludge; value in ( ) is rate of sludge application as metric tons/na.

b Value in soil on dry wt basis; value in tissues on ash-free dry wt.

Table 2-11 (Continued)

Heavy Metal	Species	Exposure Route/Concentration mg · kg^{-1} Dry Weight		Concentration in Tissues mg · kg^{-1} Dry Weight	Reference
Cd Cont'd		Soil (dredged material over acid mine spoil)	<0.01 <0.01 <0.01	2.94 ± 0.70 (plot 2) 3.02 ± 0.39 (plot 3) 9.67 ± 0.39 (plot 4)	
Cu	*L. terrestris*	Roadside soils	NI	0.83 ± 0.06 - 7.5 ± 2.70	Ash and Lee (1980)
	A. chlorotica	Roadside soils	NI	0.20 ± 0.03 - 8.9 ± 1.25	
	L. rubellus	Roadside soils	NI		
	L. rubellus	Soil	26 ± 6.0	10 ± 3.0 (mature adults)	Carter (1983)
	Al. chlorotica	Soil	26 ± 6.0	8 ± 2.4 (mature adults)	
	Ap. spp	Soil	26 ± 6.0	11 ± 3.0 (mature adults)	
	L. rubellus	Soil	26 ± 6.0	10 ± 2.1 (immature adults)	
	L. terrestris	Soil	52 26.8 54.9 15.4 26.0 17.6 8.6	27^{+} 12^{+} 27^{+} 18.5^{+} 17.5^{+} 12^{+} 4^{+}	Czarnowska and Jopkiewicz (1978)
	E. foetida	Sludge + plant waste	863 ± 117	21 ± 9	Frank et al. (1983)
	E. foetida	Sludge	380-610	20-150	Hartenstein et al. (1980)
	Ap. tuberculata	Sludge-amended soil[a]	(0)	8.8-9.5	Helmke et al. (1979)

a First value is As in soil; 2nd value is level in sludge; value in ( ) is rate of sludge application as metric tons/ha.

Table 2-11 (Continued)

Heavy Metal	Species	Exposure Route/Concentration mg · kg^{-1} Dry Weight		Concentration in Tissues mg · kg^{-1} Dry Weight	Reference
Cu Cont'd		1450	(15)	12.3-8.3	
		1450	(30)	10.0-13.7	
	Ap. tuberculata	1450	(60)	21.7-12.0 8.0	
	L. rubellus	Soil	20 ± 1 252 ± 5 335 ± 15	13 ± 6 11 ± 1 11 ± 2	Ireland (1979)
	D. veneta		252 ± 5	14 ± 2	
	E. tetraedra		252 ± 5	8 ± 1	
	L. rubellus	Soil	1-130	12-58	Ma et al. (1983)
	E. foetida	Surface soil-transects[a] from upland to wetland and back to upland	116.0 60.0 148.0 334.0 228.0 269.0 16.5	27.7 (upland) 17.3 (transition 32.1 (wetland) 57.6 (wetland) 36.2 (transition) 46.7 (upland) 10.1	Simmers et al. (1984a)
	E. foetida	Manure control soil (dredged material over acid minespoil	NI 27.8 27.8 27.8	7.5 ± 1.1 13.75 ± 1.7 (plot 2) 11.25 ± 0.5 (plot 3) 21.25 ± 0.5 (plot 4)	Simmers et al (1984b)

a First value is As in soil; 2nd value is level in sludge; value in ( ) is rate of sludge application as metric tons/ha.

Table 2-11 (Continued)

Heavy Metal	Species	Exposure Route/Concentration mg · kg^{-1} Dry Weight		Concentration in Tissues mg · kg^{-1} Dry Weight	Reference
Pb	*A. longa*	Sludge	NI	5.9 ± 1.7	Andersen and Laursen (1982)
	A. rosea	Sludge	NI	6	
	L. terrestris	Garden soil	NI 197 ± 16.8	24 ± 6.5 (whole)	
		Garden soil	NI 197 ± 16.8	13 ± 2.5 (muscle)	
		Garden soil	NI 197 ± 16.8	54 ± 7.4 (adult, gut wall)	
		Garden soil	NI 197 ± 16.8	22 ± 11.3 (juvenile, gut wall)	
	L. terrestris	Roadside soils	NI	0.96 ± 0.15 - 274.30 ± 29.9	Ash and Lee (1980)
	A. chlorotica	Roadside soils	NI	0.31 ± 0.09 - 499.6 ± 44.0	
	L. rubellus	Roadside soils	NI	37.40 ± 8.03	
	L. terrestris	Soil	170	63*	Czarnowska and Jopkiewicz (1978)
			64	48*	
			130	50*	
			30	14*	
			170	55*	
			39	17*	
			20	7*	
	Lumbricidae (*L. terrestris*, *A. chlorotica*, *A. trapezoides*, and *A. turgida*)	Roadside soil	227.8	120.9	Gish and Christensen (1973)
				93.4	
			63.7	64.0	
				83.5	
				106.5	
				76.7	
				14.3	
				12.0	
	D. rubida	Soils	127 ± 5 (2.6 ± 0.9)**	100 ± 5	Ireland (1975b)
			1713 ± 24 (127 ± 2.0)**	4,160 ± 930	
	L. rubellus	Soil	1,314 ± 40	3,592 ± 899	Ireland (1979)

(Sheet 6 of 11)

Table 2-11 (Continued)

Heavy Metal	Species	Exposure Route/Concentration mg · kg^{-1} Dry Weight		Concentration in Tissues mg · kg^{-1} Dry Weight	Reference
Pb Cont'd			629 ± 80	9 ± 1	
			42 ± 2	28 ± 8	
	D. veneta		629 ± 80	18 ± 3	
	E. tetraedra		629 ± 80	20 ± 1	
	L. rubellus	Soil		3,592 ± 899	Ireland and Richards (1977)
		Sludge (control site)		24.7 ± 6.2	
	D. rubida	Soil		7,593 ± 1,483	
		Sludge (control site)		36.5 ± 5.3	
	E. foetida	Pb-contaminated soil (Pb-dioxide)	0	0.9*	Migula et al. (1977)
			100	4.5*	
			200	9*	
			400	10*	
			1,000	13*	
	D. rubida	Soil	5,486 ± 940 (114 ± 9.6)+	2,259 ± 477	Morgan and Morris (1982)
	L. rubellus	Soil	5,486 ± 940 (114 ± 9.6)+	813 ± 143	
	E. foetida	Manure controls	NI	1.34 ± 0.85	Simmers et al. (1984b)
		soil (dredged material over minespoil)	41.4	2.18 ± 0.65 (plot 2)	
			41.4	5.4 ± 1.13 (plot 3)	
			41.4	3.56 ± 0.42 (plot 4)	
	Unspecified Oligochaetes	Pb mine spoil	160-19,000	NI	Williamson and Evans (1973)
		Roadside soil	84-110		
		Pb-amended soil	177-399 (nitrate or chloride)	4,600 ± 1230 (juvenile gut wall)	

Table 2-11 (Continued)

Heavy Metal	Species	Exposure Route/Concentration mg · kg^{-1} Dry Weight		Concentration in Tissues mg · kg^{-1} Dry Weight	Reference
Ni	Unspecified Lumbricidae	Soil	14 (0.36)[a]	16	Beyer et al. (1982)
			12 (0.24)[a]	15	
			13 (0.09)[a]	11	
			16 (0.29)[a]	12	
			14 (0.25)[a]	14	
		Sludge	17 (1.1)[a]	13	
			18 (0.75)[a]	14	
			20 (0.75)[a]	14	
			24 (2.3)[a]	15	
			19 (1.1)[a]	14	
	E. foetida	Sludge + plant wastes	183 ± 47	13 ± 16	Frank et al. (1983)
	Lumbricidae (*L. terrestris*, *A. chlorotica*, *A. trapezoides* and *A. turgida*)	Roadside soil	25.3	26.8	Gish and Christensen (1973)
			11.4	32.3	
			13.4	25.3	
			19.2	17.3	
				13.6	25.2
	E. foetida	Manure control soil (dredged material over acid minespoil)	NI	5.6 ± 2.5	Simmers et al. (1984b)
			45.1	5.23 ± 1.35	
			45.1	5.52 ± 0.21	
			45.1	7.55 ± 0.93	
Se	*E. foetida*	Sludge + plant wastes	0.40 ± 0.16	0.22 ± 0.14	Frank et al. (1983)
	Ap. tuberculata	Sludge-amended soil[a]	(0)	20.3-25.1	Helmke et al. (1979)

a First value is Se in soil; 2nd value is level in sludge; value in ( ) is rate of sludge application as metric tons/ha.

Table 2-11 (Continued)

Heavy Metal	Species	Exposure Route/Concentration mg · kg^{-1} Dry Weight		Concentration in Tissues mg · kg^{-1} Dry Weight	Reference
Se Cont'd		0.3, 0.5	(15)	17.0-20.1	
			(30)	16.0-17.3	
			(60)	11.0-16.1	
		Soil, adjacent field	0.3	22.1	
Zn	*L. terrestris*	Garden soil	800 ± 300	610 (whole)	Andersen and Laursen (1982)
			800 ± 300	730 ± 6 (muscle)	
			800 ± 300	9,300 ± 1,400 (adult, gut wall)	
			800 ± 300	4,600 ± 1,230 (juvenile, gut wall)	
	Unspecified Lumbricidae	Soil	51 (2.7)$^{+}$	256	Beyer et al. (1982)
			67 (4.5)$^{+}$	241	
			51 (2.3)$^{+}$	225	
			56 (2.5)$^{+}$	186	
			56 (2.9)$^{+}$	228	
		Sludge-amended soil	175 (45)$^{+}$	393	
			150 (37)$^{+}$	702	
			86 (12)$^{+}$	353	
			137 (28)$^{+}$	430	
			132 (27)$^{+}$	452	
	L. rubellus	Soil	83 ± 8.1	320 ± 129 (mature adults)	Carter (1983)
	Al. chlorotica	Soil	83 ± 8.1	210 ± 45 (mature adults)	
	Ap. spp	Soil	83 ± 8.1	380 ± 114 (mature adults)	
	L. rubellus	Soil	83 ± 8.1	260 ± 84 (immature adults)	
	L. terrestris	Soil	275	1,950*	Czarnowska and Jopkiewicz (1978)
			103	1,650*	
			170	1,650*	

Table 2-11 (Continued)

Heavy Metal	Species	Exposure Route/Concentration mg · kg^{-1} Dry Weight		Concentration in Tissues mg · kg^{-1} Dry Weight	Reference
Zn Cont'd			57	1,250*	
			225	1,250*	
		Soil	105	1,200*	
			40	800*	
	E. foetida	Sludge + plant wastes	2,233 ± 476	92 ± 88	Frank et al. (1983)
	Lumbricidae (*L. terrestris*, *A. chlorotica*, *A. trapezoides* and *A. turgida*	Roadside soil	134.6	520.1	Gish and Christensen (1973)
			55.0	397.8	
			57.5	296.7	
			81.2	324.6	
			42.3	223.8	
	Ap. tuberculata	Sludge-amended soil	(0)	210-290	Helmke et al. (1979)
		100, 3,400[a]	(15)	140-410	
			(30)	340-440	
			(60)	200-450	
		Soil, adjacent field	100	260	
	D. rubida	Cwmystwyth soil		1.250 ± 0.17 (posterior gut) 0.446 ± 0.05 (anterior gut) 0.210 ± 0.01 (body wall) 0.659 ± 0.20 (coelomic fluid) 0.394 ± 0.04 (gonad)	Ireland (1975a)
		Campus (control) soil		0.214 ± 0.01 (posterior gut) 0.280 ± 0.067 (anterior gut) 0.118 ± 0.007 (body wall) 0.119 ± 0.014 (coelomic fluid)	

Table 2-11 (Concluded)

Heavy Metal	Species	Exposure Route/Concentration mg · kg^{-1} Dry Weight		Concentration in Tissues mg · kg^{-1} Dry Weight	Reference
Zn Cont'd	*D. rubida*	Soil	172 ± 15 (18 ± 0.25)[a]	114 ± 4	Ireland (1975b)
			1,975 ± 2 (10 ± 1.08)[a]	584 ± 110	
	L. rubellus	Soil	138 ± 1	739 ± 231	Ireland (1979)
			992 ± 53	676 ± 25	
			100 ± 2	416 ± 34	
	D. veneta		992 ± 53	134 ± 5	
	E. tetraedra		992 ± 53	353 ± 45	
	L. rubellus	Soil		739 ± 181	Ireland and Richards (1977)
		Sludge (control)		646 ± 77	
		Soil		309 ± 38	
	D. rubida	Sludge (control)		251 ± 25	
	D. rubida	Soil Campus	0.172 ± 0.006	0.09, 0.12, 0.12, 0.12[b]	Ireland and Wooton (1976)
		Ystwyth	0.286 ± 0.030	0.46, 0.81, 0.82, 0.57[b]	
		Cwmystwyth	0.880 ± 0.300	0.44, 0.59, 0.57, 0.53[b]	
	L. rubellus	Soil	10-1,220	717-3,500	Ma et al. (1983)
	D. rubida	Soil	29,270 ± 1,250 (9,842 ± 1,108)	1,876 ± 210	Morgan and Morris (1982)
			29,270 ± 1,250 (9,842 ± 1,108)	2,763 ± 291	

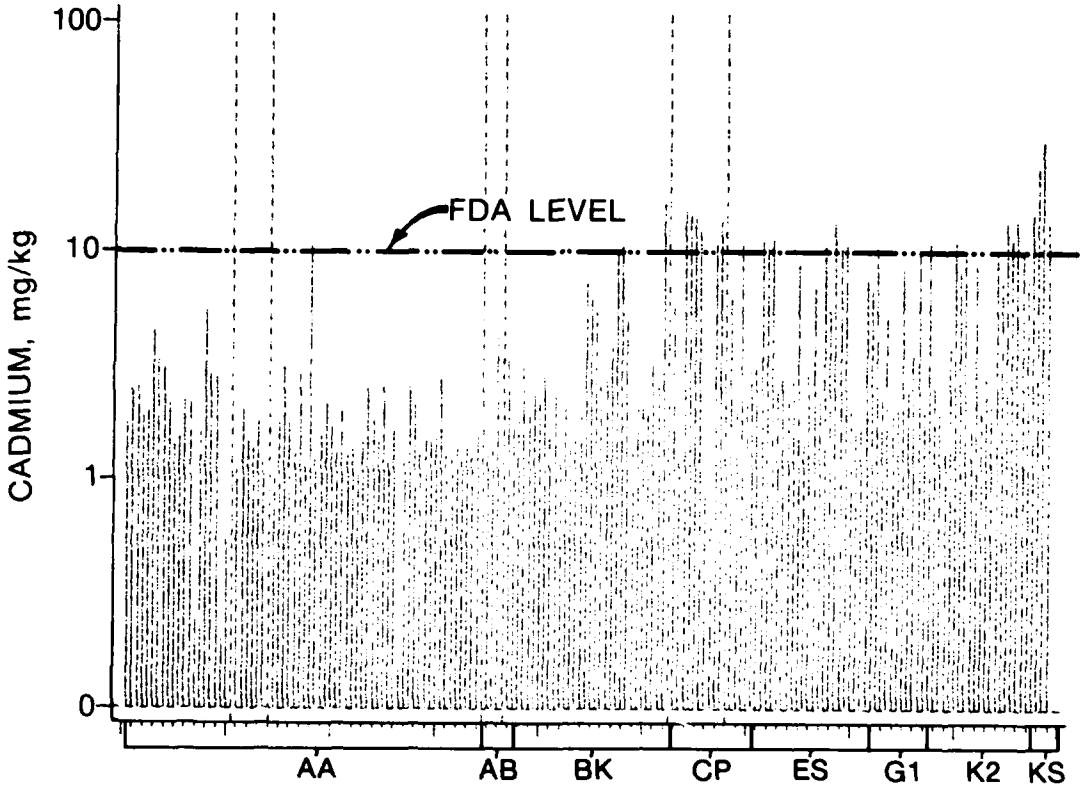
a First value is As in soil; 2nd value is level in sludge; value in ( ) is rate of sludge application as metric tons/ha.
b mg · g^{-1}.

Cadmium concentrations in the earthworms are shown in Figures 2-53. The 10 mg/kg FDA criterion for tissue Cd was exceeded in 1 sample from AA, 1 from BK, 9 from the CP area on Parcel 581, 7 in the ES area on Parcel 579, 2 in G-1 area on Parcel 575, 8 in the K-2 area on Parcels 573 and 574, and 4 in the KS area on Parcel 572. The maximum Cd concentration in the bioassay earthworm (53.7 mg/kg) in Table 2-10 was within the ranges reported in recent literature (Table 2-11). Recent literature suggests that environmental Cd (see soils data, Section 2.2.1) and bioaccumulation at the concentration observed in the bioassays would have little currently detectable impact on earthworm populations that may occur in the field at NWS Concord. Hartenstein et al. (1981) reported that up to 100 mg Cd/kg in $CdSO_4$-amended sewage sludge and up to 170 mg Cd/kg in the tissues were not toxic to E. foetida. Hartenstein et al. (1981) reported growth inhibition of E. foetida at 1800-18,000 mg/kg and mortality at 3500-35,000 mg/kg in Cd-amended sewage sludge but did not indicate the concentration of the Cd in the tissues. Growth reduction of E. foetida increased linearly and cocoon production was completely inhibited by Cd concentrations from 100-1000 mg/kg in Cd-amended manure (Neuhauser et al. 1983). While adverse physiological effects may not occur from the level of bioaccumulation observed in the earthworm bioassay, there is a potential for the transfer of Cd from the CP area on Parcel 581, the K-2 area on Parcel 574, the KS area on Parcel 572, and the ES area on Parcel 579 through the food chain to higher animals where chronic effects may possibly occur. The threat movement of Cd bioaccumulated by soil-dwelling organisms from areas CP, K-2, KS, and ES through the food chains to higher animals where chronic effects may occur does exist. The threat of Cd to produce long-term chronic effects rather than short-term acute or toxic manifestations is reason for concern at NWS Concord.

2.1.2.4.2.2.3 Lead

The initial concentrations (Time = 0) of Pb in bioassay worms averaged 0.009 ± 0.003 mg/kg. Lead in the tissues of bioassay worms is shown in Figure 2-54. The numbers of values exceeding established FDA criteria (25 mg/kg) for Pb were 0 in the AA area on Parcel 572, the AB area on Parcel 572, and the KS area of Parcel 572; 1 in the BK area; 3 in the CP on Parcel 581; 4 in the ES on Parcel 579; 1 in the G-1 area on Parcel 575; and

EARTHWORM TISSUE ANALYSIS



LOCATION

AA - ALLIED SITE A
AB - ALLIED SITE B
BK - REFERENCE SITES
CP - COKE PILE SITE
ES - ADJACENT TO C&P/ESI
G1 - G-1 SITE
K2 - K-2 SITE
KS - KILN SITE

----------EARTHWORM TOXICITY

Figure 2-53. Earthworm tissue cadmium content

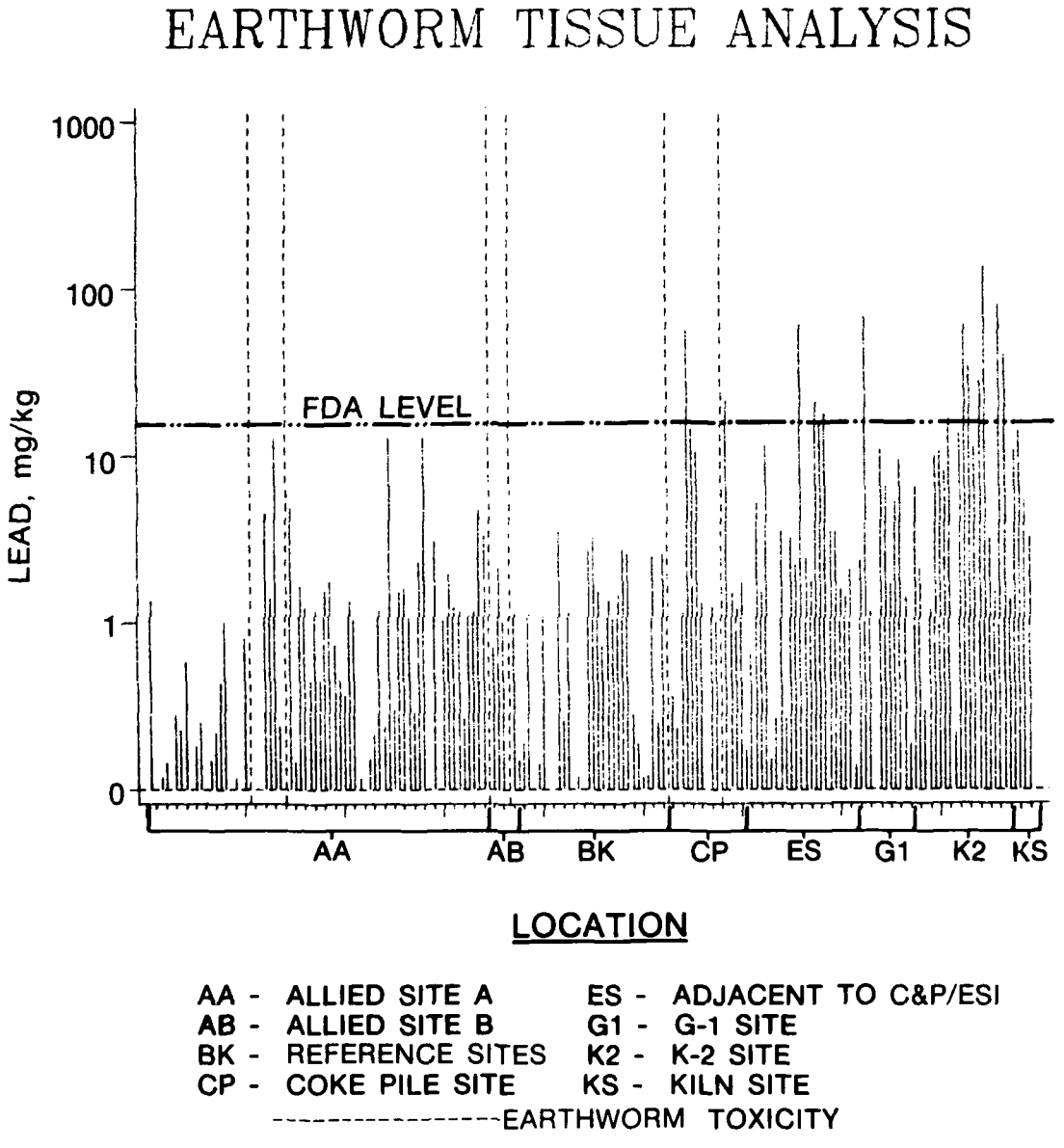


Figure 2-54. Earthworm tissue lead content

7 in the K-2 area on Parcel 574. The high values in the CP site are correlated with a similar high soil Pb, whereas the high values in the G-1 and K-2 areas may be more closely related to differences in bioavailability. The maximum Pb level (224.6 mg/kg) in the bioassay worms Table 2-10 is well within the ranges reported for earthworms (Table 2-11) and more than 10 times lower than reported in recent literature. This indicates that in many cases earthworms are very resistant to Pb accumulation. Neuhauser et al. (1983) found growth reduction of E. foetida at soil contents of 40,000 mg/kg and reduced reproduction at 5000 mg/kg Pb in Pb-amended manure. Williamson and Evans (1973) observed no toxic effects of Pb upon lubricids at concentrations up to 19,000 mg/kg in soils. The Pb concentrations in the tissues of the worms were not indicated in either study, however. The influence of Pb on metabolism, enzyme activity, and subcellular morphology have been studied and suggest that chronic effects of Pb occur at lower environmental exposure levels than reported in these two studies. Ireland and Fisher (1978) reported the reduction of d-aminolaevulinic acid dehydratase and decreased Fe(+++) in the intestine following exposure of L. terrestris to 1 µg Pb/100 ml in the form of $PbCl_2$. Migula et al. (1977) indicated that exposure to 400-1000 mg/kg Pb in the soil depressed both metabolic rate and hemoglobin content and decreased respiration and oxygen consumption in E. foetida; the concentrations of Pb in the worms were 10 and 13 mg/kg, respectively, at 400 and 1,000 mg/kg in the soil. Wielgus-Serafinska (1979) reported that exposure to Pb-amended soil containing 200 mg/kg Pb produced morphological changes in epithelial gland cells, and that increased secretory activity in E. foetida. Ultrastructural damage in the cristae of the mitochondria was produced by 50 mg/kg Pb in soil (Wielgus- Serafinska 1980). Pb also produced a decrease in mitochondrial protein and decreased ATP-ase activity due to interference with oxidative phosphorylation (Wielgus-Serafinska 1979). Ireland (1975b; 1979) showed that the presence of Cd lowers the uptake of Pb in earthworms. These data suggest that the effects of Pb vary widely and probably indicate differing bioavailability. While the acutely toxic effect of Pb does not appear to be a factor for earthworms at NWS Concord, there may be a moderate potential for lead accumulated in soil-dwelling organisms to be transferred into the food chains associated with the sites.

2.1.2.4.2.2.4 Selenium

Initial concentrations (Time = 0) of Se in bioassay worms averaged 0.034 ± 0.006 mg/kg. The FDA action-level criterion of 10 mg/kg Se was exceeded in 1 sample from the BK area, 10 from the CP area on Parcel 581, 1 from the G-1 area on Parcel 575, 1 from the K-2 area on Parcels 573 and 574, and 1 from the KS area on Parcel 572. There were no bioassay samples from the AA and AB areas on Parcel 572 which exceeded the criterion. Selenium data for bioassay earthworms is shown in Figure 2-55 and are well within data reported in recent literature (Table 2-11). The high Se bioaccumulation from CP site soils suggests that Se has a high potential for mobility into earthworms at that site, although no data were found in the literature concerning the toxic effects of Se on growth or reproduction of earthworms. The potential for toxic effects of Se in animals feeding on earthworms or other soil-dwelling animals may be substantial, particularly in light of recent Se poisoning of birds in the Kesterson National Wildlife Refuge in 1983 and 1984 (Smith 1985, Ohlendorf 1984, Ohlendorf et al. 1985 unpublished manuscript).

2.1.2.4.2.2.5 Zinc

Initial concentrations (Time = 0) of Zn in bioassay worms averaged 1.600 ± 0.150 mg/kg. The concentrations of Zn in bioassay earthworms are summarized in Figure 2-56. There were no cases in which Zn in earthworms exceeded the FDA action-level criterion. The maximum Zn in bioassay worms (Table 2-10) was well within the range reported for earthworms in soils (Table 2-11). Some effects of Zn on earthworms have been reported. Hartenstein et al. (1980) reported that 10,000 mg/kg Zn in Zn acetate-amended sludge was not toxic to E. foetida. Subsequent studies reported growth inhibition at 1300-13,000 mg/kg and mortality at 26,000 mg/kg for E. foetida exposed to sludge amended with ionic Zn (Hartenstein et al. 1981). However, tissue levels of Zn were not reported. Ireland (1975b, 1979) reported that Zn uptake apparently was well regulated in earthworms. The concentrations of soil Zn at the NWS Concord used in the earthworm bioassays do not appear to be high enough to cause either acute or chronic problems in the earthworms. The potential for an adverse effect upon animals eating earthworms is uncertain, but Gish and

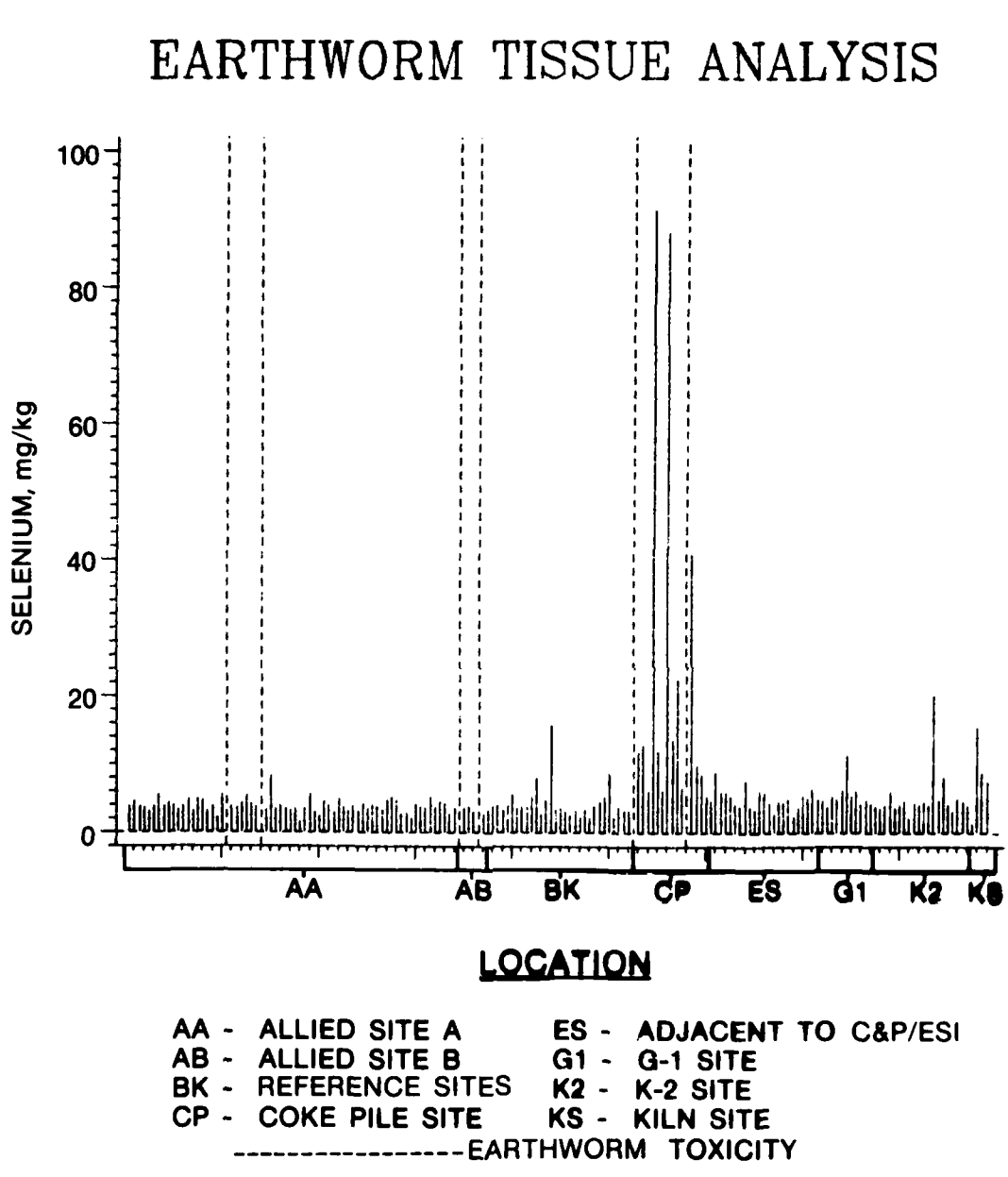


Figure 2-55. Earthworm tissue selenium content

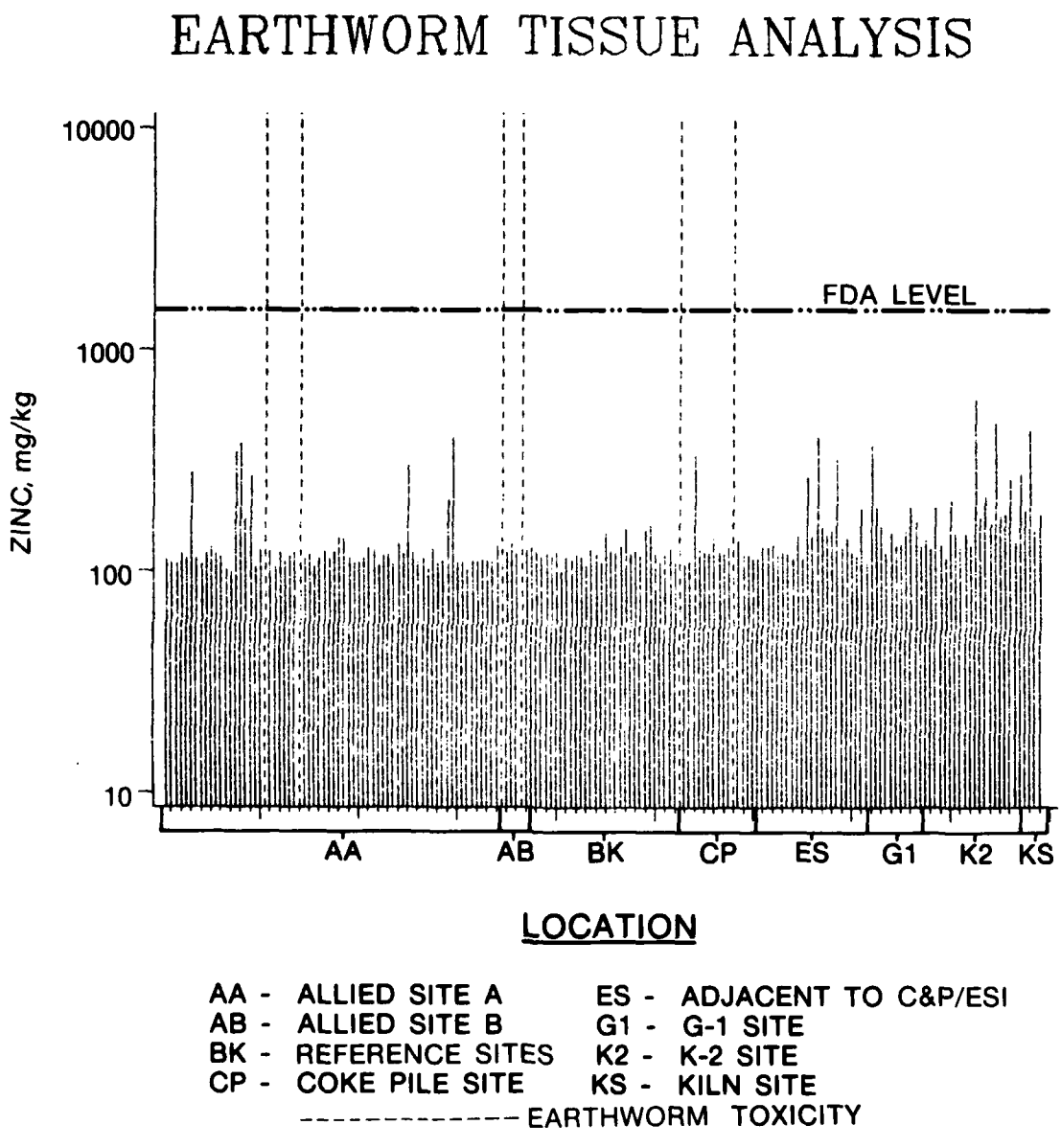


Figure 2-56. Earthworm tissue zinc content

Christensen (1973) have suggested that "high" Zn concentrations in earthworms could be lethal to earthworm-eating animals.

2.1.2.4.2.2.6 Copper

Initial Cu concentrations (Time = 0) in bioassay worms averaged 0.130 ± 0.017 mg/kg. The levels of Cu in bioassay earthworms are shown in Figure 2-57. Concentrations of Cu in worms did not exceed the FDA action level following a 28-day laboratory exposure. The maximum level (187.7) of Cu in worm tissue (Table 2-10) falls well within concentrations reported in recent literature (Table 2-11). The concentrations of Cu in the worm bioassay soil samples exceeded the 1100 mg Cu/kg reported to inhibit the growth of E. foetida (Hartenstein et al. 1981) on only five occasions; only 2 of the samples resulted in elevated Cu in the earthworms. Very high copper concentrations (22,000 mg/kg) in Cu-amended sludge have been reported to cause mortality of E. foetida (Hartenstein et al. 1981). Copper is well regulated in earthworms irrespective of the levels in the soil (Ireland 1979) and is unlikely to be a problem for earthworms and probably not for other soil invertebrates. Food-web biomagnification is also unlikely to be a problem as there are few species present that are known to extensively accumulate Cu.

2.1.2.4.2.2.7 Nickel

Initial Ni levels (Time = 0) in the bioassay worms averaged 0.028 ± 0.010 mg/kg. Earthworm tissues are shown in Figure 2-58. Nickel in bioassay earthworms varied from undetectable to 14.3 mg/kg and were similar from all sites at NWS Concord. There was no established criterion for Ni with which to compare the results of the earthworm bioassay. A comparison of the data with recent literature (Table 2-11) shows that the results of the worm bioassay are well within the ranges reported for earthworms. Neuhauser et al. (1982) indicated that growth and reproduction of E. foetida were reduced at 500 mg/kg and 300-400 mg/kg, respectively, of Ni in Ni-amended manure; the maximum Ni exposure permitting survival and reproduction were 2000 and 500 mg/kg, respectively. The tissue burdens of Ni were not indicated in these studies, however. The earthworms in the present study were not exposed to Ni in NWS Concord soils in concentrations high enough (as suggested by

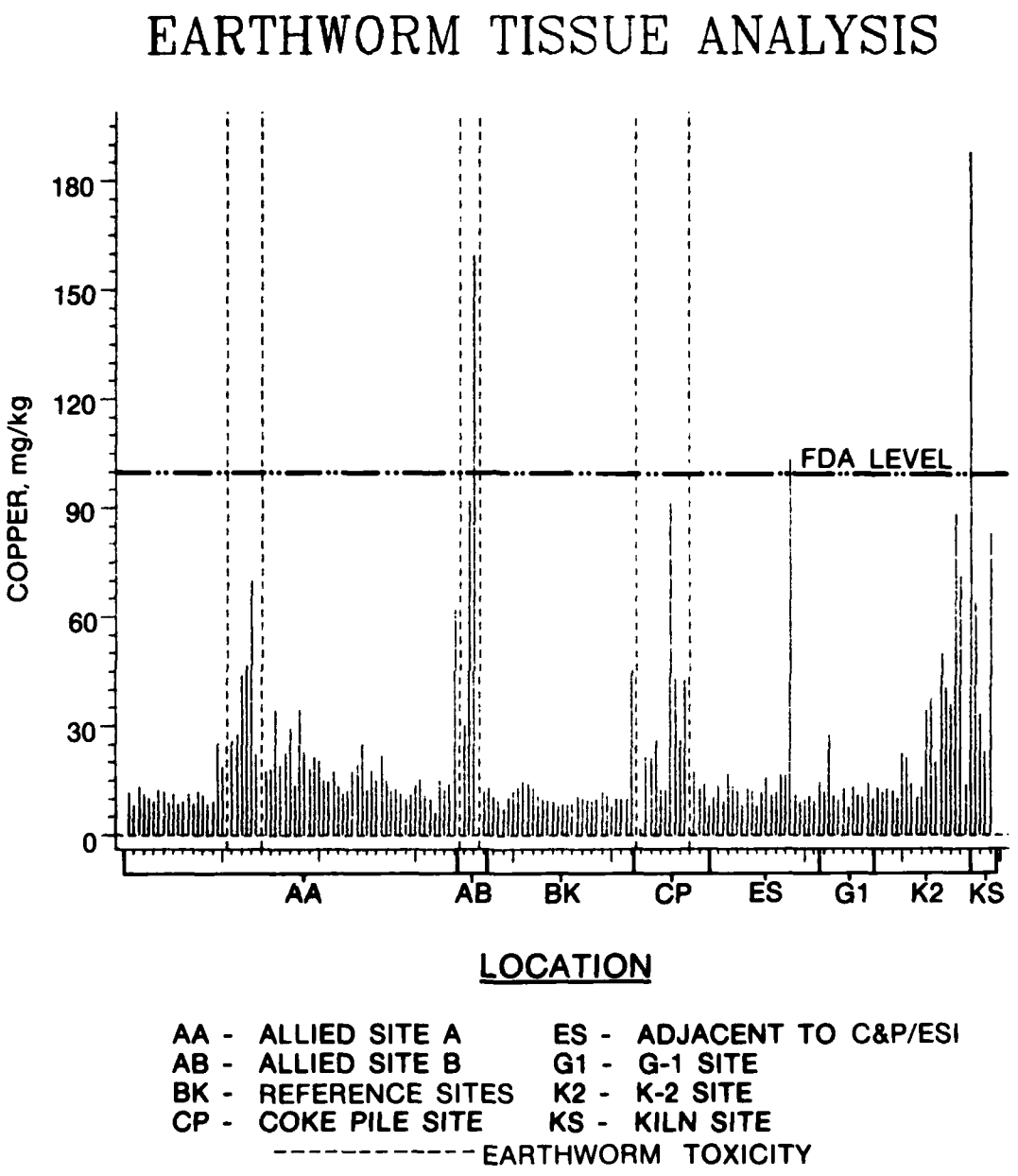


Figure 2-57. Earthworm tissue copper content and toxicity

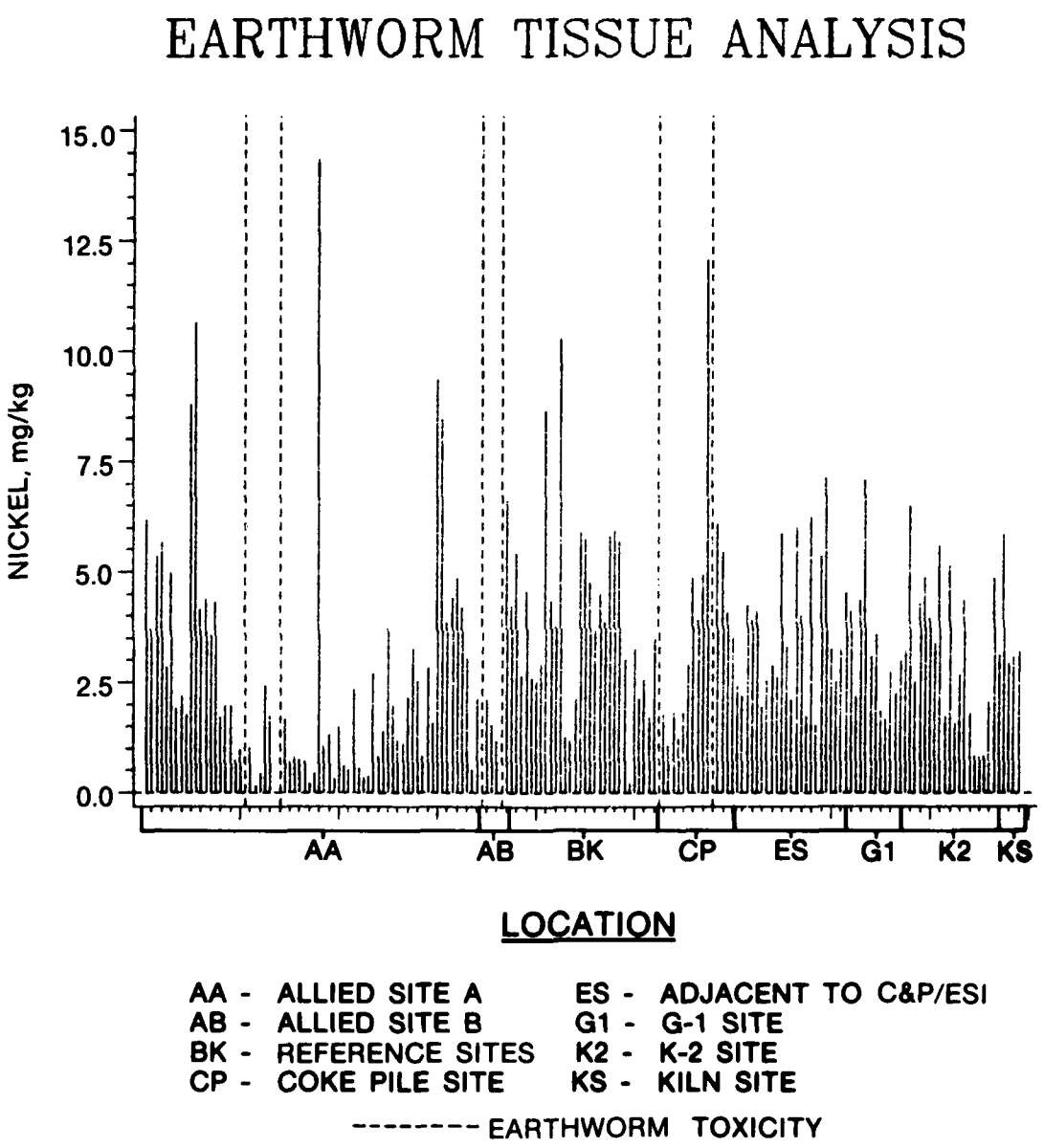


Figure 2-58. Earthworm tissue nickel content and toxicity

literature) to affect growth, reproduction, or survival. Consequently, the potential for soil Ni at NWS Concord to have a deleterious effect upon soil-dwelling animals at any of the sites appears to be low.

2.1.2.4.2.3 Summary

The potential combined effects of the seven metals analyzed is difficult to assess. However, the earthworm bioassay has provided information on potential bioaccumulation of these metals and the overall suitability of the specific soils to support the survival of soft-bodied soil-dwelling animals.

The bioassay earthworms lost weight in soils from all sites in comparison to manure controls. The weight loss in many cases appeared to be related to the physical characteristics of the soil rather than to direct metal toxicity. The lack of good growth in worms on soil from the remote reference areas with low soil metals content and the relatively low metal concentrations in the worms in comparison to the recent literature regarding metal effects suggest that the worms were limited by insufficient food. In the field, moisture may be a problem in some areas during the dry season, as many of the upland soils are very coarse textured, hard, and dry and appeared to contain very little organic matter to hold water. Very few native earthworms were found in these areas. In the laboratory, soil moisture was maintained at levels suitable for earthworms growth and survival and, therefore, was not a negative factor affecting worm survival.

The potential effects of metal bioaccumulation in soft-bodied soil invertebrates upon invertebrate-eating animals may be of some concern with respect to As, Pb, Cd, and Se. Arsenic was very high in the earthworms in many of the samples from the AA area on site 572 and should be considered a potential problem in that area. Site CP appears to be a potential problem with respect to Se. The other metals Cu, Ni and Zn probably pose no threat to earthworms and other soil-dwelling invertebrates. Although the earthworm may not be the primary food source on the NWS Concord sites, the earthworm was used as an indicator for bioaccumulation in soft-bodied soil-dwelling animals. A more detailed discussion of the toxicological importance of these data is found in Section 4.4.

2.2 Contaminant Distribution and Mobility Across the Site

2.2.1 Soil Samples

Results of the soil analysis indicate that considerable numbers of sample sites contain concentrations of metals that either are in excess of As concentrations found in the remote reference sites (BK), or are statistically greater than the rest of the sample sites, or exceed the soil content established for the maximum allowable sewage sludge application (MASSA). The distribution of these sites at NWS Concord is shown in Figures 2-59 through 2-64 for each metal. These figures include the results of soil analyses of additional sampling sites collected by Brown and Caldwell Consulting Engineers (Appendix Table 2-B11 and Appendix Figures 2-B1-B9). The extent of metal migration across the parcels are clearly indicated. Similar areas (Figure 2-65) although smaller in size, were found to exceed the TTLC for soil metal contents at NWS Concord, determined by an earlier investigation (Anderson Geotechnical 1984). Corrective measures to minimize further release or potential release of metals into food chains and the environment in these areas must be considered.

2.2.2 Clam Biomonitoring

Results of the clam biomonitoring indicate that there is potential for Pb to move from the soil into bivalve molluscs at sampling sites in the K-2 area on Parcels 573 and 574, and the G-1 area on Parcel 575 (Figure 2-66). There also is a potential for Cd to bioaccumulate at the G-1 area and the AA area on Parcel 571 (Figure 2-67). The significant increase in Cd in clams at the end of the stream draining the wetland into the canal on Parcel 571 indicates that Cd is moving through the wetland into the stream. Since clams in the canal closer to the bay did not contain elevated Cd contents, the Cd contamination came from the stream draining the wetland areas on Parcels 571, 572, 573, and 574. While tissue concentrations for those metals are below FDA action levels and do not pose an immediate threat, the potential for release of Cd into the canal and eventually into the bay could have longer term consequences to food chains associated with Suisun Bay. A potential exists for Zn to bioaccumulate at the K-2 area, the G-1 area, and the ES area on Parcel 579 (Figure 2-68).

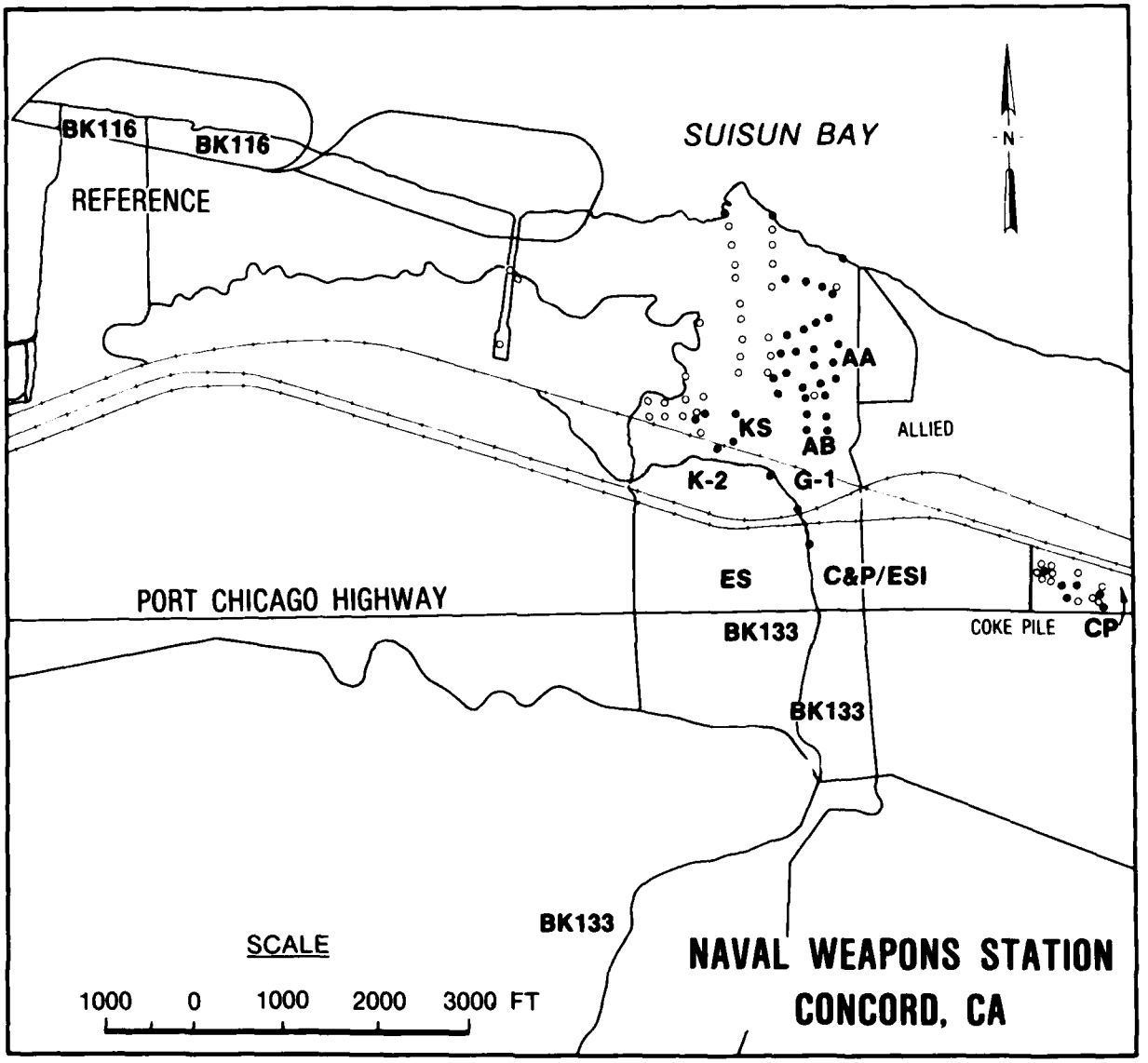


Figure 2-59. Distribution of soil arsenic concentrations in excess of 6.6 µg/g As (highest value for remote reference areas, BK). Solid circles were WES collected samples, open circles were Brown and Caldwell collected samples

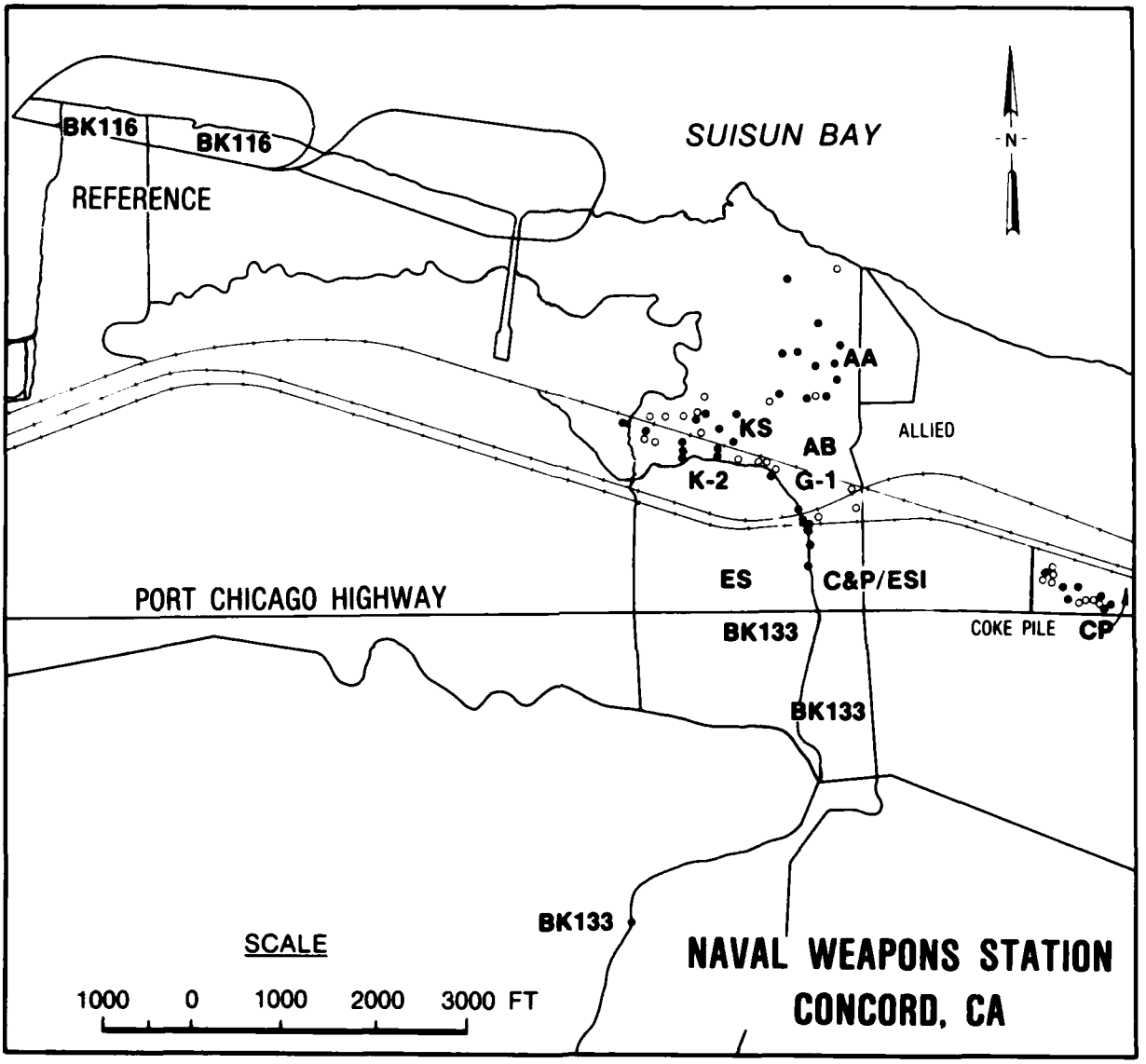


Figure 2-60. Distribution of soil cadmium concentrations in excess of 8 mg/kg. Solid circles were WES collected samples, open circles were Brown and Caldwell collected samples

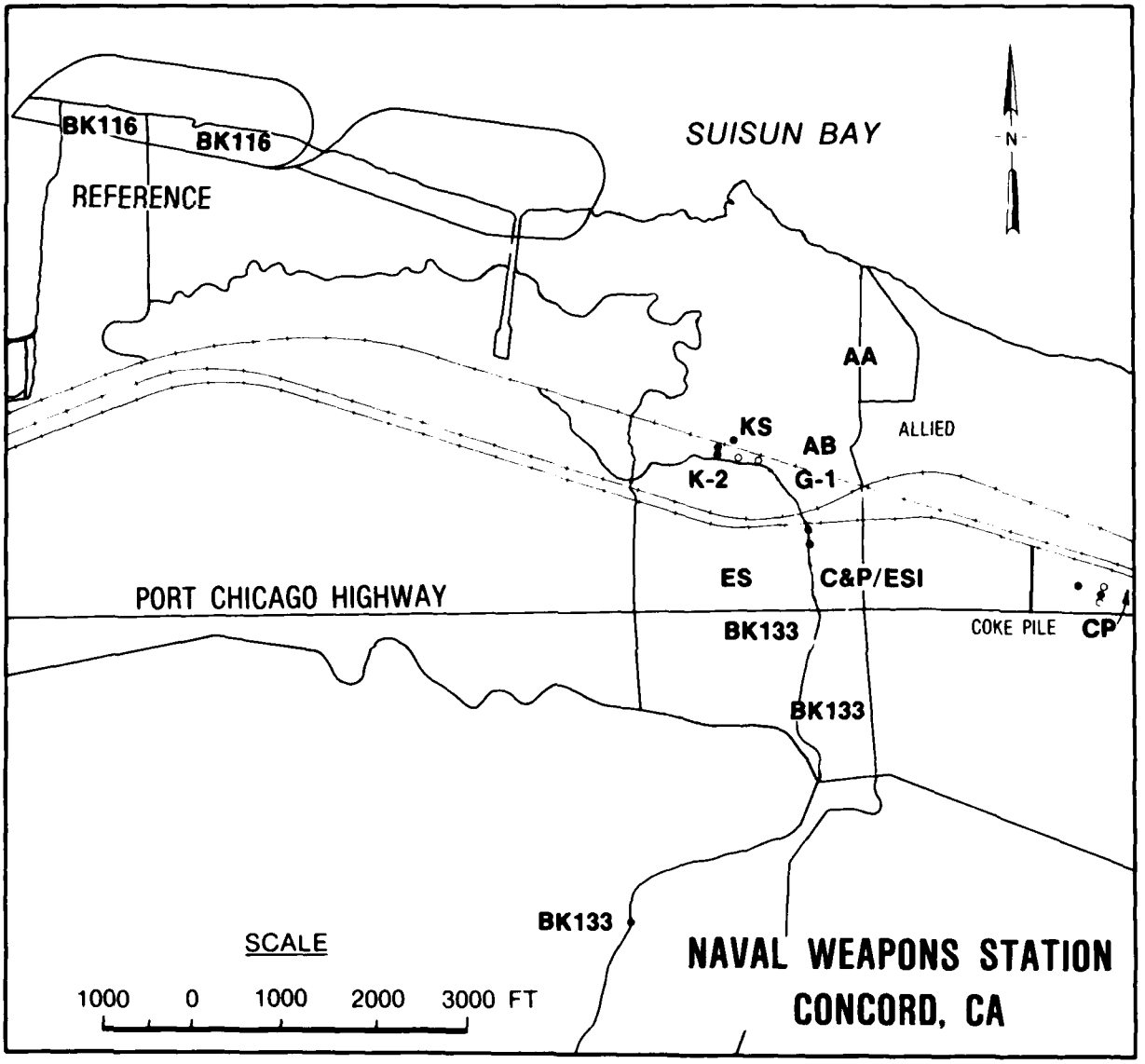


Figure 2-61. Distribution of soil lead in excess of 500 mg/kg (Table 2-4). Solid circles were WES collected samples, open circles were Brown and Caldwell collected samples

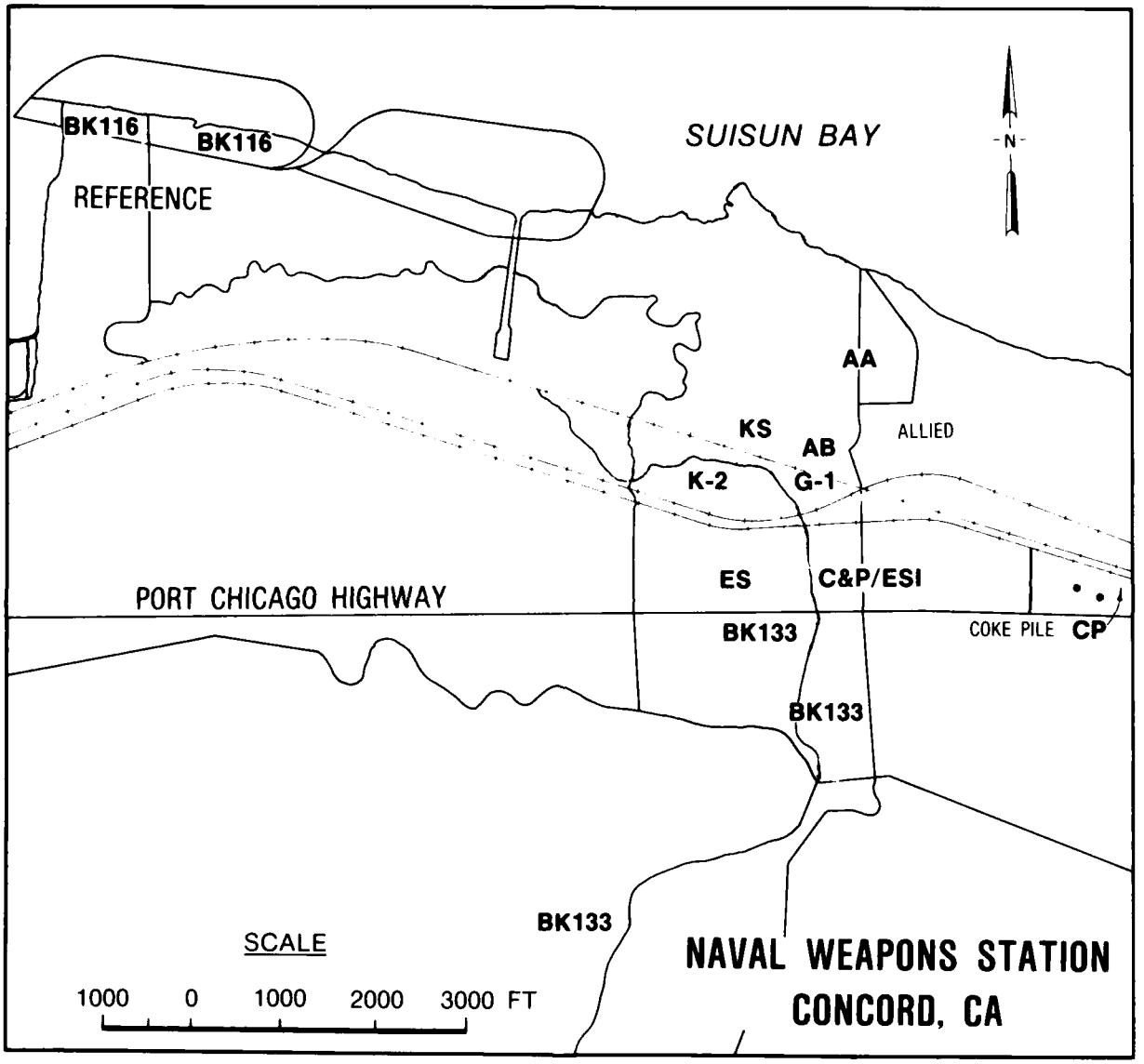


Figure 2-62. Distribution of soil selenium in excess of 100 mg/kg

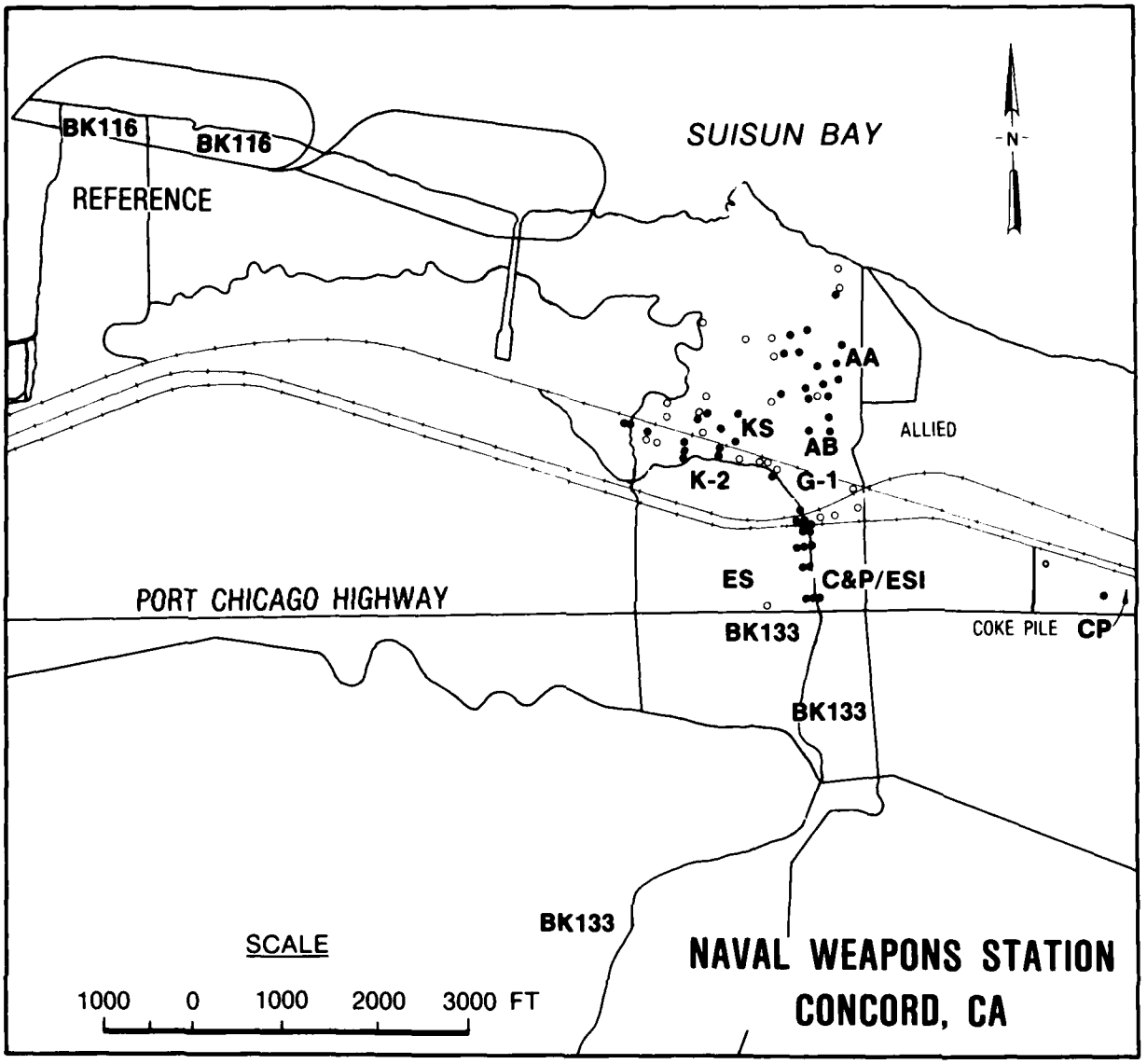


Figure 2-63. Distribution of soil zinc in excess of 250 mg/kg (Table 2-4). Solid circles were WES collected samples, open circles were Brown and Caldwell collected samples

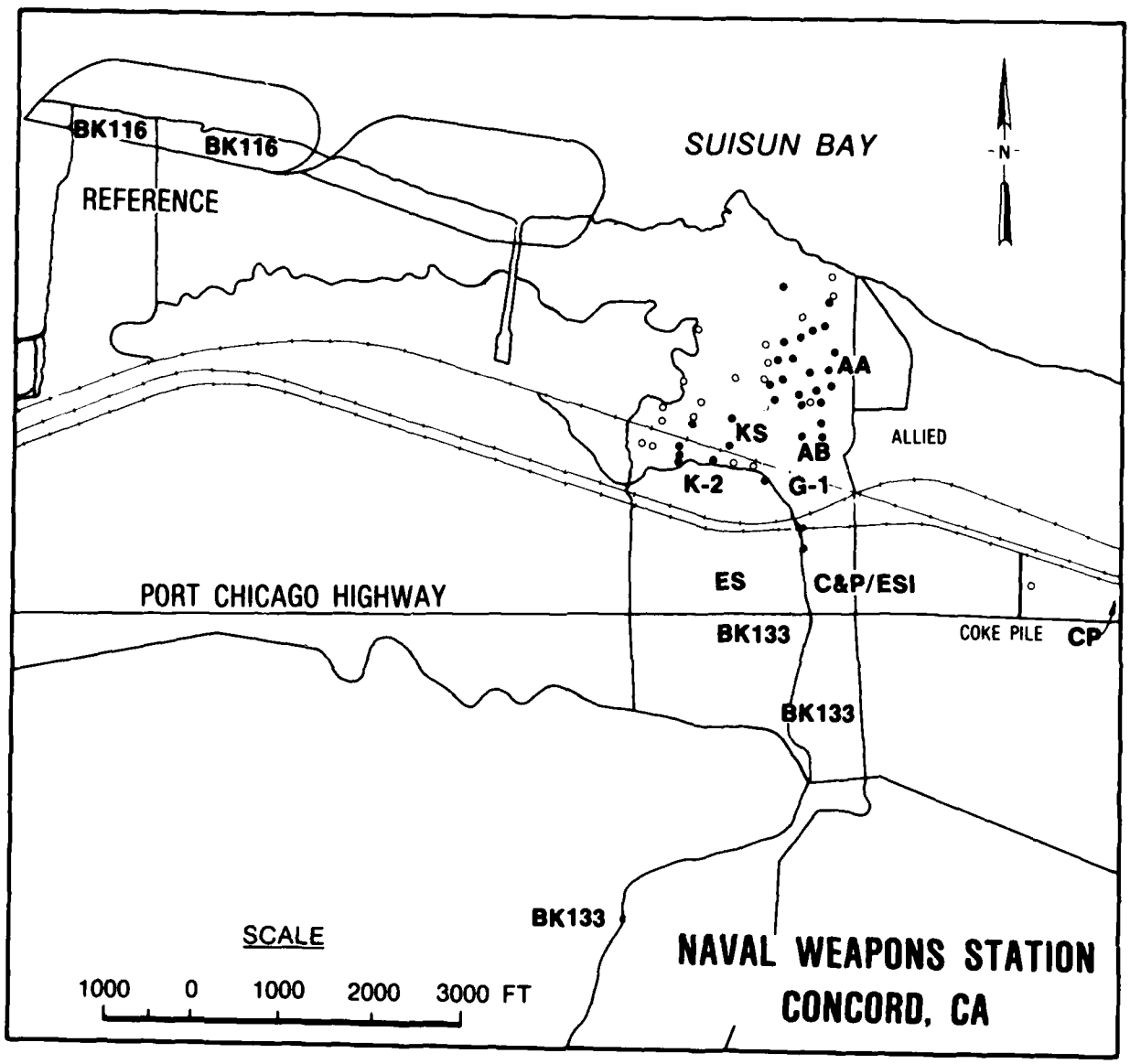


Figure 2-64. Distribution of soil copper in excess of 125 mg/kg (Table 2-4). Solid circles were WES collected samples, open circles were Brown and Caldwell collected samples

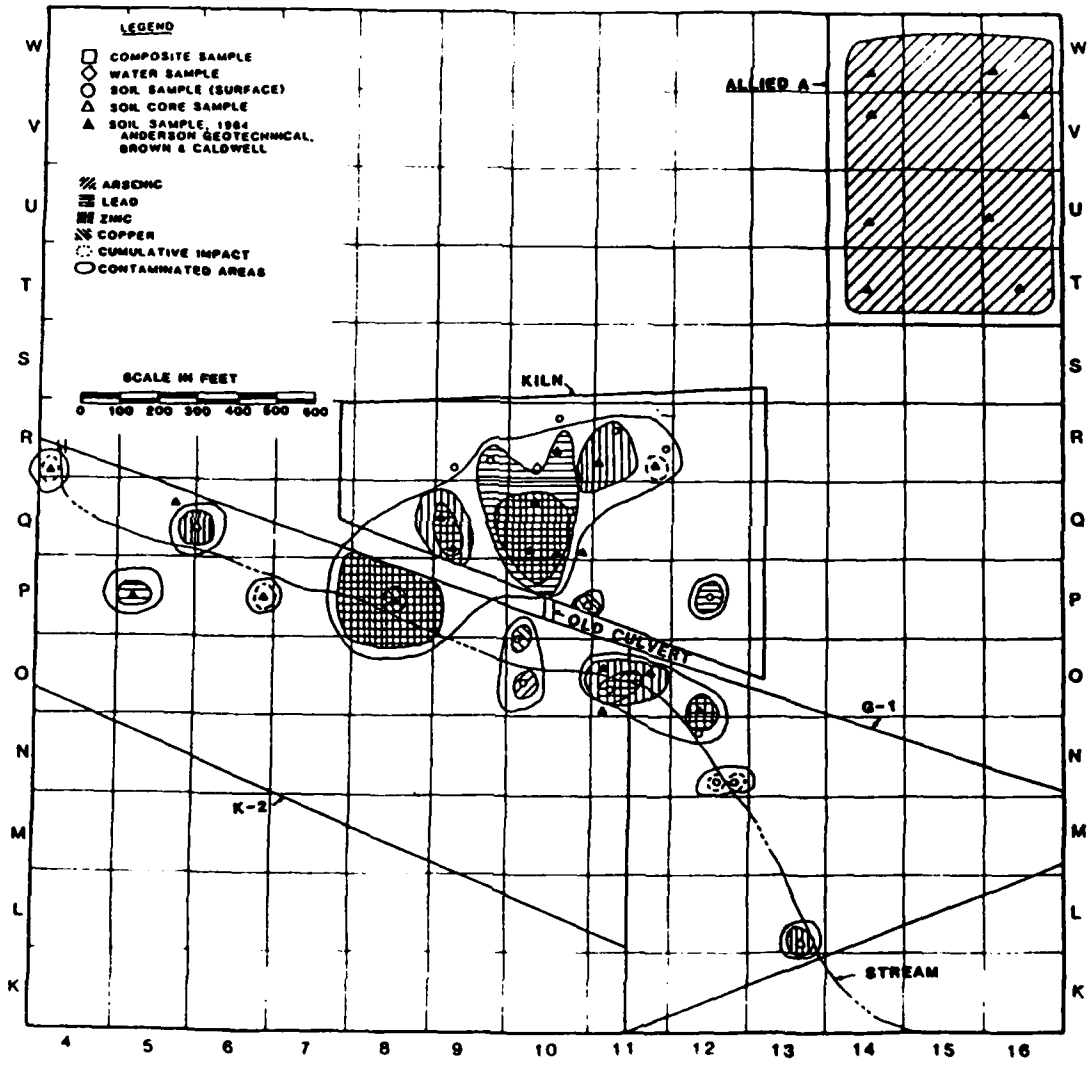


Figure 2-65. Areas of metal contamination exceeding TTLC

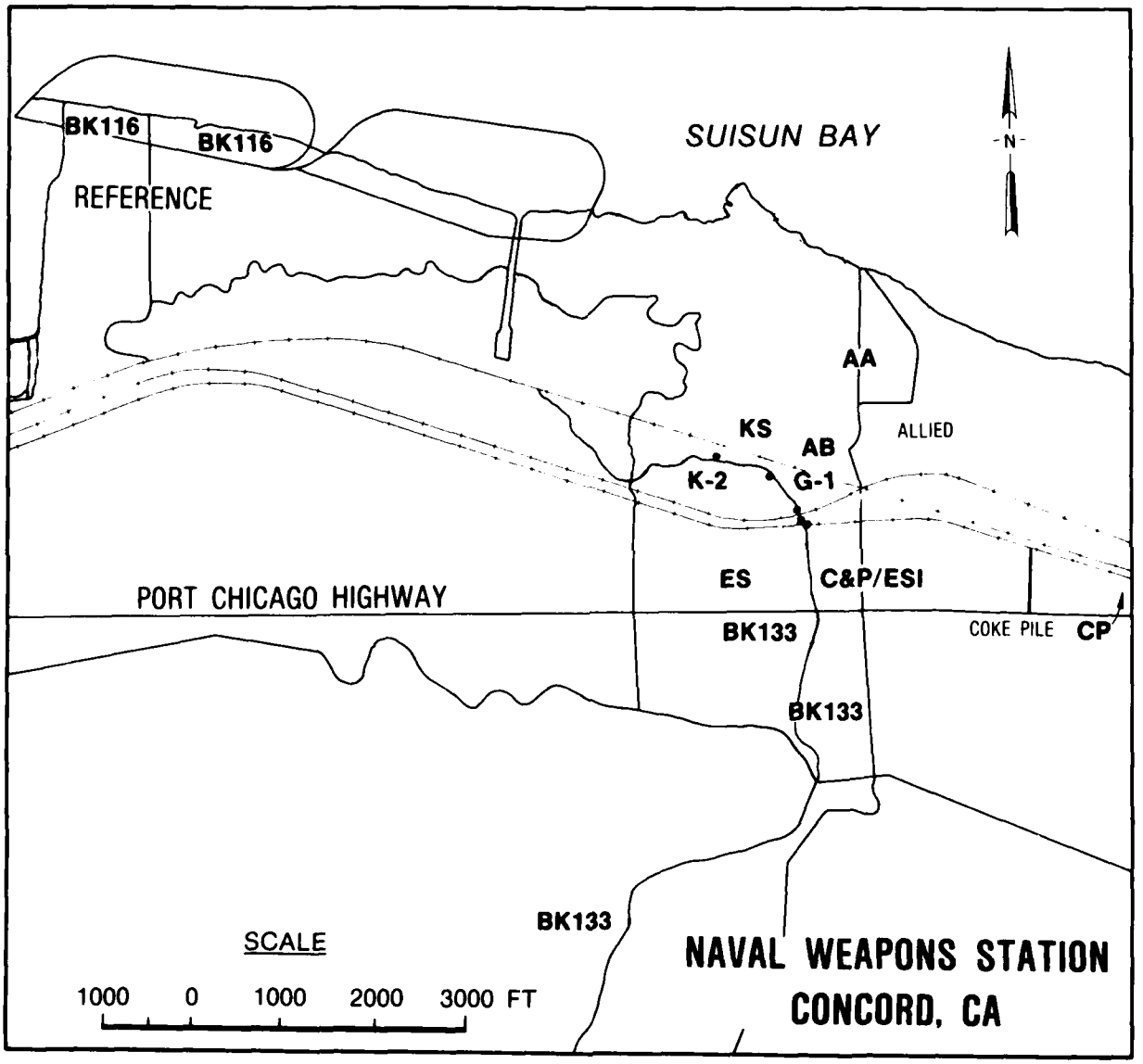


Figure 2-66. Locations with potential for lead mobility into aquatic organisms

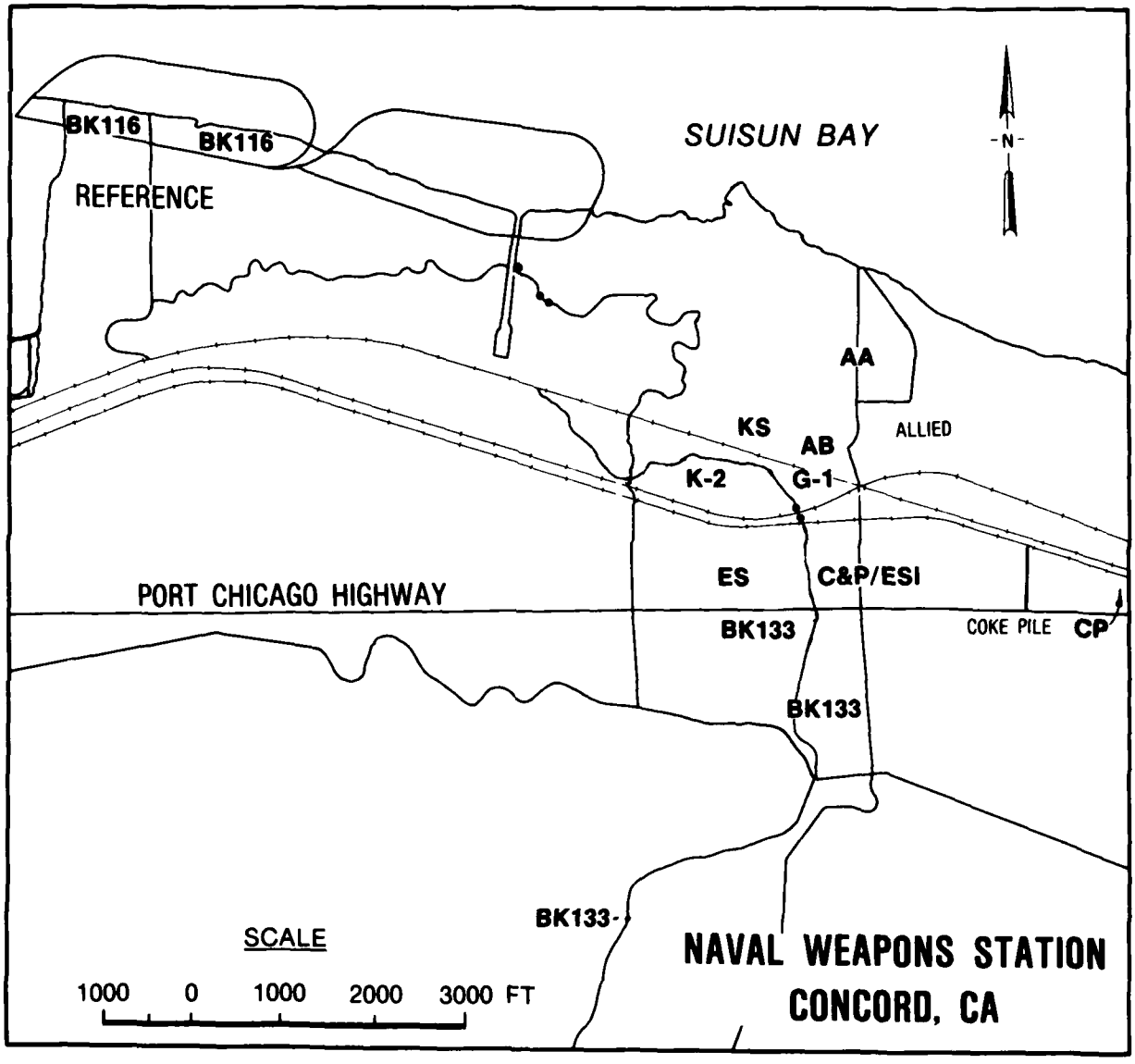


Figure 2-67. Locations with potential for cadmium mobility into aquatic organisms

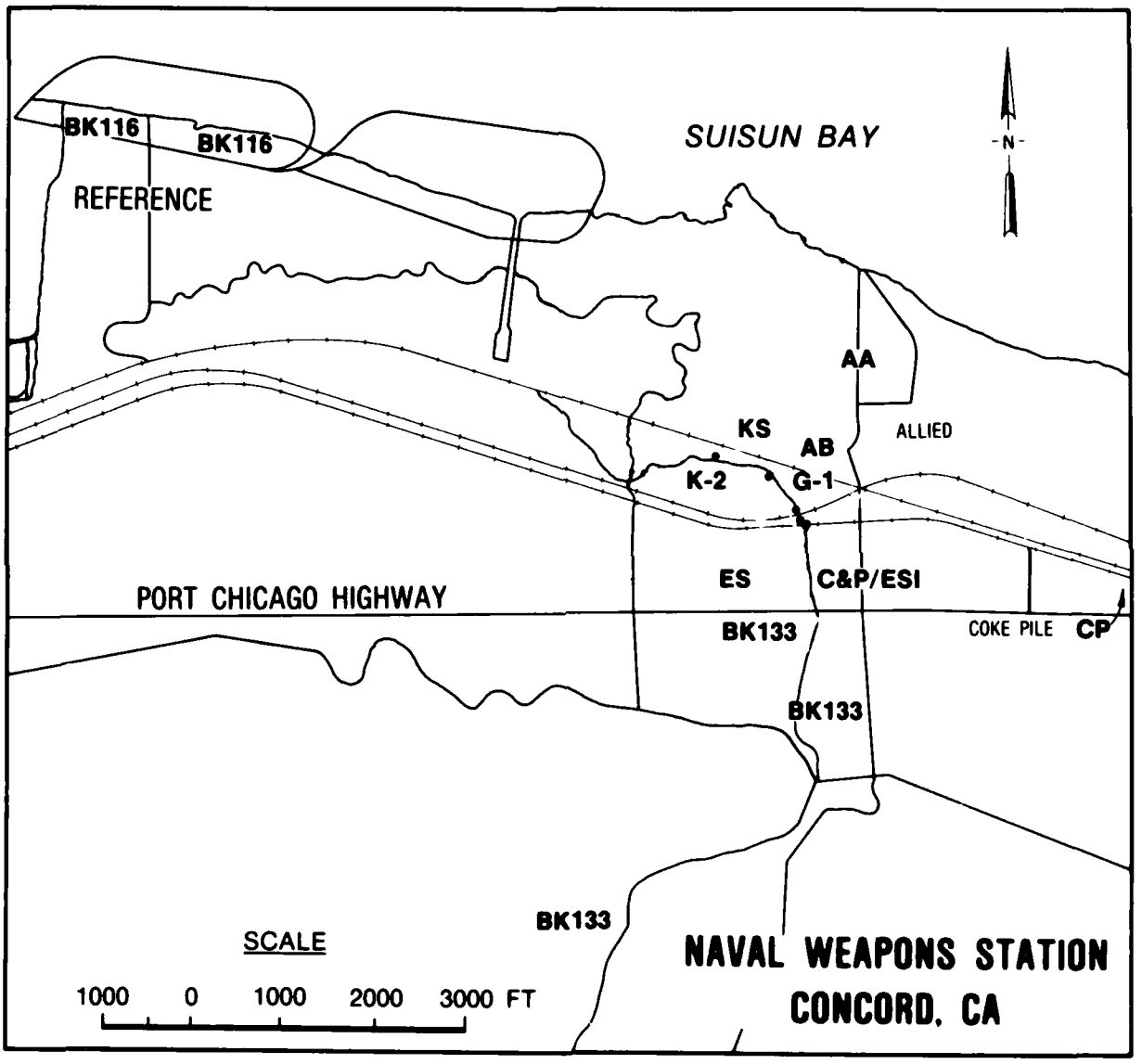


Figure 2-68. Locations with potential for zinc mobility into aquatic organisms

These areas will require consideration of corrective measures to minimize the release or potential release of Pb, Cd, and Zn into the environment.

2.2.3 Plant Bioassay

2.2.3.1 Plant Death

Considerable plant death was observed in the AA area on Parcel 572, the AB area on Parcel 572, the CP area on Parcel 581, and the K-2 area on Parcels 573 and 574 (Figure 2-69). There is high potential that these sampling sites will be toxic to plants growing there.

2.2.3.2 Plant Metal Content

Results of the plant bioassay indicate that there is a high potential for movement of As, Cd, Pb, Se, Zn, and Cu into plants at specific sampling sites. The locations of these sampling sites for Cd and Zn are shown in Figure 2-70 and Figure 2-71.

2.2.3.3 Relationship of Plant Metal Content to Soil Metal Content

Plant metal content was correlated to soil metal content to examine the relationship between the metal contents of plants and soils. Such relationships were used to estimate potential plant metal contents from additional soil data obtained by Brown and Caldwell Consulting Engineers. Plant bioassay tests were not conducted on these additional soil samples. Therefore, potential plant metal content was predicted from these relationships. The most effective relationships obtained were those using the natural logs (LN) of plant metal content and soil metal content. In each case, +1 was added to both the plant metal content and the soil metal content to alleviate the generation of zero values. Significant relationships were found for the following:

regression of LN plant tissue Cd vs LN soil Cd r=0.76 (Figure 2-72)
regression of LN plant tissue Zn vs LN soil Zn r=0.73 (Figure 2-73)

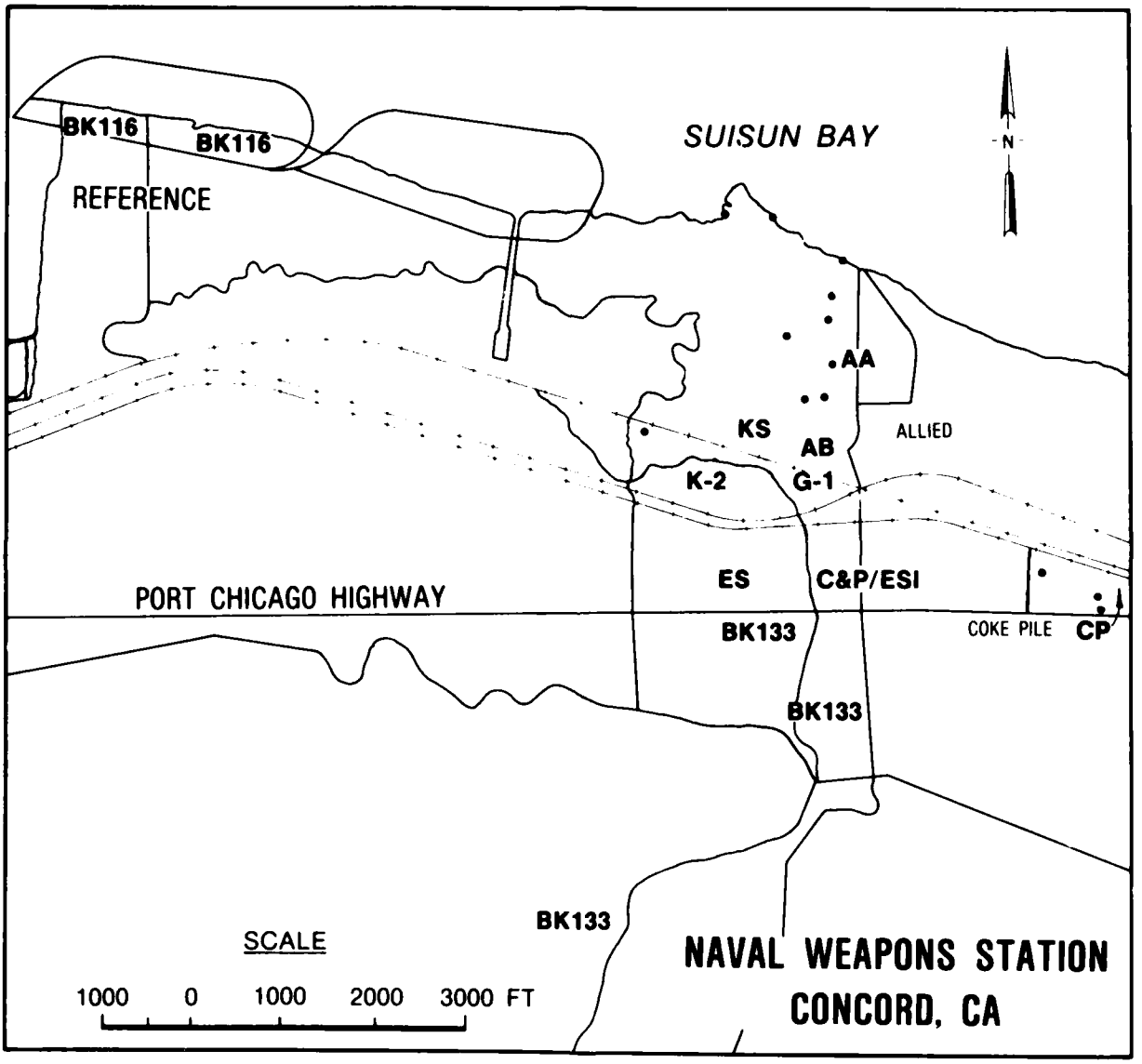


Figure 2-69. Locations of plant death at NWS Concord

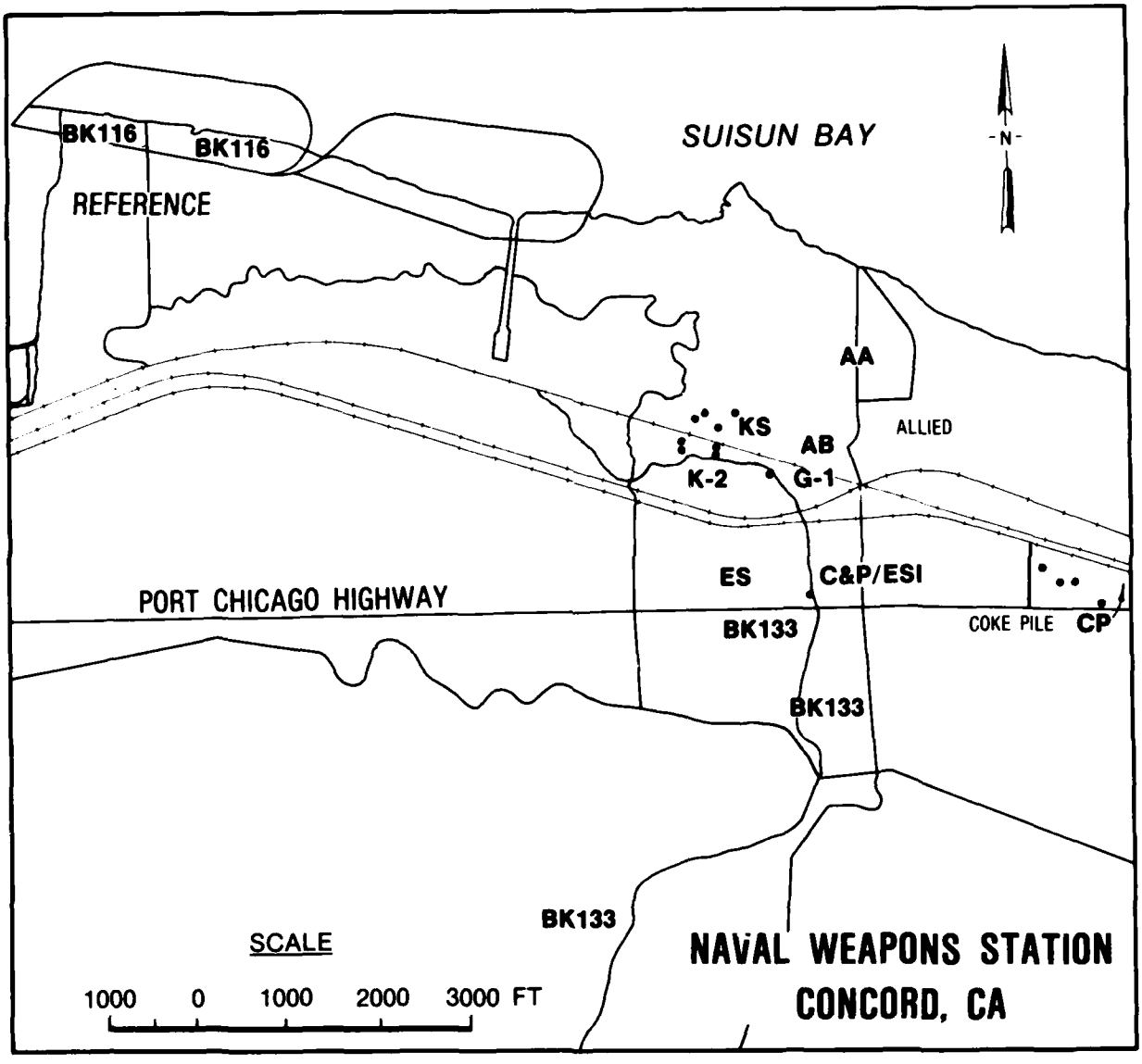


Figure 2-70. Locations where plant bioassay tests showed plant cadmium contents in excess of 8 mg/kg

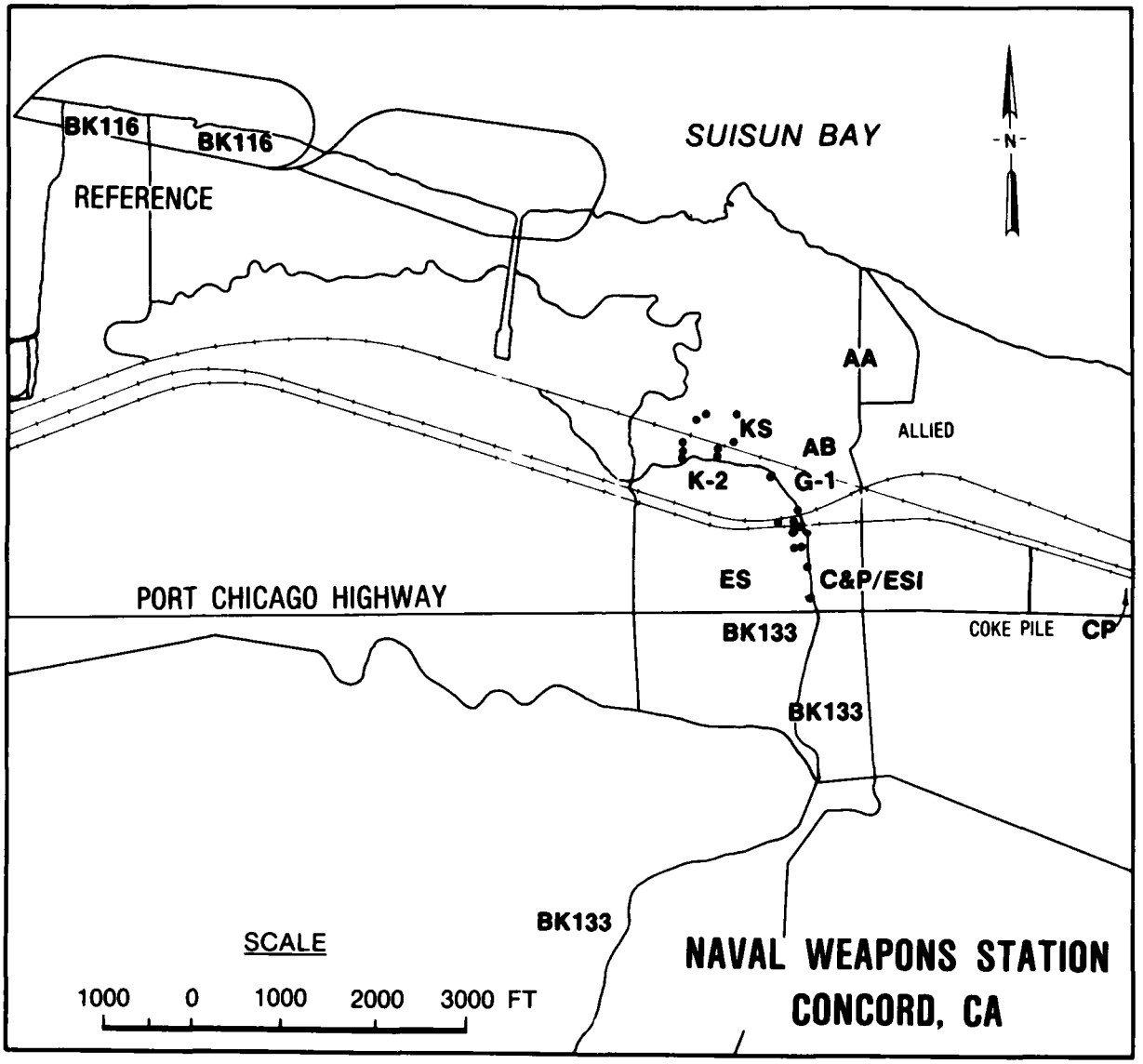


Figure 2-71. Locations where plant bioassay tests showed plant zinc contents in excess of 290 mg/kg

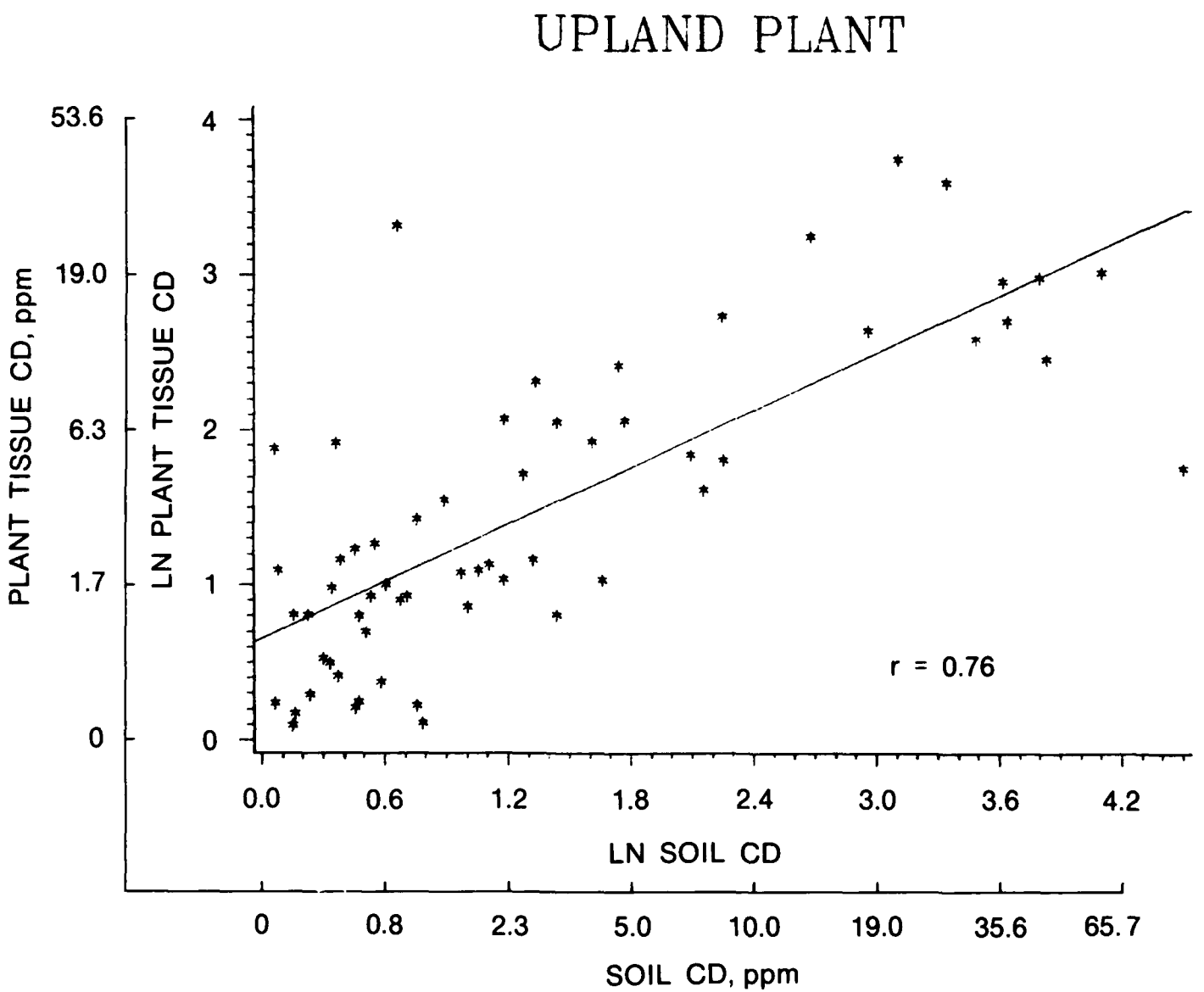


Figure 2-72. Regression of natural log (LN) plant tissue cadmium content on natural log (LN) soil cadmium content

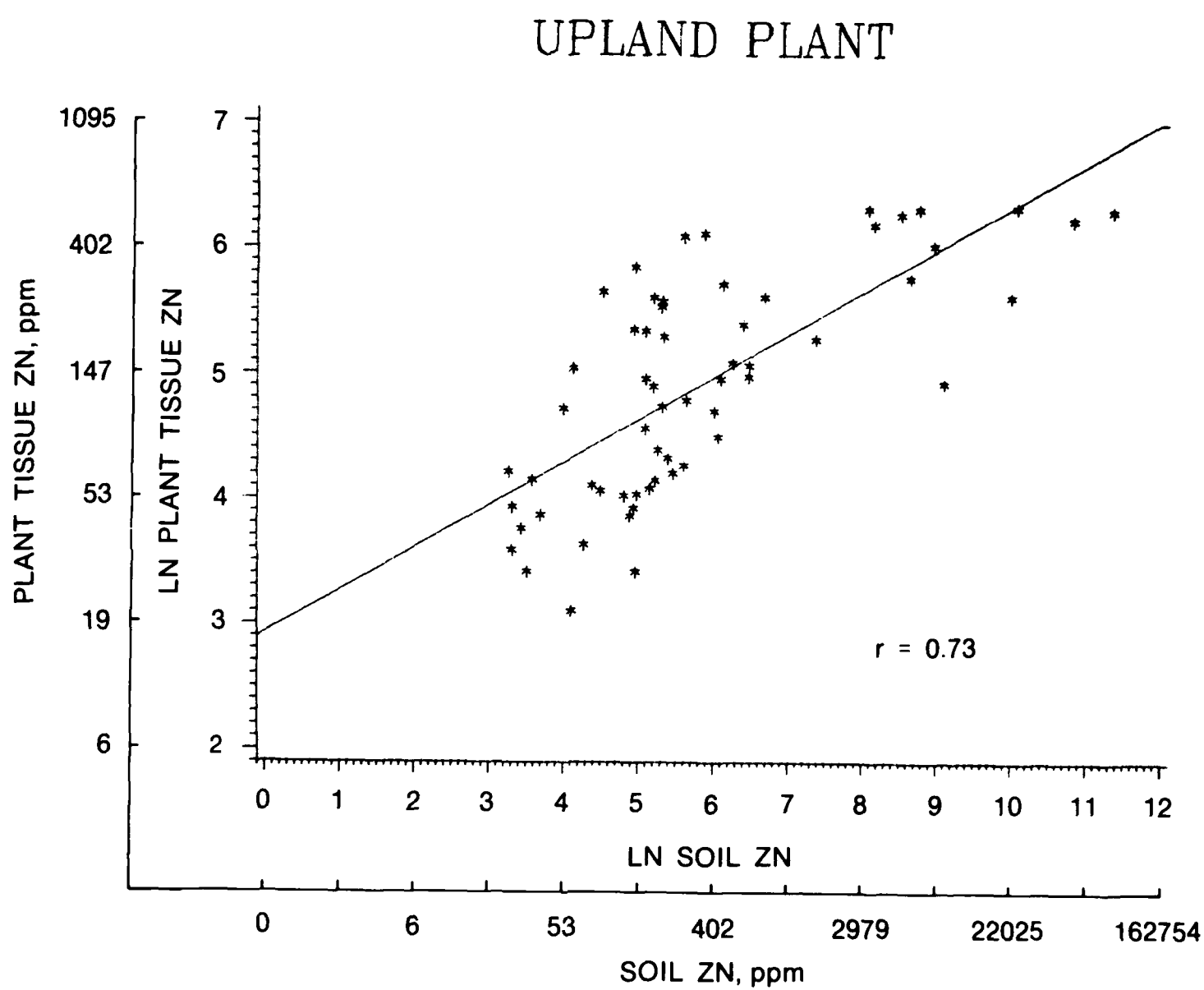


Figure 2-73. Regression of natural log (LN) plant tissue zinc content on natural log (LN) soil zinc content

These relationships were used to estimate plant tissue contents of each metal for the additional soil samples obtained by Brown and Caldwell Consulting Engineers. Sampling sites that resulted in plant-tissue metal content above critical contents (Table 2-7) were plotted on Figures 2-60 and 2-63 as open circles.

2.2.3.4 Relationship of Field Plant Content to Greenhouse Plant Content

Field-collected Typha metal content was correlated to greenhouse-grown plant-tissue metal content to examine the relationship between field and greenhouse plants. Such relationships give an indication of how well the plant bioassay predicts potential metal uptake by native plants growing at the field site. The most effective relationship obtained was for plant tissue Zn content (Figure 2-74). This good relationship indicates that the plant bioassay test species, Cyperus esculentus, related significantly to the tissue Zn content of field-collected Typha. For example, when C. esculentus contained low Zn concentrations, Typha also contained low concentrations. When C. esculentus contained high Zn concentrations, Typha also contained high concentrations. These data indicate that plant uptake of Zn in the plant bioassay did reflect the potential plant uptake by Typha at the field site.

2.2.4 Earthworm Bioassay

2.2.4.1 Earthworm Toxicity

Results of the earthworm bioassay indicated that 11 soil samples from a total of 9 sampling sites were unsuitable for the survival of earthworms during a 28-day bioassay (Figure 2-75). Soils from these sites will not support many soil invertebrates and would not be expected to contain large numbers of soil-dwelling animals. (See Section 3.4.)

2.2.4.2 Earthworm Tissue Content

A high potential for bioaccumulation of As, Cd, Pb, Se, and Zn into soft-bodied soil-dwelling organisms at certain sampling sites was indicated from the results of the earthworm bioassay. The distribution of these

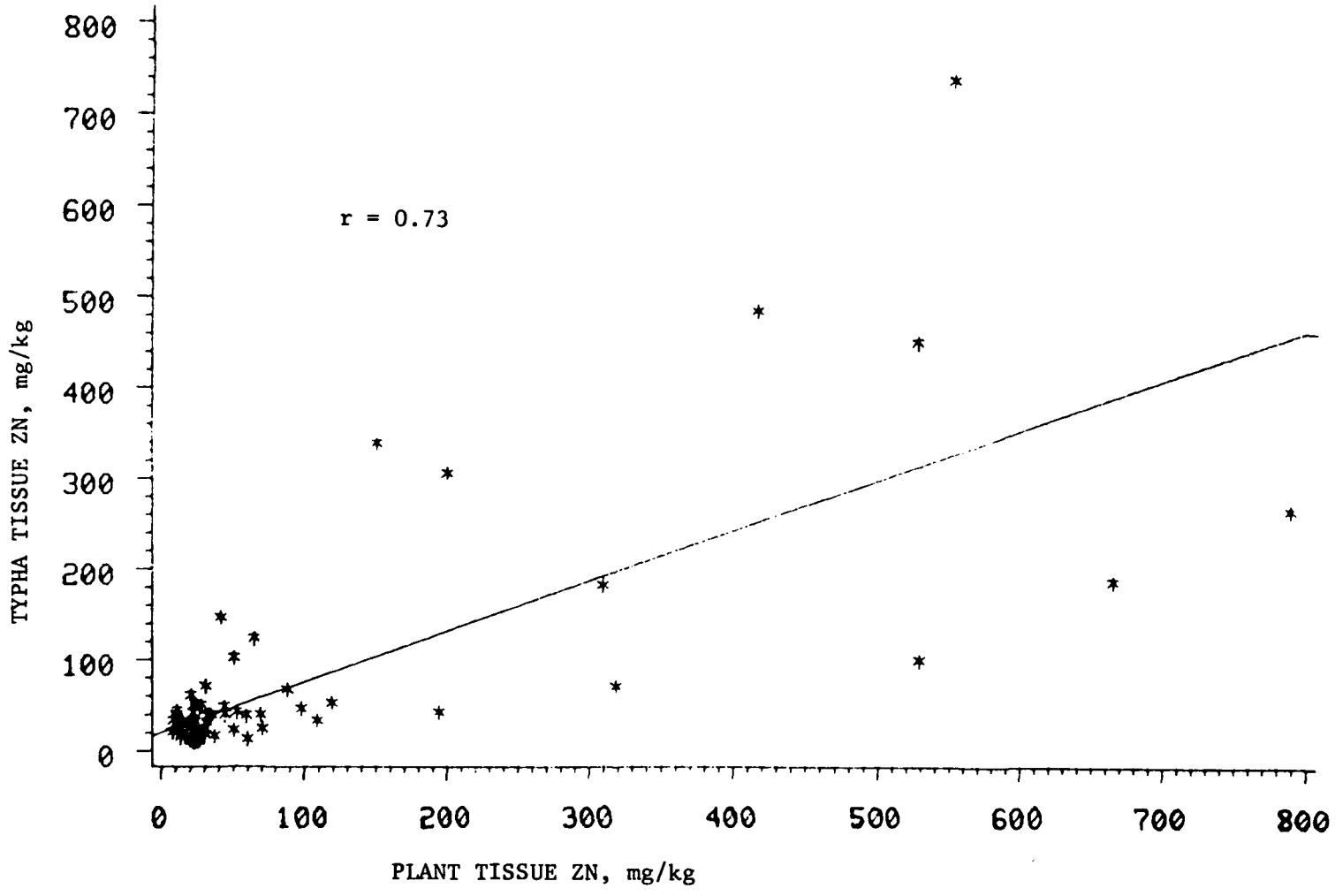


Figure 2-74. Regression of field Typha tissue zinc content on greenhouse plant tissue zinc content

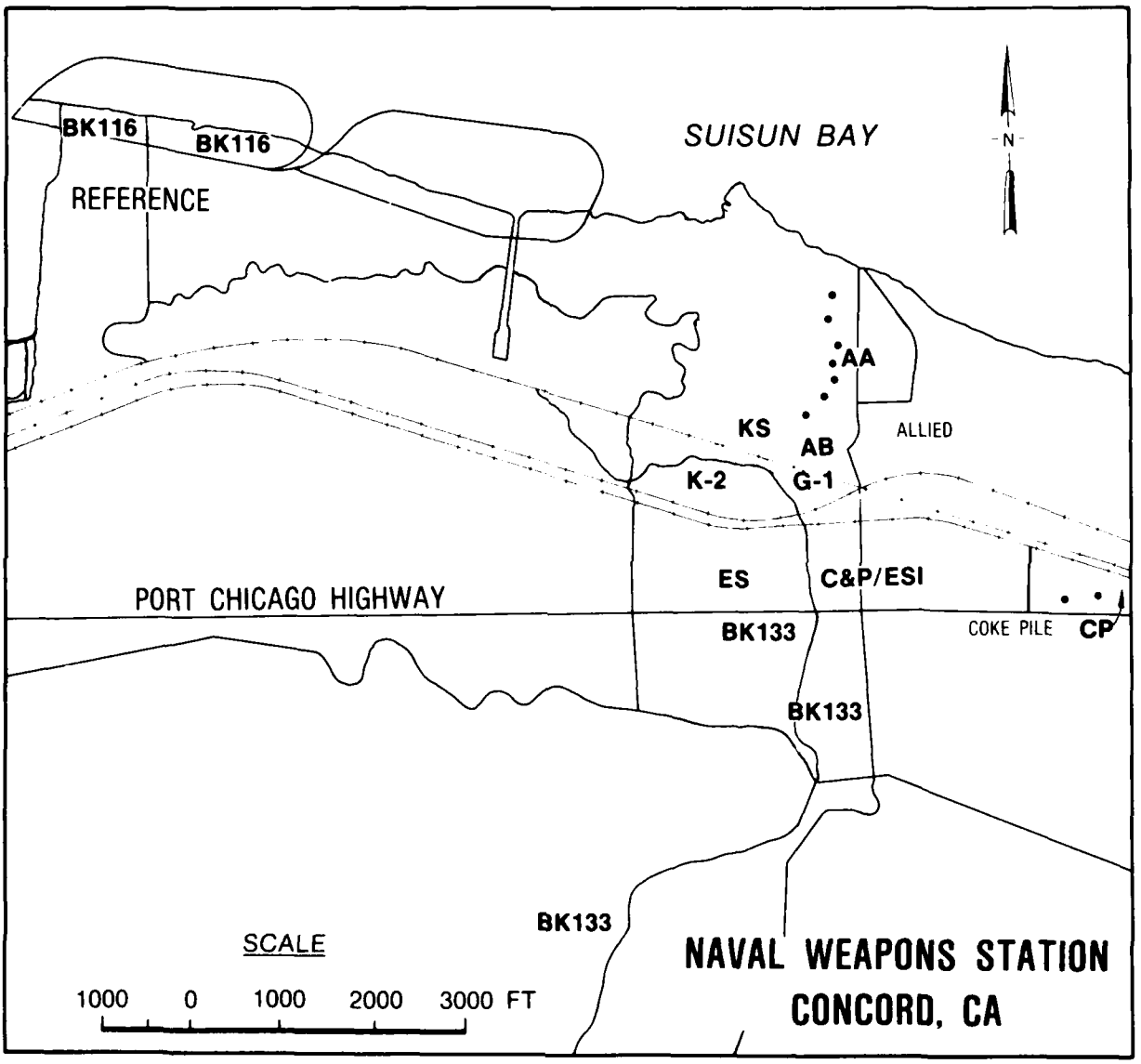


Figure 2-75. Locations where earthworm bioassay tests showed earthworm toxicity at NWS Concord

sampling sites is shown for As, Cd, Pb, and Se metal in Figures 2-76 through 2-79. Consideration of corrective measures are required at these sampling sites to minimize the further release or potential release of these metals into food chains and the environment.

2.2.4.3 Correlations Between Earthworm Metal Content and Soil Metal Content

Earthworm metal content was correlated to soil metal content in the same manner as the correlation of plant metal content described in Section 2.2.3.3 to examine the relationship between earthworm metal content and soil metal content. The most effective relationships obtained were those using either earthworm-tissue content and soil content or the natural logs (LN) of earthworm-tissue and soil content. In each case, +1 was added to both the earthworm tissue content and the soil content to alleviate the generation of zero values. Significant relationships were found for the following correlations:

LN earthworm-tissue As on LN soil As, r=0.76 (Figure 2-80)
LN earthworm-tissue Cd on LN soil Cd, r=0.38 (Figure 2-81)
LN earthworm-tissue Cu on LN soil Cu, r=0.63 (Figure 2-82)
earthworm-tissue Pb on LN soil Pb, r=0.64 (Figure 2-83)
earthworm-tissue Se on LN soil Se, r=0.86 (Figure 2-84)
earthworm-tissue Zn on LN soil Zn, r=0.43 (Figure 2-85)

These relationships were used to predict earthworm metal content for each metal for the additional soil samples obtained by Brown and Caldwell Consulting Engineers. Sampling sites that resulted in predicted earthworm metal content above FDA levels (Table 2-5) were plotted for each metal on Figures 2-76 through 2-79 as open circles.

2.2.4.4 Correlations Between Earthworm Metal Content to Plant Metal Content

An indication of the bioavailability of metals from soil was obtained by correlating earthworm metal content to plant metal content for each sampling

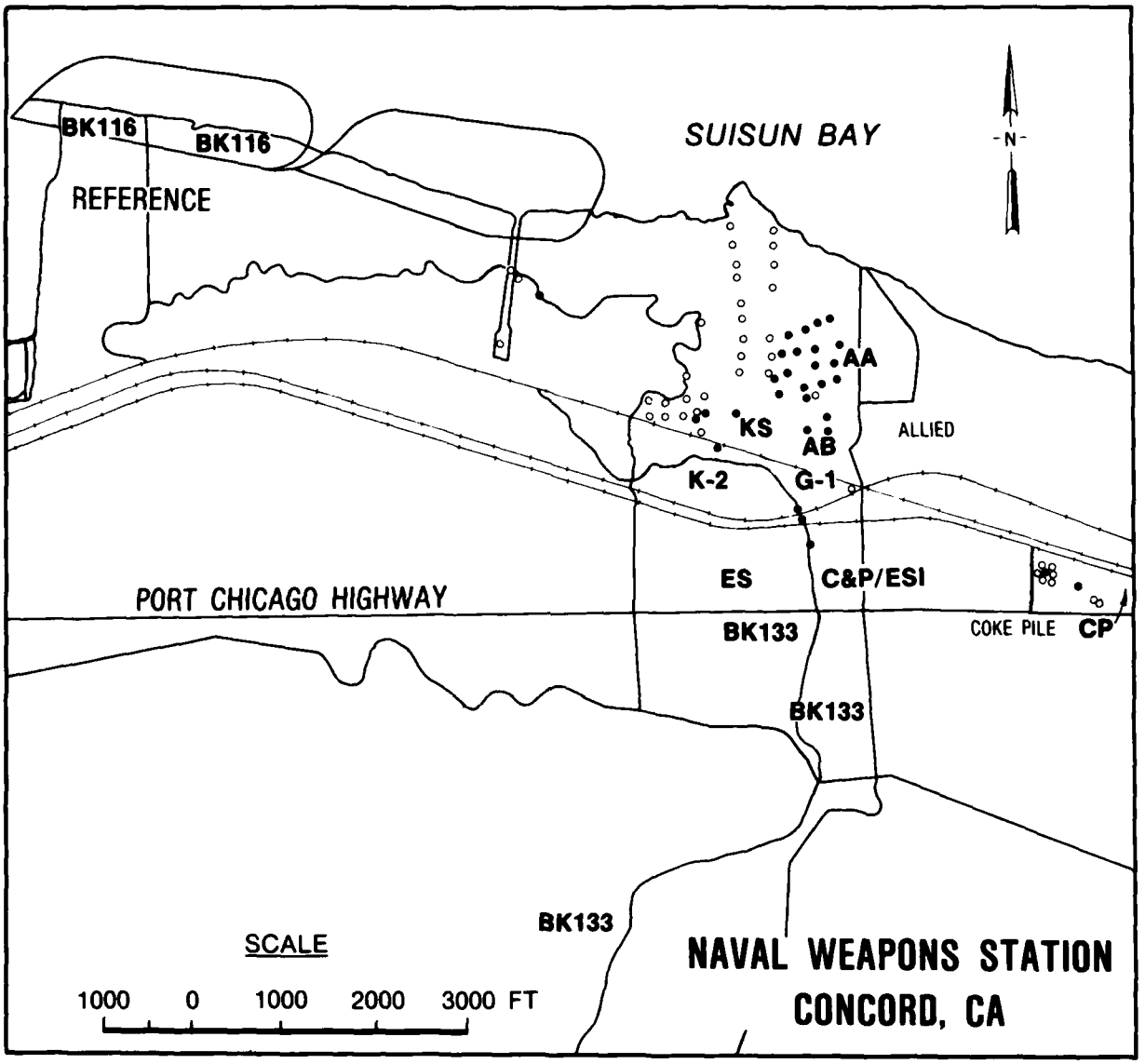


Figure 2-76. Distribution of earthworm arsenic content in excess of FDA level, 10 mg/kg. Soil circles were WES collected samples, open circles were Brown and Caldwell collected samples

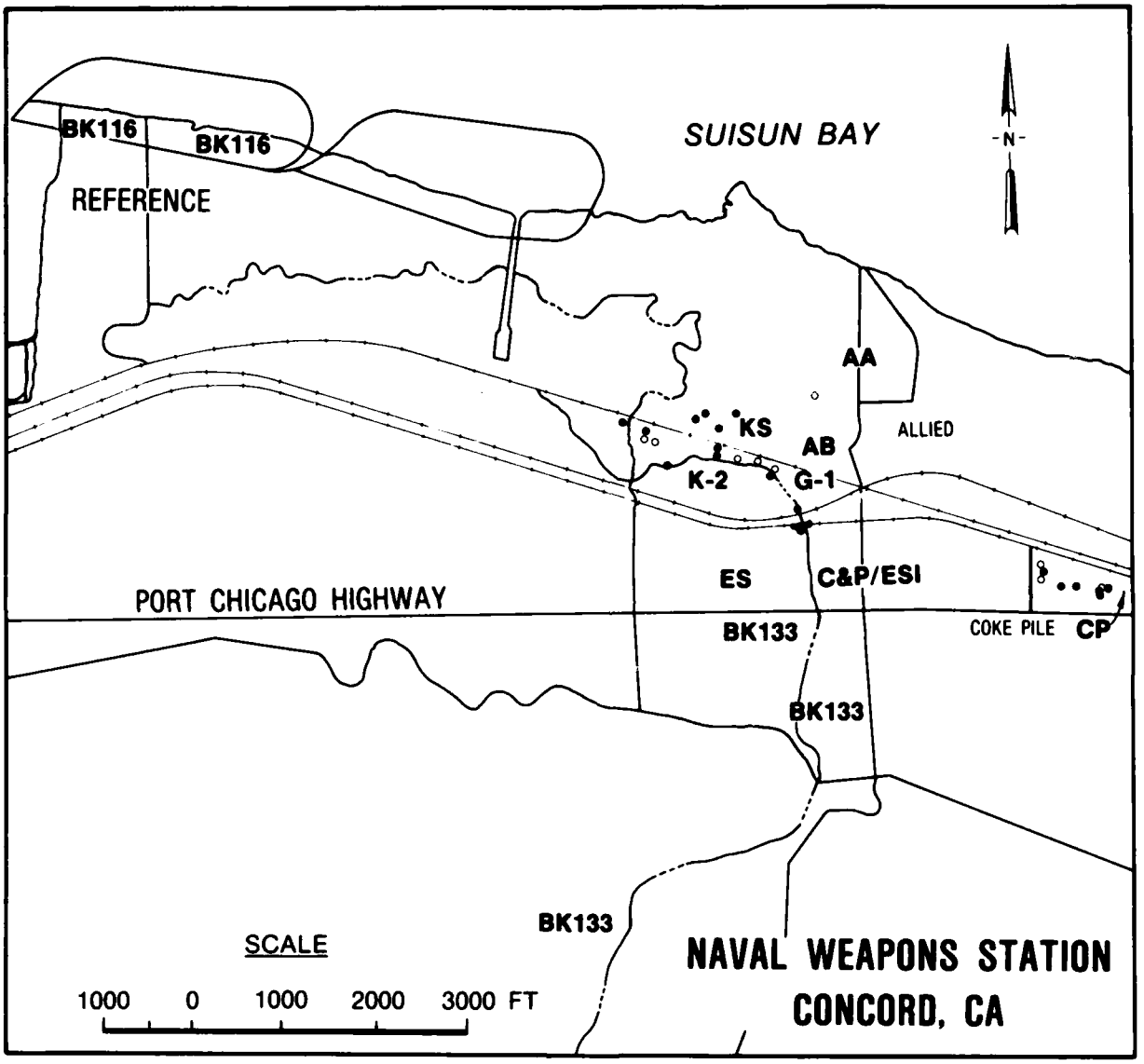


Figure 2-77. Distribution of earthworm cadmium content in excess of FDA level, 10 mg/kg. Solid circles were WES collected samples, open circles were Brown and Caldwell collected samples

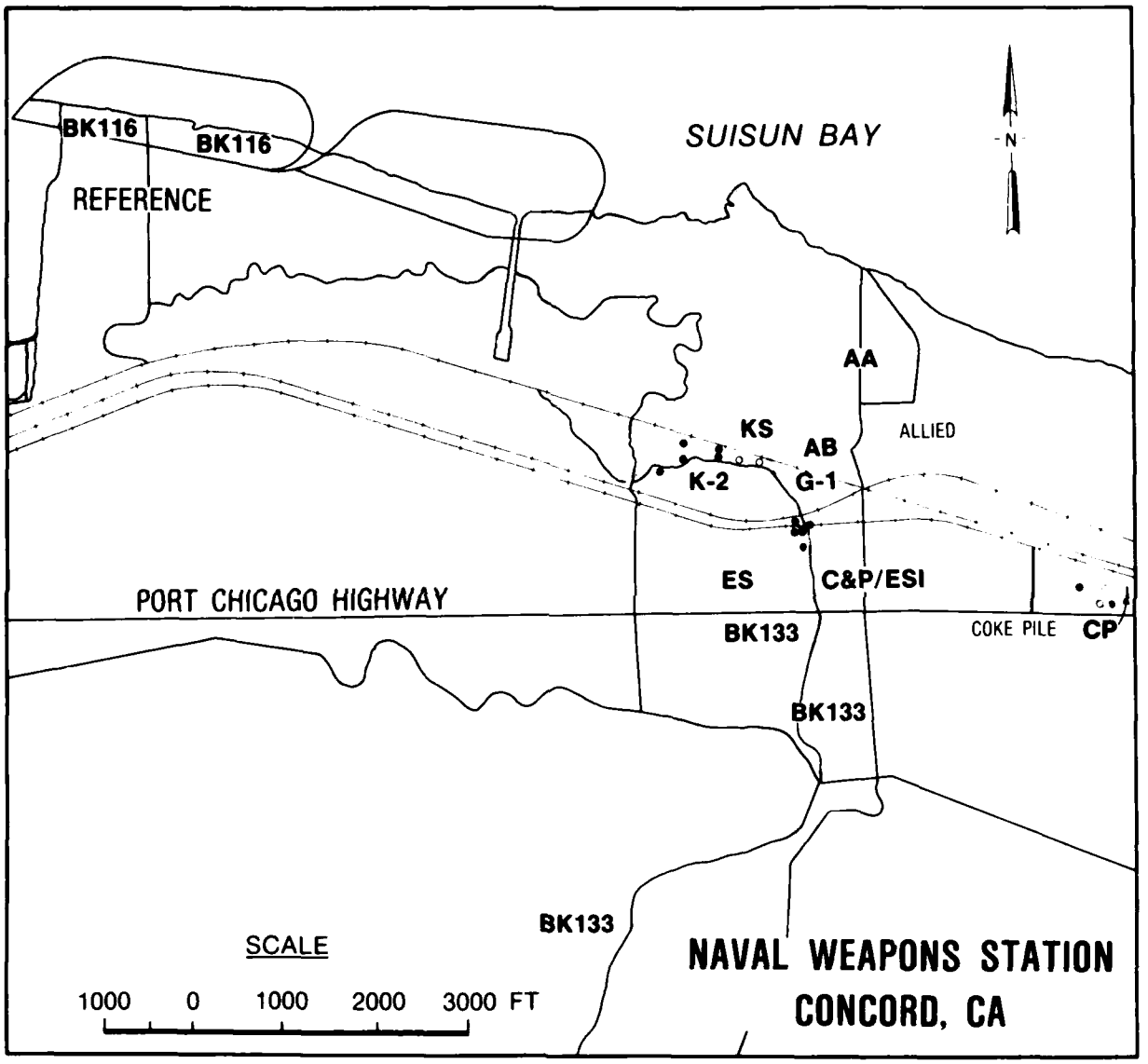


Figure 2-78. Distribution of earthworm lead content in excess of FDA level, 15 mg/kg. Solid circles were WES collected samples, open circles were Brown and Caldwell collected samples

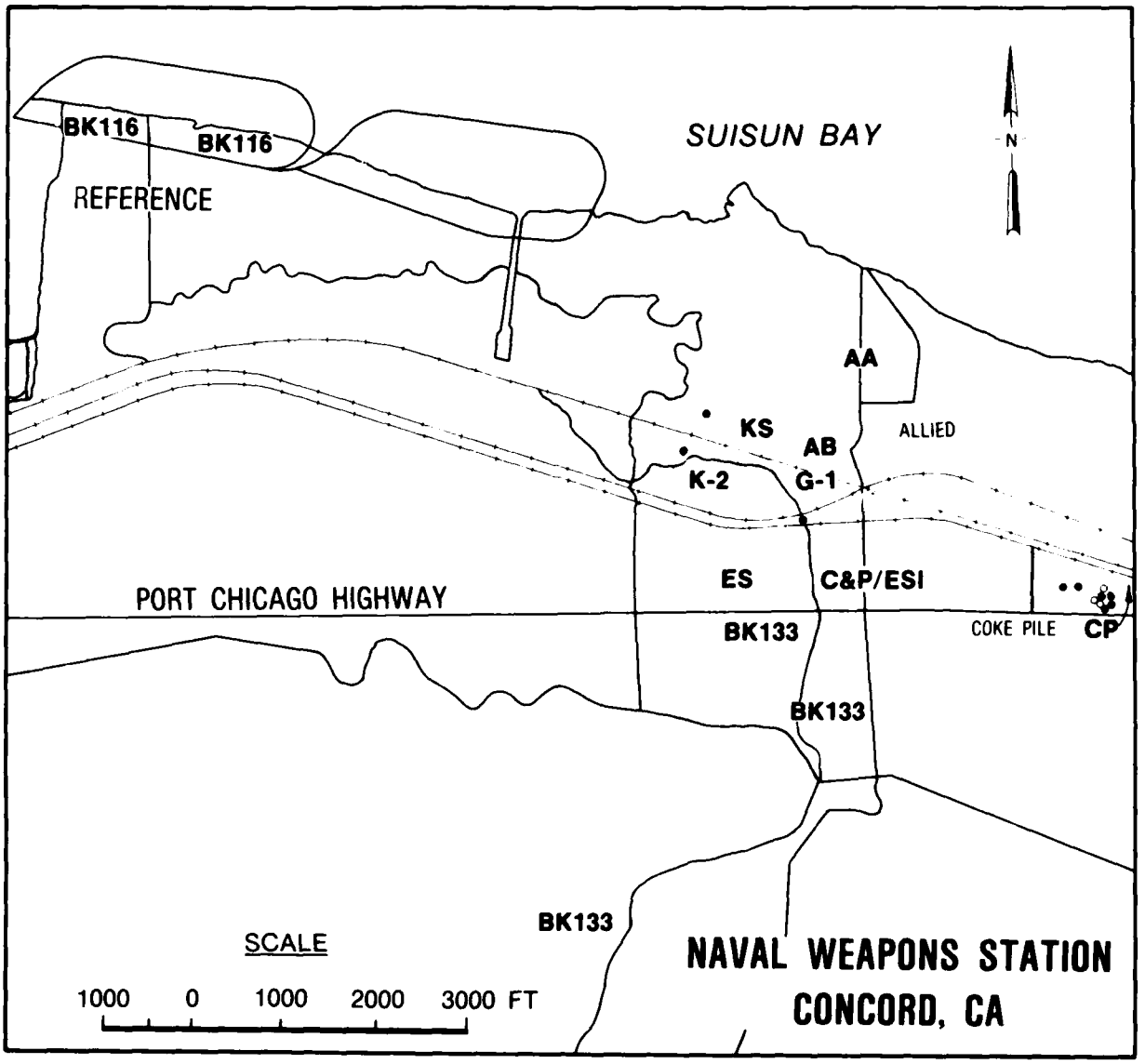


Figure 2-79. Distribution of earthworm selenium content in excess of FDA level, 10 mg/kg. Solid circles were WES collected samples, open circles were Brown and Caldwell collected samples

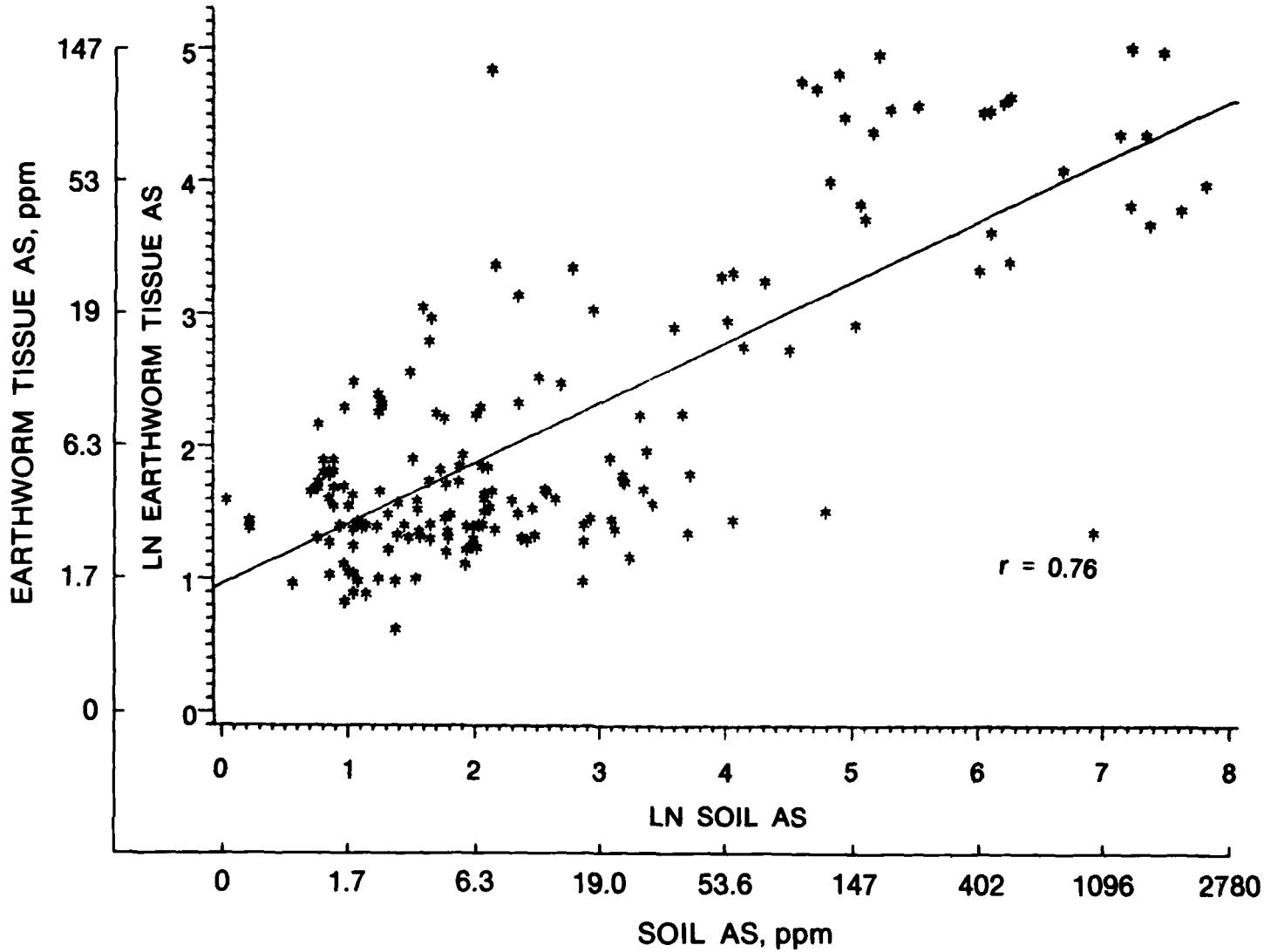


Figure 2-80. Regression of natural log (LN) earthworm tissue arsenic on natural log (LN) soil arsenic content

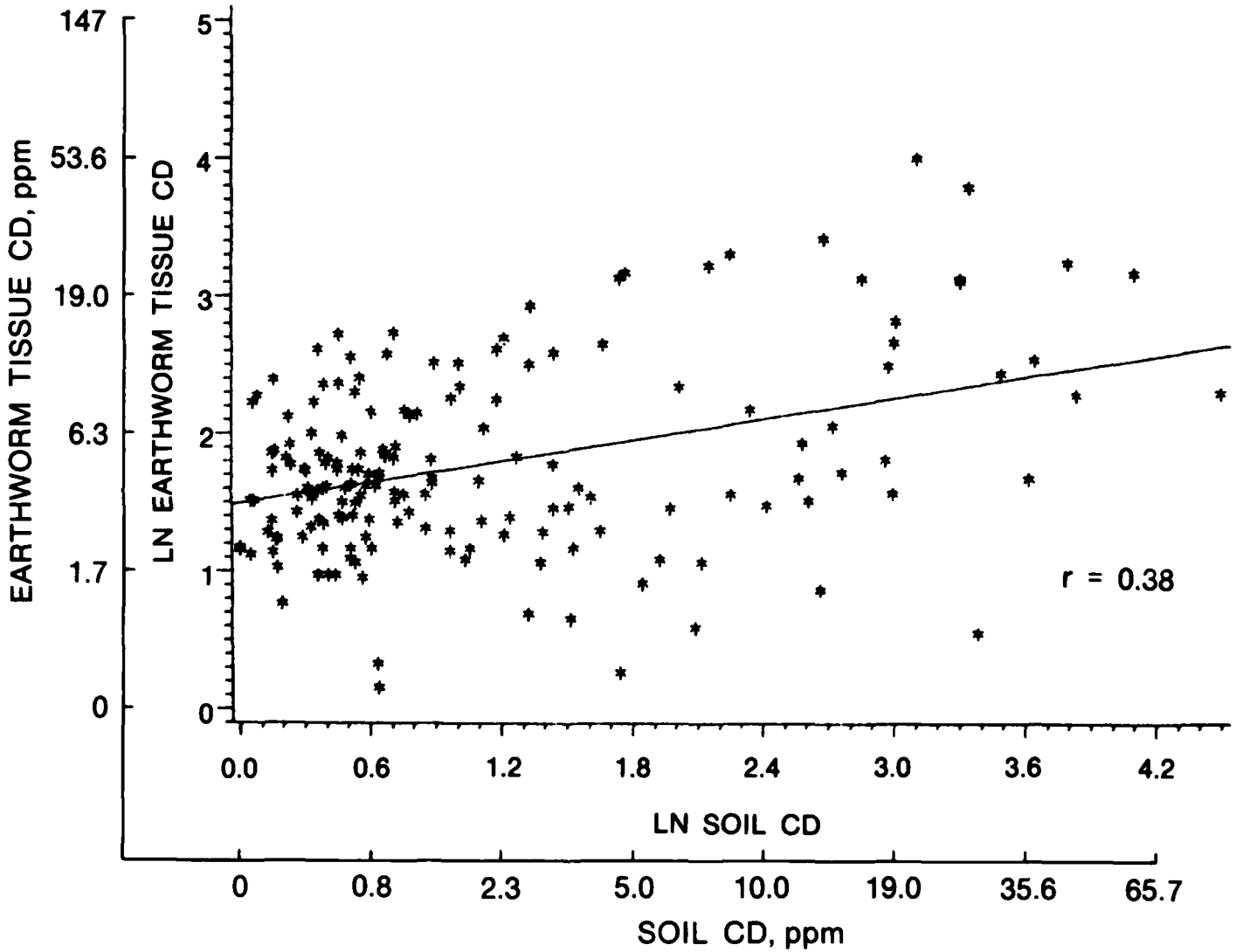


Figure 2-81. Regression of natural log (LN) earthworm tissue cadmium on natural log (LN) soil cadmium content

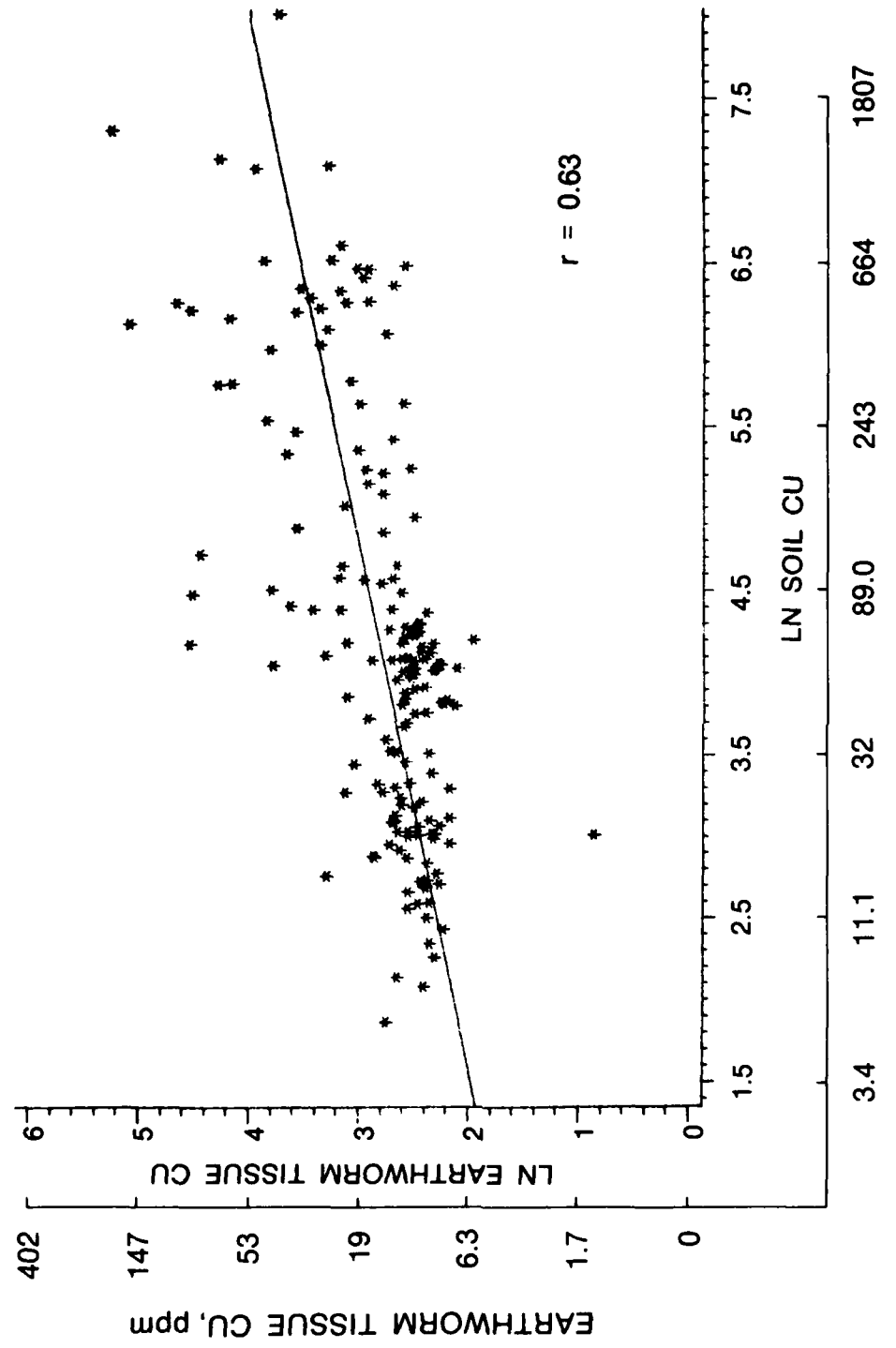


Figure 2-82. Regression of natural log (LN) earthworm tissue copper on natural log (LN) soil copper content

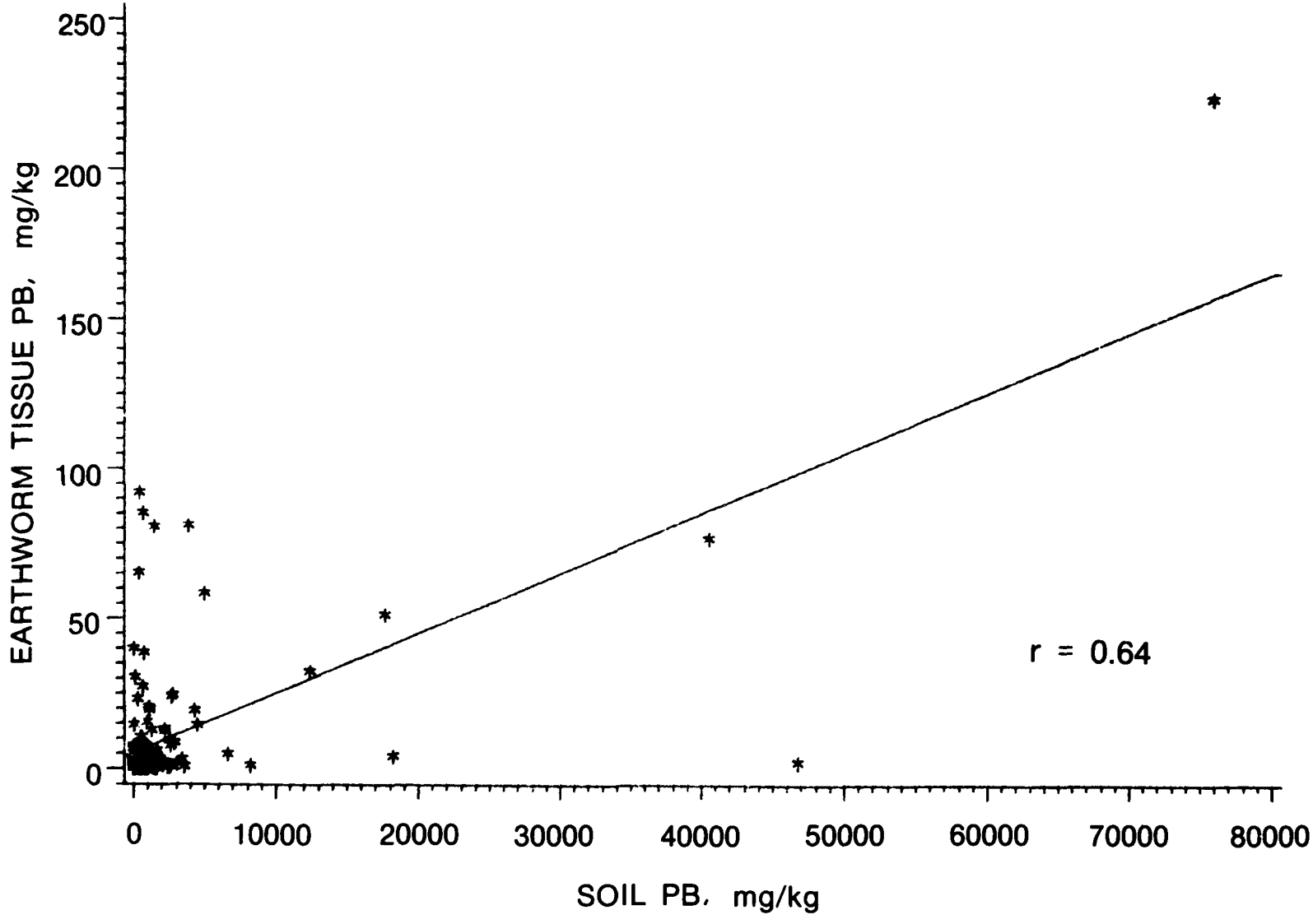


Figure 2-83. Regression of earthworm tissue lead on soil lead content

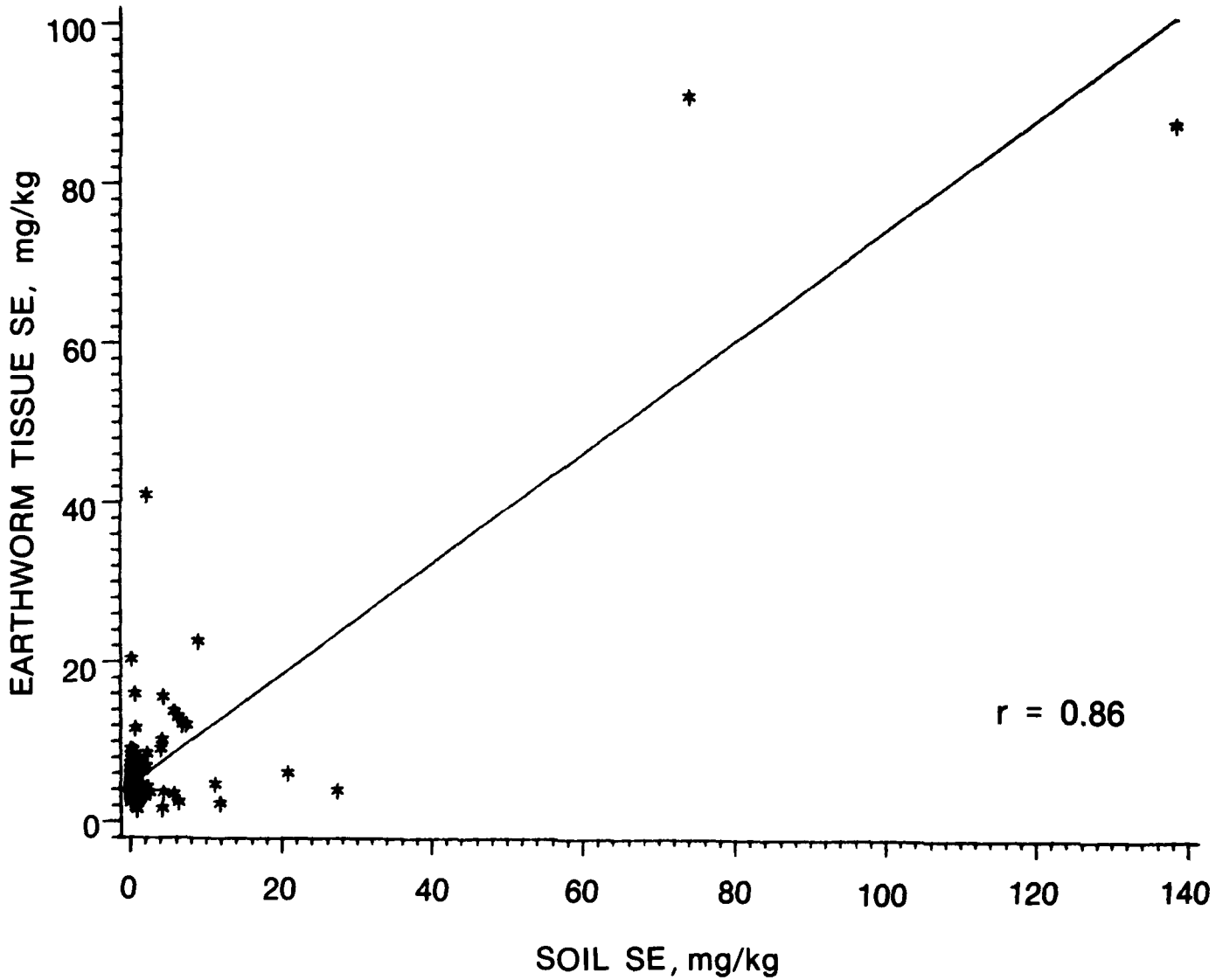


Figure 2-84. Regression of earthworm tissue selenium on soil selenium content

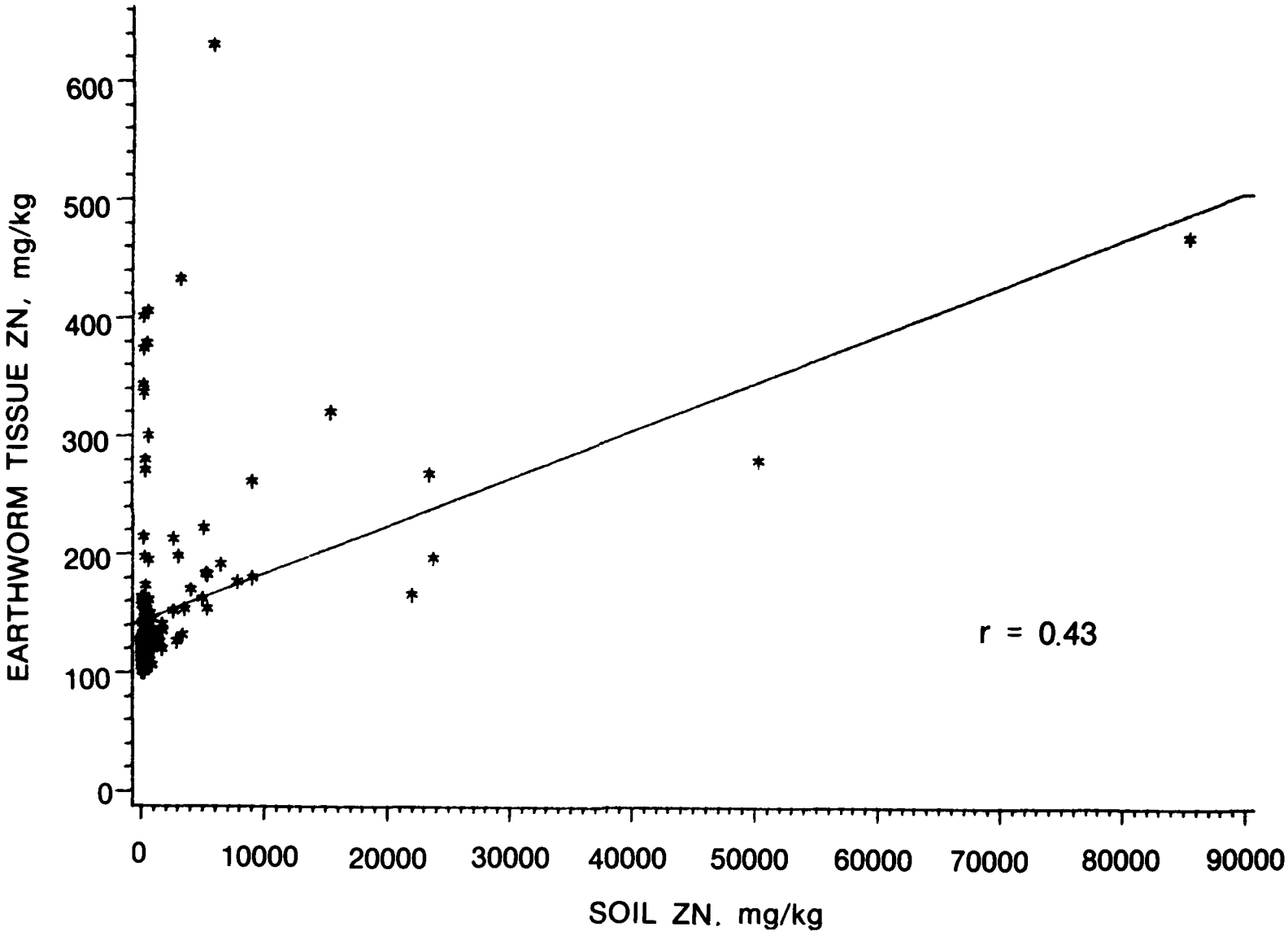


Figure 2-85. Regression of earthworm tissue zinc on soil zinc content

site. This shows that the metals are bioavailable to different biological components of the ecosystem and may have a high potential to move into plants and soil-dwelling organisms at the field site.

The most effective relationships obtained were those using earthworm tissue metal content and either Typha-tissue metal content or greenhouse- plant-tissue metal content. Significant relationships were found for the following regressions:

earthworm tissue Pb on Typha Pb, r=0.72 (Figure 2-86)
earthworm tissue As on Typha As, r=0.76 (Figure 2-87)
earthworm tissue Cd on greenhouse plant tissue Cd, r=0.77 (Figure 2-88)
earthworm tissue Se on greenhouse plant tissue Se, r=0.72 (Figure 2-89)

These relationships indicated a definite bioavailability of these metals in soils at NWS Concord and a high potential for release of these metals into the food chains and into the environment.

2.2.5 Summary of Contaminated Area

A combined distribution map for every metal that was above a critical concentration in soils, plants, and earthworms is shown in Figure 2-90. Since soil MASSA values were established for upland agricultural soils and not specifically for wetland soils, it would be conservative to apply these criteria to AA and AB. Consequently, the area of contamination in AA and AB was determined using those metal concentrations in soil samples that were statistically greater than surrounding soil sample sites. The shaded areas in AA and AB include soil containing greater than 544 mg/kg As, 12.7 mg/kg Cd, 2511 mg/kg Zn and 344 mg/kg Cu. Included in the shaded areas are those soil samples in which plants and earthworms died and earthworms bioaccumulated statistically higher tissue contents of more than 26.5 mg/kg As and 53 mg/kg Cu. The shaded areas in KS, K-2, G-1, Parcel 576, and ES represent soil, plant, and earthworm metal concentrations in excess of MASSA values, or FDA values, or critical tissue contents for reduced plant growth. These areas are drier during the summer and represent soil conditions for which MASSA values can be applied.

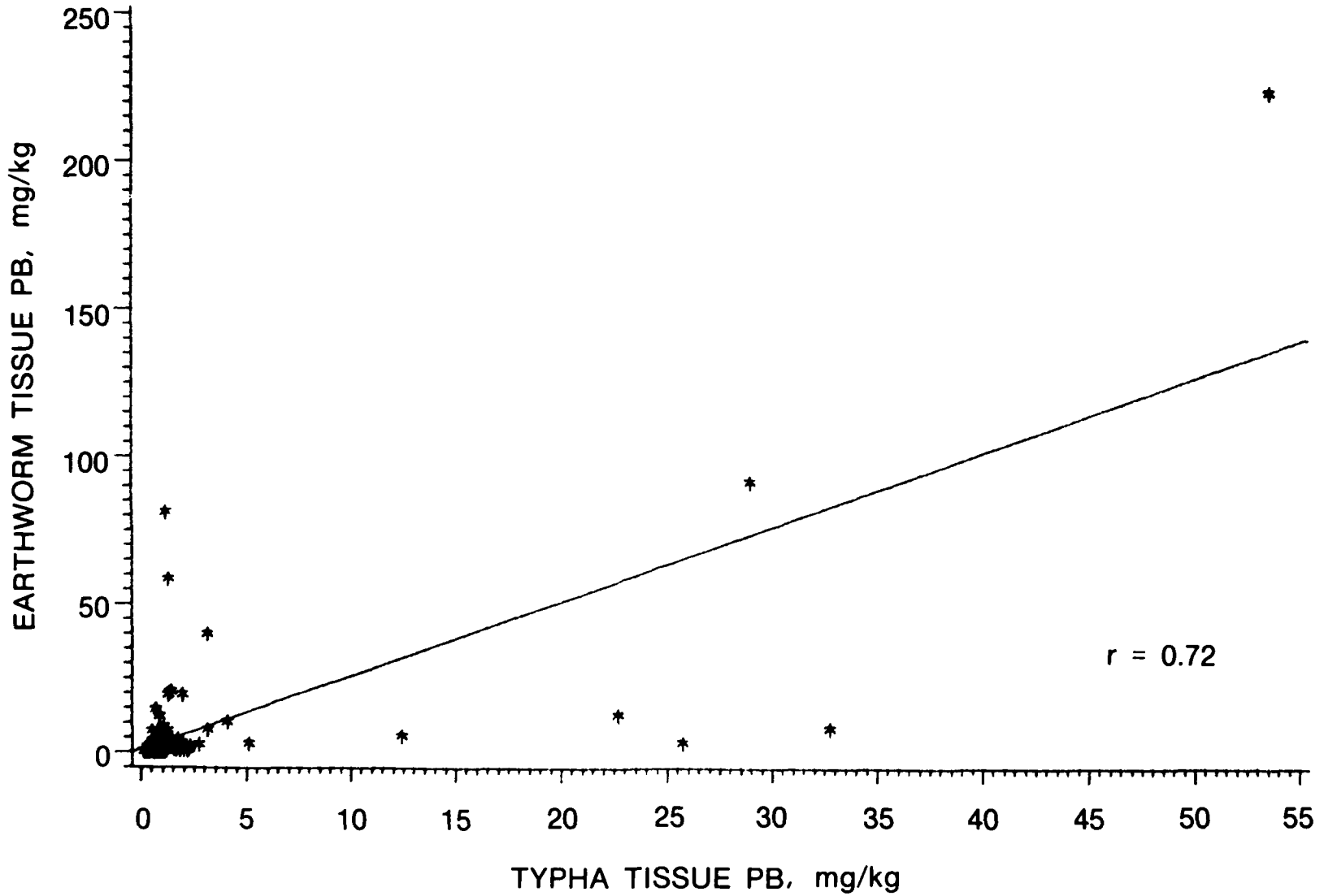


Figure 2-86. Regression of earthworm tissue lead on Typha tissue lead content

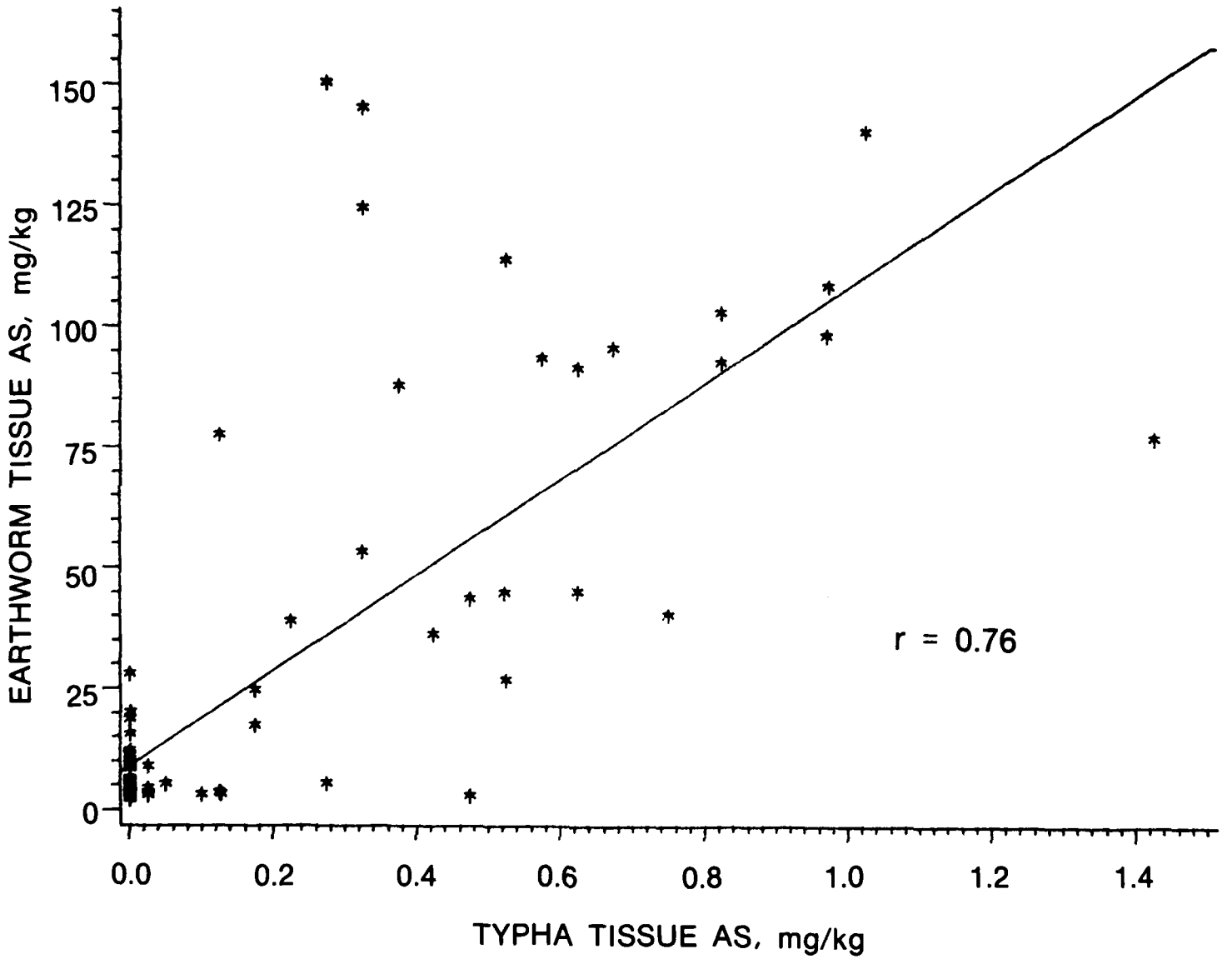


Figure 2-87. Regression of earthworm tissue arsenic on Typha tissue arsenic content

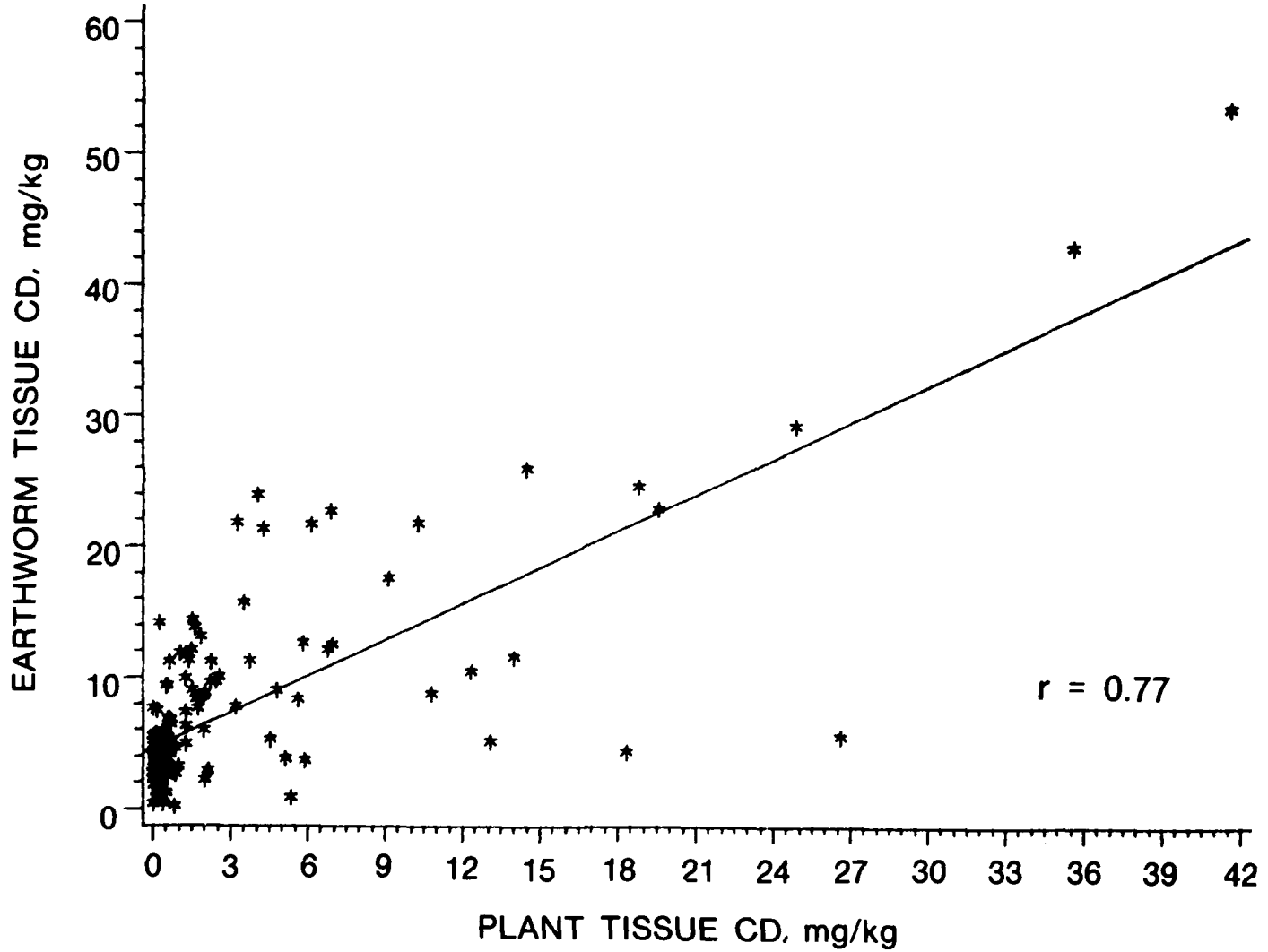


Figure 2-88. Regression of earthworm tissue cadmium on greenhouse plant tissue cadmium content

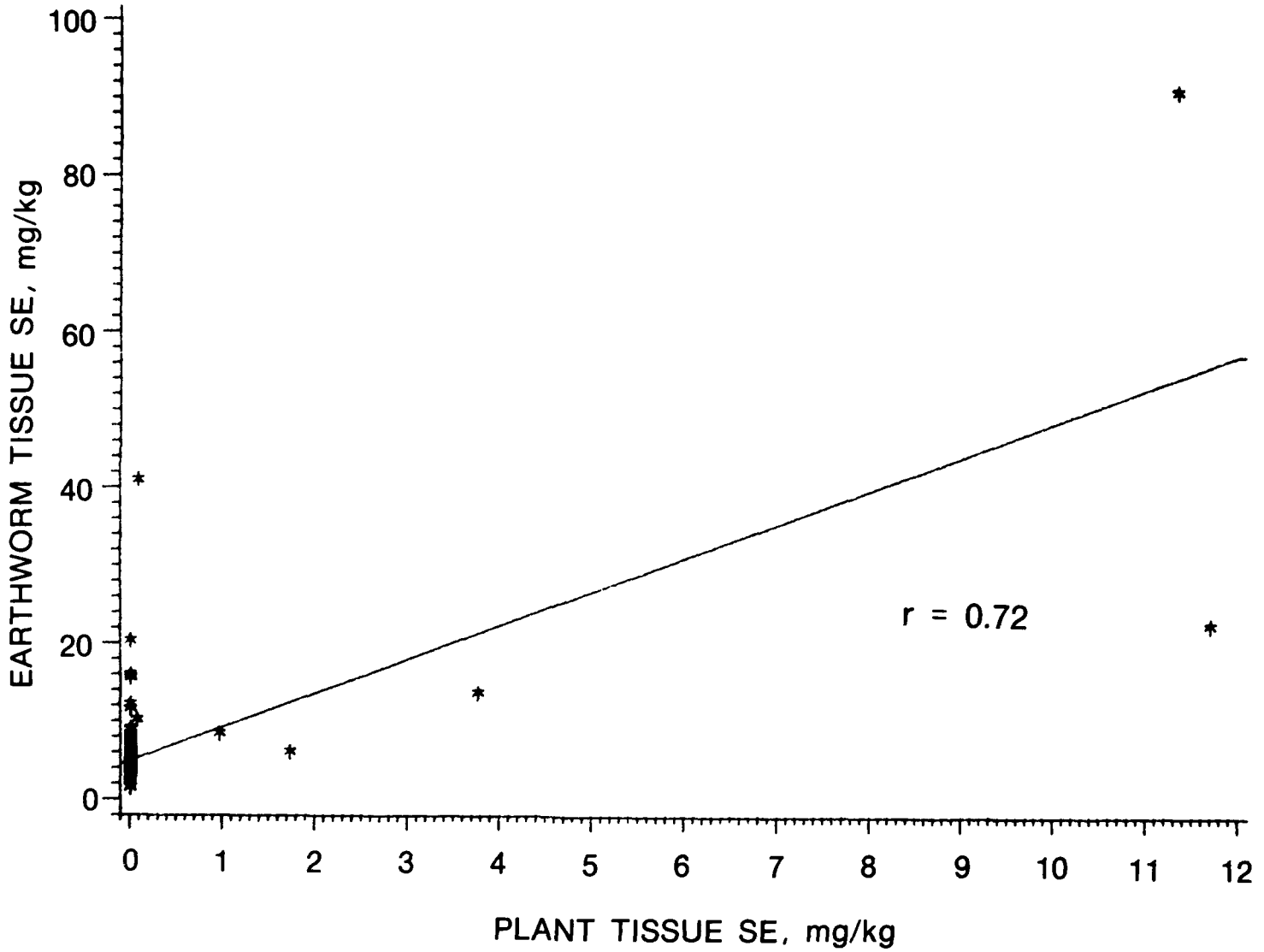


Figure 2-89. Regression of earthworm tissue selenium on greenhouse plant tissue selenium content

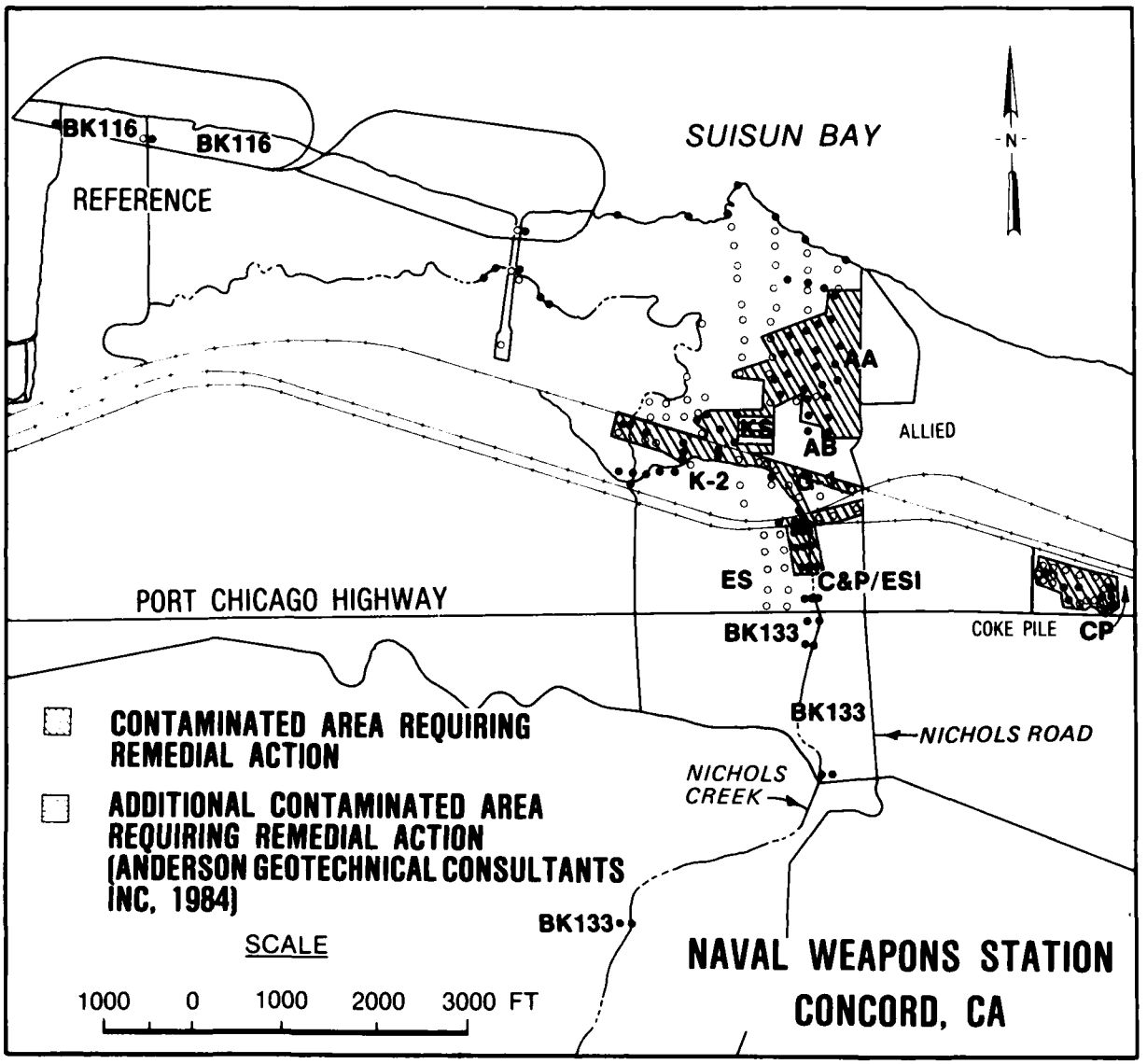


Figure 2-90. Combined distribution map of contaminated areas at NWS Concord

2.2.6 Hydrologic Evaluation

2.2.6.1 Geomorphology and Soils

The marsh and adjacent uplands at NWS Concord are formed from alluvium of three different ages and modes of deposition (Figure 2-91 from Dibblee 1980). At the mouths of canyons and footslopes are terrace remnants of Pleistocene alluvial fans and floodplain deposits, consisting of irregularly interstratified sand, gravel, silt, and clay (Qoa). The Pleistocene deposits are overlain by Holocene floodplain deposits (Qa) consisting of irregularly interstratified sand, silt, gravel, and clay. These are overlain at the margin of Suisun Bay by bay mud (Qbm), consisting of unconsolidated silt and clay with admixed organic material. The Pleistocene and Holocene alluvial deposits are up to 500 ft thick and comprise a locally important aquifer with highly variable permeability.

Most of the alluvium underlying the marsh was deposited when the sea level was lower than present today. As the base level rose, the alluvial fans at the mouth of Nichols Creek and nearby tributaries accumulated to higher levels, were reworked and in places covered with floodplain deposits by the Sacramento River. As the rate of sea-level rise decreased, the present marsh deposits of peat and fine-grained alluvium began to accumulate.

An important feature of the marsh at the bay margin is the tidal drainage pattern, which is orientated parallel to the shoreline. Wave action at the shoreline builds up debris and sediment slightly higher than the elevation of the rest of the marshy plain. This prevents direct tidal drainage into Suisun Bay. The relative low density of tributary slough channels is another noteworthy feature of the marsh.

The USDA Soil Conservation Service Soil Survey Report (1978) identifies those soil series on the site. The marsh soils are identified as Joice Muck series. In the system of the National Cooperative Soil Survey, these marsh soils are clastic, euic, thermic Terric Medisaprists. The upland soils (on terrace deposits of alluvium) are classed as Antioch loam (fine, montmorillonitic, thermic Typic Natrixeralfs) or Capay clay (fine, montmorillonitic, thermic Typic chromoxererts). The soil survey map for the site is shown in Figure 2-92. It appears that the AA and KS areas on Parcel 572 were

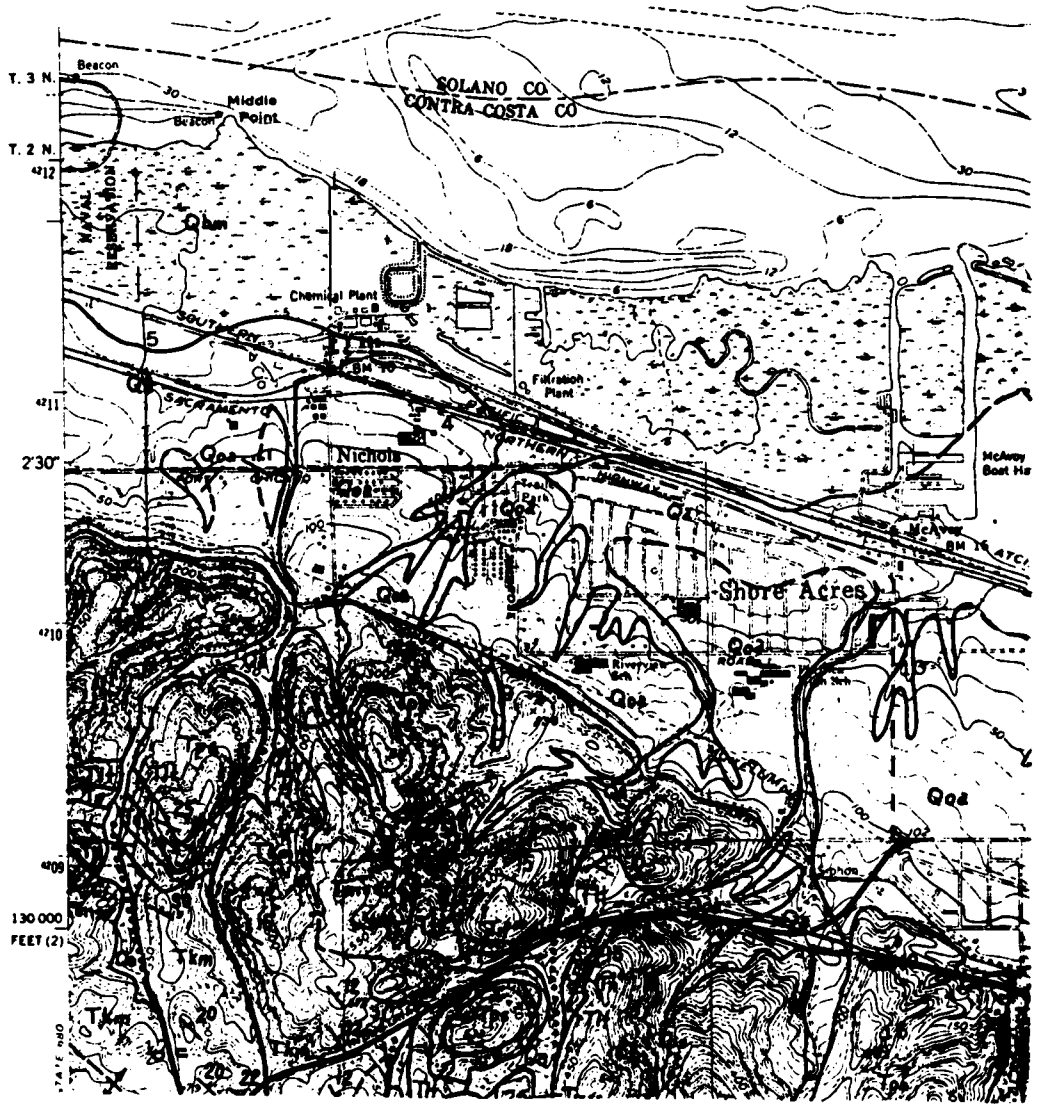


Figure 2-91. Geologic map (Dibblee 1980)

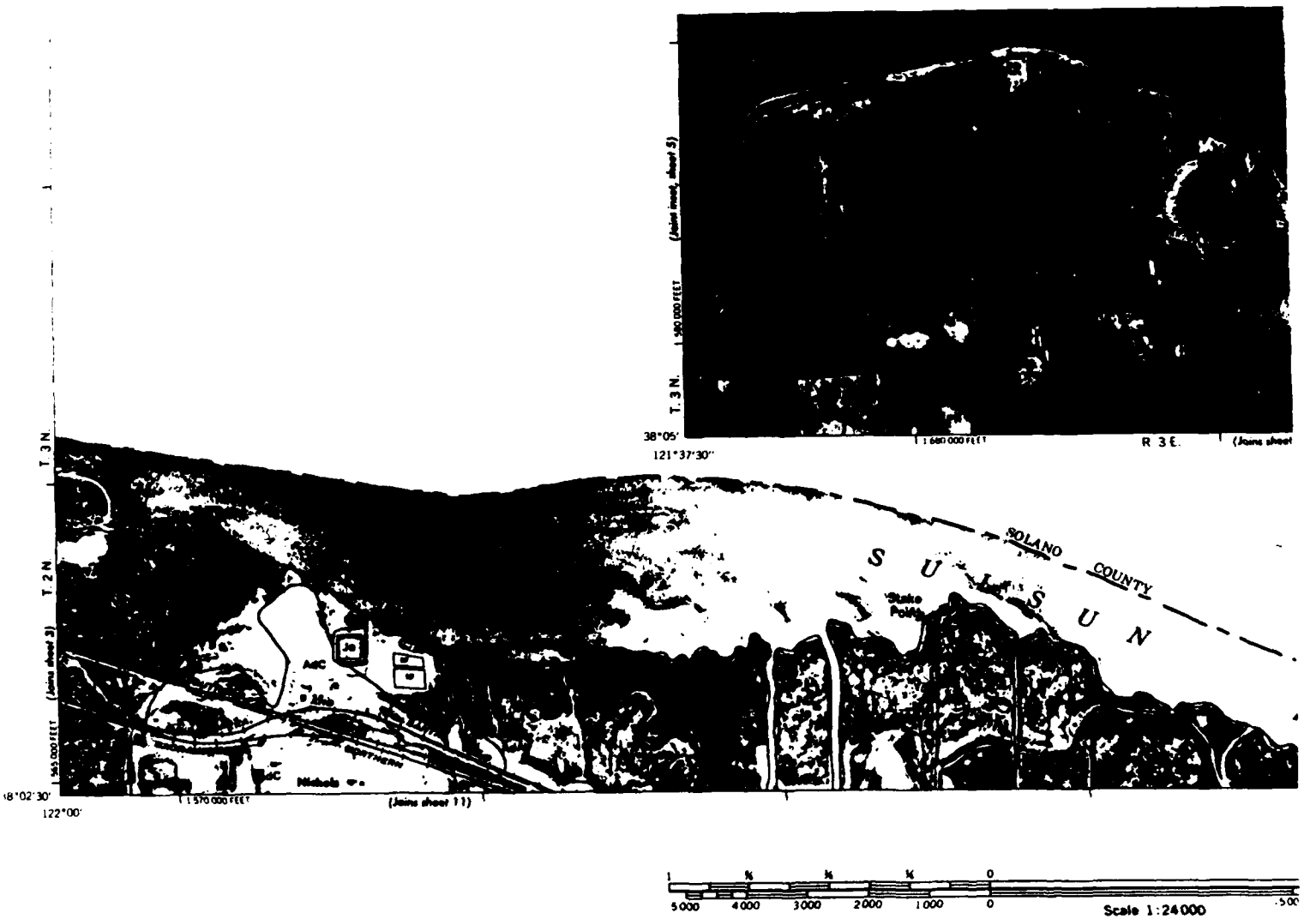


Figure 2-92. Soil survey map

incorrectly mapped as AdC (Antioch loam), probably because of their light appearance on aerial photographs.

The shoreline at the bayward edge of the marsh is in a dynamic state, having undergone both erosion and recent deposition. Sawn boards and other debris of human origins are exposed in the eroding bank at the marsh margin. Fig. 2-93 is a portion of a map (1:24,000 scale) showing the present shoreline, and the shoreline and historic margins of the marshland as they existed in 1866 at the time of the first topographic survey in the area (T1029) (Nichols and Wright 1971). Figures 2-94, 2-95 and 2-96 are copies of old 1866 surveys for T1029, T1793 and T1803, respectively. Wind-generated waves play an important role in both shoreline erosion and, during extreme tides, in the erosion of exposed sediment on the marsh plain.

Aside from shoreline erosion and deposition, three other significant long-term hydrologic trends influence the site. First, the sea level is rising at a rate of about 0.5 ft per hundred years. This is expected to continue at an increasing rate due to global climatic changes (EPA 1983). The high tide of December 1983 was the highest tide ever recorded and now forms the basis for the estimate of the 100-year high tide (US Army Corps of Engineers 1984). Second, hydraulic mining in the Sierra Nevada during the last century substantially increased the sediment input to the Bay-Delta system, resulting in extensive shoaling and filling of intertidal areas. Third, grazing in upland areas adjacent to NWS Concord has doubtlessly increased the sediment yield of streams discharging into the marsh.

2.2.6.2 Precipitation, Runoff, and Upland Drainage

Mean annual precipitation at Port Chicago is 15.4 in. (Goodridge 1982). Two methods are available for estimating short duration rainfall events and peak discharges for the watersheds draining through the study site.

First, recording raingage data are available at Martinez (about 10 miles west of the site) for short-duration events. These can be converted to data for Port Chicago by multiplying by 0.716, the ratio of one-day precipitation at Port Chicago to one-day precipitation at Martinez. These short-duration data can be used to estimate peak discharges using the rational method.

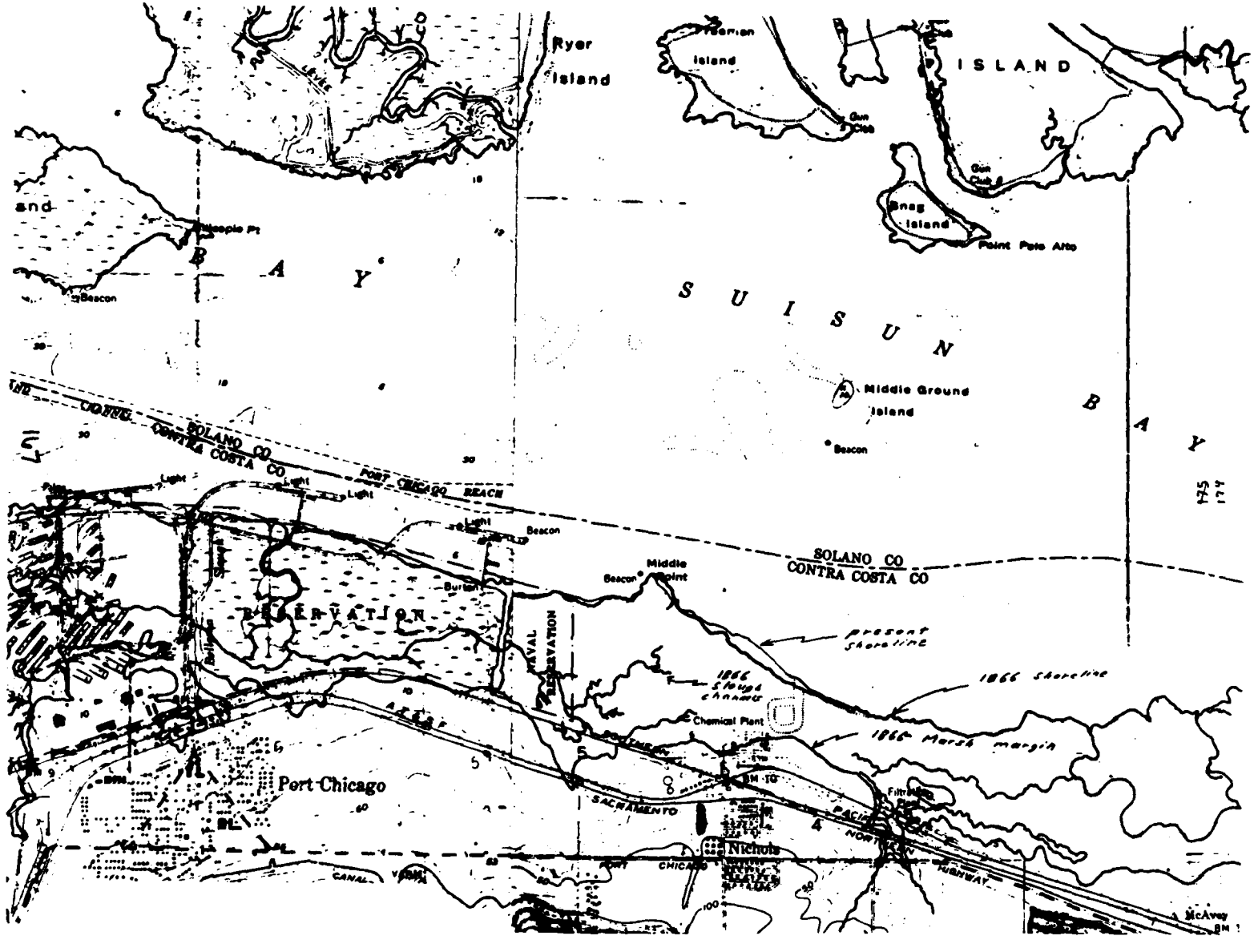


Figure 2-93. Copy of map of Nichols and Wright (1971)

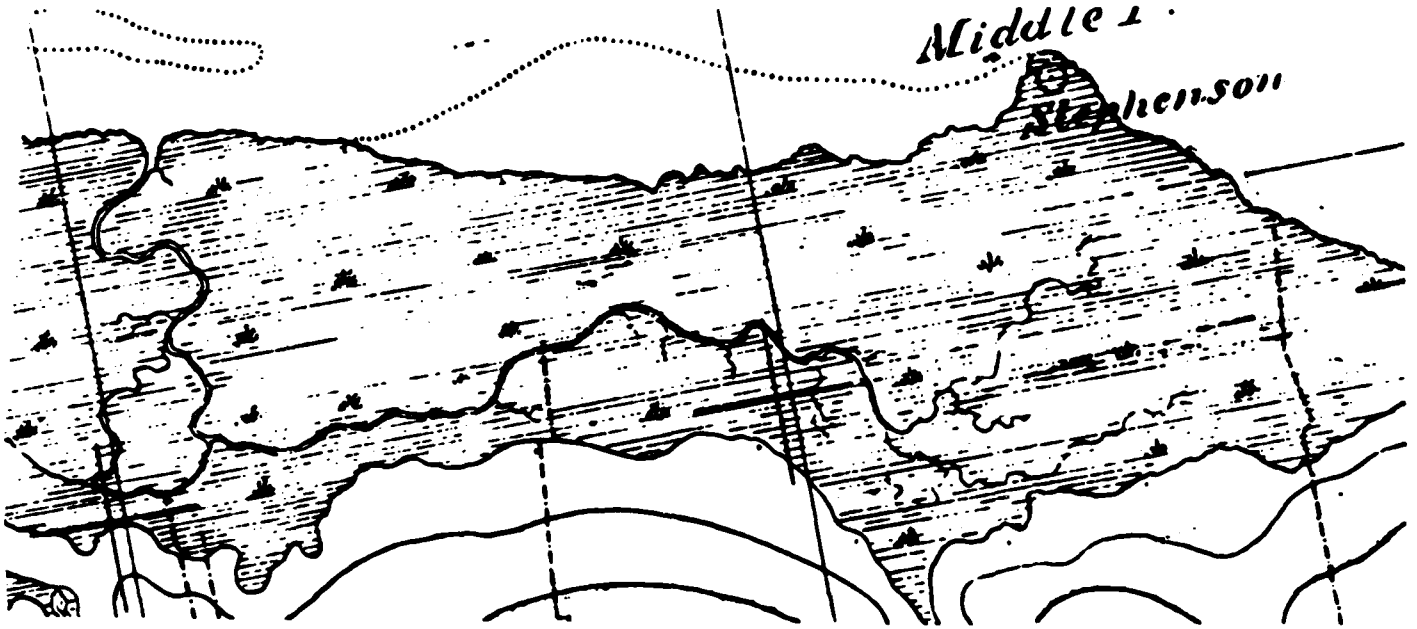


Figure 2-94. Topographic survey of 1866 (T1029)

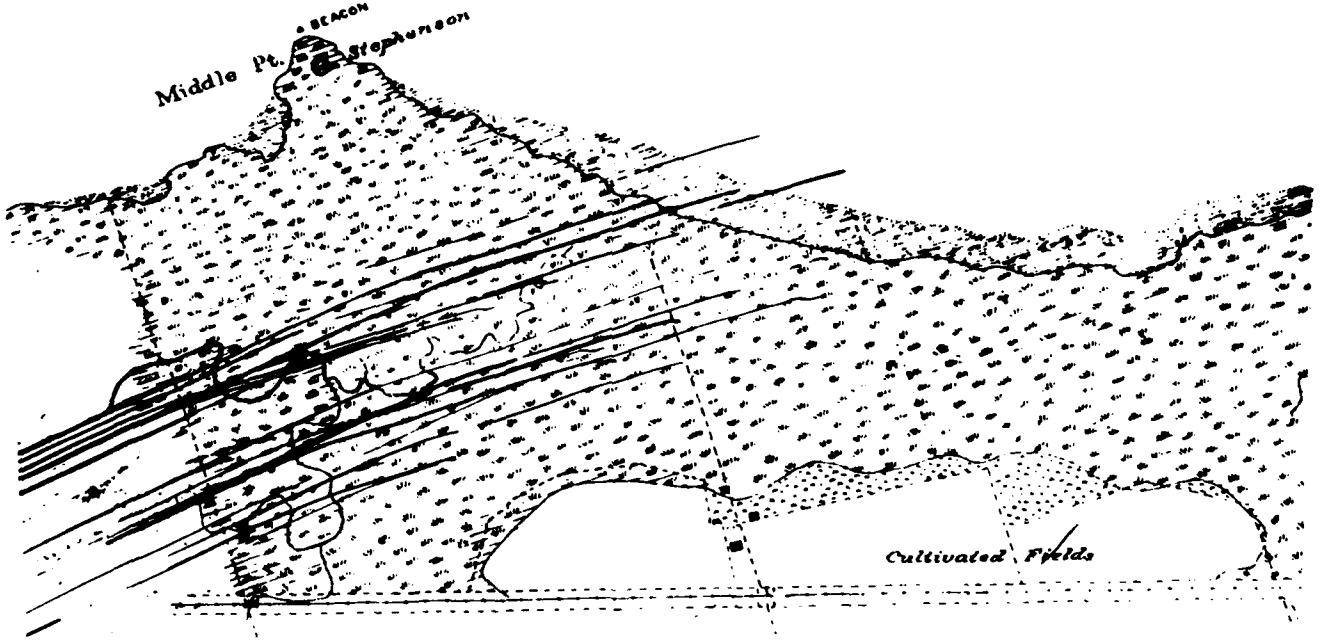


Figure 2-95. Topographic survey of 1886 (T1793)

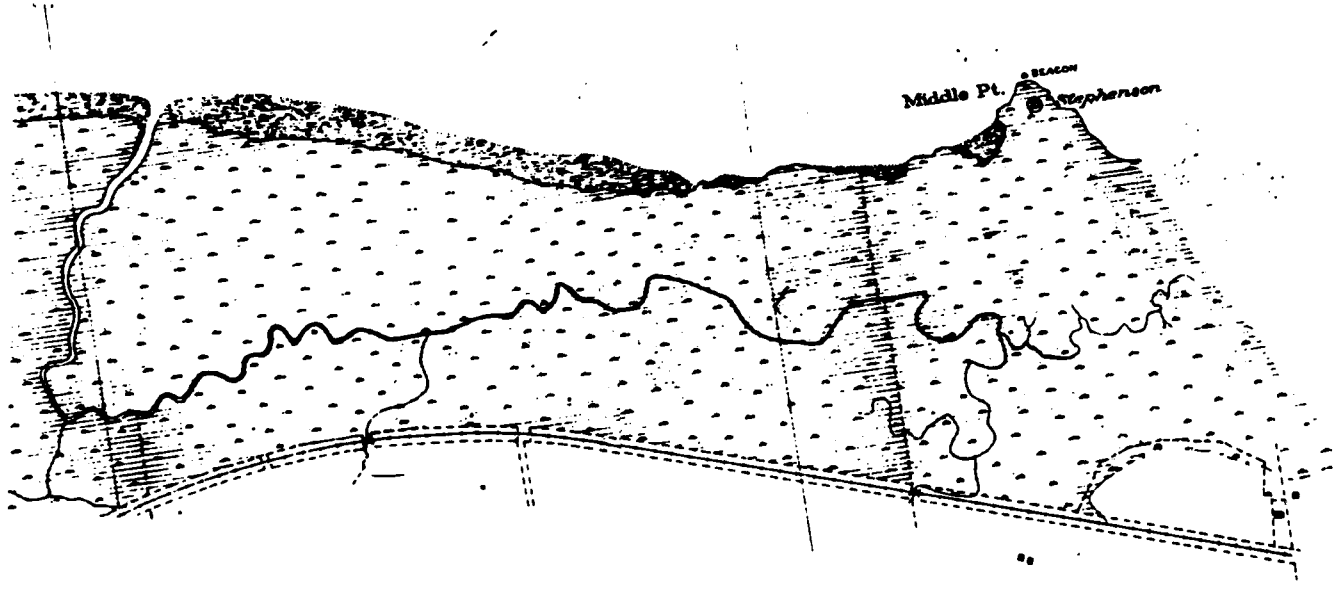


Figure 2-96. Topographic survey of 1886 (T1803)

A second method for predicting peak discharges is based on streamflow records and is available in Waananen and Crippen (1977). This method uses equations relating flood magnitudes of selected frequency to basin characteristics such as drainage area, precipitation, and altitudes for six regions of California.

Both methods have been used to estimate the peak discharge for the watershed areas during through the contaminated area. The two methods predict approximately the same peak discharge for recurrence intervals of 50 yr, but the method of Waananen and Crippen predicts a lower discharge for recurrence intervals less than 50 yr. It is thought that the method of Waananen and Crippen may be more accurate, but calculations made by both methods have been presented in Table 2-12.

The contaminated area is traversed by a small stream (which will be called Nichols Creek) that originates in the hills south of the study site (see Figure 2-97). The watershed area for this creek is slightly over one square mile. North of Port Chicago Highway, the stream runs adjacent to the Chemical and Pigment Company plant, under two railroad right-of-ways (the Sacramento Northern and AT&SF tracks), under one unpaved road, and finally under a Southern Pacific railroad trestle into the marsh area. A second stream (which will be called the tributary stream) from a watershed west of Nichols Creek joins Nichols Creek just before passing under the railroad trestle.

Between the Port Chicago Highway and the marsh where Nichols Creek terminates, the stream channel is full of a dense stand of cattail (Typha angustifolia). Adjacent to the Chemical and Pigment Company the channel also supports a luxuriant growth of watercress (Nasturtium sp.).

The stream must pass through culverts under the Port Chicago Highway, under the two railroads, and under the unpaved road. Some of these culverts are at present largely blocked with sediment, and some may be too small to allow peak discharges of major storms to pass without ponding. Any ponding behind the culverts may represent a control on the actual peak discharges passing down the streambed to the trestle where it discharges into the marsh.

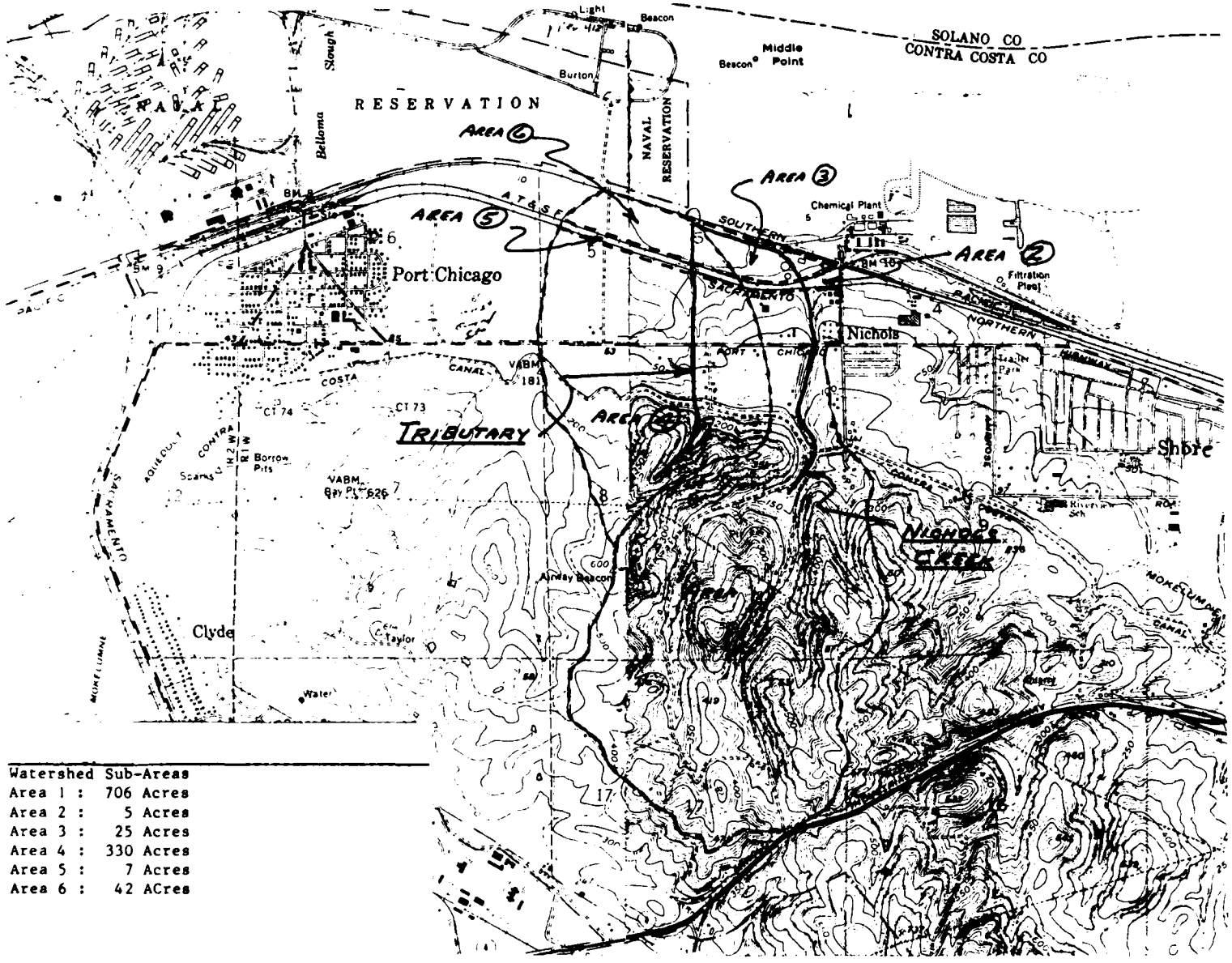
Water which backs up behind the culverts under the railroad tracks would form a reservoir upstream, but water blocked by the single small culvert under the unpaved road north of the AT&SF tracks on Parcel 575 (G-1 area) would

Table 2-12. Discharge in Nichols Creek and Tributary

Recurrence Interval, yr	Discharge Calculated by Rational Method, cfs			Discharged Calculated by Method in Waananen and Crippen (1977), cfs		
	Nichols Creek*	Tributary **	Total	Nichols Creek*	Tributary **	Total
2	136	70	206	40	19	59
5	188	97	285	94	47	141
10	225	115	340	145	74	219
20	260	133	393			
25	271	139	410	223	116	339
40	289	149	438			
50	306	158	464	292	154	446
100	335	173	508	369	197	566
200	364	188	552			

* Nichols Creek discharge includes precipitation from watershed areas 1, 2, and 3 of Figure 2-97.

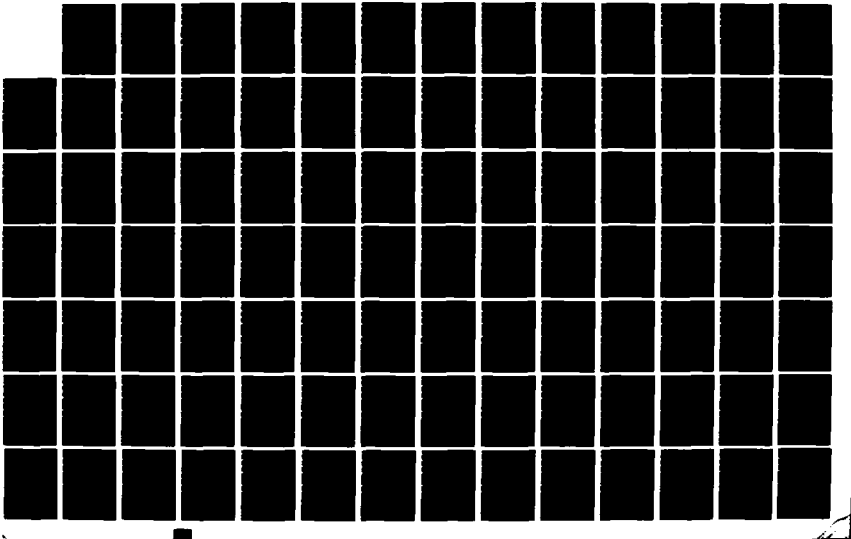
** Tributary discharge includes precipitation from watershed areas 4, 5, and 6 of Figure 2-97.

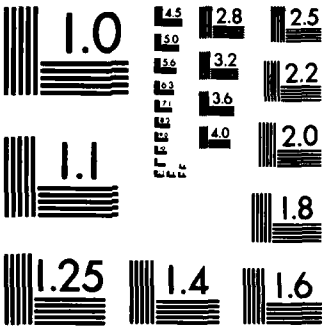


Watershed Sub-Areas	
Area 1 :	706 Acres
Area 2 :	5 Acres
Area 3 :	25 Acres
Area 4 :	330 Acres
Area 5 :	7 Acres
Area 6 :	42 ACres

Figure 2-97. Drainage basins of Nichols Creek and tributary

AD-A165 127 REMEDIAL INVESTIGATION OF CONTAMINANT MOBILITY AT NAVAL 3/7
WEAPONS STATION C... (U) ARMY ENGINEER WATERWAYS
EXPERIMENT STATION VICKSBURG MS ENVIR... C R LEE ET AL.
UNCLASSIFIED JAN 86 WES/MP/EL-86-2 F/G 6/6 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

increase in depth until it flowed over the road. From the road much of the overflow would flow in the right overbank area of the stream bed (G-1 area), down the hill, and into the ditch which runs beside the Southern Pacific tracks (north of G-1 area). This possibility will be discussed in more detail below.

The present course of Nichols Creek is quite different from its original course. The pre-railroad survey of 1866 (T1029) shows Nichols Creek entering the marsh at approximately the Kiln Site, with a bulge in the contours that suggests a small fan in the marsh at the mouth of the creek. When the railroad was built in the late 1860s, a stream crossing was apparently installed. It is unclear how long this structure functioned effectively. Aerial photography dated 1939 and 1959 shows the creek passing under the Southern Pacific tracks through the culvert. It appears from available air photos that at some time during the 1960s Nichols Creek was diverted to flow on the south side of the Southern Pacific tracks to the trestle where it now terminates. This diversion was accomplished by filling the stream channel into the culverts and building up a small berm along the south side of the Southern Pacific tracks, which kept the creek constrained to its new channel running through the K-2 area to the trestle. A curious depression (about 50 ft east of the culverts) that appears to have resulted from a cave-in marks what could be the old channel. The culverts under the Southern Pacific tracks (twin 32-in.-diameter CMP) are half-filled with sediment and receive drainage only from the ditch on the south side of the tracks east of the culverts. Old maps from 1886 (T1793) show cultivated fields north of the Southern Pacific tracks below the culvert.

Any contamination picked up by Nichols Creek as it runs past the Chemical and Pigment Company plant would be transported to the kiln site if the flow could reach the old Southern Pacific culverts. There are three ways that this might occur.

First, the water depth in Nichols Creek as it flows west past the location of the old route through the culvert could rise to a surface elevation that would overtop the berm protecting the culvert. Any such overtopping of the berm in this area would flow directly to the culvert.

Second, if the right bank of the creek (looking downstream) overflowed at a location about 400 to 500 ft or more upstream of the area near the culvert, the water would flow straight north to the curious depression or cave-in noted

above and from there would flow into the ditch which runs along the south side of the tracks and then westward to the culvert.

Third, as noted above, if water were backed up by the single culvert under the unpaved road just north of the AT&SF tracks, when the water began to overflow the road, the water from the right bank would flow north to the cave-in noted in the second possibility above and from there into the ditch to the culvert.

To study the peak discharge conditions which might lead to the first two possibilities outlined above, the water surface profiles of the creek under various discharge conditions were modeled. This was accomplished with HEC-2, a program developed by the Hydrologic Engineering Center of the US Army Corps of Engineers. Nine cross sections of the creek and overbank areas were used as input, along with peak flows for Nichols Creek and the tributary stream (Figure 2-98).

It was decided to begin by ignoring the possibility that the various culverts upstream (at the unpaved road and at the railroad tracks) might restrict the peak flows during a storm event and to assume that the calculated peak discharge for the recurrence interval was flowing in the creek channel at the locations of interest. Peak discharges calculated by both the rational method and by the method of Waananen and Crippen (1977) were considered (Table 2-12).

If the calculated water surface elevation at section 8 rose above 10.0 ft, then overflow of the berm directly into the culvert (as outlined in possibility number one above) would occur. If the calculated water surface elevation at section 9 rose above 13.5 ft, then overflow of the right bank with flow to the cave-in and ditch would occur (as outlined in possibility number two above).

Discharges of 219 and 340 cfs were used. These correspond to recurrence intervals of about 3 and 10 yr by the rational formula, and 10 and 25 yr by the Waananen and Crippen method. A discharge of 219 cfs did <u>not</u> produce overflow to the culvert by either of the possibilities above. A discharge of 340 cfs, however, <u>did</u> produce overflow to the culvert by overflowing the banks of the stream at section 9; that is, by overflowing as outlined in possibility number two above.

Finally, the third possibility outlined above was briefly considered. Here, the culvert pipe under the unpaved road (a single 18-in.-diameter CMP pipe) could cause the water to back up behind the culvert until it began to

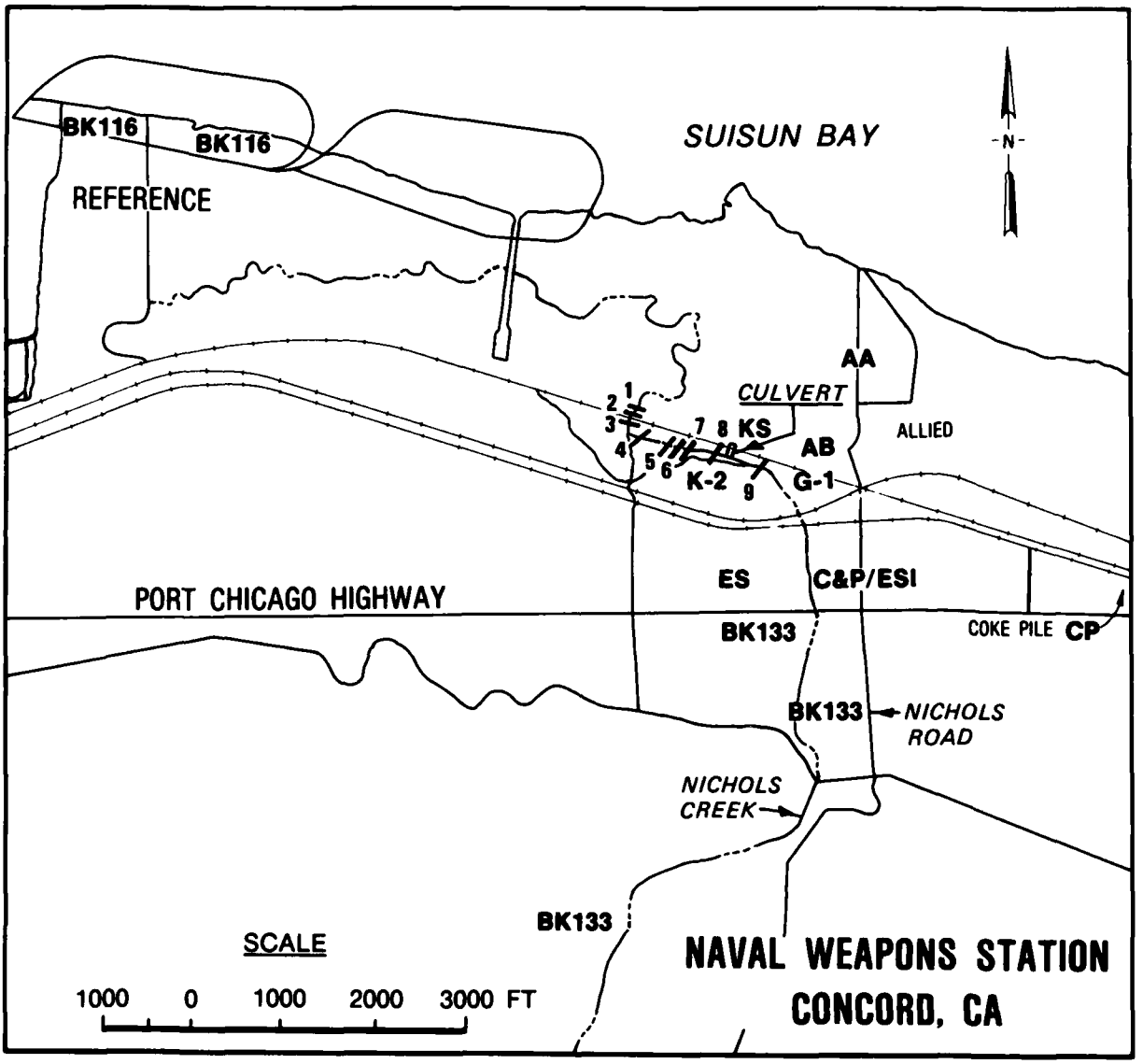


Figure 2-98. Cross-section locations used for HEC-2 analysis

overflow the road. If this happened, a significant part of the flow would continue downhill over G-1 area and into the right overbank area to the cave-in depression and the ditch, rather than returning to the stream channel.

It appears that the culvert in the G-1 area is completely inadequate and that it is not able to pass the peak discharge of even a 2-yr event (Portland Cement Association, 1969). The culvert pipe appears to be fairly new, and it is not known how long this culvert configuration has been in position. However, it appears that overflow into the right overbank area must occur fairly frequently.

2.2.6.3 Tidal Drainage

The first alteration of tidal drainage occurred sometime after 1888, and probably in the early 20th century. Channels were dredged southward from the shoreline, and the naturally occurring slough channels connected to these. This probably increased tidal action in the marsh, resulting in higher highs and lower lows of tidal range.

The second alteration of the local tidal drainage pattern occurred in prior to 1959 when the local mosquito abatement district excavated a network of ditches in the marsh to improve drainage. These have been cleared out subsequently and have substantially increased the circulation of tidal water through the marsh.

The third alteration of marsh drainage occurred as a result of the overflow from Allied Chemical waste lagoon in area AA. This flow of waste lagoon sludge over the marsh plain raised the elevation locally and filled the heads of natural slough channels.

2.2.6.4 Tidal Inundation

A major possible mode of contaminant transport at the site is tidal action. To determine the likelihood of high tides dispersing contaminated sediments around or out of the marsh, it is necessary to know the frequency and duration of the tidal heights in the marsh and in the sloughs.

Table 2-13 shows heights of high and low tides (NGVD datum) at Middle Point. These are based on interpolation between tidal stations at Port Chicago and Mallard Island Ferry wharf, about one mile to the east.

Table 2-13

Tidal Elevations Near NWS Concord

	Elevation, ft					
	Port Chicago		Middle Point		Mallard Is.	
	MLLW	NGVD	MLLW	NGVD	MLLW	NGVD
MHHW	4.7	3.02	4.4	2.90	4.0	2.80
MHW	4.15	2.47	3.8	2.3	3.45	2.25
MTL	2.4	0.72	2.2	0.7	2.0	0.8
1929 MSL	1.68	0	1.55	0	1.20	0
MLW	0.65	-1.03	0.60	-0.9	0.55	-0.65
MLLW	0	-1.68	0	-1.5	0	-1.25
Mean Range		3.5		3.2		2.9
Mean Diurnal Range		4.7		4.4		4.0
Relation to Ft. Point, San Francisco						
Time (hrs)						
high	+2:36		+2:59		+3:26	
low	+3:08		+3:33		+4:03	
Ht						
high	-1.0		-1.3		-1.7	
low	-0.4		-0.45		-0.5	

In order to derive the curve for duration of tidal height at Middle Point, it was necessary to use the established curve for Ft. Point (San Francisco) and adjust for local conditions. First, the normalized curve (Harris 1981) was multiplied by 1/2 the mean diurnal range at the site (from Table 2-13). This curve is based on predicted astronomical tides. Assuming that the Mean High Water (MHW) and Mean Higher High Water (MHHW) are equalled or exceeded at Ft. Point and Middle Point for the same percentage of the time, the curve was then adjusted to fit local MHW and MHHW. Figure 2-99 shows the adjusted curve.

The duration and frequency of tide heights in the marsh, however, differ from that in the bay. In order to establish the relationship, staff gages and stage level recorders were installed in sloughs and ditches at four location. These locations are shown on Figure 2-100. Gage #1 is at the slough mouth, near Pier 4. Gage #2 is in about the middle of the marsh, 100 ft northwest of survey control point No. 11. Gage #3 is near the upper end of the eastern area of the slough, and Gage #4 is in a mosquito ditch about 450 ft west of the dike in area AA. Gages #1 and #2 were surveyed by differential leveling from bench marks established by Towill, Inc., with one instrument setup each. Gages #3 and #4 were surveyed from a Coast and Geodetic Bench Mark at the Allied Chemical Company Plant. Closure error was 0.03 ft, and this error was distributed. The elevations of four spring higher high tides were then read at each location. Table 2-14 shows the results. The data indicate that high tides are slightly attenuated (about 0.6 ft) as the tidal wave moves up the slough into the marsh, and that most of the attenuation occurs in the lower half of the slough channel.

A fifth gage was placed at control point No. 11 (elev 3.10). The tides of June 2nd and 3rd recorded elevations of 3.46 and 3.55 at gage #2 just 100 ft away, but the vegetation on the marsh plain (mostly salt grass here) prevented water from flowing over the surface to the control point. The soil, however, was moist on the days following the high tides.

Because vegetation on the marsh plain has such a retarding effect on tides that just barely flood the marsh plain, it is not feasible to draw an accurate map on tidal inundation frequency using just topographic information. It is possible, however, to infer something about the extent and frequency of tidal flooding for different portions of the marsh. Table 2-15 shows the frequency and duration of tide height for different areas of the marsh. Mean

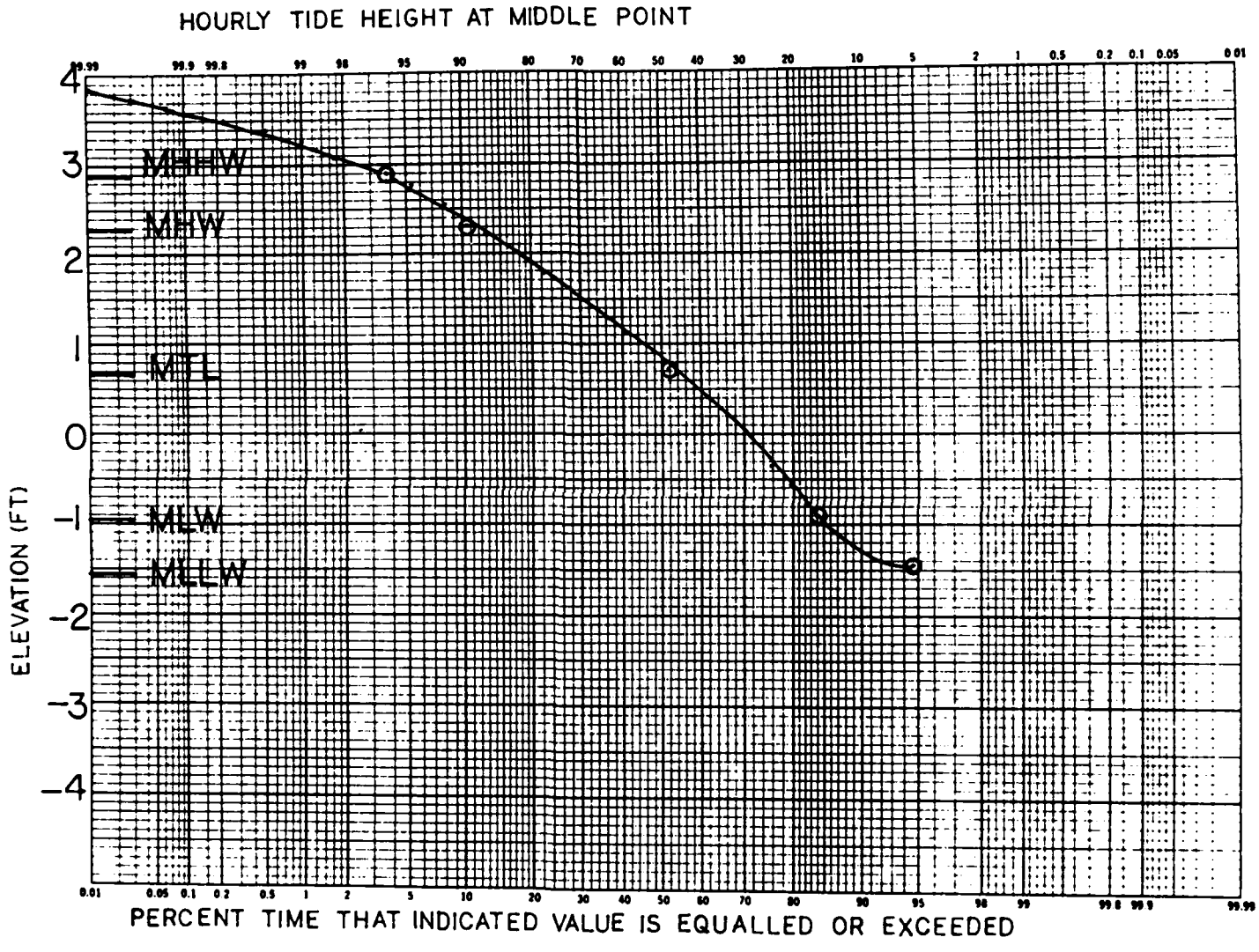


Figure 2-99. Duration of tide height at Middle Point

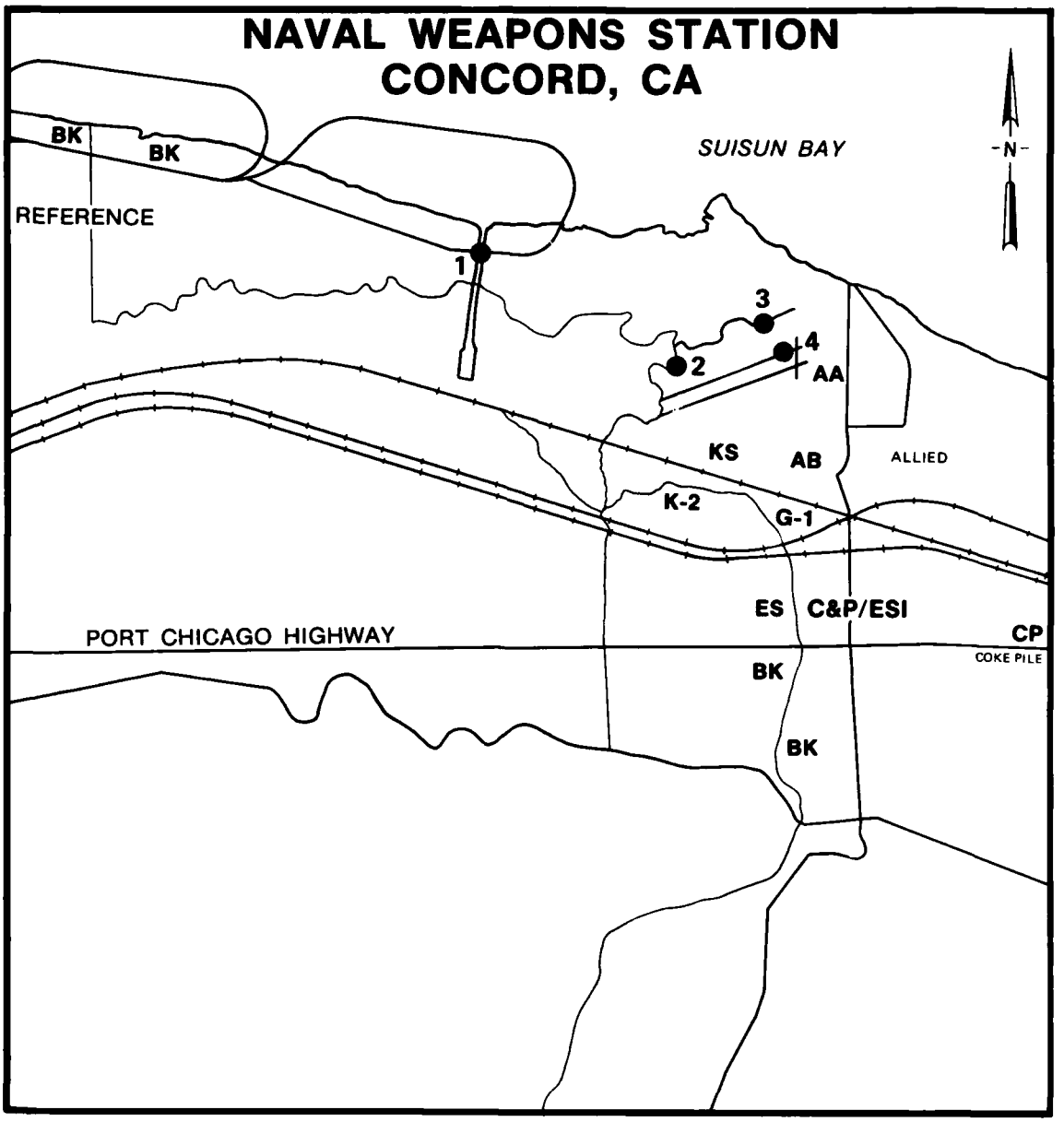


Figure 2-100. Tide staff gage locations on Parcels 571 and 572 at NWS Concord

Table 2-14

Maximum Tide Height at Staff Gages in NWS Concord Marsh

Gage No.	Date of Measurement, 1985 - Maximum tide height, ft (NGVD)			
	June 2	June 3	June 19	July 2
1	3.81	3.92	3.81	3.99
2	3.46	3.55	3.52	3.55
3	3.42	3.54	3.50	3.50
4	--	3.33	3.32	3.31

Table 2-15

Tidal Duration and Frequency for NWS Marsh Based on Adjusted Curve for Ft. Point and Staff-Gage Readings in the Marsh

Tide	Duration % hours	Frequency higher highs	Times per yr	Elevation, ft (NGVD)		
				Slough Mouth	Mid Slough	Upper Slough
MHHW	3	.35	123	2.90	2.55	2.51
	15	.146	51.5	2.30	2.95	2.91
	0.1	.021	7.4	3.60	3.25	3.21
	0.01	.0037	1.3	3.80	3.45	3.41
10-yr high tide	--	2.8×10^{-4}	0.1	5.7	5.35*	5.31*
100-yr high tide	--	2.8×10^{-5}	.01	6.2	5.85*	5.81*

* These elevations are based on the questionable assumption that extreme high tides are attenuated as much as more frequent high tides. The actual extreme high tide elevations probably are not much different from the elevations at the slough mouth.

higher high water is equalled or exceeded 3 percent of the time, or 123 times per year. Such a tide fills sloughs and ditches in the marsh to within about 0.5 ft of the bank top. The ditches and sloughs are completely filled by a high tide that is equalled or exceeded about 52 times per year, or 1 percent of the time. High tides of 3.6 to 3.8 ft NGVD at the slough mouth are equalled or exceeded 0.1 to 0.01 percent of the time (7.4 to 1.3 times per year) and result in maximum water elevations in the upper marsh of 3.2 to 3.4 ft. These tides flood the depressions in the marsh plain near sloughs and ditches, but areas remote from sloughs with dense vegetation are moistened but not inundated.

As a result of the record high tides of 1983, the Army Corps of Engineers undertook a new 100-yr high tide study (Army Corps of Engineers, 1984). The 10-yr and 100-yr high tide elevations from that study are also shown in Table 2-16. They represent a different statistical distribution than the predicted astronomical tides because they reflect actual measurements of storm surges during high tides.

Table 2-16

Velocity at Two Flow Conditions in Nichols Creek above Southern Pacific Railroad Tracks Based on HEC-2 Results

	Flow, cfs - Velocity, ft/sec					
	219 cfs			340 cfs		
Section No.	Left Overbank	Channel	Right Overbank	Left Overbank	Channel	Right Overbank
8	0.84	1.47	0.90	1.01	1.64	1.10
9	--	3.54	--	.01	1.87	1.68

The 10-year and 100-year high tides reach elevations of 5.7 and 6.2 ft NGVD respectively, at the slough mouth. These tides are not attenuated by slough channels and marsh vegetation as somewhat lower tides. Consequently, the 10-year high tide would completely inundate the marsh plain (including the area AA on Parcel 572), lapping against the dike and railroad embankments, and covering part of the contaminated KS area on Parcel 572. This tide would

reach under the trussel of the Southern Pacific tracks and inundate the lower portion of the contaminated K-2 area on Parcel 573 above the Southern Pacific tracks.

2.2.6.5 Ground Water

There is a ground water well on the Chemical and Pigment Company land located between the holding pond and the Sacramento Northern right-of-way. This well is not listed in the California Department of Water Resources Water Data Information System. In a study for the Chemical and Pigment Company, Kleinfelder and Associates (1983) installed and sampled three monitoring wells for zinc and copper. All samples were within drinking water standards for the two metals. Data are not available, however, for lead, arsenic, cadmium, or selenium for the monitoring wells or the supply well. Water samples from this well should be analyzed for the latter elements as well as the former. Kleinfelder found that the direction of water movement is toward the northeast.

Brown and Caldwell installed soil water extractors (lysimeters) at five locations in the contaminated area in 1985. Samples of soil water were collected from two depths (12 and 24 in.) and analyzed for arsenic, selenium, and heavy metals. The results suggested limited contamination of soil water at two locations. In the KS site of Parcel 572, a sample from 24 in. exceeded EPA criteria (1976) for drinking water by a factor of 80 for cadmium and by a factor of 28 for zinc; in the AA area of Parcel 572, the criteria were exceeded for arsenic by a factor of 3, at 12-in. depth. Unfortunately, the collection of water by the soil water extractors was not very successful, and only a few samples were analyzed.

The potential for ground-water contamination depends not only on the degree to which the metals are adsorbed or precipitated, but also on the permeability of the soil overlying the water table. A study by Harding-Lawson Associates (1977) found that although the peat of the undisturbed marsh is fairly permeable, the marsh soils are underlain 15 to 20 ft below the surface by a relatively impermeable layer of stiff sandy silt. The presence of this relatively impermeable layer makes contamination of the ground water unlikely. Lateral movement of contaminants within the surface permeable peat is

possible; however, peat has an exceptional adsorptive capacity for metals and would restrict migration laterally. In addition, metals are likely to be precipitated as sulfides and carbonates, further restricting their movement through the marsh soil.

Selenium, which is still present in the CP site on Parcel 581, is more mobile than most metal ions. While ground-water samples have not been analyzed for selenium, the CP site seems to represent a relatively small and localized potential source.

2.2.6.6 Modes of Transport of Contaminants

Analysis of water samples as well as the known physical chemistry of heavy metals indicates that the copper, zinc, lead, and cadmium on NWS Concord are most likely adsorbed or precipitated in relatively insoluble compounds (Huang et al. 1977). Though held in solid form, the contaminants may still be transported by water. Even relatively low water velocities could effectively move contaminated sediment.

Contaminated particles are moved by several different mechanisms individually or in combination.

2.2.6.6.1 Bank and surface erosion during flood flows on Nichols Creek

The HEC-2 results for discharges of 219 and 340 cfs suggest some inferences about potential erosion or deposition of sediment. Table 2-16 shows the calculated average velocities at the upper two cross sections that were used in the model. At section 8, Nichols Creek would spill into the old culverts; at section 9 (upstream from 8) it would flow into the cave-in and then into the ditch next to the Southern Pacific tracks. The results at section 9 show that at the higher discharge, velocity in the channel 9 is lower. This is because (in the model, at least) the flow is spread over a larger area. Maximum velocity along the bank at the outside of the channel bend would be greater than the average.

A simple calculation using the shield equation (Henderson 1966) indicates that at a flow of 219 cfs, the stream could theoretically entrain sediment particles as large as 0.6 in. in diameter at section 8 and even larger

particles at section 9. The actual erosion rate would depend on the degree of consolidation and density of vegetation.

Before the old culvert was diverted (probably in the 1960s), suspended solid material was deposited west of the Kiln Site below the Southern Pacific tracks. The results of computed water surface profiles indicated that flood flows from a 25-yr storm would carry suspended solids over the creek bank through the culvert onto Parcel 572 at the Kiln Site. Any contamination from ES (Parcel 579D), Parcel 576, and G-1 (Parcel 575) would be released onto Parcel 572.

Velocities in Nichols Creek adjacent to the Chemical Pigment Company (above the railroad tracks) were not calculated. Since the channel is narrower and steeper, velocity at this location should be greater than below the tracks. The culverts under the tracks might pond the stream temporarily. The magnitude of this effect would depend largely on the amount of sediment deposited in the culverts, which is not ascertainable for historic conditions.

2.2.6.6.2 Tidal Scouring

Once contaminated sediments have been deposited in the marsh, they are remobilized by tidal action. Sediments deposited in slough channels where velocities are higher can scour fairly rapidly and redistribute into the tidal drainage system, eventually moving out to Suisun Bay. Sediments deposited on the marsh plain tend to be less mobile because of lower velocities and lower frequency of inundation. The tidal frequency analysis indicates that a tide that would be expected on the average 1.3 times per year is capable of distributing fine sediment over much of the marsh plain.

The actual rate of spread of contaminants by tidal action depends on the interaction of several variables that are difficult to quantify. These include the particle size and density of contaminated sediment, the density of vegetation growing on contaminated areas of the marsh, and the magnitude and frequency of wind-generated waves during high tides. Regardless of the complexity of the mechanisms and variables involved, however, the distribution of heavy metal contaminants in the marsh indicated in Figure 2-90 corresponds to a large extent with the tidal drainage network.

2.2.6.6.3 Wave Action - Erosion of the Marsh Plain

Large amounts of contaminated sediment are mobilized by wave action during extreme tides. Extreme tides are caused by the superimposition of storm surges on normal high tides. These occur during the winter months and can be

accompanied by local storm conditions. For example a 10-yr high tide will flood the marsh plain to depths of about 2-1/2 ft. With the long fetch of Suisun Bay to the west, considerable wave action is generated that erodes surface sediments and redistributes such sediments on the marsh and into Suisun Bay. The erosion is limited by the presence of vegetation and the degree of cohesion of the sediment.

2.2.6.6.4 Wave Action - Erosion of the Bayward Margin

Intense wave action, even at normal high tides, cause erosion of the bayward margin of the marsh plain. In the past, the edge of the marsh has experienced both erosion and accretion. However, in the future, it is more likely to undergo additional erosion than accretion. This is due to the reduction of sediment supply to Suisun Bay over the last 50 yr caused by dam construction, the dissipation of the "wave" of sediment carried into the system due to hydraulic mining in the nineteenth century, and the sea-level rise. Sea-level rise is now predicted to accelerate due to global climatic changes (EPA 1983). This would cause substantial erosion of the shoreline, distributing deposited sediments into Suisun Bay.

2.2.6.6.5 Wind Erosion

The high energy wind environment on the site results in the transport of contaminated sediments by wind action. This process is limited by the presence of sheltering vegetation, the cohesion of the sediment, and wetting due to high water table. Frequent tidal inundation will tend to stabilize particles, consequently the drier, higher elevation areas such as the Kiln Site (KS) on Parcel 572 will be more susceptible to wind erosion.

Table 2-17 shows the percentage frequency of wind direction and speed at the Pittsburg power plant, on the shoreline a few miles east of the site. Velocity measurements were taken 33 ft above the ground, and wind speed at the soil surface would be less. The numbers indicate that 30.2 percent of the time, the wind blows from the southeast to west northwest at 13 mph or more, and that wind speeds exceeding 25 mph occur 0.5 percent of the time, or about 44 hr per yr.

Table 2-17

Percentage Frequency of Wind Direction and Speed at Pittsburg Power Plant

(from California DWR 1978)

SURFACE WINDS

PERCENTAGE FREQUENCY OF WIND DIRECTION AND SPEED (FROM HOURLY OBSERVATIONS)

STATION: Pittsburg Power Plant, CA (STATION NAME)

YEARS: December 1970 thru November 1973

ALL (MONTHS)

ALL WEATHER (CLASS)

ALL (HOURS (L.S.T.))

38°03', 121°54', 20' (LOCATION)

33 feet (HEIGHT ABOVE GROUND)

SPEED (MPH) DIR.	1-3	4-7	8-12	13-18	19-24	25-33	34-44					%	MEAN WIND SPEED
N	0.8	0.7	0.5	0.6	0.3	0.2	0.0					3.1	10.1
NNE	0.5	0.4	0.2	0.1	0.0	0.0						1.2	6.0
NE	0.7	0.7	0.1	0.0	0.0							1.6	4.8
ENE	0.7	1.3	0.3	0.0	0.0							2.4	4.8
E	1.5	2.7	0.9	0.2	0.0	0.0						5.3	5.5
ESE	1.3	1.7	1.0	0.3	0.1	0.0						4.5	6.5
SE	1.4	0.8	0.4	0.2	0.0							2.8	5.2
SSE	0.9	0.4	0.1	0.1	0.0							1.6	4.4
S	1.2	0.4	0.3	0.1	0.1	0.0						2.0	5.1
SSW	1.0	0.6	0.7	0.5	0.2	0.0	0.0					3.0	7.9
SW	1.1	1.8	3.9	1.4	0.7	0.1	0.0					11.9	11.3
WSW	0.9	2.6	7.4	8.2	1.9	0.0						21.1	12.2
W	1.0	3.0	7.6	8.9	1.8	0.0						22.3	12.1
WNW	0.7	1.8	3.3	3.8	0.4	0.0						10.0	11.0
NW	0.7	1.2	0.9	0.8	0.1	0.0						3.8	8.5
NNW	0.7	0.5	0.3	0.4	0.4	0.1						2.4	10.1
CALM												0.2	10.1
0.9	15.2	20.6	280	28.6	6.1	0.5	0.0					99.9	

DATA FROM Pacific Gas and Electric Company

TOTAL NUMBER OF OBSERVATIONS 23,568

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2.4 Appendixes

Appendix 2-A contains statistical comparison of mean values for sampling sites having triplicate samples. Data from each sampling site where three samples were collected were analyzed using analysis of variance and mean values were compared according to Duncan's New Multiple Range. Mean values within a column followed by different letters are significantly different at P=0.05. Mean values within a column followed by no letters are not significantly different from each other. The data in appendixes A thru E have the following units:

Variable	unit
WEIGHT,DRY_WT,TOT_WT,MTOT_WT,MYIELD	Grams(g)
LEAVES,STEMS,DEAD,SEED,OTHER	"
MAS (Arsenic), MCD(Cadmium),MCU(Copper), MPB(Lead), MNI(Nickel),MSE(Selenium),MZN (Zinc)As,Cd,Cu,Pb,Ni,Se,Zn	mg/kg or parts per million(ppm) " "
MUPTKAS,MUPTHCD,MUPTKCU,MUPTKPB, MUPTKNI,MUPTKSE,MUPTKZN	Milligrams(mg) "
VOLUME	Milliliter(ml)
EC(Electrical Conductivity)	Decisiman per Meter(dS/m)
T_SOLIDS,RWET_WT	PERCENT

ID No: AA SCW1241R1

AA - Sample site area
- AA: Allied A
- AB: Allied B
- KS: Kiln site
- K-2: K-2
- G-1: G-1 Getty
- ES: ES
- BK: Remote reference site
- CP: Coke pile site

SC - Sample type
- SC: Soil core - soil sample for chemical analysis
- PC: Plant core - soil sample for plant bioassay test
- AC: Animal core - soil sample for earthworm bioassay test
- CL: Clam bioassay sample

W1241 - Specific WES sample site location
- 124-1 Label for sample site
- 16u Label for sample site
- R1, R2, R3 Triplicate samples

2.4.1 Appendix 2-A Statistical Analysis of Triplicated Samples. Mean values compared by Duncans New Multiple Range test.

2.4.2 Appendix 2-B Soil Analyses, individual samples. QA/QC data on blanks, and National Bureau of Standards (NBS) river sediment.

2.4.3 Appendix 2-C Water Quality and Clam Analyses. Summary of field-collected water quality data on day 1 (28, 29 Aug 1985) and day 28 (25, 26 Sep 1985). Clam analyses, individual samples and QA/QC data on blanks and National Bureau of Standards oyster tissue.

2.4.4 Appendix 2-D Field and Greenhouse Plant Analyses, individual samples. QA/QC data on blanks and National Bureau of Standards (NBS) plant material.

2.4.5 Appendix 2-E Earthworm Analyses, individual samples. QA/QC data on blanks, National Bureau of Standards (NBS) oyster tissue, and earthworm tissue analysis from a reference manure media.

Table 2-A1

Soil Analysis

ID	MAS		MCD		MCU		MPB	MNI		MSE	MZN		MPH		MEC	
AASCW1241	8.6	E	0.92	F	40.8	DE	15.8	56.70	CDEF	0.00	148.9	D	6.5	GHIJKL	3.151	DEFGHIJK
AASCW1242	7.2	E	5.32	EF	60.0	DE	17.8	82.68	AB	0.00	281.0	D	6.1	IJKLMNO	4.483	ABCDEFGH
AASCW1243	6.4	E	1.33	EF	60.1	DE	17.3	82.75	AB	0.00	303.3	D	6.6	EFGHIJKL	2.343	FGHIJKL
AASCW1244	7.0	E	1.55	EF	50.8	DE	32.4	70.75	BCD	0.00	158.9	D	5.8	KLMNOPQ	2.967	DEFGHIJKLM
AASCW1245	21.0	E	0.77	F	53.3	DE	31.4	65.41	BCDE	0.02	167.1	D	4.8	QRS	7.004	A
AASCW1246	6.8	E	1.23	F	59.9	DE	19.7	78.84	ABC	0.00	312.7	D	6.2	IJKLMN	2.036	HIJKLM
AASCW16U1	957.5	B	23.92	A	703.6	A	127.5	43.82	EFGHI	4.75	2552.6	C	7.3	ABCDEFG	7.171	A
AASCW16U4	805.0	BC	1.33	EF	780.1	A	190.2	27.58	HIJK	0.71	328.3	D	5.1	OPQRS	5.243	ABCD
AASCW16V1	554.9	CD	3.95	EF	278.1	CDE	47.9	17.26	IJK	1.94	362.5	D	7.2	ABCDEFGJ	5.153	ABCDE
AASCW16V4	122.8	E	0.81	F	344.6	BC	27.9	16.89	JK	0.00	249.6	D	5.1	PQRS	4.721	ABCDEFG
AASCW16W1	2024.9	A	3.54	EF	547.0	AB	226.8	22.15	IJK	3.59	289.2	D	7.0	BCDEFGHI	6.824	AB
AASCW16W4	369.1	DE	2.12	EF	305.6	CD	178.2	31.17	GHIJ	0.55	333.7	D	5.4	MNOPQR	4.916	ABCDEF
AASCW16X1	119.1	E	0.89	F	178.4	CDE	22.9	16.23	JK	0.12	86.8	D	6.7	DEFGHIJK	4.757	ABCDEFG
AASCW16X4	544.2	CD	0.65	F	659.4	A	197.3	65.39	BCDE	0.30	661.5	D	5.0	PQRS	6.336	ABC
AASCW16Y1	60.4	E	0.61	F	173.3	CDE	98.0	53.47	DEFG	0.25	279.9	D	5.1	PQRS	4.613	ABCDEFG
AASCW16Y4	27.0	E	1.75	EF	68.7	DE	84.4	50.23	DEFGH	0.02	102.9	D	4.9	QRS	6.947	A
AASCW16Z1	14.6	E	0.36	F	79.0	DE	1.7	66.34	A	0.15	143.1	D	4.3	S	4.497	ABCDEFGH
BKSCW1161	5.6	E	1.48	EF	54.5	DE	33.4	72.80	BCD	0.00	127.6	D	5.9	KLMNOP	4.034	CDEFGHI
BKSCW1162	5.5	E	1.07	F	39.6	DE	17.2	82.28	AB	0.00	286.6	D	6.2	HIJKLMN	4.155	BCDEFGHI
BKSCW1331	0.2	E	0.39	F	8.3	E	15.4	11.47	JK	0.08	32.3	D	7.9	AB	1.104	JKLM
BKSCW1332	1.3	E	0.63	F	18.2	E	11.7	20.03	IJK	0.10	136.2	D	7.7	ABCD	2.019	GHIJKLM
BKSCW1333	1.3	E	0.07	F	10.6	E	2.2	16.88	JK	0.15	31.1	D	8.0	AB	2.222	FGHIJKLM
BKSCW1334	2.4	E	0.44	F	18.7	E	46.3	21.04	IJK	0.00	141.6	D	5.7	KLMNOPQ	0.397	LM
BKSCW1335	1.7	E	0.34	F	15.1	E	2.5	22.72	IJK	0.00	72.5	D	5.7	LMNOPQ	0.364	LM
BKSCW1336	1.6	E	0.36	F	15.3	E	33.8	16.91	JK	0.38	47.8	D	5.1	PQRS	0.329	LM
BKSCW1337	1.7	E	0.35	F	16.7	E	18.6	18.12	IJK	3.66	40.6	D	7.4	ABCDEF	1.768	HIJKLM
BKSCW1338	1.5	E	0.13	F	12.9	E	16.1	15.36	JK	11.16	29.3	D	8.1	A	0.331	LM
CPSCPCW27	9.2	E	8.32	DE	17.8	E	55.6	3.23	K	8.58	62.8	D	4.6	RS	4.003	CDEFGHI
CPSCPCW28	35.6	E	5.08	EF	48.5	DE	1485.4	22.17	IJK	27.67	157.0	D	5.2	NOPQRS	3.057	DEFGHIJKL
CPSCPCW29	9.8	E	3.70	EF	56.2	DE	101.5	11.78	JK	51.04	81.7	D	4.4	RS	3.507	DEFGHIJ
ESSCW13F2	1.5	E	0.72	F	24.4	E	52.8	17.44	IJK	0.00	148.1	D	7.9	ABC	0.675	KLM
ESSCW13F3	2.7	E	1.45	EF	32.9	E	75.7	19.36	IJK	0.00	329.1	D	6.3	GHIJKLM	0.287	M
ESSCW13H1	1.4	E	0.88	F	21.8	E	3.5	17.91	IJK	0.00	265.0	D	7.5	ABCDE	1.094	JKLM
ESSCW14F1	2.1	E	0.80	F	27.1	E	85.3	19.82	IJK	0.08	385.1	D	7.6	ABCD	2.464	EFGHIJKLM
G1SCW13L4	3.5	E	12.69	CD	40.1	DE	221.9	19.98	IJK	0.20	2511.4	C	7.8	ABC	2.671	DEFGHIJKLM
G1SCW13M1	3.2	E	15.22	BC	56.9	DE	142.7	21.38	IJK	0.00	4081.7	B	7.7	ABC	0.870	JKLM
K2SCPCW8P	2.7	E	20.64	AB	161.8	CDE	95.1	18.87	IJK	0.03	6514.1	A	7.1	ABCDEFGHI	0.701	KLM
K2SCW4N1R	5.3	E	0.57	F	40.4	DE	18.9	32.69	FGHIJ	0.00	337.7	D	6.9	CDEFGHI	1.476	IJKLM

Table 2-A2

Clam Tissue Analysis

ID	MAS		MCD		MCU		MPB		MNI	MSE		MZN	
AACLW1241	2.01	AB	0.71	CD	66.32	ABCDEFGH	0.29	C	1.07	0.99	HIJ	119.78	EFG
AACLW1242	1.72	ABCDEFGH	1.39	B	68.23	ABCDEFG	0.26	C	0.43	1.40	EF	152.58	DE
AACLW1243	1.80	ABCDEFG	2.02	A	63.46	BCDEFGHIJ	0.40	C	2.04	1.00	HIJ	139.31	EDGF
AACLW1244	1.91	ABCD	0.63	D	78.93	AB	0.37	C	0.96	1.07	GHIJ	141.28	DEF
AACLW1245	1.85	ABCDEF	0.59	D	56.63	DEFGHI	0.41	C	4.24	0.94	IJ	128.45	EDGF
AACLW1246	1.89	ABCDEF	1.23	BC	63.38	BCDEFGHIJ	0.28	C	0.46	1.03	HIJ	126.65	EDGF
AACLW16V2	1.90	ABCDE	0.96	BCD	51.97		0.15	C	0.19	0.99	HIJ	109.01	GF
AACLW16V3	1.30	DEFGH	0.86	CD	47.67		0.06	C	0.15	0.98	HIJ	107.07	GF
AACLW16V4	1.43	BCDEFGH	0.89	BCD	51.55		0.40	C	0.34	1.11	GHI	123.45	EGF
AACLW16Z4	1.94	ABC	0.90	BCD	75.41	ABC	0.47	C	1.09	1.05	GHIJ	117.48	GF
BACLW1161	1.88	ABCDEF	0.87	CD	80.09	A	0.27	C	1.38	1.05	GHIJ	128.87	EDGF
BACLW1162	1.96	ABC	0.72	CD	64.28	ABCDEFGHI	0.28	C	0.52	1.00	HIJ	129.39	EDGF
BACLW1331	2.26	A	0.84	CD	71.38	ABCDE	0.58	C	1.40	2.03	A	120.43	EGF
BACLW1332	1.71	ABCDEFGH	0.63	D	48.02		1.01	C	1.09	1.95	AB	125.47	EDGF
BACLW1333	2.12	A	0.72	CD	54.39		0.43	C	0.81	1.86	ABC	110.32	GF
BACLW1334	2.03	AB	0.75	CD	59.96	CDEFGHIJ	0.79	C	1.45	1.45	EF	106.11	G
BSCLW13H1	1.94	ABC	1.11	BCD	60.14	CDEFGHIJ	0.81	C	0.53	1.94	AB	125.15	EDGF
BSCLW13J1	1.38	CDEFGH	1.12	BCD	54.01		0.77	C	0.74	1.74	BCD	133.28	EDGF
BSCLW13K1	1.15	H	0.92	BCD	61.75	CDEFGHIJ	1.31	C	1.83	1.41	EF	157.42	D
BSCLW13L1	1.44	BCDEFGH	0.96	BCD	72.53	ABCD	3.21	B	3.38	1.73	BCD	235.78	AB
BSCLW14F1	1.99	ABC	0.76	CD	55.01		0.76	C	1.29	1.82	ABC	132.87	EDGF
GICLW12N2	1.27	FGH	1.05	BCD	65.54	ABCDEFGH	5.31	A	0.26	1.33	EFG	208.16	BC
GICLW13L4	1.17	H	1.40	B	69.22	ABCDEF	3.50	C	0.15	1.60	CDE	255.76	A
GICLW13M1	1.22	GH	1.22	BC	66.39	ABCDEFGH	6.12	A	0.26	1.47	DEF	199.64	C
KSCLW4R1R	1.20	GH	0.63	D	51.04		0.11	C	0.37	0.81	J	138.69	EDGF
KSCLWBP3R	1.28	FGH	0.92	BCD	76.30	ABC	5.82	A	0.06	1.28	FGH	212.24	BC

Table 2-A3

Field Analysis

ID	MAS	MCD	MCU	MPB	MNI	MSE	MZN
AAPVW1241	0 00 C	0. 09 DE	3. 87 DEF	0. 47 C	5. 48 AB	0. 00	12. 76 C
AAPVW1242	0 00 C	0. 09 DE	5. 00 CDEF	0. 83 C	2 98 CDEFG	0. 00	13. 17 C
AAPVW1243	0 03 C	0. 08 DE	5. 19 CDEF	0. 45 C	3. 20 CDEF	0. 00	19. 96 C
AAPVW1244	0 00 C	0. 10 DE	3. 39 EF	0. 54 C	4. 44 BCD	0. 00	14 28 C
AAPVW1245	0. 00 C	0. 20 CDE	4. 31 DEF	1. 07 C	3. 29 CDEF	0. 00	11. 97 C
AAPVW1246	0. 00 C	0. 10 DE	3. 73 DEF	0. 23 C	1. 60 FGHIJ	0. 00	16. 47 C
AAPVW16U1	0. 94 B	0. 08 DE	7. 10 ABC	1. 11 C	1. 12 HIJ	0. 00	34. 13 C
AAPVW16U4	0 56 B	0. 11 DE	3. 33 EF	1. 40 C	1. 19 HIJ	0. 00	24. 63 C
AAPVW16V1	0. 92 A	0. 14 CDE	7. 14 ABC	0. 75 C	0. 91 IJ	0. 00	23. 17 C
AAPVW16V4	0 66 AB	0. 14 CDE	3. 60 DEF	1. 96 C	1. 39 GHIJ	0. 00	30. 27 C
AAPVW16W4	0. 87 A	0. 19 CDE	3. 74 DEF	1. 32 C	1. 47 GHIJ	0. 00	51. 26 C
AAPVW16X1	0. 37 B	0. 05 E	4. 04 DEF	0. 63 C	1. 28 HIJ	0. 00	28. 35 C
AAPVW16X4	0 55 B	0. 12 DE	5. 76 BCDE	1. 82 C	3. 23 CDEF	0. 00	48. 23 C
AAPVW16Y1	0 06 C	0. 08 DE	4. 48 DEF	1. 11 C	2. 53 EFGHI	0. 00	40 22 C
AAPVW16Y4	0 00 C	0. 07 DE	4. 20 DEF	1. 09 C	3. 82 CDE	0. 00	20. 71 C
AAPVW16Z1	0. 01 C	0. 19 CDE	2. 90 F	0. 49 C	3. 00 CDEFG	0. 00	12. 03 C
BKPVW1161	0. 00 C	0. 13 DE	7. 94 AB	0. 72 C	4. 53 BC	0. 00	14. 23 C
BKPVW1162	0 00 C	0. 11 DE	5. 44 CDE	0. 44 C	8. 01 BCDE	0. 00	17. 46 C
BKPVW1337	0 00 C	0. 35 BC	2. 68 F	0. 72 C	2. 78 DEFGH	0. 00	43. 40 C
G1PVW13L4	0. 00 C	1. 26 A	8. 44 A	27. 05A	0 80 IJ	0. 02	123. 77 B
G1PVW13M1	0. 00 C	0. 27 BCD	3. 92 DEF	3. 28 C	1. 07 HIJ	0. 00	275. 68 A
K2PVW4N1R	0. 01 C	0. 11 DE	6. 09 ABCD	0. 79 C	6. 22 A	0. 00	47. 86 C
K2PVW8P3R	0. 01 C	0. 43 B	8. 24 A	15. 47B	0. 78 J	0. 02	302. 55 A

Table 2-A4

Field Total Uptake

ID	MUPTKAS		MUPTKCD		MUPTKCU		MUPTKPB		MUPTKNI		MUPTKSE	MUPTKZN		MYIELD	
AAPVW1241	0.00	D	22.05	B	1314.88	C	176.52	C	1964.15	A	0.00	4277.16	D	346.52	B
AAPVW1242	0.00	D	19.27	B	1087.61	C	181.10	C	651.49	BCD	0.00	2847.61	D	216.58	BCD
AAPVW1243	2.13	D	7.64	B	455.39	C	40.15	C	273.86	BCDE	0.00	1670.24	D	87.60	DEF
AAPVW1244	0.00	D	18.40	B	554.88	C	94.87	C	740.22	BC	0.00	2388.17	D	170.86	CDEF
AAPVW1245	0.00	D	44.22	B	1010.64	C	256.77	C	772.33	B	0.00	2709.77	D	216.44	BCD
AAPVW1246	0.00	D	18.09	B	803.35	C	45.17	C	359.09	BCDE	0.00	3582.04	D	216.62	BCD
AAPVW16U1	18.09	BC	2.98	B	276.18	C	48.52	C	49.12	E	0.00	1421.66	D	37.84	F
AAPVW16U4	49.42	C	11.63	B	288.91	C	122.05	C	98.86	DE	0.00	2064.76	D	88.60	DEF
AAPVW16V1	43.23	BC	6.10	B	304.60	C	34.10	C	41.94	E	0.00	1007.81	D	44.14	F
AAPVW16V4	82.36	A	20.26	B	473.39	C	274.85	C	167.25	CDE	0.00	4003.52	D	142.61	DEF
AAPVW16W4	90.94	A	16.95	B	372.36	C	163.12	C	147.39	CDE	0.00	5075.65	D	103.02	DEF
AAPVW16X1	42.01	BC	4.21	B	394.27	C	68.47	C	137.29	DE	0.00	2913.63	D	100.31	DEF
AAPVW16X4	49.85	B	11.21	B	569.42	C	167.31	C	305.36	BCDE	0.00	4546.85	D	93.61	DEF
AAPVW16Y1	4.70	D	5.62	B	336.92	C	81.10	C	192.91	BCDE	0.00	3078.53	D	75.09	DEF
AAPVW16Y4	0.00	D	4.77	B	280.91	C	74.62	C	261.14	BCDE	0.00	1419.74	D	67.93	DEF
AAPVW16Z1	1.79	D	33.77	B	626.78	C	94.08	C	636.58	BCDE	0.00	2563.44	D	209.04	BCDE
BKPVW1161	0.00	D	16.00	B	1224.05	C	113.02	C	646.72	BCD	0.00	2017.70	D	133.49	DEF
BKPVW1162	0.00	D	13.62	B	773.11	C	58.00	C	541.73	BCDE	0.00	2087.81	D	139.15	DEF
BKPVW1337	0.00	D	19.21	B	127.84	C	34.79	C	128.68	DE	0.00	2089.20	D	48.62	EF
G1PVW13L4	0.00	D	639.25	A	4480.36	A	13034.31	A	418.69	BCDE	8.55	65216.16	B	512.97	A
G1PVW13M1	0.00	D	49.34	B	667.09	C	527.06	C	175.62	CDE	0.00	48744.31	C	167.54	CDEF
K2PVW4N1R	0.44	D	5.52	B	307.00	C	39.85	C	316.91	BCDE	0.00	2413.26	D	50.19	EF
K2PVW8P3R	2.39	D	108.77	B	2555.21	B	3736.08	B	209.48	BCDE	12.21	83119.37	A	318.31	BC

Table 2-A5

GREENHOUSE FLOODED PLANT ANALYSIS

OBS	ID	MAS	MCD	MCU	MPB	MNI	MSE	MZN	MTOT_WT
1	AAPCW1242	0.10 B	0.33 BC	3.13 BCD	0.13	0.99	0.00	35.59 C	8.43 BCD
2	AAPCW1243	0.23 B	0.06 C	3.04 BCD	0.07	0.74	0.00	19.17 C	10.08 BC
3	AAPCW1244	0.50 B	0.11 C	1.99 D	0.12	0.52	0.00	17.53 C	5.29 CD
4	AAPCW1245	0.00 B	0.04 C	4.47 BCD	0.11	1.01	0.00	20.34 C	7.53 BCD
5	AAPCW1246	0.18 B	0.12 C	3.68 BCD	0.06	0.67	0.00	27.33 C	8.86 BCD
6	AAPCW16U1	10.9 A	0.62 BC	5.33 BCD	1.94	0.35	0.00	24.70 C	0.72 D
7	AAPCW16U4	1.07 B	0.23 BC	4.78 BCD	0.72	0.67	0.00	18.87 C	1.43 D
8	AAPCW16V4	2.43 B	0.16 C	5.39 BCD	0.40	0.46	0.00	18.27 C	1.63 D
9	AAPCW16W1	2.36 B	0.71 BC	5.21 BCD	1.24	1.14	0.00	32.58 C	0.74 D
10	AAPCW16W4	1.35 B	0.42 BC	3.76 BCD	0.35	0.16	0.00	16.93 C	2.18 CD
11	AAPCW16Y4	0.00 B	0.10 C	7.11 C	0.43	0.93	0.00	36.02 C	1.07 D
12	BKPCW1162	0.26 B	0.04 C	3.73 BCD	0.16	0.45	0.00	25.26 C	4.80 CD
13	BKPCW1331	0.00 B	0.09 C	2.34 CD	0.46	0.76	0.00	27.93 C	4.93 CD
14	BKPCW1332	0.00 B	0.16 C	1.66 D	0.58	0.05	0.00	22.31 C	30.57 A
15	BKPCW1333	0.00 B	0.08 C	1.65 D	0.23	0.58	0.00	25.11 C	14.83 B
16	BKPCW1337	0.00 B	0.21 BC	3.95 BCD	0.21	0.21	0.00	39.01 C	1.44 D
17	ESPCW13H1	0.00 B	0.40 BC	4.36 BCD	0.39	1.91	0.00	26.59 C	7.16 CD
18	ESPCW14F1	0.00 B	0.25 BC	2.43 CD	0.32	1.69	0.00	23.95 C	3.72 CD
19	G1PCW13L4	0.12 B	0.36 BC	2.16 D	4.05	0.78	0.00	51.83 C	1.64 D
20	G1PCW13M1	0.07 B	1.10 B	6.91 BC	1.36	1.06	0.00	219.26 B	1.58 D
21	K2PCWBP3R	0.00 B	4.27 A	14.71 A	5.34	3.14	0.00	659.97 A	0.76 D

Table 2-A6

FLOODED TOTAL UPTAKE

OBS	ID	MAS	MCD	MCU	MPB	MNI	MSE	MZN	
1	AAPCW1242	1.27	3.34 AB	21.04 BCDE	1.38 B	4.47 BC	0.00	231.18	CDE
2	AAPCW1243	2.57	0.76 BC	29.45 ABC	0.81 B	7.36 ABC	0.00	186.63	CDE
3	AAPCW1244	1.53	0.70 BC	9.15 ED	0.34 B	2.34 BC	0.00	102.33	DE
4	AAPCW1245	0.00	0.28 BC	38.83 AB	0.54 B	8.73 AB	0.00	159.81	CDE
5	AAPCW1246	1.66	0.83 BC	31.63 ABC	0.58 B	6.01 ABC	0.00	238.14	CDE
6	AAPCW16U1	7.71	0.35 BC	3.77 ED	0.97 B	0.21 C	0.00	14.77	E
7	AAPCW16U4	1.73	0.32 BC	7.44 ED	0.91 B	1.02 BC	0.00	27.27	E
8	AAPCW16V4	4.32	0.32 BC	9.24 ED	0.81 B	0.93 BC	0.00	33.77	E
9	AAPCW16W1	1.94	0.43 BC	3.80 ED	0.76 B	0.70 BC	0.00	21.42	E
10	AAPCW16W4	2.65	1.13 BC	9.02 ED	0.59 B	0.60 BC	0.00	48.73	E
11	AAPCW16Y4	0.00	0.11 C	7.05 ED	0.48 B	1.00 BC	0.00	37.69	E
12	BKPCW1162	0.54	0.15 C	19.28 CDE	0.31 B	2.04 BC	0.00	123.28	CDE
13	BKPCW1331	0.00	0.83 BC	8.16 ED	1.70 B	2.17 BC	0.00	105.03	DE
14	BKPCW1332	0.00	5.58 A	47.10 A	22.06 A	1.28 BC	0.00	670.60	A
15	BKPCW1333	0.00	1.02 BC	23.24 BCD	2.52 B	8.49 ABC	0.00	368.83	BC
16	BKPCW1337	0.00	0.11 C	2.91 E	0.42 B	0.43 BC	0.00	39.09	
17	ESPCW13H1	0.00	2.95 ABC	31.29 ABC	2.74 B	12.90 A	0.00	188.68	CDE
18	ESPCW14F1	0.00	1.06 BC	9.33 ED	1.26 B	7.58 ABC	0.00	90.81	DE
19	G1PCW13L4	0.24	0.67 BC	3.72 ED	6.11 B	1.15 BC	0.00	80.46	DE
20	G1PCW13M1	0.13	1.72 BC	10.98 ED	2.16 B	1.69 BC	0.00	320.76	BCD
21	K2PCW8P3R	0.00	2.81 ABC	10.39 ED	2.34 B	1.46 BC	0.00	518.76	AB

Table 2-A7

GREENHOUSE UPLAND PLANT ANALYSIS

OBS	ID	MAS	MCD	MCU	MPB	MNI	MSE	MZN	MTOT_WT
1	BKPCW1334	0.00	1.78	7.80	0.22	2.85	0.00	171.38 A	4.26
2	BKPCW1335	0.00	0.55	4.81	0.26	2.75	0.00	38.23 B	3.46
3	BKPCW1336	0.00	1.16	5.60	0.63	1.75	0.00	51.76 B	4.83
4	BKPCW1338	0.00	0.18	6.08	0.30	1.34	0.00	35.29 B	3.21
5	CPPCW28F1	0.53	6.67	7.98	22.13	2.75	3.79	60.42 B	5.80
6	ESPCW13F2	0.00	9.19	6.53	0.35	1.34	0.00	71.88 B	3.84
7	ESPCW13F3	0.00	1.31	6.95	1.38	2.06	0.00	205.55 A	2.56

Table 2-A8

UPLAND TOTAL UPTAKE

OBS	ID	MAS	MCD	MCU	MPB	MNI	MSE	MZN
1	BKPCW1334	0.00	7.56	33.17	0.94	12.24	0.00	734.99
2	BKPCW1335	0.00	1.77	15.67	0.87	10.45	0.00	123.19
3	BKPCW1336	0.00	5.48	26.80	2.64	8.12	0.00	256.24
4	BKPCW1338	0.00	0.56	19.24	0.87	3.87	0.00	113.11
5	CPPCW28F1	2.77	42.71	41.58	112.91	15.54	19.37	412.01
6	ESPCW13F2	0.00	20.87	26.07	1.75	4.62	0.00	288.00
7	ESPCW13F3	0.00	3.95	21.13	2.24	3.78	0.00	467.68

Table 2-A9

Earthworm Tissue Analysis

ID1	MAS		MCD		MCU		MPB		MNI		MSE		MZN
AAEACW1241	7.86	E	4.12	DEF	11.07	B	0.78	B	5.07	ABCDEFG	4.02	B	111.16
AAEACW1242	4.07	E	4.69	DEF	10.29	B	0.20	B	4.49	ABCDEFGHI	3.54	B	172.30
AAEACW1243	2.64	E	5.11	DEF	10.95	B	0.37	B	1.95	DEFGHI	4.67	B	115.03
AAEACW1244	3.24	E	3.09	EF	9.61	B	0.22	B	7.87	A	3.70	B	121.83
AAEACW1245	5.77	E	2.43	F	10.54	B	0.38	B	4.08	ABCDEFGHI	4.31	B	181.52
AAEACW1246	3.42	E	5.94	CDEF	9.59	B	0.35	B	1.87	DEFHI	3.85	B	273.81
AAEACW16U4	120.84	A	2.65	EF	53.53	A	9.37	B	1.52	EFGHI	4.49	B	117.87
AAEACW16V4	109.69	A	3.49	EF	23.65	B	1.33	B	0.55	I	3.55	B	117.52
AAEACW16W1	58.11	B	5.71	CDEF	23.58	B	2.19	B	5.25	ABCDEF	2.78	B	135.72
AAEACW16W4	110.04	A	2.98	EF	16.68	B	1.27	B	0.86	HI	3.69	B	117.29
AAEACW16X1	41.12	C	1.76	F	14.00	B	0.08	B	1.08	GHI	3.85	B	117.66
AAEACW16X4	26.47	D	3.55	EF	18.79	B	6.69	B	1.97	DEFGHI	3.57	B	184.96
AAEACW16Y1	3.93	E	1.60	F	18.14	B	2.24	B	1.42	EFGHI	3.71	B	116.35
AAEACW16Y4	2.72	E	2.85	EF	11.19	B	8.42	B	2.06	DEFGHI	3.45	B	144.49
AAEACW16Z1	3.30	E	3.42	EF	13.32	B	1.54	B	6.44	AB	3.35	B	208.05
BKEACW1161	2.95	E	4.05	DEF	11.84	B	0.64	B	5.41	ABCDE	3.40	B	124.36
BKEACW1162	2.78	E	4.42	DEF	8.96	B	0.53	B	3.27	BCDEFGHI	3.77	B	118.13
BKEACW1331	3.36	E	3.99	DEF	13.20	B	.	B	4.69	ABCDEFGH	4.22	B	113.03
BKEACW1332	5.92	E	3.28	EF	12.55	B	2.59	B	6.12	ABC	6.14	B	116.27
BKEACW1333	3.94	E	2.87	EF	9.52	B	0.03	B	1.51	EFGHI	7.78	B	118.89
BKEACW1334	1.42	E	8.19	CD	8.32	B	4.40	B	5.46	ABCD	3.44	B	128.14
BKEACW1335	1.89	E	5.31	DEF	9.65	B	1.38	B	4.01	ABCDEFGHI	2.71	B	137.72
BKEACW1336	1.51	E	9.70	BC	9.51	B	4.06	B	5.84	ABCD	3.12	B	122.09
BKEACW1337	6.65	E	3.41	EF	10.01	B	0.26	B	2.16	CDEFGHI	6.48	B	146.78
BKEACW1338	4.49	E	4.55	DEF	9.88	B	1.66	B	2.13	CDEFGHI	3.06	B	119.48
CPEACW28F1	8.38	E	21.43	A	16.78	B	37.64	A	1.99	DEFGHI	36.64	A	124.27
CPEACW29E1	2.82	E	4.77	DEF	53.35	A	1.32	B	4.56	ABCDEFGHI	41.43	A	128.02
ESEACW13F2	5.99	E	5.00	DEF	10.49	B	1.42	B	2.71	BCDEFGHI	6.04	B	119.19
ESEACW13F3	3.90	E	13.20	B	13.03	B	8.39	B	4.09	ABCDEFGHI	5.52	B	127.28
ESEACW13H1	4.57	E	4.59	DEF	10.95	B	2.17	B	2.44	CEDFGHI	5.32	B	121.44
ESEACW14F1	5.92	E	3.20	EF	9.82	B	3.01	B	2.99	BCDEFGHI	5.51	B	145.88
Q1EACW13L4	14.80	DE	5.55	CDEF	10.97	B	8.05	B	2.84	BCDEFGHI	8.09	B	139.05
Q1EACW13M1	13.76	DE	7.19	CDE	11.72	B	6.54	B	2.20	CDEFGHI	5.31	B	173.71
K2EACW4N1R	4.01	E	3.58	EF	12.08	B	2.07	B	4.44	ABCDEFGHI	4.42	B	151.75
K2EACW8P3R	3.56	E	19.77	A	65.17	A	33.36	A	1.23	FGHI	4.07	B	208.42

Table 2-B1.

Soil Analysis

OBS	ID	WEIGHT	AS	CD	CU	PB	N.	SE	ZN	PH	LOCATION	EC
.	AASCW1241R1	1.00	9.50	1.17	51.98	1.97	71.96	0.00	219.1	6.6	1	4.294
2	AASCW1241R2	1.00	11.24	0.90	44.38	45.37	60.00	0.00	160.4	6.3	2	0.007
3	AASCW1241R3	1.00	4.98	0.68	26.07	0.00	38.95	0.00	67.3	6.6	3	5.153
4	AASCW1242R1	1.01	7.70	0.70	54.65	2.25	75.10	0.00	253.0	5.7	4	7.210
5	AASCW1242R2	1.00	7.00	1.04	60.98	2.42	84.16	0.00	323.6	6.3	5	3.120
6	AASCW1242R3	1.00	6.84	14.23	64.35	48.82	88.28	0.00	266.5	6.3	6	3.120
7	AASCW1243R1	1.00	6.89	1.05	66.41	0.41	85.77	0.00	336.2	6.5	7	2.120
8	AASCW1243R2	1.00	6.50	0.96	58.98	1.87	80.56	0.00	306.1	6.6	8	2.576
9	AASCW1243R3	1.00	5.93	1.99	54.76	49.72	81.73	0.00	267.5	6.6	9	2.332
10	AASCW1244R1	1.00	7.39	2.36	53.37	49.32	74.91	0.00	154.2	6.5	10	3.616
11	AASCW1244R2	1.00	4.23	1.62	44.60	46.73	62.80	0.00	135.0	5.3	11	2.710
12	AASCW1244R3	1.00	9.50	0.67	54.48	1.07	74.56	0.00	187.6	5.5	12	2.576
13	AASCW1245R1	1.00	13.20	0.63	57.75	48.72	72.76	0.00	167.9	6.2	13	3.529
14	AASCW1245R2	1.00	23.25	0.89	56.48	1.57	73.06	0.00	223.6	4.6	14	9.369
15	AASCW1245R3	1.00	26.67	0.81	45.69	43.78	50.40	0.05	109.7	3.6	15	8.115
16	AASCW1246R1	1.00	6.34	1.25	68.41	56.86	81.87	0.00	371.2	5.8	16	2.061
17	AASCW1246R2	1.00	7.00	1.03	56.98	1.17	80.56	0.00	278.6	6.4	17	2.156
18	AASCW1246R3	1.00	6.99	1.41	54.42	1.16	74.48	0.00	288.3	6.4	18	1.890
19	AASCW16U1R1	1.00	1374.75	4.71	1204.48	76.41	30.66	11.75	853.1	7.3	19	11.450
20	AASCW16U1R2	1.00	447.96	28.55	281.85	64.66	39.75	0.35	2806.8	7.2	20	4.910
21	AASCW16U1R3	1.00	1049.75	38.51	624.48	241.41	61.05	2.15	3998.1	7.3	21	5.153
22	AASCW16U2	1.00	151.79	13.32	446.14	85.16	23.18	0.35	1393.9	7.4	22	5.153
23	AASCW16U3	1.00	408.12	1.34	507.45	159.28	25.25	1.25	318.8	5.1	23	5.153
24	AASCW16U4R1	1.00	99.55	0.33	392.69	4.41	13.73	0.00	299.5	4.9	24	5.153
25	AASCW16U4R2	1.00	524.75	0.46	679.48	137.42	19.71	0.00	247.6	5.5	25	5.424
26	AASCW16U4R3	1.01	1790.80	3.19	1268.14	428.77	49.91	2.14	437.9	5.0	26	5.153
27	AASCW16V1R1	1.00	201.85	0.75	103.27	50.31	10.73	0.10	135.8	7.4	27	5.153
28	AASCW16V1R2	1.00	194.36	8.34	89.80	14.39	18.17	0.00	461.1	7.1	28	5.153
29	AASCW16V1R3	1.01	1268.41	2.75	641.27	79.02	22.89	5.72	490.6	7.1	29	5.153
30	AASCW16V2	1.00	798.15	6.20	608.26	145.62	57.84	2.20	1674.7	6.0	30	4.294
31	AASCW16V3	1.01	139.05	0.16	237.29	5.29	19.56	0.00	183.1	4.8	31	4.685
32	AASCW16V4R1	1.01	111.69	0.30	211.42	3.55	16.72	0.00	228.9	5.4	32	4.685
33	AASCW16V4R2	1.00	249.25	1.63	742.99	74.27	20.96	0.00	290.0	4.9	33	4.793
34	AASCW16V4R3	1.00	7.49	0.50	79.40	5.91	12.99	0.00	229.8	4.9	34	4.684
35	AASCW16W1R1	1.01	2484.84	5.33	580.99	243.95	29.18	2.49	544.8	6.8	35	4.910
36	AASCW16W1R2	1.00	2041.58	2.35	495.99	339.56	19.23	4.03	166.4	6.9	36	10.410
37	AASCW16W1R3	1.00	1548.20	2.96	563.91	96.82	18.04	4.25	156.4	7.2	37	5.153
38	AASCW16W2	1.00	174.58	1.35	94.88	1.51	19.24	0.00	218.8	4.4	38	5.757
39	AASCW16W3	1.01	521.62	3.74	526.32	140.57	41.56	1.29	644.2	5.4	39	5.153
40	AASCW16W4R1	1.00	423.90	2.46	323.83	256.40	41.02	0.85	423.7	5.1	40	4.910
41	AASCW16W4R2	1.00	184.57	3.61	160.82	68.85	21.78	0.05	401.2	5.6	41	5.153
42	AASCW16W4R3	1.00	498.75	0.30	432.11	209.50	30.69	0.75	176.2	5.4	42	4.684
43	AASCW16X1R1	1.00	73.53	1.80	170.97	10.13	14.01	0.00	79.3	6.8	43	4.910
44	AASCW16X1R2	1.00	124.75	0.66	224.98	30.42	16.15	0.00	99.1	6.4	44	4.680
45	AASCW16X1R3	1.01	158.96	0.21	139.28	28.27	18.51	0.35	82.1	6.9	45	4.680
46	AASCW16X2	1.00	1593.38	3.00	281.85	141.35	13.65	1.79	97.2	5.4	46	4.480
47	AASCW16X3	1.00	1394.17	0.36	527.37	141.35	40.19	0.65	355.6	5.1	47	4.910
48	AASCW16X4R1	1.00	449.30	0.60	643.83	125.29	64.99	0.35	692.4	5.0	48	6.736
49	AASCW16X4R2	1.00	164.59	0.78	678.80	107.31	83.97	0.15	757.3	5.1	49	4.910
50	AASCW16X4R3	1.01	1018.64	0.57	655.55	359.26	47.22	0.40	534.8	4.9	50	7.361
51	AASCW16Y1R1	1.00	40.25	0.51	187.48	103.91	56.55	0.10	337.1	5.4	51	4.480
52	AASCW16Y1R2	1.00	119.63	0.44	183.30	106.31	48.41	0.60	187.9	4.4	52	4.680
53	AASCW16Y1R3	1.00	21.21	0.89	149.18	83.75	55.44	0.05	314.9	5.3	53	4.680
54	AASCW16Y2	1.00	29.72	0.43	126.35	79.84	61.99	0.00	209.8	4.9	54	4.910

Table 2-B1.
(Continued)

ID	WEIGHT	AS	CD	CU	PB	NI	SE	ZN	PH	LOCATION	EC
AAECW16Y3	1.00	28.44	0.72	87.80	49.82	54.9	0.25	108.3	5.7	55	6.780
AAECW16Y4R1	1.01	16.67	0.37	58.69	103.40	61.7	0.00	147.3	5.1	56	8.379
AAECW16Y4R2	1.00	39.63	0.66	69.77	97.12	43.7	0.00	81.8	5.0	57	5.102
AAECW16Y4R3	1.01	24.60	4.21	77.51	52.60	45.1	0.05	79.6	4.4	58	7.361
AAECW16Z1R1	1.01	10.20	0.38	46.44	0.00	58.7	0.00	106.5	5.1	59	4.910
AAECW16Z1R2	1.00	11.98	0.14	95.79	2.06	65.4	0.05	157.7	4.1	60	3.553
AAECW16Z1R3	1.00	21.68	0.57	92.70	2.96	74.8	0.40	165.1	3.8	61	5.027
AAECW16Z2	1.01	7.21	0.16	55.20	0.16	67.7	0.00	128.4	4.8	62	5.285
AAECW16Z3	1.00	5.73	0.19	41.95	0.81	49.4	0.00	78.3	4.8	63	2.061
AAECW16Z4	1.00	17.71	0.00	65.85	1.21	76.4	0.45	148.3	4.4	64	6.870
AAECW16Z5	1.00	5.15	0.05	25.33	0.00	38.4	0.00	50.1	4.0	65	3.817
AAECW16Z6	1.00	16.75	0.19	53.98	0.77	44.3	0.00	97.6	5.4	66	3.220
AAECW16Z7	1.00	7.75	0.70	57.98	1.07	70.0	0.00	150.1	6.1	67	4.385
BAECW1161R1	1.00	3.80	0.26	39.13	0.00	49.0	0.00	78.1	6.0	74	2.712
BAECW1161R2	1.00	6.35	0.68	51.48	52.42	82.5	0.00	149.6	6.0	75	4.727
BAECW1161R3	1.00	6.63	3.50	72.76	47.77	86.7	0.00	155.1	5.8	76	4.663
BAECW1162R1	1.00	5.85	0.75	60.48	4.26	83.0	0.00	250.6	6.4	77	2.061
BAECW1162R2	1.00	4.84	1.04	55.37	45.32	81.3	0.00	137.8	6.6	78	6.441
BAECW1162R3	1.00	5.94	1.42	62.85	1.91	82.3	0.00	471.6	5.7	79	3.964
BAECW1331R1	1.00	0.05	0.4	11.92	32.88	13.0	0.00	32.5	8.1	80	1.222
BAECW1331R2	1.01	0.25	0.24	7.44	12.35	11.6	0.25	32.4	7.8	81	1.171
BAECW1331R3	1.00	0.25	0.47	5.46	0.91	9.7	0.00	31.9	7.9	82	0.920
BAECW1332R1	1.00	1.65	0.89	18.04	2.36	20.71	0.10	160.7	7.6	83	1.198
BAECW1332R2	1.00	1.15	0.55	17.46	24.89	18.79	0.10	88.0	7.7	84	1.040
BAECW1332R3	1.00	1.25	0.43	19.21	7.81	20.58	0.10	159.9	7.8	85	3.820
BAECW1333R1	1.00	1.85	0.00	13.73	3.62	21.05	0.00	42.6	8.1	86	2.100
BAECW1333R2	1.00	1.05	0.15	9.40	3.06	17.5	0.00	25.7	7.9	87	2.169
BAECW1333R3	1.00	1.15	0.05	8.55	0.00	12.0	0.45	25.0	7.9	88	2.397
BAECW1334R1	1.00	2.94	0.08	21.56	59.74	18.2	0.00	208.4	5.7	89	0.448
BAECW1334R2	1.00	2.45	0.41	20.43	54.41	23.5	0.00	164.1	6.0	90	0.264
BAECW1334R3	1.00	1.95	0.83	14.00	24.87	21.3	0.00	52.4	5.6	91	0.479
BAECW1335R1	1.00	1.85	0.35	15.00	1.26	24.2	0.00	70.9	5.6	92	0.381
BAECW1335R2	1.01	1.64	0.26	14.16	1.71	23.7	0.00	59.3	5.7	93	0.368
BAECW1335R3	1.00	1.74	0.39	16.06	4.45	20.1	0.00	87.2	5.7	94	0.344
BAECW1336R1	1.00	1.35	0.17	12.35	0.00	16.3	1.15	26.0	5.1	95	0.202
BAECW1336R2	1.00	1.84	0.66	19.32	74.69	16.4	0.00	78.3	4.7	96	0.355
BAECW1336R3	1.00	1.65	0.25	14.34	26.83	17.9	0.00	38.9	5.5	97	0.429
BAECW1337R1	1.00	1.15	0.18	19.61	21.39	21.5	10.99	48.5	7.8	98	1.750
BAECW1337R2	1.01	1.44	0.38	12.25	0.00	13.5	0.00	29.9	7.3	99	1.472
BAECW1337R3	1.00	2.45	0.49	18.29	34.35	19.2	0.00	43.5	7.1	100	2.082
BAECW1338R1	1.00	1.84	0.06	13.64	19.36	17.8	6.23	32.0	8.0	101	0.286
BAECW1338R2	1.00	1.45	0.18	14.03	3.92	17.7	27.25	30.1	8.2	102	0.295
BAECW1338R3	1.00	1.35	0.16	11.16	25.11	10.5	0.00	26.0	8.0	103	0.412
EBECW13F2R1	1.00	1.45	0.79	45.23	68.91	20.6	0.00	191.6	7.7	120	0.448
EBECW13F2R2	1.00	1.35	0.45	6.97	0.36	10.4	0.00	34.5	7.9	121	0.934
EBECW13F2R3	1.00	1.64	0.93	21.04	89.06	21.1	0.00	218.2	8.1	122	0.644
EBECW13F3R1	1.00	2.04	0.57	18.85	1.86	19.7	0.00	138.5	6.2	123	0.210
EBECW13F3R2	1.00	3.54	2.75	57.86	139.64	24.3	0.00	646.8	7.5	124	0.396
EBECW13F3R3	1.01	2.44	1.03	21.92	85.49	13.9	0.00	202.0	5.1	125	0.255
EBECW13H1R1	1.00	1.45	0.82	30.68	7.22	23.9	0.00	381.6	7.2	126	2.021
EBECW13H1R2	1.00	1.35	0.96	10.31	1.66	11.9	0.00	49.0	7.8	127	0.005
EBECW13H1R3	1.00	1.35	0.87	24.48	1.52	17.8	0.00	364.6	7.5	128	1.256
EBECW13H2	1.00	1.35	3.20	16.58	58.74	19.0	0.00	179.0	5.8	129	2.454
EBECW13H3	1.01	2.14	0.47	25.87	92.86	25.9	0.00	460.3	5.8	130	0.606

Table 2-B1.
(Concluded)

OBS	ID	WEIGHT	AS	CD	CU	PB	NI	SE	ZN	PH	LOCATION	EC
109	ESSCW13J1	1.00	18.25	10.21	187.98	1818.92	37.91	0.30	23378.1	7.5	131	1.272
110	ESSCW13J2	1.01	1.14	2.56	26.77	145.54	20.58	0.00	803.2	7.1	132	2.944
111	ESSCW13K1	1.00	4.93	1.42	13.23	11.62	47.07	0.00	525.9	8.1	134	1.158
112	ESSCW13K2	1.00	4.65	3.21	16.68	67.41	50.55	0.00	643.1	7.8	135	0.644
113	ESSCW13K3	1.00	1.85	1.12	16.79	62.79	10.43	0.00	274.5	5.2	136	0.736
114	ESSCW13L1	1.00	6.25	26.31	524.48	1243.91	38.41	0.45	15328.1	7.6	137	1.597
115	ESSCW13L3	1.00	2.95	0.96	19.41	63.85	13.34	0.00	183.4	5.7	139	
116	ESSCW14F1R1	1.01	2.54	0.75	32.42	170.56	18.01	0.00	445.8	7.4	140	2.576
117	ESSCW14F1R2	1.00	1.25	1.07	20.23	67.92	19.90	0.25	181.6	7.7	141	2.576
118	ESSCW14F1R3	1.00	2.45	0.58	28.63	17.52	21.55	0.00	528.1	7.9	142	2.240
119	Q1SCW11L1	1.01	3.03	0.70	35.25	64.09	12.59	0.00	205.5	5.2	143	
120	Q1SCW13L4R1	1.00	3.95	12.61	44.18	216.91	19.35	0.00	2583.1	7.8	148	3.979
121	Q1SCW13L4R2	1.00	4.15	18.96	43.68	288.92	18.70	0.55	3273.1	8.0	149	2.944
122	Q1SCW13L4R3	1.00	2.54	6.49	32.53	159.94	21.89	0.05	1678.0	7.8	150	1.090
123	Q1SCW13M1R1	1.00	4.25	14.86	67.48	259.92	26.91	0.00	5328.1	8.1	151	0.699
124	Q1SCW13M1R2	1.00	3.45	12.21	23.88	55.92	19.15	0.00	2983.1	7.7	152	0.921
125	Q1SCW13M1R3	1.00	1.85	18.59	79.40	112.30	18.09	0.00	3934.1	7.4	153	0.991
126	K2SCW3P1	1.00	3.24	1.13	58.30	69.71	37.64	0.00	131.7	6.2	154	0.573
127	K2SCW3R1	1.00	5.55	4.26	103.48	45.91	39.75	0.00	1598.1	6.4	155	0.286
128	K2SCW4N1R1	1.01	4.23	0.49	26.99	0.66	29.81	0.00	117.5	6.5	156	0.457
129	K2SCW4N1R2	1.00	4.15	0.40	23.33	4.06	29.91	0.00	167.6	7.1	157	3.554
130	K2SCW4N1R3	1.00	7.50	0.84	70.98	51.91	38.36	0.00	728.1	7.1	158	0.416
131	K2SCW4P1	1.00	3.64	0.60	48.98	42.29	45.77	0.00	202.4	5.7	159	0.746
132	K2SCW4Q1	1.00	2.15	19.04	79.40	214.20	28.13	0.10	2570.5	4.7	160	5.153
133	K2SCW5O1	1.00	4.94	0.74	32.88	13.37	13.17	0.00	164.1	4.5	162	2.576
134	K2SCW5P1	1.00	3.74	0.60	69.34	51.31	51.45	1.30	270.5	6.4	163	0.448
135	K2SCW6O1	1.00	3.39	0.57	19.67	22.85	13.12	0.00	60.9	4.7	164	0.172
136	K2SCW6Q2	1.00	2.55	36.16	30.28	1.07	16.80	0.00	4953.1	6.4	167	1.717
137	K8SCW10P1	1.00	27.64	88.51	1498.48	4675.21	57.33	0.05	50276.9	8.2	174	2.061
138	K8SCW8R2	1.00	54.70	21.39	96.38	61.35	38.82	0.15	3504.5	5.2	177	1.610

Table 2-B2.

Blank Analysis

OBS	ID	AS	CD	CU	PB	NI	SE	ZN
1	BLANK50M	.005	.003	0.01	0.00	0.03	.005	0.43
2	BLANK50M	.005	.001	0.01	0.02	0.03	.005	0.48
3	BLANK50M	.005	.002	0.01	0.03	0.04	.005	0.52
4	BLANK50M	.005	.002	0.01	0.02	0.03	.005	0.34
5	BLANK50M	.005	.002	0.01	0.01	0.03	.005	0.37
6	BLANK50M	.005	.004	0.01	0.04	0.04	.005	0.53
7	BLANK50M	.005	.003	0.01	0.02	0.02	.005	0.40
8	BLANK50M	.005	.003	0.01	0.01	0.02	.005	0.45
9	BLANK50M	.005	.003	0.01	0.01	0.03	.005	0.52
10	BLANK50M	.005	.001	0.01	0.03	0.02	.005	0.28
11	BLANK50M	.005	.002	0.01	0.07	0.03	.005	0.42
12	BLANK50M	.005	.003	0.01	0.01	0.03	.005	0.47
13	BLANK50M	.005	007	0.01	0.01	0.03	.005	0.47
14	BLANK50M	.005	005	0.01	0.02	0.03	.005	0.48

Table 2-B3.

Blank Analysis Summary

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE	C. V.
AS	14	0.005	0.000	0.005	0.005	0.000	0.070	0.000	0.000
CD	14	0.003	0.002	0.001	0.007	0.000	0.040	0.000	55.597
CU	14	0.010	0.002	0.007	0.013	0.001	0.146	0.000	21.839
PB	14	0.022	0.017	0.001	0.071	0.005	0.304	0.000	79.631
NI	14	0.029	0.006	0.017	0.039	0.002	0.405	0.000	20.628
SE	14	0.005	0.000	0.005	0.005	0.000	0.070	0.000	0.000
ZN	14	0.439	0.071	0.284	0.526	0.019	6.145	0.005	16.153

Table 2-B4

NBS River Sediment Analysis

OBS	ID	WEIGHT	AS	CD	CU	PB	NI	SE	ZN
1	RIVERSED	1	35.50	9.36	93.48	628.92	31.56	0.00	1498.05
2	RIVERSED	1	28.75	7.21	76.48	508.91	25.46	0.00	1168.05
3	RIVERSED	1	34.75	8.81	90.48	598.91	30.81	0.00	1473.05
4	RIVERSED	1	36.75	9.86	94.48	633.91	32.91	0.00	1553.05
5	RIVERSED	1	33.75	9.31	83.48	533.91	28.41	0.00	1403.05
6	RIVERSED	1	36.75	10.16	94.98	643.91	31.51	0.00	1573.05
7	RIVERSED	1	25.75	7.01	66.48	443.41	22.65	4.45	1043.05
8	RIVERSED	1	31.75	9.86	89.98	608.91	31.61	0.00	1413.05
9	RIVERSED	1	35.75	9.61	94.98	623.91	33.26	0.00	1498.05
10	RIVERSED	1	36.75	9.56	95.48	638.92	33.46	0.00	1578.05
11	RIVERSED	1	32.75	8.21	84.48	583.91	31.81	0.00	1433.05
12	RIVERSED	1	34.75	9.16	86.98	633.91	33.91	0.00	1583.05
13	RIVERSED	1	36.75	9.46	84.48	588.92	29.31	0.00	1463.05

Table 2-B5.

NBS River Sediment Analysis Summary*

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE	C.V
WEIGHT	13	1.000	0.000	1.000	1.000	0.000	13.000	0.000	0.000
[illegible]	13	33.885	3.401	25.750	36.750	0.943	440.500	11.569	10.038
[illegible]	13	9.045	0.990	7.010	10.160	0.275	117.580	0.981	10.951
[illegible]	13	87.402	8.529	66.479	95.479	2.366	1136.220	72.744	9.758
[illegible]	13	590.030	60.211	443.415	643.915	16.699	7670.395	3625.340	10.205
[illegible]	13	30.509	3.312	22.655	33.905	0.919	396.615	10.971	10.857
[illegible]	13	0.342	1.234	0.000	4.450	0.342	4.450	1.523	360.555
[illegible]	13	1436.900	161.221	1043.053	1583.053	44.715	18679.695	25992.308	11.220

*Standards

NBS River Sediment Analysis Values

AS	66.0	
CD	8.7	11.7
CU	90.0	128.0
PB	686.0	742.0
NI	42.9	48.7
SE	1.5	
ZN	1550.0	1890.0

Table 2-B6.

Additional Soil Analysis

OBS	ID	WEIGHT	AS	CD	CU	PB	NI	SE	ZN	PH	LOCATION	EC
1	ABSCPCW14Q1	1.00	9.50	2.04	320.31	60.72	15.30	0.00	519.2	7.1	68	0.515
2	ABSCPCW14R1	1.00	9.25	2.11	119.81	37.82	14.15	0.00	259.2	7.0	69	2.642
3	ABSCPCW14S1	1.01	133.42	5.84	537.93	51.21	34.21	0.45	860.6	7.1	70	6.100
4	ABSCPCW15Q1	1.00	15.25	1.88	503.31	31.77	21.55	0.00	444.7	7.4	71	3.440
5	ABSCPCW15R1	1.00	57.25	2.07	460.81	38.67	12.50	0.00	357.7	7.1	72	4.294
6	ABSCPCW15S1	1.00	122.25	5.00	391.81	52.22	43.75	0.55	789.2	7.2	73	3.554
7	CPSCPCW26G1	1.00	89.75	13.60	253.81	25.02	12.50	0.00	183.7	5.2	104	1.171
8	CPSCPCW27E1R1	1.00	6.75	8.25	8.61	68.23	3.25	12.75	48.7	6.6	105	4.794
9	CPSCPCW27E1R2	1.00	11.00	9.40	19.41	53.72	2.70	6.75	74.2	2.9	106	5.153
10	CPSCPCW27E1R3	1.00	9.75	7.30	25.26	44.97	3.55	6.25	65.7	4.3	107	2.061
11	CPSCPCW27F1	1.02	37.75	8.48	64.52	30.76	17.79	1.47	143.8	5.2	108	2.061
12	CPSCPCW28F1R1	1.00	62.25	7.60	59.81	4054.73	19.75	73.75	140.7	5.1	109	4.110
13	CPSCPCW28F1R2	1.00	23.50	4.85	47.36	275.73	21.50	7.25	169.2	5.2	110	3.221
14	CPSCPCW28F1R3	1.00	21.00	2.80	38.26	125.73	24.55	2.00	161.2	5.5	111	1.840
15	CPSCPCW29E1R1	1.01	16.58	3.56	64.17	163.09	14.75	138.37	83.3	3.5	112	4.481
16	CPSCPCW29E1R2	1.00	10.75	7.10	89.81	62.73	13.25	5.75	136.7	4.7	113	2.061
17	CPSCPCW29E1R3	1.00	1.95	0.43	14.71	78.73	7.15	9.00	25.0	5.0	114	3.979
18	CPSCPCW29E2	1.00	23.75	4.70	56.31	824.72	15.30	20.75	121.2	6.9	115	3.964
19	CPSCPCW29F1	1.01	26.49	19.41	14.22	7.65	5.30	103.71	49.2	6.7	116	2.945
20	CPSCPCW30E1	1.00	3.05	0.06	40.46	0.53	36.70	2.00	277.2	5.9	117	4.910
21	CPSCPCW30F1	1.00	9.00	4.00	64.31	138.73	54.20	4.15	401.2	6.9	118	4.481
22	CPSCPCW30F2	1.00	6.75	2.25	70.31	210.23	47.10	4.00	427.2	6.7	119	5.153
23	ESSCPCW13L3	1.00	2.75	1.63	22.96	47.62	12.50	0.00	357.7	5.2	133	3.964
24	ESSCPCW13L4	1.00	5.00	1.73	41.56	22.58	15.25	0.00	604.2	5.5	138	0.644
25	G1SCPCW12L1	1.00	0.75	2.25	19.11	664.72	6.40	0.00	142.2	6.5	144	0.234
26	G1SCPCW12N1	1.00	12.25	37.00	406.31	65.73	66.70	0.35	23694.2	6.9	145	1.145
27	G1SCPCW12N2	1.01	2.52	11.98	72.09	307.15	30.15	0.30	4944.7	7.3	146	2.082
28	G1SCPCW12N3	1.00	1.55	1.19	21.21	31.57	22.20	0.00	232.2	7.1	147	0.479
29	K2SCPCW4R1	1.01	4.46	1.76	46.50	251.21	47.12	0.00	230.4	5.5	161	4.276
30	K2SCPCW6P1	1.02	4.80	8.48	130.21	382.08	24.51	0.00	5680.5	8.3	165	2.712
31	K2SCPCW6Q1	1.00	5.50	18.30	206.81	499.72	24.45	0.15	7744.2	6.9	166	4.312
32	K2SCPCW8P1	1.00	13.75	31.75	1188.3	1769.73	45.55	0.25	21894.2	7.2	168	0.866
33	K2SCPCW8P2	1.00	57.25	45.15	3053.3	7599.72	94.30	0.60	85494.2	6.7	169	3.918
34	K2SCPCW8P3R1	1.00	2.75	16.40	80.81	119.23	17.75	0.00	5294.2	7.0	170	0.845
35	K2SCPCW8P3R2	1.00	1.75	19.25	87.31	130.72	15.95	0.00	5244.2	7.2	171	0.648
36	K2SCPCW8P3R3	1.01	3.71	26.29	317.14	35.37	24.41	0.10	9004.1	7.0	172	0.610
37	K2SCPCW9Q1	1.00	3.75	1.44	20.91	35.32	12.65	0.00	91.7	4.9	173	3.948
38	KSSCPCW10R1	1.00	35.37	43.50	477.31	449.72	65.70	0.65	6394.2	6.8	175	1.052
39	KSSCPCW8R1	1.00	52.25	27.25	573.31	263.73	50.00	4.25	3184.2	5.5	176	4.258
40	KSSCPCW9Q1	1.01	6.44	59.16	111.69	163.59	49.31	1.19	8954.6	7.3	178	4.294

Table 2-B7.

Additional Blank Analysis

OBS	ID	AS	CD	CU	PB	NI	SE	ZN
1	BLANK	0.005	.008	0.030	0.006	0.030	0.005	0.036
2	BLANK	0.005	.004	0.039	0.007	0.054	0.005	0.197
3	BLANK	0.005	.007	0.036	0.005	0.030	0.005	0.121
4	BLANK	0.005	.001	0.030	0.004	0.030	0.005	0.113

Table 2-B8.

Additional Blank Analysis Summary

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE	C. V.
AS	4	0.005	0.000	0.005	0.005	0.000	0.020	0.000	0.000
CD	4	0.005	0.003	0.001	0.008	0.002	0.020	0.000	60.128
CU	4	0.034	0.004	0.030	0.039	0.002	0.135	0.000	13.333
PB	4	0.006	0.001	0.004	0.007	0.001	0.022	0.000	23.473
NI	4	0.036	0.012	0.030	0.054	0.006	0.144	0.000	33.333
SE	4	0.005	0.000	0.005	0.005	0.000	0.020	0.000	0.000
ZN	4	0.117	0.066	0.036	0.197	0.033	0.467	0.004	56.368

Table 2-B9.

Additional NBS River Sediment Analysis

OBS	ID	WEIGHT	AS	CD	CU	PB	NI	SE	ZN
1	RIVER-SED	1	35.75	9.50	97.31	62.22	33.90	0	1704.16
2	RIVER-SED	1	32.25	7.25	87.81	212.23	30.30	0	1474.16
3	RIVER-SED	1	36.75	9.40	98.81	343.73	31.45	0	1594.16
4	RIVER-SED	1	36.75	9.05	98.81	333.73	34.60	0	1604.16

Table 2-B10.

Additional NBS River Sediment Analysis Summary*

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE	C V
WEIGHT	4	1.000	0.000	1.000	1.000	0.000	4.000	0.000	0.000
[illegible]	4	35.375	2.136	32.250	36.750	1.068	141.500	4.562	6.038
[illegible]	4	8.800	1.051	7.250	9.500	0.526	35.200	1.105	11.945
[illegible]	4	95.685	5.297	87.810	98.810	2.649	382.740	28.063	5.536
[illegible]	4	242.975	130.604	62.225	343.725	65.302	971.900	17057.417	53.752
[illegible]	4	32.562	2.025	30.300	34.600	1.012	130.250	4.099	6.218
[illegible]	4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
[illegible]	4	1594.160	94.163	1474.160	1704.160	47.081	6376.640	8866.667	5.907

*Standards

NBS River Sediment Analysis Values		
AS	66.0	
CD	8.7	11.7
CU	90.0	120.0
PB	686.0	742.0
NI	42.9	48.7
SE	1.5	
ZN	1550.0	1890.0

Table 2-B11.
Contract Soil Samples

OBS	ID	CU	CR	AS	CD	PB	NI	ZN	PH	T_SOLIDS	SE	LOCATION
1	AASCW10AA1	46.67	53.33	130.00	0.67	46.67	66.67	73.3	6.7	30	.	1
2	AASCW10BB1	50.00	59.37	37.50	0.63	31.25	81.25	71.9	6.6	32	.	2
3	AASCW10T1	400.00	32.86	1142.86	0.95	266.67	38.10	276.2	5.2	21	.	3
4	AASCW10U1	74.29	42.86	205.71	0.57	180.00	40.00	94.3	4.4	35	.	4
5	AASCW10V1	180.56	61.11	186.11	1.67	69.44	94.44	694.4	7.3	36	.	5
6	AASCW10W1	60.67	57.33	533.33	1.33	66.67	59.33	86.7	6.5	15	.	6
7	AASCW10X1	46.67	50.00	43.33	0.67	46.67	50.00	83.3	5.7	30	.	7
8	AASCW10Y1	86.36	59.09	63.64	0.91	81.82	63.64	68.2	6.2	22	.	8
9	AASCW10Z1	50.00	50.00	137.50	0.83	50.00	62.50	75.0	6.5	24	.	9
10	AASCW116Q	47.22	44.44	5.56	0.56	27.78	69.44	102.8	6.0	36	.	10
11	AASCW116H	66.67	50.00	6.67	0.67	40.00	76.67	113.3	6.9	30	.	11
12	AASCW11R1	233.33	30.77	5.13	16.41	48.72	53.85	1538.5	7.1	39	.	12
13	AASCW124A	91.89	54.05	27.03	3.24	43.24	100.00	783.8	6.0	37	.	13
14	AASCW124B	43.48	54.35	28.26	0.87	21.74	104.35	121.7	7.3	46	.	14
15	AASCW124C	120.00	52.50	42.50	4.25	52.50	100.00	825.0	6.2	40	.	15
16	AASCW124D	54.17	47.92	27.08	0.42	22.92	72.92	68.8	6.5	48	.	16
17	AASCW124E	37.31	38.81	2.99	0.30	22.39	52.24	179.1	7.2	67	.	17
18	AASCW12AA1	67.50	52.50	115.00	0.50	52.50	62.50	107.5	5.3	40	.	18
19	AASCW12BB1	78.05	53.66	129.27	0.49	78.05	95.12	151.2	6.5	41	.	19
20	AASCW12S1	50.00	29.55	13.64	0.91	22.73	81.82	163.6	7.1	22	.	20
21	AASCW12T1	580.65	41.94	1096.77	0.65	354.84	61.29	283.9	5.9	31	.	21
22	AASCW12U1	126.67	63.33	160.00	0.67	66.67	43.33	316.7	6.1	30	.	22
23	AASCW12V1	500.00	48.95	73.68	5.26	84.21	100.00	2894.7	6.0	19	.	23
24	AASCW12W1	55.17	58.62	6.90	0.69	65.52	65.52	169.0	5.2	29	.	24
25	AASCW12X1	113.64	63.64	18.18	0.91	113.64	72.73	240.9	5.1	22	.	25
26	AASCW12Y1	53.85	61.54	96.15	0.77	46.15	50.00	73.1	5.1	26	.	26
27	AASCW12Z1	87.50	50.00	162.50	0.63	84.38	59.37	90.6	4.3	32	.	27
28	AASCW14AA1	81.82	70.45	109.09	0.45	109.09	86.36	204.5	6.1	44	.	28
29	AASCW14S1	368.42	29.82	19.30	75.44	36.84	70.18	1052.6	6.2	57	.	29
30	AASCW14W1	133.33	42.00	26.67	3.33	86.67	66.67	666.7	6.6	15	.	30
31	AASCW14X1	333.33	36.36	139.39	0.61	106.06	54.55	163.6	5.6	33	.	31
32	AASCW14Y1	84.21	39.47	26.32	0.53	105.26	57.89	126.3	5.6	38	.	32
33	AASCW14Z1	53.49	53.49	76.74	0.47	72.09	62.79	104.7	5.8	43	.	33
34	AASCW16V2	105.88	32.35	276.47	1.18	58.82	70.59	1588.2	6.8	17	.	34
35	AASCW16X1	275.00	59.37	59.37	0.63	121.88	93.75	468.7	6.1	32	.	35
36	AASCW16Y1	333.33	50.00	5.56	0.56	88.89	80.56	805.6	6.6	36	.	36
37	AASCW5R1	131.25	53.12	112.50	0.63	71.88	50.00	281.2	5.7	32	.	37
38	AASCW5S1	90.00	40.00	27.50	6.25	52.50	75.00	1175.0	6.5	40	.	38
39	AASCW6R1	191.11	42.22	97.78	0.44	117.78	73.33	444.4	5.6	45	.	39
40	AASCW6S1	217.39	32.61	67.39	5.87	126.09	63.04	2826.1	6.5	46	.	40
41	AASCW7R1	78.38	32.43	108.11	0.54	56.76	40.54	200.0	4.9	37	.	41
42	AASCW7S1	91.43	37.14	20.00	2.57	57.14	48.57	571.4	5.9	35	.	42
43	AASCW7T1	50.94	45.28	24.53	0.38	22.64	62.26	109.4	6.7	53	.	43
44	AASCW8R1	566.67	53.33	33.33	9.67	66.67	83.33	1633.3	6.8	30	.	44
45	AASCW8S1	843.75	43.75	103.13	17.81	75.00	75.00	4375.0	6.9	32	.	45
46	AASCW8W1	159.46	56.76	116.22	2.43	86.49	94.59	2108.1	6.3	37	.	46
47	CPSCW26F1	48.81	30.95	30.95	10.71	26.19	36.90	178.6	5.1	84	2.38	47
48	CPSCW26F2	160.92	47.13	51.72	13.79	42.53	20.69	218.4	4.4	87	2.30	48
49	CPSCW2602	55.29	28.24	36.47	5.76	23.53	24.71	200.0	4.9	85	2.35	49
50	CPSCW2603	41.86	27.91	40.70	2.09	31.40	37.21	50.0	4.6	86	2.33	50
51	CPSCW2604	106.33	62.03	87.34	29.11	24.05	64.56	405.1	5.9	79	2.53	51
52	CPSCW2605	109.20	45.98	39.08	18.39	33.33	25.29	172.4	4.4	87	2.30	52
53	CPSCW2701	32.56	25.58	6.98	1.05	84.88	25.58	87.2	4.8	86	2.33	53
54	CPSCW28E1	33.33	51.85	28.40	14.81	24.69	97.53	222.2	4.5	81	2.47	54

Table 2-B11.
(Concluded)

OBS	ID	CU	CR	AS	CD	PB	NI	ZN	PH	T_SOLIDS	SE	LOCATION
55	CPSCW28E2	16.28	29.07	6.98	1.63	13.95	45.35	87.2	4.1	86	2.33	55
56	CPSCW28D1	32.14	38.10	14.29	0.48	39.52	51.19	108.3	5.1	84	2.38	56
57	CPSCW29E3	44.30	36.71	31.65	5.19	253.16	24.05	96.2	4.5	79	5.06	57
58	CPSCW29E4	72.29	132.53	8.43	9.04	46.99	14.46	89.2	4.1	83	2.41	58
59	CPSCW29E5	37.04	37.04	13.58	3.95	555.56	30.86	103.7	4.5	81	41.98	59
60	CPSCW29E6	53.42	39.73	13.70	2.60	1780.82	36.99	232.9	5.3	73	72.60	60
61	CPSCW29E7	32.47	24.68	2.60	0.26	125.97	32.47	109.1	7.0	77	2.60	61
62	CPSCW29E8	30.99	36.62	15.49	6.90	92.96	59.15	140.8	4.8	71	2.82	62
63	CPSCW29F2	31.40	29.07	17.44	1.40	26.74	24.42	67.4	3.8	86	2.33	63
64	CPSCW29F3	68.06	40.28	29.17	9.44	1263.89	22.22	86.1	4.6	72	45.83	64
65	CPSCW29G1	26.51	38.55	2.41	0.24	27.71	59.04	63.9	5.1	83	2.41	65
66	CPSCW29G2	21.98	17.58	2.20	0.22	20.88	28.57	41.8	5.2	91	2.20	66
67	CPSCW30F3	28.92	32.53	2.41	0.24	38.55	49.40	73.5	4.8	83	2.41	67
68	ESSCW11F1	33.72	15.12	2.33	0.70	81.40	20.93	441.9	5.3	86	.	68
69	ESSCW11G1	20.93	15.12	9.30	0.47	40.70	18.60	95.3	5.3	86	.	69
70	ESSCW11H1	21.05	17.11	2.63	0.26	26.32	23.68	100.0	5.2	76	.	70
71	ESSCW11J1	21.69	16.87	2.41	0.24	19.28	21.69	54.2	5.0	83	.	71
72	ESSCW11K1	18.82	14.12	2.35	0.24	21.18	18.82	75.3	4.8	85	.	72
73	ESSCW12F1	19.05	14.29	8.33	0.24	29.76	27.38	94.0	6.7	84	.	73
74	ESSCW12G1	17.24	14.94	2.30	0.23	12.64	17.24	58.6	5.8	87	.	74
75	G1SCW10M1	18.60	16.28	2.33	0.23	15.12	17.44	64.0	5.5	86	.	75
76	G1SCW10N1	22.97	16.22	2.70	0.27	22.97	18.92	48.6	5.6	74	.	76
77	G1SCW10P1	1181.82	227.27	3.03	28.79	7272.73	116.67	69697.0	6.3	66	.	77
78	G1SCW11G1	157.14	34.29	2.86	18.57	1285.71	50.00	9714.3	6.8	70	.	78
79	G1SCW12M1	25.88	23.53	10.59	0.24	20.00	34.12	69.4	6.6	85	.	79
80	G1SCW12N4	39.08	19.54	6.90	0.34	96.55	31.03	390.8	7.1	87	.	80
81	G1SCW12G1	131.88	30.43	5.80	23.19	695.65	36.23	4927.5	7.1	69	.	81
82	G1SCW12G2	39.53	18.60	2.33	2.79	36.05	41.86	1116.3	7.0	86	.	82
83	G1SCW13M2	23.17	20.73	6.10	0.24	20.73	26.83	75.6	7.4	82	.	83
84	G1SCW14L1	71.79	19.23	2.56	9.49	512.82	38.46	6410.3	6.8	78	.	84
85	G1SCW14M1	23.26	16.28	2.33	0.23	29.07	24.42	81.4	5.9	86	.	85
86	G1SCW14O1	20.78	24.68	2.60	0.26	20.78	37.66	350.6	6.5	77	.	86
87	G1SCW15L1	16.09	14.94	2.30	0.46	17.24	16.09	367.8	4.8	87	.	87
88	G1SCW16L1	19.77	12.79	2.33	3.14	38.37	19.77	953.5	4.8	86	.	88
89	G1SCW16N1	66.67	257.58	303.03	8.94	303.03	257.58	651.5	4.3	66	.	89
90	K2SCW12H1	20.00	15.29	2.35	0.24	17.65	20.00	57.6	5.6	85	.	90
91	K2SCW12J1	17.44	15.12	2.33	0.47	18.60	17.44	59.3	4.8	86	.	91
92	K2SCW12K1	20.00	15.29	2.35	0.24	17.65	21.18	211.8	5.4	85	.	92
93	K2SCW4G2	141.67	27.08	4.17	2.92	91.67	60.42	1645.8	5.3	48	.	93
94	K2SCW5P2	320.00	50.00	4.00	26.00	860.00	70.00	11600.0	6.3	50	.	94
95	K2SCW6P1	198.00	38.00	4.00	26.00	140.00	70.00	15000.0	6.1	50	.	95
96	K2SCW7O1	23.08	14.10	2.56	0.26	30.77	15.38	112.8	4.5	78	.	96
97	KSSCW8Q1	105.56	31.48	70.37	8.89	70.37	53.70	740.7	6.9	54	.	97

Table 2-B12.

	Contract NBS River Sediment Analysis	NBS River Sediment Analysis Value
As	44.0	66.0
Cd	8.0	8.7 - 11.7
Cu	110.0	90.0 - 128.0
Pb	--ND*	686.0 - 742.0
Ni	42.0	42.9 - 48.7
Se	<2.0	1.5
Zn	1,600.0	1,550.0 - 1,890.0
Cr	22,000.0	26,800 - 32,400

* ND - Not determined.

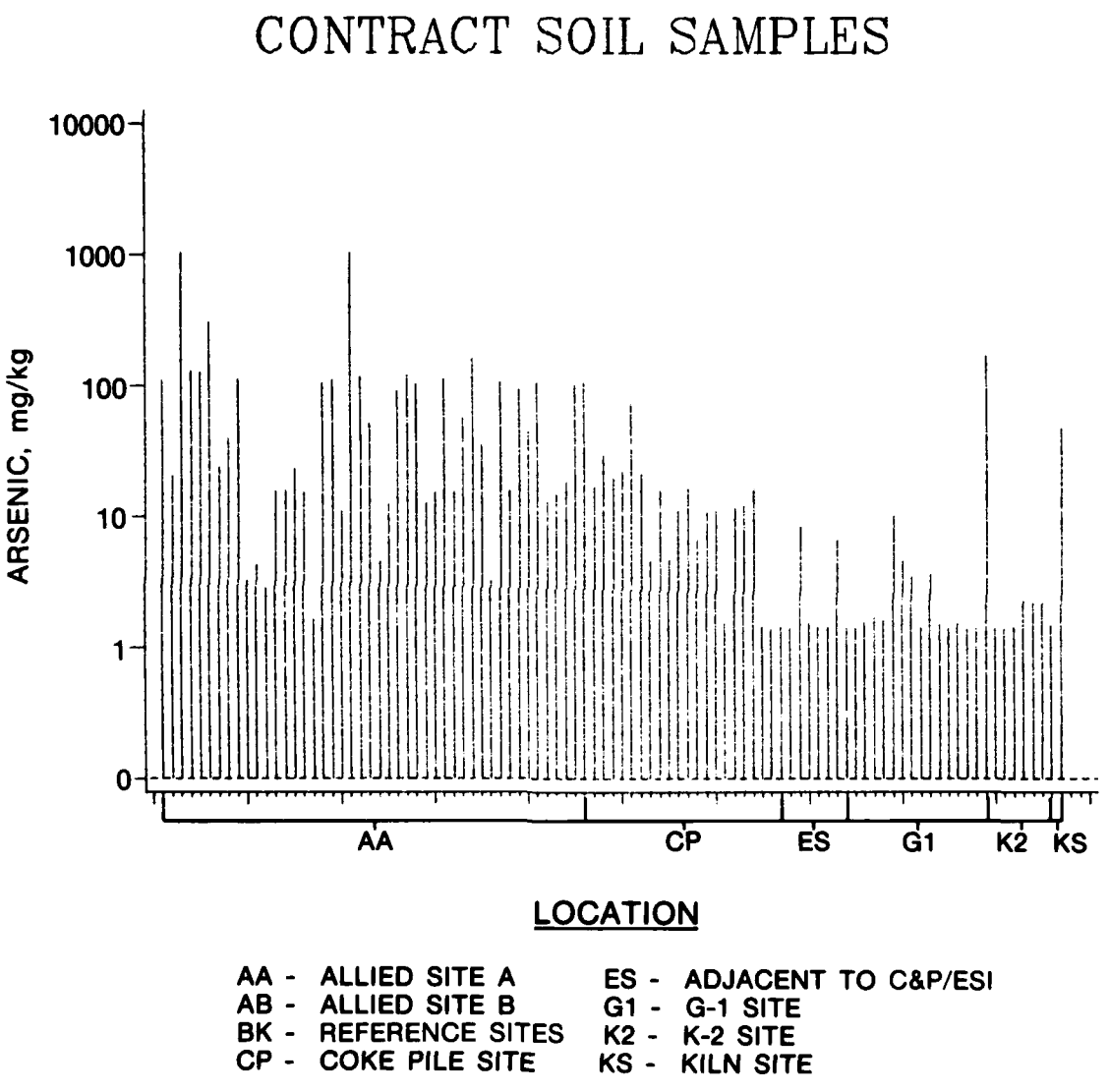
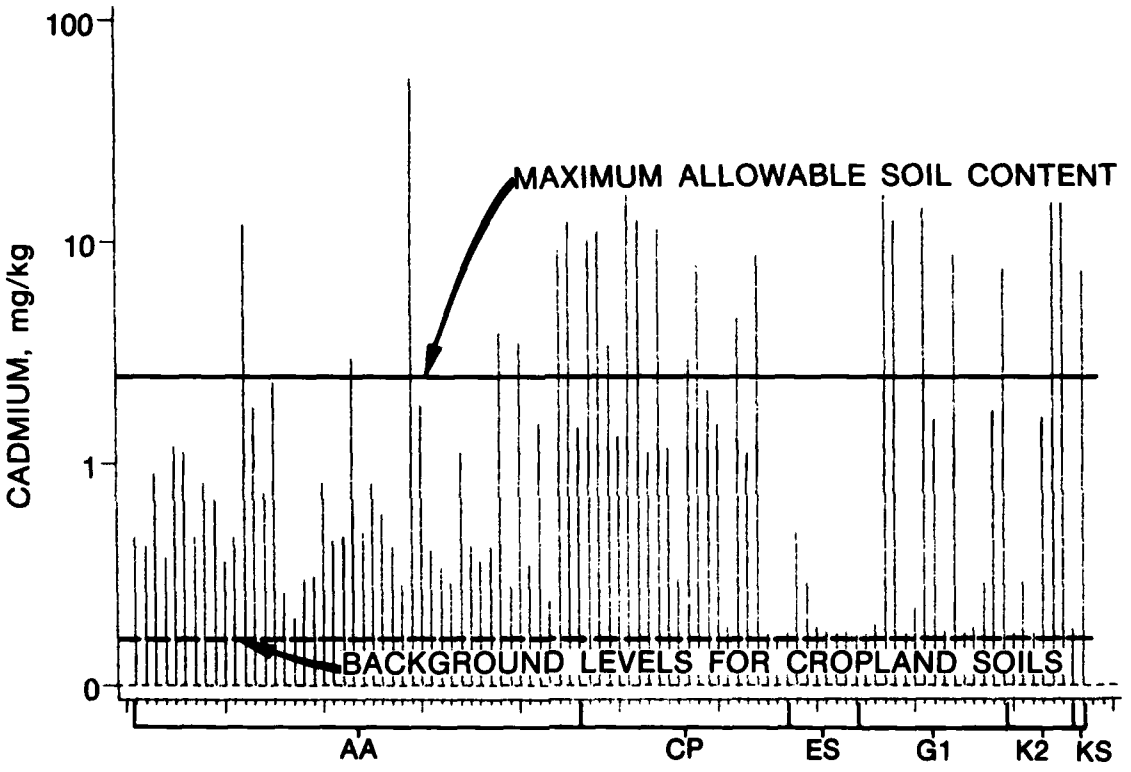


Figure 2-B1. Soil arsenic content

CONTRACT SOIL SAMPLES

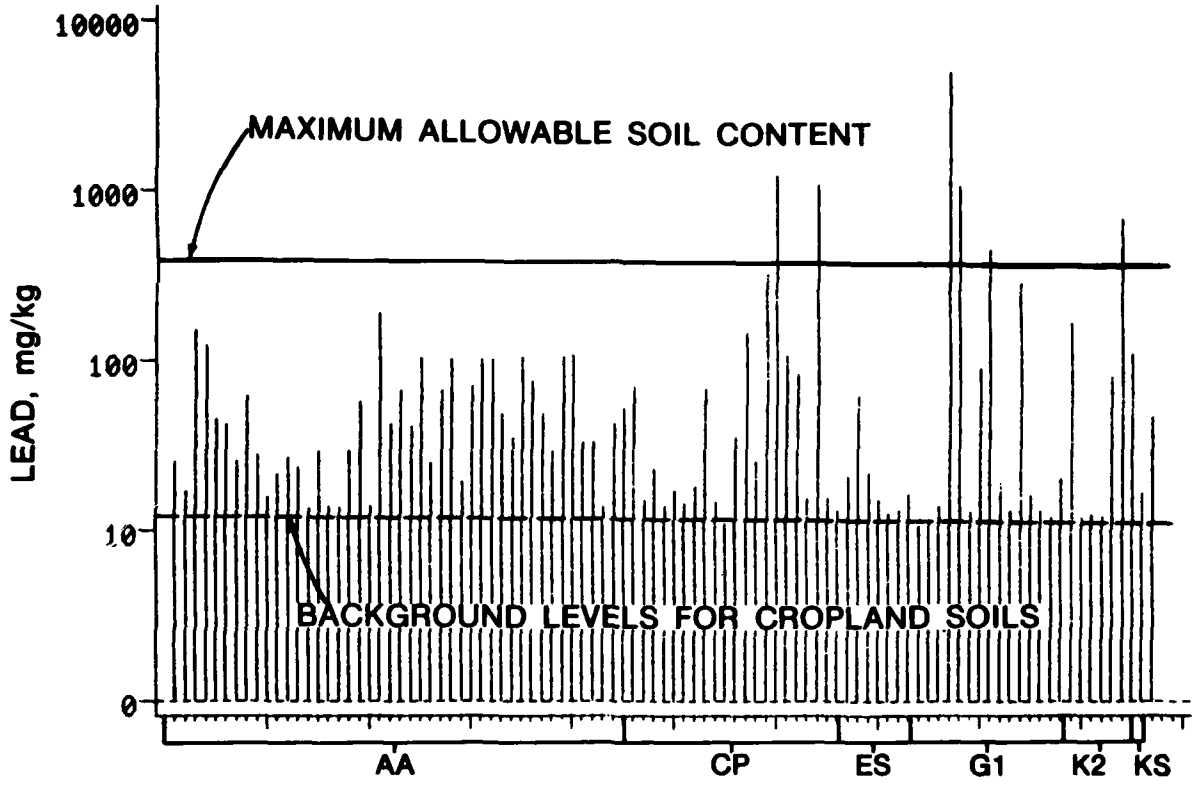


LOCATION

AA -	ALLIED SITE A	ES -	ADJACENT TO C&P/ESI
AB -	ALLIED SITE B	G1 -	G-1 SITE
BK -	REFERENCE SITES	K2 -	K-2 SITE
CP -	COKE PILE SITE	KS -	KILN SITE

Figure 2-B2. Soil cadmium content

CONTRACT SOIL SAMPLES

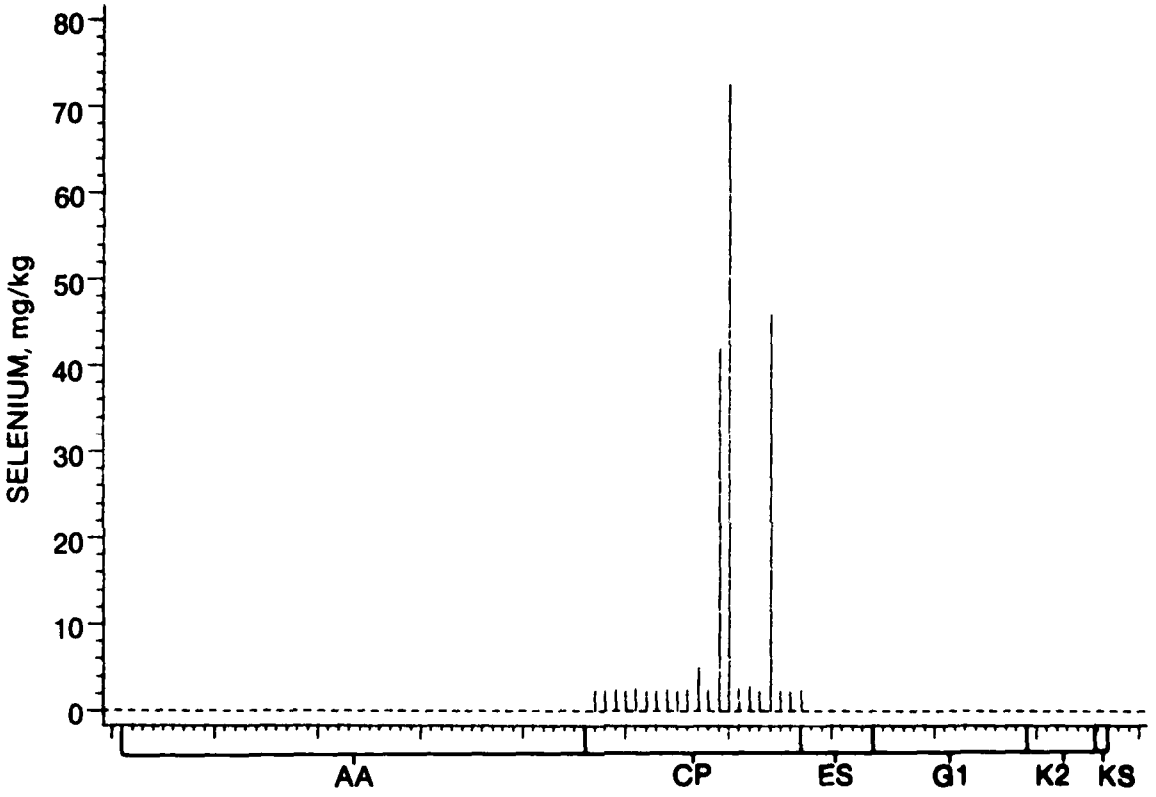


LOCATION

AA -	ALLIED SITE A	ES -	ADJACENT TO C&P/ESI
AB -	ALLIED SITE B	G1 -	G-1 SITE
BK -	REFERENCE SITES	K2 -	K-2 SITE
CP -	COKE PILE SITE	KS -	KILN SITE

Figure 2-B3. Soil lead content

CONTRACT SOIL SAMPLES



LOCATION

AA -	ALLIED SITE A	ES -	ADJACENT TO C&P/ESI
AB -	ALLIED SITE B	G1 -	G-1 SITE
BK -	REFERENCE SITES	K2 -	K-2 SITE
CP -	COKE PILE SITE	KS -	KILN SITE

Figure 2-B4. Soil selenium content

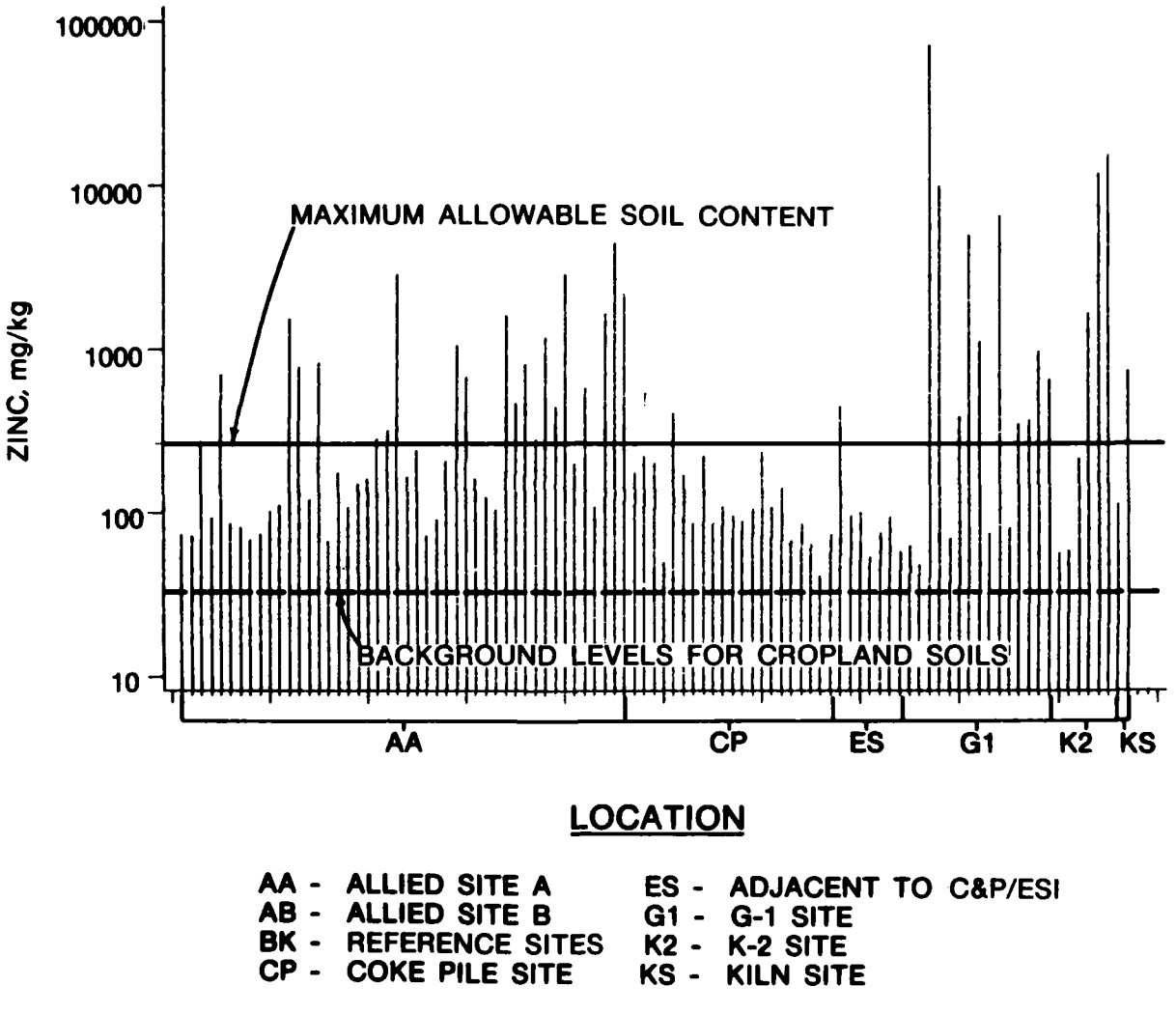


Figure 2-B5. Soil zinc content

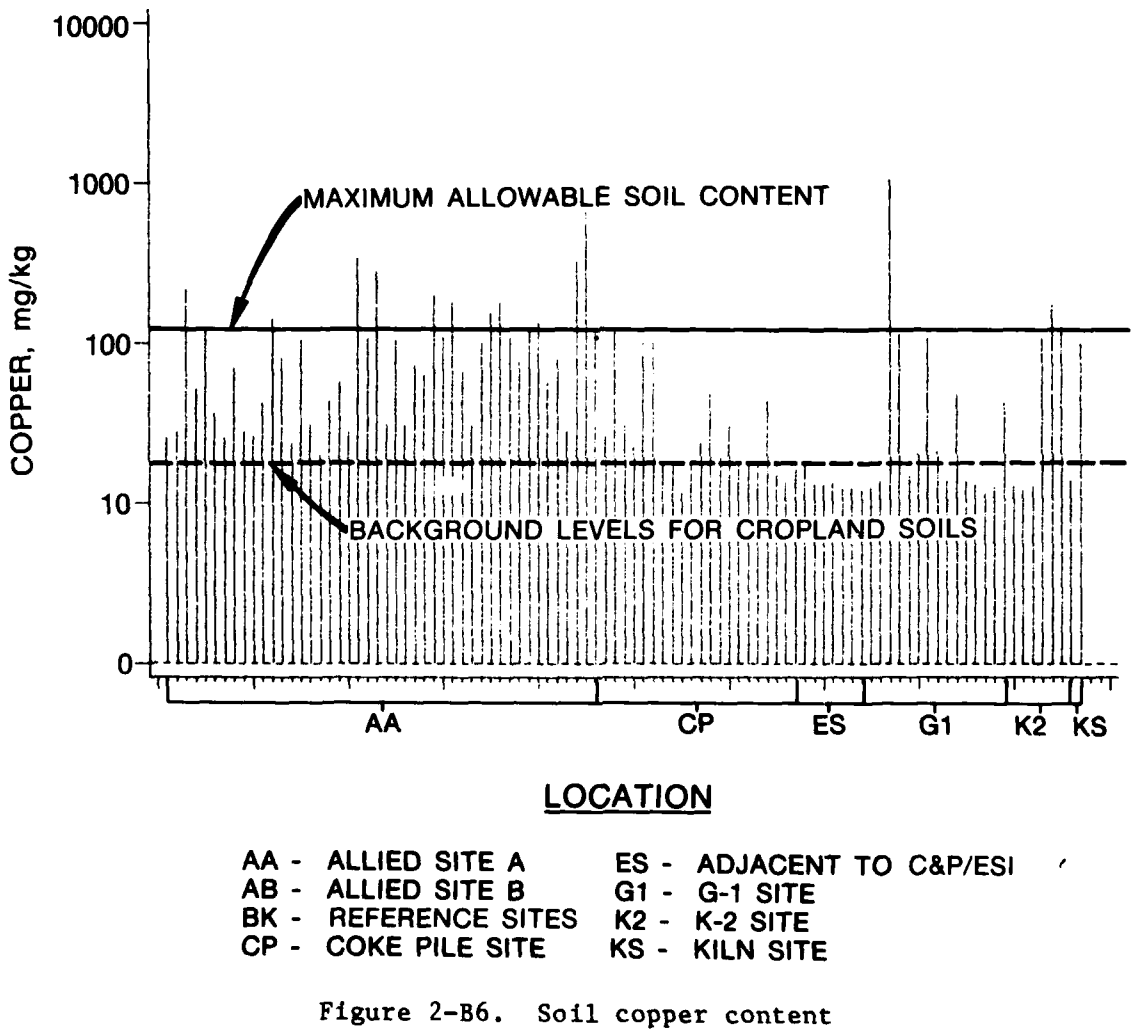


Figure 2-B6. Soil copper content

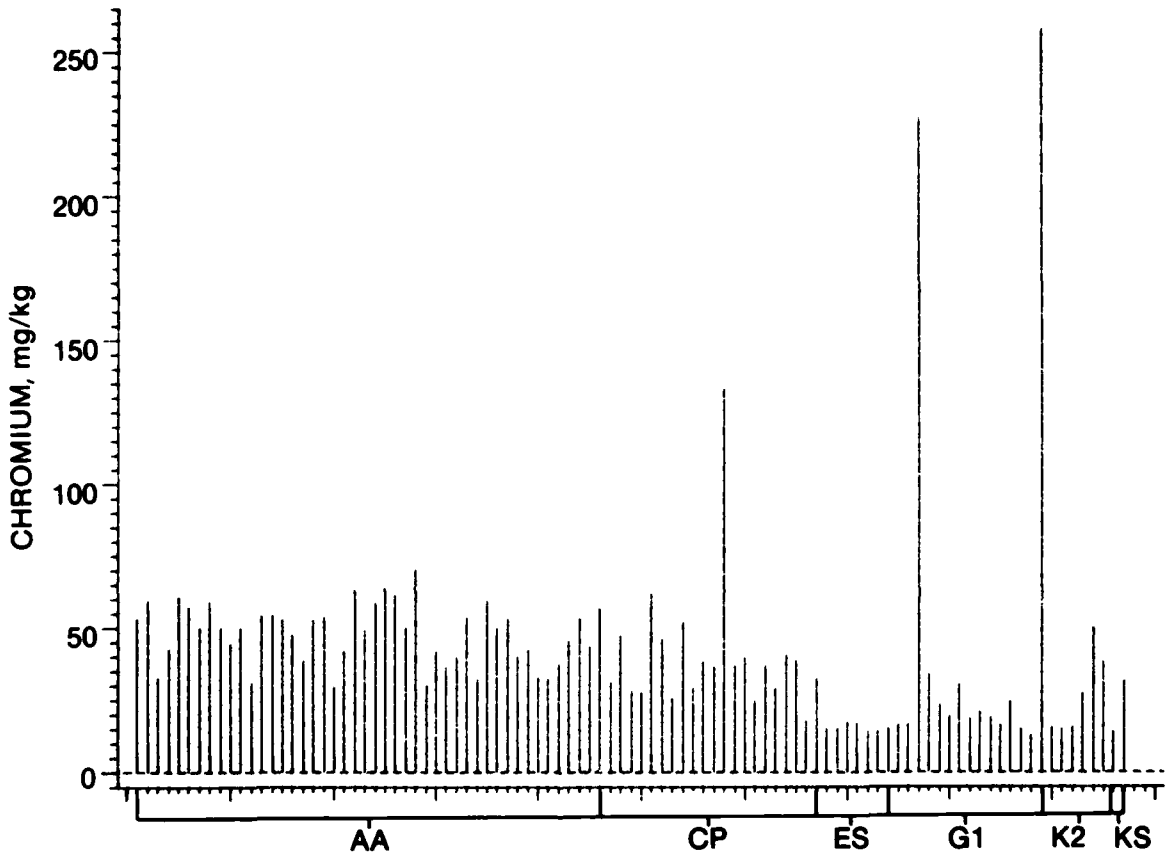


Figure 2-B7. Soil chromium content

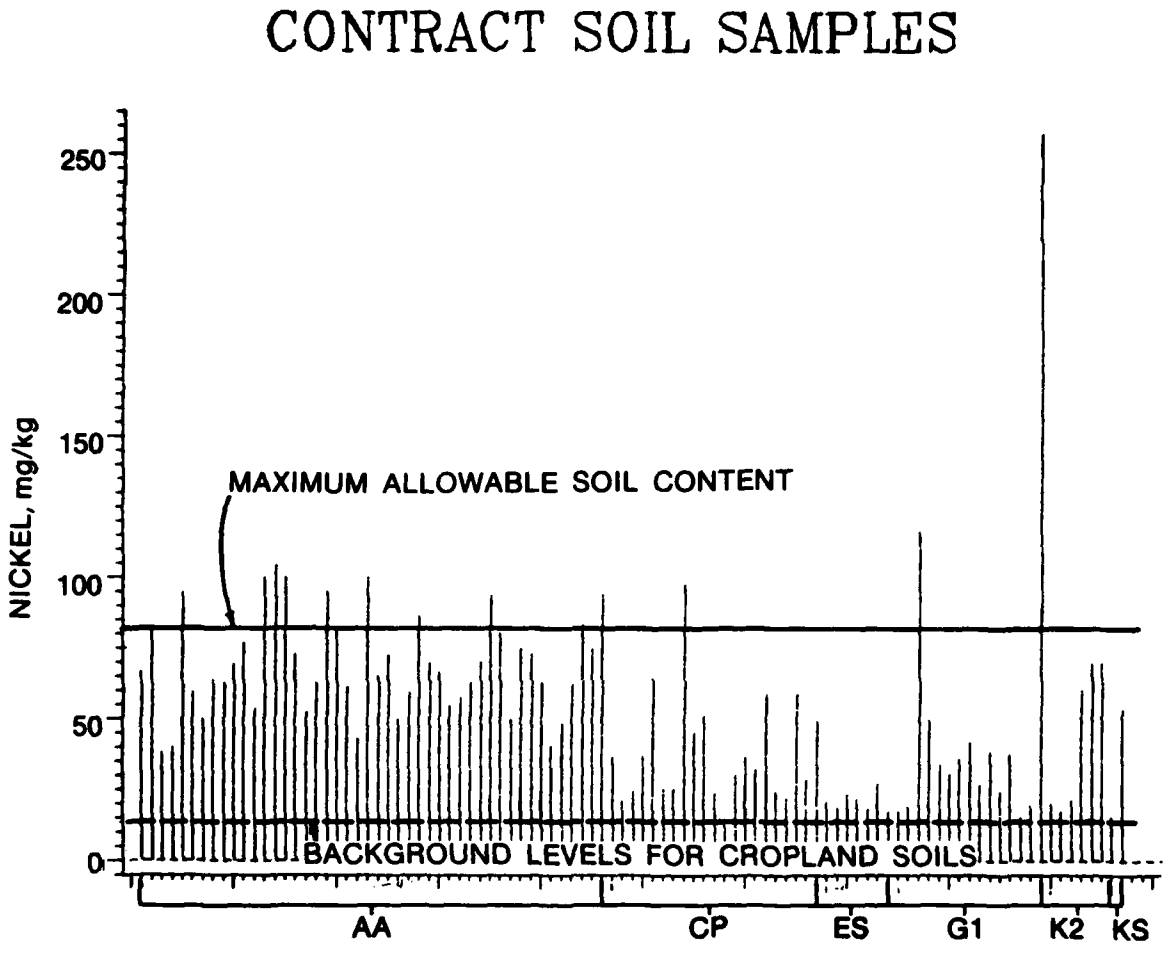
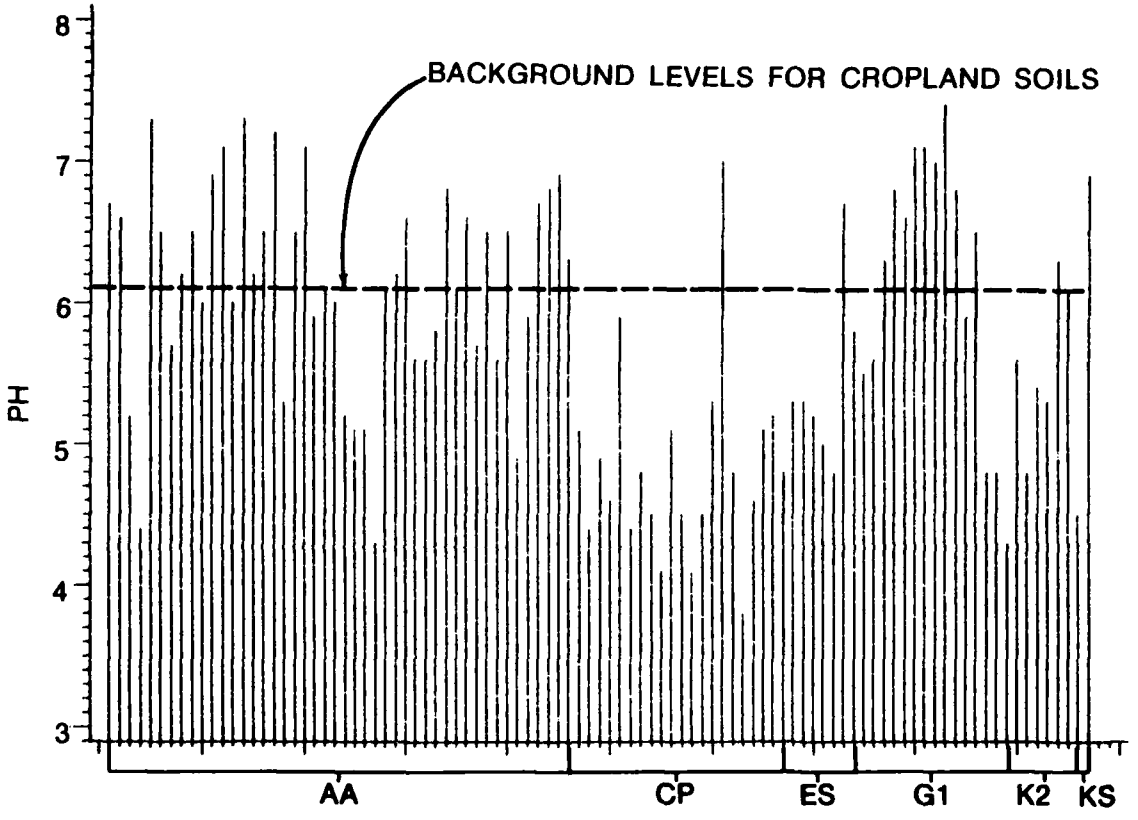


Figure 2-B8. Soil nickel content

CONTRACT SOIL SAMPLES



LOCATION

AA - ALLIED SITE A	ES - ADJACENT TO C&P/ESI
AB - ALLIED SITE B	G1 - G-1 SITE
BK - REFERENCE SITES	K2 - K-2 SITE
CP - COKE PILE SITE	KS - KILN SITE

Figure 2-B9. Soil pH

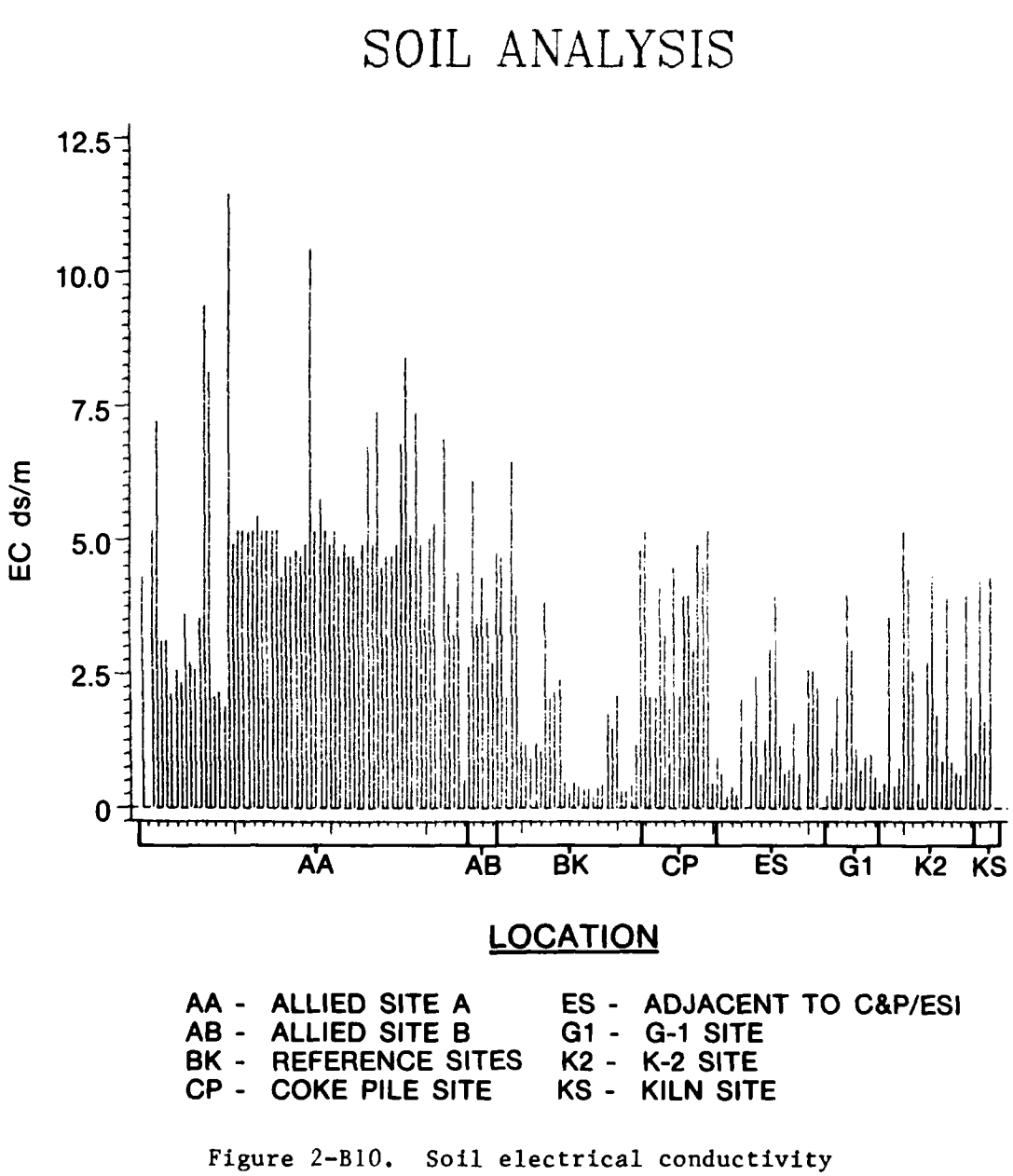


Figure 2-B10. Soil electrical conductivity

Table 2-C1
Summary of Field-Collected Water Quality Data

Day 1 (28-29 Aug 84)

Area	PH	D/O	Temp	Sal
BK		6.3 (2.5-7.8)	23.1 (21.5-27)	2.9 (2.0-4.4)
ES		6.6 (5.4-7.8)	16.9 (16.5-17.5)	1.1 (0-5)
K2		6.8 (5.0-7.9)	21.1 (20.0-22.4)	2.08 (2-2.5)
G1		6.8 (5.6-7.7)	17.3 (16.8-18.0)	1.1 (1-2)
AA		6.4 (5.2-8.2)	20.5 (19.2-23.0)	5.0 (3.0-6.5)

Day 28 (25-26 Sep 84)

Area	PH	D/O	Temp.	Sal
BK	7.7 (7.4-8.4)	7.8 (6.4-9.2)	17.7 (12.7-22.5)	0.29 (0-1.0)
ES	8.04 (7.9-8.4)	7.2 (5.6-8.7)	16.6 (15.0-18.8)	2.4 (1.0-4.0)
K2	7.5 (6.9-8.1)	8.8 (8.2-9.3)	20.1 17.8-22.2)	2.5 (0-5.0)
G1	8.06 (7.9-8.2)	8.2 (7.6-8.7)	16.5 (15.5-17.2)	1.6 (1.0-2.0)
AA	6.9 (6.8-7.7)	6.2 (4.3-7.9)	18.8 (16.4-22.2)	2.2 (0.75-4.0)

Table 2-C2.

Clam Tissue Analysis

OBS	ID	WEIGHT	VOLUME	AS	CD	CU	PB	NI	SE	ZN	CLAM_OUT	DRY_WT	LOCATION	CLAM_IN
1	AACLW1241R1	.577	50	2.17	0.45	76.36	0.30	0.85	0.55	110.6	8	2.03	1	10
2	AACLW1241R2	.540	50	1.94	0.32	65.02	0.23	0.73	1.02	123.8	10	1.99	2	10
3	AACLW1241R3	.543	50	1.93	0.84	57.57	0.32	1.64	1.11	124.9	10	1.88	3	10
4	AACLW1242R1	.517	50	2.03	1.82	68.30	0.15	0.56	1.26	139.0	10	2.09	4	10
5	AACLW1242R2	.508	50	1.67	1.50	65.47	0.34	0.48	1.48	151.3	10	2.04	5	10
6	AACLW1242R3	.581	50	1.46	0.86	70.93	0.30	0.24	1.56	167.5	7	1.82	6	10
7	AACLW1243R1	.516	50	1.94	1.74	61.94	0.44	0.76	0.07	139.2	10	2.10	7	10
8	AACLW1243R2	.532	50	1.97	2.71	76.15	0.61	4.50	1.13	137.9	10	1.74	8	10
9	AACLW1243R3	.503	50	1.49	1.60	52.31	0.15	0.88	1.19	140.8	10	2.46	9	10
10	AACLW1244R1	.504	50	2.08	0.96	82.66	0.25	0.98	1.19	144.5	9	1.89	10	10
11	AACLW1244R2	.515	50	1.84	0.68	66.23	0.63	0.95	1.07	130.8	9	2.46	11	10
12	AACLW1244R3	.524	50	1.81	0.25	87.90	0.24	0.94	1.15	148.5	9	2.26	12	10
13	AACLW1245R1	.509	50	2.08	0.77	56.55	0.35	0.97	1.09	125.4	10	2.10	13	10
14	AACLW1245R2	.525	50	2.00	0.22	52.88	0.33	1.13	0.86	112.1	10	2.23	14	10
15	AACLW1245R3	.513	50	1.46	0.78	60.45	0.54	10.61	0.28	147.8	10	1.97	15	10
16	AACLW1246R1	.557	50	1.89	1.50	72.64	0.31	0.16	1.17	134.4	9	2.03	16	10
17	AACLW1246R2	.514	50	1.46	1.45	58.39	0.24	0.76	0.68	131.0	10	2.17	17	10
18	AACLW1246R3	.627	50	2.31	0.76	59.11	0.28	0.46	1.24	114.6	10	2.39	18	10
19	AACLW1251R1	.564	50	2.22	1.12	51.79	0.00	0.00	0.98	100.8	10	2.41	30	10
20	AACLW1251R2	.571	50	1.84	0.93	57.90	0.31	0.42	1.15	117.1	10	1.89	30	10
21	AACLW1251R3	.560	50	1.64	0.84	46.22	0.13	0.16	0.75	109.2	9	2.38	30	10
22	AACLW1253R1	.540	50	1.20	0.78	48.26	0.05	0.08	1.02	108.0	9	2.02	31	10
23	AACLW1253R2	.501	50	1.10	0.97	51.22	0.00	0.00	0.80	107.5	10	2.60	31	10
24	AACLW1253R3	.533	50	1.59	0.83	43.55	0.14	0.36	1.03	105.7	9	2.25	31	10
25	AACLW1254R1	.527	50	1.23	0.92	47.84	0.52	0.74	1.24	142.0	8	1.51	32	10
26	AACLW1254R2	.520	50	1.44	0.88	51.17	0.43	0.27	1.26	118.9	10	2.13	33	10
27	AACLW1254R3	.524	50	1.62	0.88	55.65	0.24	0.00	1.24	109.4	10	1.99	34	10
28	AACLW1261R1	.545	50	1.56	0.86	60.02	0.05	0.99	0.93	116.2	10	1.91	59	10
29	AACLW1261R2	.510	50	1.86	0.79	83.25	0.93	1.16	1.08	117.3	10	2.30	60	10
30	AACLW1261R3												61	10
31	AACLW1264R1	.542	50	2.12	1.02	71.70	0.97	0.91	1.11	115.0	6	1.31	64	10
32	AACLW1264R2	.530	50	1.42	0.60	70.87	0.24	1.12	1.14	112.9	5	0.98	64	10
33	AACLW1264R3	.595	50	2.29	0.87	83.66	0.21	1.25	1.10	124.5	10	2.05	64	10
34	AACLW1266R1	.551	50	2.45	0.02	75.65	0.77	0.93	1.18	112.9	9	1.68	66	10
35	AACLW1266R2	.559	50	1.88	0.62	64.42	0.13	0.52	1.16	115.1	10	1.96	66	10
36	AACLW1266R3												66	10
37	ACLW1361R1	.513	50	2.44	0.80	65.50	0.15	1.06	1.17	140.0	10	2.29	74	10
38	ACLW1361R2	.536	50	1.59	0.92	68.77	0.33	1.10	1.13	123.8	10	1.81	75	10
39	ACLW1361R3	.528	50	1.61	0.90	86.00	0.33	1.97	1.14	122.8	9	1.79	76	10
40	ACLW1362R1	.506	50	1.48	0.80	67.31	0.00	0.97	0.19	130.1	10	1.70	77	10
41	ACLW1362R2	.550	50	2.09	0.69	62.02	0.50	0.00	1.10	130.6	10	2.01	78	10
42	ACLW1362R3	.501	50	2.30	0.67	62.50	0.35	0.58	1.10	127.4	9	2.00	79	10
43	ACLW1371R1	.538	50	1.79	0.81	58.57	0.42	1.21	1.17	117.2	9	2.15	80	10
44	ACLW1371R2	.573	50	2.53	0.84	71.13	0.92	1.64	2.11	129.7	10	2.19	81	10
45	ACLW1371R3	.545	50	2.46	0.88	84.42	0.41	1.36	2.11	114.4	10	2.69	82	10
46	ACLW1372R1	.501	50	1.50	0.69	48.92	1.25	1.28	1.10	108.5	10	2.70	83	10
47	ACLW1372R2	.579	50	1.81	0.58	39.91	0.82	1.37	2.13	132.7	8	2.52	84	10
48	ACLW1372R3	.546	50	1.83	0.61	55.24	0.96	0.63	1.23	135.2	8	2.34	85	10
49	ACLW1373R1	.512	50	1.95	0.73	56.17	0.24	1.25	2.15	111.0	10	2.49	86	10
50	ACLW1373R2	.526	50	1.81	0.72	52.40	0.33	0.36	2.10	109.0	9	2.32	87	10
51	ACLW1373R3	.598	50	2.59	0.72	54.62	0.71	0.82	1.42	110.9	10	2.60	88	10
52	ACLW1374R1	.534	50	2.15	0.75	68.00	0.89	0.55	1.19	99.9	6	1.29	89	10
53	ACLW1374R2	.511	50	1.86	0.70	49.73	0.93	2.14	1.17	113.2	7	1.41	90	10
54	ACLW1374R3	.502	50	2.09	0.79	62.17	0.55	1.68	1.19	105.3	8	1.65	91	10

Table 2-C2.
(Concluded)

OBS	ID	WEIGHT	VOLUME	AS	CD	CU	PB	NI	SE	ZN	CLAM_OUT	DRY_WT	LOCATION	CLAM_IN
59	F5CLW13H1R1	.558	50	2.42	1.20	69.46	1.03	0.97	2.06	130.5	10	2.09	126	10
5A	F5CLW13H1R2	515	50	1.65	1.09	59.53	1.02	0.47	1.84	113.3	8	2.24	127	10
5B	F5CLW13H1R3	599	50	1.75	1.05	51.44	0.38	0.15	1.82	131.6	10	2.59	128	10
5C	F5CLW13J1R1	545	50	1.93	1.28	56.81	0.69	0.63	1.38	120.8	9	2.03	131	10
5D	F5CLW13J1R2	577	50	1.13	1.21	54.52	0.74	1.11	2.08	151.4	10	2.21	131	10
5E	F5CLW13J1R3	598	50	1.09	0.86	50.69	0.88	0.49	1.76	127.7	10	2.28	131	10
5F	F5CLW13K1R1	525	50	0.86	0.89	60.97	0.81	5.22	1.24	156.8	8	1.78	134	10
60	F5CLW13K1R2	508	50	1.08	0.89	60.55	1.82	0.18	1.48	159.1	10	2.24	134	10
61	F5CLW13K1R3	562	50	1.51	0.98	63.72	1.29	0.07	1.91	156.3	9	2.49	134	10
62	F5CLW13L1R1	580	50	1.47	0.23	73.90	2.80	10.07	1.71	179.9	9	2.01	137	10
63	F5CLW13L1R2	617	50	1.38	1.23	62.50	1.90	0.00	1.94	255.8	10	2.58	137	10
64	F5CLW13L1R3	513	50	1.46	1.43	81.21	4.92	0.08	1.85	271.6	10	2.29	137	10
65	F5CLW14F1R1	573	50	2.36	0.86	74.10	0.65	1.12	1.03	131.5	9	2.53	140	10
66	F5CLW14F1R2	511	50	1.86	0.87	44.05	0.83	2.14	1.86	133.7	9	2.54	141	10
67	F5CLW14F1R3	651	50	1.77	0.56	46.87	0.81	0.60	1.77	133.4	8	2.00	142	10
68	F5CLW12N2R1	552	50	1.18	1.01	56.81	4.57	0.35	1.26	167.3	10	2.37	146	10
69	F5CLW12N2R2	533	50	1.41	1.22	61.74	4.64	0.36	1.41	201.4	10	2.10	146	10
6A	F5CLW12N2R3	533	50	1.22	0.94	78.07	6.71	0.08	1.22	255.8	10	2.25	146	10
6B	F5CLW13L4R1	509	50	1.19	1.22	78.31	0.83	0.38	1.47	241.3	10	2.42	148	10
6C	F5CLW13L4R2	510	50	0.88	1.54	62.08	5.34	0.00	1.67	284.0	10	2.11	149	10
6D	F5CLW13L4R3	516	50	1.45	1.44	67.27	4.31	0.08	1.55	241.9	10	2.53	150	10
6E	F5CLW13M1R1	513	50	1.07	1.15	54.60	2.10	0.00	1.46	200.5	10	2.16	151	10
6F	F5CLW13M1R2	551	50	1.36	1.05	72.61	8.39	0.62	1.74	180.3	10	2.21	152	10
70	F5CLW13M1R3	531	50	1.22	1.46	71.96	7.86	0.17	1.41	218.2	8	1.48	153	10
71	F5CLW45J1R1	515	50	0.87	0.69	50.02	0.15	0.18	0.68	133.7	10	2.45	161	10
72	F5CLW45J1R2	532	50	1.22	0.64	52.18	0.05	0.36	0.75	147.3	10	2.38	161	10
73	F5CLW45J1R3	502	50	1.49	0.57	50.92	0.15	0.58	0.90	135.1	10	2.61	161	10
74	F5CLW8P3R1	545	50	1.01	0.81	68.00	4.63	0.00	1.19	209.8	10	2.28	170	10
75	F5CLW8P3R2	551	50	1.54	1.12	83.14	9.21	0.17	1.26	196.6	10	1.85	171	10
76	F5CLW8P3R3	503	50	1.29	0.82	77.75	3.63	0.00	1.29	230.3	10	2.32	172	10

Table 2-C3.

Initial Clam Tissue Content

OBS	ID	WEIGHT	VOLUME	AS	CD	CU	PB	NI	SE	ZN
1	CL-BKGD-1	0.557	50	1.17	0.85	44.09	0.85	1.24	0.81	111.92
2	CL-BKGD-2	0.516	50	0.87	0.95	59.61	0.00	0.00	0.87	98.53
3	CL-BKGD-3	0.532	50	1.22	0.90	68.44	0.33	0.36	1.03	110.60
4	CL-BKGD-4	0.523	50	1.05	0.93	62.07	0.14	0.00	0.86	97.21
5	CL-BKGD-5	0.546	50	0.64	0.89	50.02	0.14	0.35	0.92	99.52
6	CL-BKGD-6	0.513	50	0.68	1.17	48.46	0.54	0.18	0.88	107.88
7	CL-BKGD-7	0.575	50	1.13	0.80	70.02	0.22	0.00	0.96	101.46
8	CL-BKGD-8	0.514	50	1.26	0.71	62.18	0.44	0.86	0.88	118.37
9	CL-BKGD-9	0.510	50	0.69	0.76	44.82	0.15	0.28	0.69	105.57
10	CL-BKGD-10	0.511	50	1.66	0.90	58.53	0.34	0.00	0.68	114.17
11	CL-BKGD-11	0.521	50	0.48	0.59	41.57	0.14	0.18	0.67	99.50

Table 2-C4.

Initial Clam Tissue Summary

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE	C.V
WEIGHT	11	0.529	0.022	0.510	0.575	0.006	5.818	0.000	4.070
VOLUME	11	50.000	0.000	50.000	50.000	0.000	550.000	0.000	0.000
AS	11	0.987	0.349	0.480	1.663	0.105	10.860	0.122	35.341
CD	11	0.858	0.148	0.592	1.167	0.045	9.438	0.022	17.202
CU	11	55.438	10.048	41.574	70.017	3.030	609.815	100.961	18.125
PB	11	0.299	0.241	0.000	0.853	0.073	3.287	0.058	80.482
NI	11	0.313	0.399	0.000	1.241	0.120	3.443	0.159	127.566
SE	11	0.840	0.117	0.672	1.034	0.035	9.242	0.014	13.931
ZN	11	105.884	7.193	97.208	118.366	2.169	1164.722	51.734	6.793

Table 2-C5.

Blank Analysis

OBS	ID	VOLUME	AS	CD	CU	PB	NI	SE	ZN
1	CL-BLANK-1	50	0.01	0.00	0.01	0.01	0.01	0.01	0.1
2	CL-BLANK-10	50	0.01	0.00	0.00	0.00	0.00	0.01	0.0
3	CL-BLANK-11	50	0.01	0.00	0.01	0.00	0.00	0.01	0.1
4	CL-BLANK-12	50	0.01	0.00	0.01	0.01	0.02	0.01	0.1
5	CL-BLANK-2	50	0.01	0.00	0.01	0.00	0.02	0.01	0.1
6	CL-BLANK-3	50	0.01	0.00	0.02	0.00	0.03	0.01	0.1
7	CL-BLANK-4	50	0.01	0.00	0.01	0.00	0.01	0.01	0.1
8	CL-BLANK-5	50	0.01	0.00	0.01	0.00	0.01	0.01	0.1
9	CL-BLANK-6	50	0.01	0.00	0.00	0.00	0.03	0.01	0.0
10	CL-BLANK-7	50	0.01	0.00	0.01	0.01	0.01	0.01	0.1
11	CL-BLANK-8	50	0.01	0.00	0.01	0.00	0.00	0.01	0.1
12	CL-BLANK-9	50	0.01	0.00	0.01	0.00	0.00	0.01	0.1

Table 2-C6.

Blank Analysis Summary

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE	C V
VOLUME	12	50.000	0.000	50.000	50.000	0.000	600.000	0.000	0.000
AS	12	0.005	0.000	0.005	0.005	0.000	0.060	0.000	0.000
CD	12	0.001	0.001	0.000	0.003	0.000	0.009	0.000	117.499
CU	12	0.008	0.004	0.002	0.017	0.001	0.094	0.000	51.015
PB	12	0.004	0.002	0.001	0.006	0.000	0.042	0.000	47.964
NI	12	0.011	0.011	0.001	0.034	0.003	0.134	0.000	94.529
SE	12	0.005	0.000	0.005	0.005	0.000	0.060	0.000	0.000
ZN	12	0.083	0.026	0.030	0.119	0.008	0.998	0.001	31.354

Table 2-C7.

NBS Oyster Tissue Analysis

OBS	ID	WEIGHT	VOLUME	AS	CD	CU	PB	NI	SE	ZN
1	CL-OYS-1	526	50	1.81	3.81	66.3	0.43	2.27	0.48	893.2
2	CL-OYS-10	503	50	1.29	0.29	58.6	0.55	0.08	0.30	892.3
3	CL-OYS-11	501	50	1.30	1.95	62.5	0.35	0.00	0.30	891.9
4	CL-OYS-12	499	50	1.30	0.09	60.7	0.55	0.08	0.50	868.4
5	CL-OYS-2	515	50	2.82	5.22	67.9	0.53	0.57	0.49	904.5
6	CL-OYS-3	544	50	2.11	3.31	69.1	0.41	0.35	0.46	911.5
7	CL-OYS-4	505	50	1.88	4.22	68.8	0.54	1.47	0.50	907.6
8	CL-OYS-5	556	50	2.25	4.39	68.5	0.40	0.70	0.63	927.8
9	CL-OYS-6	554	50	1.90	3.72	64.1	0.41	0.17	0.63	876.1
10	CL-OYS-7	528	50	1.80	4.09	65.2	0.33	0.65	0.66	882.3
11	CL-OYS-8	517	50	1.64	4.42	63.1	0.24	2.69	0.68	898.1
12	CL-OYS-9	536	50	1.87	4.08	63.3	0.98	0.17	0.65	886.8

Table 2-C8.

NBS Oyster Tissue Analysis Summary*

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE	C. V
WEIGHT	12	0.524	0.020	0.499	0.556	0.006	6.284	0.000	3.893
VOLUME	12	50.000	0.000	50.000	50.000	0.000	600.000	0.000	0.000
AS	12	1.830	0.439	1.292	2.816	0.127	21.962	0.193	23.999
CD	12	3.299	1.648	0.087	5.220	0.476	39.584	2.716	49.964
CU	12	64.873	3.336	58.867	69.136	0.963	778.476	11.130	5.143
PB	12	0.478	0.186	0.242	0.979	0.054	5.731	0.035	38.929
NI	12	0.766	0.900	0.000	2.691	0.260	9.196	0.810	117.471
SE	12	0.522	0.132	0.298	0.677	0.038	6.268	0.018	25.349
ZN	12	895.047	16.289	868.417	927.770	4.702	10740.568	265.346	1.820

*Standards

NBS Oyster Tissue Analysis Values

AS	11.5	15.3
CD	3.1	3.9
CU	66.5	79.5
PB	.44	.52
NI	.84	1.22
SE	1.6	2.6
ZN	838.0	866.0

Table 2-D1.

Field Analysis

OBS	ID	WEIGHT	AS	CD	CU	PB	NI	SE	ZN	LEAVES	STEMS	DEAD	SEED	OTHER	LOCATION
1	AAPVW1241R1	2.00	0.00	0.07	4.30	0.48	4.35	0.00	11.44	76.3	88.3	92.5	45.4	13.1	1
2	AAPVW1241R2	2.00	0.00	0.00	3.42	0.63	6.60	0.00	11.49	120.9	218.6	49.0	102.6	.	2
3	AAPVW1241R3	2.00	0.00	0.19	3.90	0.30	5.50	0.00	15.36	37.2	78.4	52.7	34.1	30.7	3
4	AAPVW1242R1	2.00	0.00	0.09	5.11	0.80	3.32	0.00	12.89	30.8	31.0	82.6	29.0	78.3	4
5	AAPVW1242R2	2.00	0.00	0.09	5.47	1.00	2.70	0.00	13.34	45.5	38.2	68.5	16.8	38.6	5
6	AAPVW1242R3	2.01	0.00	0.09	4.41	0.70	2.94	0.00	13.28	23.1	25.9	95.8	15.2	30.5	6
7	AAPVW1243R1	2.00	0.10	0.11	6.09	0.50	3.24	0.00	25.60	35.7	14.7	1.3	.	12.3	7
8	AAPVW1243R2	2.00	0.00	0.10	5.24	0.48	2.90	0.00	16.61	59.1	32.3	21.4	.	19.5	8
9	AAPVW1243R3	2.00	0.00	0.03	4.25	0.38	3.47	0.00	17.66	37.5	21.2	.	.	7.7	9
10	AAPVW1244R1	2.00	0.00	0.15	2.29	0.63	3.62	0.00	11.97	70.3	72.1	51.8	19.2	.	10
11	AAPVW1244R2	2.00	0.00	0.16	4.55	0.38	5.25	0.00	16.77	32.9	24.4	88.9	.	.	11
12	AAPVW1244R3	2.01	0.00	0.00	3.33	0.62	4.45	0.00	14.10	48.3	49.1	51.0	4.6	.	12
13	AAPVW1245R1	2.00	0.00	0.19	2.64	0.50	2.04	0.00	9.60	10.4	14.8	79.3	14.4	.	13
14	AAPVW1245R2	2.00	0.00	0.27	6.31	2.12	4.42	0.00	12.15	49.1	25.0	172.9	8.2	6.2	14
15	AAPVW1245R3	2.00	0.00	0.15	3.97	0.58	3.42	0.00	14.18	40.5	22.7	199.1	6.7	.	15
16	AAPVW1246R1	2.00	0.00	0.06	3.14	0.40	1.55	0.00	18.46	125.3	49.2	6.1	.	.	16
17	AAPVW1246R2	2.00	0.00	0.06	3.82	0.13	1.77	0.00	16.12	183.7	95.7	70.8	.	.	17
18	AAPVW1246R3	2.00	0.00	0.20	4.24	0.15	1.50	0.00	14.83	31.9	15.2	.	.	72.0	18
19	AAPVW1251R1	2.01	0.52	0.02	6.25	0.13	0.45	0.00	26.56	8.1	2.6	2.0	.	14.0	19
20	AAPVW1251R2	2.00	0.82	0.12	7.19	1.48	1.12	0.00	28.10	9.2	3.5	6.0	.	11.3	20
21	AAPVW1251R3	2.01	0.27	0.08	7.85	1.72	1.79	0.00	47.75	6.9	2.8	3.2	.	43.9	21
22	AAPVW1252	2.00	0.17	0.15	7.36	0.83	1.12	0.00	46.32	9.1	3.3	1.3	.	13.2	22
23	AAPVW1253	2.00	0.52	0.08	3.94	0.18	1.32	0.00	31.34	12.2	12.3	7.1	.	.	23
24	AAPVW1254R1	2.00	0.52	0.24	2.74	1.20	0.67	0.00	14.74	31.1	28.8	2.9	10.2	39.5	24
25	AAPVW1254R2	2.01	0.82	0.03	4.01	1.72	1.37	0.00	29.80	11.2	11.1	5.1	4.2	47.8	25
26	AAPVW1254R3	2.00	0.32	0.07	3.24	1.28	1.52	0.00	29.35	15.2	9.7	10.6	1.8	36.7	26
27	AAPVW1261R1	2.00	0.58	0.19	9.07	0.63	0.62	0.00	25.39	18.5	9.3	2.6	.	3.0	27
28	AAPVW1261R2	2.01	0.77	0.12	6.36	0.68	0.77	0.00	23.83	13.1	10.8	14.6	1.5	7.0	28
29	AAPVW1261R3	2.00	1.43	0.13	6.00	0.95	1.32	0.00	20.29	24.0	16.5	9.5	.	2.1	29
30	AAPVW1262	.	.	.	.	.	.	.	.	.	.	.	.	.	30
31	AAPVW1263	2.00	0.37	0.10	2.22	1.35	1.57	0.00	21.58	43.6	49.9	6.7	10.5	20.6	31
32	AAPVW1264R1	2.00	0.97	0.15	4.34	2.25	1.92	0.00	31.09	20.7	39.3	15.1	18.0	10.5	32
33	AAPVW1264R2	2.00	0.67	0.15	4.09	1.77	1.79	0.00	39.81	28.9	48.6	4.7	16.6	18.5	33
34	AAPVW1264R3	2.00	0.33	0.13	2.37	1.85	0.45	0.00	19.91	18.7	41.4	.	14.5	132.5	34
35	AAPVW1271R1	.	.	.	.	.	.	.	.	.	.	.	.	.	35
36	AAPVW1271R2	2.00	0.48	0.19	4.25	0.68	0.90	0.00	37.89	.	9.7	10.4	.	48.0	36
37	AAPVW1271R3	2.01	0.12	0.01	2.83	0.53	0.87	0.00	13.93	17.5	14.6	10.7	.	64.6	37
38	AAPVW1272	.	.	.	.	.	.	.	.	.	.	.	.	.	38
39	AAPVW1273	.	.	.	.	.	.	.	.	.	.	.	.	.	39
40	AAPVW1274R1	2.00	0.62	0.14	3.40	1.00	1.67	0.00	70.60	55.0	.	25.6	.	7.8	40
41	AAPVW1274R2	2.00	1.03	0.28	4.37	0.75	1.45	0.00	43.39	32.3	24.0	0.4	.	1.5	41
42	AAPVW1274R3	2.01	0.97	0.14	3.46	2.20	1.29	0.00	39.77	35.2	57.7	37.4	19.2	13.1	42
43	AAPVW1281R1	2.01	0.17	0.13	4.91	0.28	0.77	0.00	24.33	12.2	9.4	50.4	.	13.2	43
44	AAPVW1281R2	2.00	0.32	0.02	3.84	0.65	1.27	0.00	28.33	17.2	14.3	37.2	.	9.9	44
45	AAPVW1281R3	2.00	0.63	0.00	3.37	0.95	1.80	0.00	32.39	42.0	48.8	19.1	.	27.0	45
46	AAPVW1282	2.00	0.22	0.08	2.89	0.55	1.40	0.00	38.33	19.9	10.6	3.6	.	38.3	46
47	AAPVW1283	2.00	0.27	0.03	4.56	1.90	2.39	0.00	29.08	24.4	34.2	15.0	14.5	70.9	47
48	AAPVW1284R1	2.01	0.42	0.11	8.15	1.60	3.44	0.00	50.74	21.0	32.3	1.1	9.2	55.2	48
49	AAPVW1284R2	2.00	0.75	0.06	4.57	1.90	3.64	0.00	50.34	15.5	33.3	10.5	10.7	11.3	49
50	AAPVW1284R3	2.00	0.47	0.19	4.57	1.95	2.62	0.00	43.62	13.0	27.6	1.2	8.2	30.8	50
51	AAPVW1291R1	2.00	0.05	0.11	3.65	0.93	2.87	0.00	36.66	24.7	35.9	20.4	6.1	3.3	51
52	AAPVW1291R2	2.01	0.12	0.00	6.00	1.07	2.44	0.00	55.70	15.5	27.1	16.8	5.7	11.8	52
53	AAPVW1291R3	2.01	0.00	0.12	3.79	1.32	2.27	0.00	28.32	26.7	22.1	7.5	0.6	1.2	53
54	AAPVW1292	2.00	0.00	0.06	3.17	1.15	4.02	0.00	22.39	25.8	47.6	11.7	4.9	66.0	54

Table 2-D1.

(Concluded)

OBS	ID	WEIGHT	AS	CD	CU	PB	NI	SE	ZN	LEAVES	STEMS	DEAD	SEED	OTHER	LOCATION
55	AAPVW16Y3	2.00	0.00	0.08	3.27	1.65	3.80	0.00	18.74	17.9	25.3	7.1	8.1	19.1	55
56	AAPVW16Y4R1	2.00	0.00	0.02	5.37	1.35	4.10	0.00	22.79	32.0	17.0	18.5	.	.	56
57	AAPVW16Y4R2	2.00	0.00	0.11	4.30	0.78	3.37	0.00	17.25	12.7	8.8	17.3	.	21.1	57
58	AAPVW16Y4R3	2.00	0.00	0.09	2.92	1.13	3.99	0.00	22.10	17.8	15.6	22.9	.	20.1	58
59	AAPVW16Z1R1	2.00	0.00	0.38	2.07	0.63	2.12	0.00	9.99	22.0	16.9	.	.	101.3	59
60	AAPVW16Z1R2	2.00	0.00	0.16	2.94	0.28	2.40	0.00	11.88	30.3	119.1	.	17.8	104.8	60
61	AAPVW16Z1R3	2.00	0.02	0.03	3.67	0.55	4.47	0.00	14.23	42.2	61.4	5.2	8.0	98.2	61
62	AAPVW16Z2	2.00	0.00	0.20	3.47	0.98	7.13	0.00	14.65	19.2	16.6	.	.	87.1	62
63	AAPVW16Z3	2.00	0.00	0.05	3.57	1.38	5.74	0.00	13.59	27.0	19.2	.	.	87.4	63
64	AAPVW16Z4	2.00	0.00	1.13	3.07	0.80	3.89	0.00	27.85	19.5	16.9	2.8	.	71.6	64
65	AAPVW16Z5	2.01	0.00	0.17	3.21	0.95	2.64	0.00	9.13	17.8	23.3	1.4	.	74.4	65
66	AAPVW16Z6	2.00	0.00	0.30	3.30	1.73	2.95	0.00	12.66	9.8	34.2	.	13.2	77.3	66
67	AAPVW16Z7	2.00	0.00	0.29	2.99	0.50	3.57	0.00	11.32	21.5	40.2	.	3.5	42.4	67
68	ABPVW15S1	2.00	0.37	1.12	14.80	0.93	1.27	0.00	76.03	15.7	.	37.8	.	.	73
69	BKPVW1161R1	2.00	0.00	0.12	7.26	0.55	3.27	0.00	13.46	43.7	42.5	.	3.6	.	74
70	BKPVW1161R2	2.00	0.00	0.10	11.63	1.10	5.48	0.00	16.90	53.5	40.3	123.7	4.7	.	75
71	BKPVW1161R3	2.00	0.00	0.18	4.94	0.50	4.86	0.00	12.32	36.6	36.9	9.7	5.4	.	76
72	BKPVW1162R1	2.01	0.00	0.16	6.81	0.30	3.09	0.00	11.34	30.6	86.2	18.4	3.9	.	77
73	BKPVW1162R2	2.00	0.00	0.11	4.29	0.63	4.94	0.00	30.86	21.3	23.0	36.9	8.3	.	78
74	BKPVW1162R3	2.01	0.00	0.05	5.73	0.40	3.99	0.00	10.19	51.8	44.9	73.0	19.1	.	79
75	BKPVW1337R1	1.00	0.00	0.26	2.20	0.46	2.25	0.00	39.58	41.1	.	.	.	.	98
76	BKPVW1337R2	1.00	0.00	0.19	3.40	1.01	4.00	0.00	49.28	39.1	.	.	.	.	99
77	BKPVW1337R3	1.00	0.00	0.61	2.45	0.71	2.09	0.00	41.33	65.7	.	.	.	.	100
78	CPPVW30E1	2.00	0.00	0.11	3.44	3.12	4.06	0.40	52.29	34.9	36.4	69.2	2.3	.	117
79	CPPVW30F1	2.01	0.00	0.06	5.43	1.87	1.97	1.02	33.31	53.2	16.8	14.3	.	.	118
80	CPPVW30F2	2.01	0.02	0.00	4.06	1.27	1.52	0.00	66.94	12.2	18.5	43.9	6.0	4.8	119
81	G1PVW12N2	2.00	0.00	0.02	4.57	0.70	0.67	0.00	41.83	81.6	103.1	265.9	10.1	.	146
82	G1PVW13L4R1	2.01	0.00	1.32	9.05	22.70	0.87	0.02	122.58	229.3	307.4	181.0	47.7	.	148
83	G1PVW13L4R2	2.00	0.00	1.41	7.27	32.76	0.80	0.02	101.59	132.1	69.5	61.5	.	.	149
84	G1PVW13L4R3	2.01	0.00	1.05	9.02	25.69	0.74	0.00	147.13	170.3	246.5	66.7	26.9	.	150
85	G1PVW13M1R1	2.00	0.00	0.22	4.05	3.08	1.15	0.00	182.89	62.3	17.6	36.5	3.6	5.9	151
86	G1PVW13M1R2	2.00	0.00	0.23	3.52	4.05	1.10	0.00	305.68	68.1	11.1	31.5	20.1	.	152
87	G1PVW13M1R3	2.00	0.00	0.37	4.20	2.70	0.97	0.00	338.47	68.3	112.5	55.9	9.2	.	153
88	K2PVW3R1	2.01	0.27	0.06	5.98	1.02	2.22	0.00	42.26	26.0	18.1	14.1	3.2	30.4	155
89	K2PVW4N1R1	2.00	0.00	0.08	5.12	0.85	7.34	0.00	38.62	29.3	15.6	3.5	2.2	.	156
90	K2PVW4N1R2	2.00	0.00	0.07	5.85	0.53	3.10	0.00	45.39	18.9	5.5	22.9	.	.	157
91	K2PVW4N1R3	2.00	0.02	0.18	7.32	0.98	8.21	0.00	59.58	11.9	12.1	28.8	.	.	158
92	K2PVW4Q1	2.01	0.00	0.03	2.02	0.82	1.07	0.00	66.66	21.7	5.1	16.1	.	.	160
93	K2PVW5P1	2.01	0.00	0.34	3.36	0.83	3.26	0.00	24.08	32.6	55.7	12.6	30.8	67.0	163
94	K2PVW6P1	2.00	0.00	0.02	2.74	1.15	1.12	0.00	70.28	35.2	40.1	17.4	.	.	165
95	K2PVW6Q1	2.01	0.00	0.38	5.08	1.22	1.72	0.00	487.18	25.9	31.3	.	13.5	.	166
96	K2PVW6Q2	2.00	0.00	0.13	2.85	0.68	0.75	0.00	100.34	47.3	88.7	13.7	8.6	.	167
97	K2PVW8P2	1.98	0.13	1.62	22.63	53.64	1.54	0.03	742.18	2.6	0.8	.	.	.	169
98	K2PVW8P3R1	2.00	0.02	0.53	9.05	12.40	1.10	0.00	268.10	139.4	121.7	18.2	7.8	.	170
99	K2PVW8P3R2	2.00	0.00	0.12	7.31	5.07	0.30	0.07	187.27	181.8	121.0	181.6	4.8	.	171
100	K2PVW8P3R3	2.01	0.00	0.66	8.35	28.94	0.94	0.00	452.28	88.3	63.6	19.0	7.8	.	172

Table 2-D2.

Blank Analysis

OBS	ID	AS	CD	CU	PB	NI	SE	ZN
1	BLANK50	005	004	042	033	030	005	066
2	BLANK50	005	003	031	016	030	005	030
3	BLANK50	005	004	042	006	031	005	043
4	BLANK50	005	002	035	004	030	005	097
5	BLANK50	005	003	032	003	030	005	097
6	BLANK50	005	004	042	004	030	005	052
7	BLANK50	005	006	037	005	030	005	030
8	BLANK50	005	003	048	005	030	005	030
9	BLANK50	005	005	043	004	030	005	045

Table 2-D3.

Blank Analysis Summary

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE	C V
AS	9	0 005	0 000	0 005	0 005	0 000	0 045	0 000	0 000
CD	9	0 004	0 001	0 002	0 006	0 000	0 033	0 000	32 009
CU	9	0 039	0 006	0 031	0 048	0 002	0 352	0 000	14 489
PB	9	0 009	0 010	0 003	0 033	0 003	0 080	0 000	110 863
NI	9	0 030	0 000	0 030	0 031	0 000	0 271	0 000	1 107
SE	9	0 005	0 000	0 005	0 005	0 000	0 045	0 000	0 000
ZN	9	0 054	0 027	0 030	0 097	0 009	0 490	0 001	49 346

Table 2-D4.

NBS Tomato Leaves Analysis

OBS	ID	WEIGHT	AS	CD	CU	PB	NI	SE	ZN
1	TLEAVES50	2.01	0	2.97	10.73	[illegible]05	0.50	0	62.39
2	TLEAVES50	2.01	0	2.28	10.17	[illegible]59	0.84	0	60.96
3	TLEAVES50	2.00	0	1.78	10.79	[illegible]65	0.97	0	60.08
4	TLEAVES50	2.00	0	2.15	10.60	[illegible]74	0.52	0	61.02
5	TLEAVES50	2.00	0	2.03	10.83	[illegible]36	0.62	0	65.51
6	TLEAVES50	2.00	0	2.58	11.32	[illegible]24	1.02	0	61.77
7	TLEAVES50	2.01	0	2.67	10.63	5.58	1.32	0	60.90
8	TLEAVES50	2.00	0	1.70	10.98	[illegible]37	1.05	0	60.52
9	TLEAVES50	2.01	0	2.67	10.49	5.44	0.67	0	61.21

Table 2-D5.

NBS Tomato Leaves Analysis Summary*

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE	C. V.
WEIGHT	9	2. 005	0. 002	2. 002	2. 008	0. 001	18. 046	0. 000	0. 101
AS	9	0. 000	0. 000	0. 000	0. 000	0. 000	0. 000	0. 000	
CD	9	2. 315	0. 436	1. 704	2. 971	0. 145	20. 836	0. 190	18. 851
CU	9	10. 726	0. 322	10. 167	11. 325	0. 107	96. 532	0. 103	2. 998
PB	9	6. 001	0. 603	5. 436	7. 363	0. 201	54. 013	0. 364	10. 046
NI	9	0. 834	0. 278	0. 496	1. 317	0. 093	7. 508	0. 077	33. 269
SE	9	0. 000	0. 000	0. 000	0. 000	0. 000	0. 000	0. 000	
ZN	9	61. 594	1. 613	60. 080	65. 509	0. 538	554. 343	2. 602	2. 619

* Standards

NBS Tomato Leaves Analysis Values		
AS	0.22	0.32
CD	3.0	
CU	10.0	12.0
PB	6.0	6.6
NI		
SE		
ZN	56.0	68.0

Table 2-D6.

Greenhouse Flooded Plant Analysis

OBS	ID	WEIGHT	AS	CD	CU	PB	NI	SE	ZN	LOCATION	TOT_WT
1	AAPCW1241R1	2.00	0.32	0.95	1.18	0.00	0.57	0.00	21.75	1	3.67
2	AAPCW1241R2	2.00	0.00	0.09	1.50	0.05	1.12	0.00	24.00	2	4.54
3	AAPCW1241R3									3	
4	AAPCW1242R1	2.00	0.00	0.21	4.75	0.08	2.27	0.00	59.77	4	2.98
5	AAPCW1242R2	2.00	0.00	0.17	3.16	0.00	0.67	0.00	26.30	5	9.53
6	AAPCW1242R3	2.00	0.30	0.61	1.48	0.30	0.62	0.00	20.71	6	12.78
7	AAPCW1243R1	2.00	0.37	0.11	2.23	0.10	0.39	0.00	14.61	7	13.60
8	AAPCW1243R2	2.00	0.20	0.00	3.10	0.00	0.17	0.00	19.61	8	7.23
9	AAPCW1243R3	2.00	0.12	0.09	3.78	0.10	1.54	0.00	23.28	9	9.42
10	AAPCW1244R1	2.00	0.07	0.15	1.48	0.00	0.27	0.00	21.31	10	10.62
11	AAPCW1244R2	2.00	0.60	0.09	2.20	0.00	0.62	0.00	18.23	11	2.35
12	AAPCW1244R3	2.00	0.83	0.11	2.28	0.36	0.57	0.00	13.04	12	2.89
13	AAPCW1245R1	2.00	0.00	0.00	5.02	0.03	0.44	0.00	22.51	13	13.42
14	AAPCW1245R2	0.64	0.00	0.02	2.73	0.17	0.14	0.00	19.16	14	0.96
15	AAPCW1245R3	2.00	0.00	0.09	5.65	0.13	2.44	0.00	19.34	15	8.22
16	AAPCW1246R1	2.00	0.15	0.00	2.68	0.05	0.64	0.00	21.51	16	11.76
17	AAPCW1246R2	2.00	0.32	0.13	4.85	0.13	0.84	0.00	36.49	17	8.49
18	AAPCW1246R3	2.01	0.07	0.21	3.52	0.00	0.52	0.00	23.99	18	6.32
19	AAPCW16U1R1	0.95	2.42	0.36	4.16	0.22	0.60	0.00	13.49	19	1.02
20	AAPCW16U1R2	0.40	26.74	0.11	7.11	1.14	0.60	0.00	17.39	20	0.72
21	AAPCW16U1R3	0.19	3.63	1.40	4.72	4.46	0.47	0.00	43.21	21	0.42
22	AAPCW16U2	2.00	0.70	0.22	5.51	0.00	2.12	0.00	97.55	22	2.27
23	AAPCW16U3	2.00	0.62	0.03	7.75	0.13	0.82	0.00	23.02	23	2.00
24	AAPCW16U4R1	1.27	1.69	0.22	6.15	0.76	0.03	0.00	16.93	24	1.27
25	AAPCW16U4R2	1.00	0.00	0.26	1.91	1.06	0.54	0.00	19.12	25	1.00
26	AAPCW16U4R3	2.01	1.52	0.20	6.29	0.35	1.04	0.00	20.54	26	2.01
27	AAPCW16V1R1									27	
28	AAPCW16V1R2	0.48	0.62	0.83	3.85	0.54	.0.19	0.00	17.99	28	0.48
29	AAPCW16V1R3									29	
30	AAPCW16V2	1.60	2.65	0.54	3.88	0.00	0.27	0.97	11.46	30	1.60
31	AAPCW16V3	0.67	1.41	0.10	2.98	1.42	0.06	0.00	10.22	31	0.67
32	AAPCW16V4R1	2.00	2.42	0.28	5.00	0.78	0.32	0.00	14.86	32	2.00
33	AAPCW16V4R2	2.00	3.43	0.19	7.06	0.43	1.07	0.00	32.54	33	2.00
34	AAPCW16V4R3	0.88	1.43	0.00	4.13	0.00	0.20	0.00	7.42	34	0.88
35	AAPCW16W1R1	0.45	5.02	0.21	7.28	0.00	0.76	0.00	15.94	35	0.78
36	AAPCW16W1R2	0.28	0.00	1.58	4.89	2.91	2.50	0.00	58.78	36	0.52
37	AAPCW16W1R3	0.68	2.05	0.34	3.45	0.82	0.25	0.00	23.01	37	0.92
38	AAPCW16W2	1.14	0.00	0.01	7.73	0.10	1.79	0.00	33.72	38	1.37
39	AAPCW16W3	1.28	1.45	0.18	3.52	0.20	0.73	0.00	21.01	39	1.30
40	AAPCW16W4R1	2.00	1.08	0.67	4.73	0.18	0.45	0.00	30.30	40	3.96
41	AAPCW16W4R2	0.88	1.88	0.27	3.60	0.58	0.60	0.00	10.41	41	1.12
42	AAPCW16W4R3	1.46	1.10	0.30	2.96	0.28	0.03	0.00	10.08	42	1.46
43	AAPCW16X1R1									43	
44	AAPCW16X1R2									44	
45	AAPCW16X1R3	0.57	7.98	0.48	3.09	0.00	0.16	0.00	8.05	45	0.84
46	AAPCW16X2	0.34	1.89	0.86	11.95	2.79	0.34	0.00	43.43	46	0.62
47	AAPCW16X3	2.00	1.20	0.25	3.43	0.03	0.79	0.00	14.89	47	3.99
48	AAPCW16X4R1	2.00	1.00	0.19	5.17	0.15	0.37	0.00	22.52	48	7.82
49	AAPCW16X4R2									49	
50	AAPCW16X4R3									50	
51	AAPCW16Y1R1	1.24	0.00	0.17	4.77	0.45	0.12	0.00	31.49	51	1.42
52	AAPCW16Y1R2									52	
53	AAPCW16Y1R3	0.08	0.00	0.80	12.47	1.36	7.90	0.00	20.25	53	0.29
54	AAPCW16Y2	0.70	0.00	0.00	3.80	0.09	0.13	0.00	25.70	54	0.91

Table 2-D6.
(Continued)

OBS	ID	WEIGHT	AS	CD	CU	PB	NI	SE	ZN	LOCATION	TOT_WT
55	AAPCW16Y3									55	
56	AAPCW16Y4R1	0.70	0.00	0.00	14.59	0.66	1.56	0.00	49.77	56	0.92
57	AAPCW16Y4R2	1.22	0.00	0.16	3.38	0.63	1.10	0.00	29.83	57	1.33
58	AAPCW16Y4R3	0.73	0.00	0.13	3.37	0.01	0.12	0.00	28.45	58	0.98
59	AAPCW16Z1R1	1.00	0.00	0.41	2.42	2.47	1.75	0.00	25.64	59	1.00
60	AAPCW16Z1R2	0.45	0.00	0.00	2.79	1.24	0.00	0.00	22.15	60	0.45
61	AAPCW16Z1R3									61	
62	AAPCW16Z2	1.80	0.11	0.00	3.06	0.00	0.85	0.00	21.13	62	1.80
63	AAPCW16Z3									63	
64	AAPCW16Z4	1.79	0.00	0.01	1.63	0.06	0.47	0.00	17.73	64	1.79
65	AAPCW16Z5									65	
66	AAPCW16Z6	2.00	0.02	0.03	2.25	0.03	0.49	0.00	21.76	66	2.00
67	AAPCW16Z7	2.00	0.00	0.18	4.45	0.00	0.49	0.00	25.53	67	2.00
68	ABPCW14R1	2.00	0.00	0.23	4.58	0.06	0.00	0.00	25.55	69	2.00
69	ABPCW14S1									70	
70	ABPCW15R1	1.40	1.39	0.65	15.10	0.15	2.68	0.00	108.43	72	1.40
71	ABPCW15S1									73	
72	BKPCW1161R1	2.00	0.20	0.38	1.48	0.00	0.42	0.00	21.25	74	4.76
73	BKPCW1161R2	2.00	0.00	0.00	3.00	0.18	0.37	0.00	23.03	75	6.25
74	BKPCW1161R3									76	
75	BKPCW1162R1	1.79	0.73	0.09	2.75	0.48	0.50	0.00	20.95	77	1.92
76	BKPCW1162R2	2.00	0.05	0.02	4.23	0.00	0.45	0.00	31.30	78	4.63
77	BKPCW1162R3	2.00	0.00	0.02	4.20	0.00	0.39	0.00	23.52	79	7.85
78	BKPCW1331R1	0.82	0.00	0.00	2.96	0.38	1.03	0.00	34.65	80	1.02
79	BKPCW1331R2	2.00	0.00	0.19	1.45	0.30	0.34	0.00	19.36	81	12.49
80	BKPCW1331R3	1.08	0.00	0.09	2.60	0.70	0.90	0.00	29.79	82	1.28
81	BKPCW1332R1	2.00	0.00	0.06	2.03	0.05	0.04	0.00	22.76	83	16.75
82	BKPCW1332R2	2.00	0.00	0.18	1.83	0.63	0.09	0.00	24.52	84	32.46
83	BKPCW1332R3	2.00	0.00	0.23	1.13	1.05	0.00	0.00	19.64	85	42.50
84	BKPCW1333R1	2.00	0.00	0.01	1.35	0.13	0.69	0.00	28.52	86	16.95
85	BKPCW1333R2	2.00	0.00	0.18	2.15	0.55	0.59	0.00	25.99	87	9.66
86	BKPCW1333R3	2.00	0.00	0.06	1.46	0.00	0.45	0.00	20.82	88	17.86
87	BKPCW1337R1	0.30	0.00	0.55	8.81	0.00	0.00	0.00	68.84	98	0.30
88	BKPCW1337R2	2.00	0.00	0.09	0.95	0.63	0.62	0.00	27.28	99	2.00
89	BKPCW1337R3	2.01	0.00	0.00	2.07	0.00	0.02	0.00	20.89	100	2.01
90	ESPCW13H1R1	2.00	0.00	0.56	4.10	0.35	0.97	0.00	23.78	126	7.95
91	ESPCW13H1R2	2.00	0.00	0.40	5.25	0.30	1.04	0.00	25.76	127	7.14
92	ESPCW13H1R3	2.01	0.00	0.23	3.72	0.50	3.8	0.00	30.22	128	6.39
93	ESPCW13J1	2.00	0.05	0.41	3.45	5.17	0.02	0.00	138.41	131	4.95
94	ESPCW13K1	2.00	0.07	0.56	4.63	1.28	0.43	0.00	103.24	134	2.98
95	ESPCW13L1	2.00	0.22	4.25	11.34	8.72	1.47	0.00	393.45	137	4.86
96	ESPCW14F1R1	2.00	0.00	0.07	2.11	0.26	0.35	0.00	22.79	140	2.44
97	ESPCW14F1R2	2.00	0.00	0.37	2.80	0.40	3.44	0.00	27.02	141	4.94
98	ESPCW14F1R3	2.00	0.00	0.31	2.38	0.30	1.29	0.00	22.02	142	3.78
99	G1PCW12N2	0.64	0.00	0.00	6.13	0.64	0.01	0.00	51.94	146	0.64
100	G1PCW13L4R1	0.90	0.00	0.13	1.73	5.56	1.17	0.00	64.47	148	0.90
101	G1PCW13L4R2	2.00	0.00	0.41	1.98	1.43	0.62	0.00	50.02	149	2.00
102	G1PCW13L4R3	2.00	0.35	0.53	2.78	5.15	0.57	0.00	40.98	150	2.00
103	G1PCW13M1R1	1.09	0.00	0.82	5.90	1.39	1.05	0.00	309.01	151	1.09
104	G1PCW13M1R2	1.64	0.09	1.90	8.75	1.10	1.00	0.00	199.02	152	1.64
105	G1PCW13M1R3	2.00	0.12	0.57	6.07	1.58	1.13	0.00	149.75	153	2.00
106	K2PCW4N1R1	0.97	0.00	0.59	4.37	2.27	2.08	0.00	34.08	156	0.97
107	K2PCW4N1R2	2.00	0.43	0.05	5.33	0.53	1.47	0.00	25.80	157	2.00
108	K2PCW4N1R3	2.00	0.13	0.12	2.78	0.08	1.06	0.00	20.12	158	2.00

Table 2-D6.
(Concluded)

OBS	ID	WEIGHT	AS	CD	CU	PB	NI	SE	ZN	LOCATION	TOT_WT
109	K2PCW4R1	2.00	0.17	0.50	3.77	0.63	1.94	0.00	39.49	161	2.00
110	K2PCW8P3R1	0.52	0.00	3.21	10.21	3.77	1.06	0.00	788.63	170	0.52
111	K2PCW8P3R2	1.54	0.00	3.48	13.78	1.72	1.45	0.00	664.67	171	1.54
112	K2PCW8P3R3	0.23	0.00	6.11	20.13	10.5	6.94	0.00	526.59	172	0.23

Table 2-D7.

Blank Analysis

OBS	ID	AS	CD	CU	PB	NI	SE	ZN
1	BLANK	0.01	0.00	0.01	0.01	0.04	0.01	0.64
2	BLANK	0.01	0.01	0.02	0.02	0.02	0.01	0.16
3	BLANK	0.01	0.00	0.01	0.02	0.02	0.01	0.03
4	BLANK	0.01	0.00	0.02	0.01	0.02	0.01	0.04
5	BLANK	0.01	0.01	0.03	0.01	0.03	0.01	0.09
6	BLANK	0.01	0.01	0.03	0.03	0.02	0.01	0.07
7	BLANK	0.01	0.01	0.01	0.02	0.02	0.01	0.13
8	BLANK	0.01	0.00	0.05	0.02	0.01	0.01	0.12
9	BLANK	0.01	0.00	0.02	0.01	0.01	0.01	0.05
10	BLANK	0.01	0.00	0.01	0.01	0.01	0.01	0.13
11	BLANK	0.01	0.00	0.01	0.02	0.04	0.01	0.12
12	BLANK	0.01	0.00	0.01	0.00	0.01	0.01	0.04
13	BLANK	0.01	0.00	0.01	0.02	0.02	0.01	0.18

Table 2-D8.

Blank Analysis Summary

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE	C.V
AS	13	0.005	0.000	0.005	0.005	0.000	0.065	0.000	0.000
CD	13	0.004	0.003	0.000	0.010	0.001	0.048	0.000	78.962
CU	13	0.018	0.012	0.006	0.052	0.003	0.232	0.000	69.494
PB	13	0.015	0.007	0.002	0.028	0.002	0.192	0.000	50.453
NI	13	0.019	0.012	0.005	0.043	0.003	0.249	0.000	60.543
SE	13	0.005	0.000	0.005	0.005	0.000	0.065	0.000	0.000
ZN	13	0.138	0.157	0.030	0.636	0.044	1.797	0.025	113.491

Table 2-D9.

NBS Tomato Leaves Analysis

OBS	ID	WEIGHT	AS	CD	CU	PB	NI	SE	ZN
1	TOMATO LEAVES	2.00	0.00	2.06	6.41	2.58	2.04	0.00	50.30
2	TOMATO LEAVES	2.00	0.00	1.83	5.36	1.81	0.30	0.00	27.54
3	TOMATO LEAVES	2.00	0.00	2.96	10.76	3.46	1.25	0.00	57.80
4	TOMATO LEAVES	2.00	0.00	3.31	12.13	5.31	1.87	0.00	64.05
5	TOMATO LEAVES	2.00	0.00	3.63	13.23	5.65	2.02	0.00	71.30
6	TOMATO LEAVES	2.00	0.00	3.11	12.48	4.93	1.22	0.00	60.54
7	TOMATO LEAVES	2.00	0.00	2.61	11.08	4.33	1.20	0.00	59.30
8	TOMATO LEAVES	2.00	0.00	3.16	12.48	4.61	1.42	0.00	67.05
9	TOMATO LEAVES	2.00	0.00	3.08	12.25	5.26	1.42	0.00	64.80
10	TOMATO LEAVES	2.00	0.00	2.78	10.08	3.73	1.05	0.00	54.04
11	TOMATO LEAVES	2.00	0.00	3.03	11.65	4.63	1.27	0.00	65.05
12	TOMATO LEAVES	2.00	0.00	2.53	11.16	5.23	1.12	0.00	68.30
13	TOMATO LEAVES	2.00	0.00	2.43	10.38	4.58	1.07	0.38	59.80

Table 2-D 10.

NBS Tomato Leaves Analysis Summary*

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE	C V
WEIGHT	13	2.000	0.000	2.000	2.000	0.000	26.000	0.000	0.000
AS	13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
CD	13	2.809	0.505	1.833	3.633	0.140	36.523	0.255	17.980
CU	13	10.726	2.345	5.355	13.230	0.650	139.440	5.497	21.858
PB	13	4.315	1.137	1.805	5.655	0.315	56.090	1.293	26.359
NI	13	1.326	0.465	0.295	2.045	0.129	17.235	0.217	35.111
SE	13	0.029	0.104	0.000	0.375	0.029	0.375	0.011	360.555
ZN	13	59.218	11.149	27.545	71.295	3.092	769.835	124.296	18.827

*Standards

NBS Tomato Leaves Analysis Values

AS	0.22	0.32
CD	3.0	
CU	10.0	12.0
PB	6.0	6.6
NI		
SE		
ZN	56.0	68.0

Table 2-D11.

Greenhouse Upland Plant Analysis

OBS	ID	WEIGHT	TOT_WT	AS	CD	CU	PB	NI	SE	ZN	LOCATION
1	ABPCW14Q1	0.71	1.28	0.00	2.09	14.66	1.83	2.61	0.00	159.72	68
2	ABPCW15Q1	2.00	5.15	0.02	1.98	16.45	3.17	1.42	0.00	140.67	71
3	BKPCW1334R1	1.91	3.94	0.00	1.98	8.96	2.21	2.33	0.00	196.94	89
4	BKPCW1334R2	2.01	4.69	0.00	1.66	7.88	2.27	3.21	0.00	206.61	90
5	BKPCW1334R3	2.00	4.16	0.00	1.71	6.55	2.17	3.00	0.00	110.58	91
6	BKPCW1335R1	1.38	2.69	0.00	0.69	5.72	1.14	1.70	0.00	36.76	92
7	BKPCW1335R2	2.00	4.64	0.00	0.33	3.20	2.17	4.32	0.00	21.11	93
8	BKPCW1335R3	2.00	3.04	0.00	0.63	5.52	1.47	2.22	0.00	56.82	94
9	BKPCW1336R1	2.00	4.66	0.00	1.24	5.15	2.60	1.92	0.00	49.61	95
10	BKPCW1336R2	2.00	6.37	0.00	1.01	5.52	2.22	1.35	0.00	59.07	96
11	BKPCW1336R3	2.00	3.46	0.00	1.23	6.15	1.07	1.97	0.00	46.61	97
12	BKPCW1338R1	1.88	2.99	0.00	0.27	6.93	0.05	1.49	0.00	29.18	101
13	BKPCW1338R2	2.00	2.91	0.00	0.18	6.39	0.85	1.47	0.00	41.82	102
14	BKPCW1338R3	2.00	3.74	0.00	0.09	4.92	0.00	0.77	0.00	34.86	103
15	CPPCW26Q1	2.00	5.05	0.87	24.89	13.09	1.45	2.25	0.00	61.57	104
16	CPPCW27E1R1	.	.	.	.	.	.	.	.	.	105
17	CPPCW27E1R2	.	.	.	.	.	.	.	.	.	106
18	CPPCW27E1R3	.	.	.	.	.	.	.	.	.	107
19	CPPCW27F1	2.00	2.97	0.25	14.47	7.44	0.37	1.42	0.00	55.30	108
20	CPPCW28F1R1	2.00	5.11	1.57	4.01	9.37	65.44	6.14	11.37	29.37	109
21	CPPCW28F1R2	1.00	1.95	0.00	6.88	8.80	0.65	0.80	0.00	57.76	110
22	CPPCW28F1R3	2.00	10.34	0.03	9.11	5.78	0.30	1.32	0.00	94.13	111
23	CPPCW29E1R1	.	.	.	.	.	.	.	.	.	112
24	CPPCW29E1R2	0.68	1.28	0.00	5.29	7.54	0.00	5.39	3.77	49.28	113
25	CPPCW29E1R3	1.39	1.79	0.00	5.79	7.68	0.03	3.46	11.72	66.57	114
26	CPPCW29E2	0.61	0.89	0.00	10.22	7.14	3.73	4.59	1.72	54.78	115
27	CPPCW29F1	.	.	.	.	.	.	.	.	.	116
28	CPPCW30E1	1.65	2.31	0.00	5.55	7.05	2.75	5.11	0.09	118.80	117
29	CPPCW30F1	2.00	2.86	0.00	5.86	7.07	3.00	1.15	0.07	108.58	118
30	CPPCW30F2	0.31	0.76	0.00	6.91	6.68	2.59	17.74	0.00	87.99	1.9
31	ESPCW13F2R1	2.00	7.13	0.00	0.45	7.14	0.60	1.02	0.00	79.30	1.
32	ESPCW13F2R2	0.82	2.19	0.00	0.51	4.99	0.12	2.31	0.00	62.36	1
33	ESPCW13F2R3	1.00	2.19	0.00	26.62	7.47	0.34	0.69	0.00	73.97	1.
34	ESPCW13F3R1	1.05	2.20	0.00	0.23	7.98	1.04	3.46	0.00	209.37	1
35	ESPCW13F3R2	2.01	4.58	0.00	2.18	9.30	0.45	0.35	0.00	156.49	1
36	ESPCW13F3R3	0.34	0.90	0.00	1.52	3.57	2.66	2.37	0.00	250.78	12.
37	ESPCW13H2	2.00	5.78	0.00	1.24	6.70	0.40	1.10	0.00	132.63	129
38	ESPCW13H3	2.00	4.93	0.00	2.18	9.78	0.37	1.64	0.00	300.28	130
39	ESPCW13J2	0.90	1.56	0.00	4.52	7.88	1.10	0.49	0.00	272.77	132
40	ESPCW13J3	0.91	1.89	0.00	1.94	9.59	0.98	9.81	0.00	451.49	133
41	ESPCW13K2	2.00	3.81	0.00	6.75	5.91	0.45	0.70	0.00	143.59	135
42	ESPCW13K3	1.72	2.29	0.00	3.16	10.35	0.73	4.17	0.00	441.26	136
43	ESPCW13L2	2.00	4.76	0.00	1.36	6.60	2.32	2.42	0.00	219.27	138
44	ESPCW13L3	2.00	5.58	0.00	1.47	8.02	1.30	1.92	0.00	268.38	139
45	G1PCW11L1	2.00	4.88	0.00	1.51	7.85	2.40	3.55	0.00	263.25	143
46	G1PCW12L1	2.00	4.12	0.00	1.81	7.55	1.72	3.95	0.00	343.38	144
47	G1PCW12N1	0.18	0.25	0.00	13.97	2.50	1.08	5.25	0.00	562.57	145
48	G1PCW12N3	0.73	1.38	0.00	0.11	6.34	3.20	1.17	0.00	65.86	147
49	K2PCW3P1	2.01	7.68	0.00	0.25	7.31	0.37	1.12	0.00	46.27	154
50	K2PCW3R1	2.00	3.46	0.00	1.81	6.72	2.80	0.82	0.00	193.44	155
51	K2PCW4P1	2.00	5.86	0.00	1.21	7.03	1.07	2.60	0.00	112.38	159
52	K2PCW4Q1	.	.	.	.	.	.	.	.	.	160
53	K2PCW5Q1	2.00	4.90	0.00	2.54	9.25	1.15	3.05	0.00	140.38	162
54	K2PCW5P1	2.00	7.24	0.00	0.27	7.39	0.00	0.77	0.00	70.03	163

Table 2-D11.
(Concluded)

OBS	ID	WEIGHT	TOT_WT	AS	CD	CU	PB	NI	SE	ZN	LOCATION
55	K2PCW6O1	0.66	1.12	0.00	2.40	5.50	0.30	1.14	0.00	153.07	164
56	K2PCW6P1	2.00	3.18	0.00	5.09	12.58	0.87	1.15	0.00	318.38	165
57	K2PCW6G1	2.00	5.12	0.00	13.07	8.74	0.75	0.55	0.00	415.47	166
58	K2PCW6G2	0.79	1.42	0.00	18.32	8.07	0.37	0.00	0.00	528.70	167
59	K2PCW8P1	2.00	5.17	0.00	12.31	9.12	0.77	1.02	0.00	273.38	168
60	K2PCW8P2	0.39	0.72	0.00	10.75	5.34	2.02	1.01	0.00	550.29	169
61	K2PCW9O1	2.01	5.65	0.00	3.68	11.42	0.65	2.64	0.00	282.67	173
62	KSPCW1OP1	0.48	0.94	0.00	4.78	13.21	24.31	1.35	0.00	511.03	174
63	KSPCW1OR1	0.10	0.53	0.00	18.79	6.80	2.86	10.63	0.00	555.95	175
64	KSPCW8R1	0.23	0.50	0.00	35.64	6.80	0.42	1.73	0.00	551.59	176
65	KSPCW8R2	0.88	1.68	0.00	41.66	7.57	1.36	1.65	0.00	488.34	177
66	KSPCW9Q1	0.14	0.36	0.00	19.54	0.00	1.37	4.54	0.00	137.06	178

Table 2-D12.

Blank Analysis

OBS	ID	AS	CD	CU	PB	NI	SE	ZN
1	BLANK	0 005	007	0 03	0 020	0 030	0 005	0 891
2	BLANK	0 005	002	0 03	0 027	0 032	0 005	0 119
3	BLANK	0 005	003	0 03	0 006	0 024	0 005	0 050
4	BLANK	0 005	008	0 03	0 006	0 017	0 005	0 049
5	BLANK	0 005	002	0 03	0 009	0 027	0 005	0 065
6	BLANK	0 005	005	0 03	0 006	0 017	0 005	0 066
7	BLANK	0 005	001	0 03	0 004	0 008	0 005	0 032
8	BLANK	0 005	001	0 03	0 011	0 006	0 005	0 046

Table 2-D13.

Blank Analysis Summary

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE	C V
AS	8	0 005	0 000	0 005	0 005	0 000	0 040	0 000	0 000
CD	8	0 004	0 003	0 001	0 008	0 001	0 026	0 000	5 774
CU	8	0 030	0 000	0 030	0 030	0 000	0 240	0 000	0 000
PB	8	0 011	0 008	0 004	0 027	0 003	0 089	0 000	73 [illegible]
NI	8	0 020	0 010	0 006	0 032	0 003	0 161	0 000	48 [illegible]
SE	8	0 005	0 000	0 005	0 005	0 000	0 040	0 000	0 000
ZN	8	0 165	0 295	0 032	0 891	0 104	1 318	0 087	178 815

Table 2-D14.

NBS Tomato Leaves Analysis

OBS	ID	WEIGHT	AS	CD	[illegible]	PB	NI	SE	ZN
1	TOMATO LEAVES	2	0 000	2 81	9 700	0 848	973	0	55 63
2	TOMATO LEAVES	2	0 000	3 29	10 400	17 8	1 57	0	69 38
3	TOMATO LEAVES	2	0 000	2 74	8 925	5 923	1 3	0	51 38
4	TOMATO LEAVES	2	0 000	2 36	8 650	6 948	9 47	0	54 13
5	TOMATO LEAVES	2	0 025	2 29	9 700	5 598	2 3	0	55 13
6	TOMATO LEAVES	2	0 000	3 04	9 950	1 123	1 22	0	58 63
7	TOMATO LEAVES	2	0 000	2 84	8 925	5 123	923	0	51 13
8	TOMATO LEAVES	2	0 000	2 66	10 125	0 898	848	0	56 63

Table 2-D15.

NBS Tomato Leaves Analysis Summary*

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE	C. V.
WEIGHT	8	2.000	0.000	2.000	2.000	0.000	16.000	0.000	0.000
AS	8	0.003	0.009	0.000	0.025	0.003	0.025	0.000	282.843
CD	8	2.753	0.328	2.288	3.288	0.116	22.025	0.108	11.928
CU	8	9.547	0.638	8.650	10.400	0.226	76.375	0.407	6.683
PB	8	5.532	5.550	0.848	17.798	1.962	44.255	30.805	100.332
NI	8	2.326	2.925	0.848	9.472	1.034	18.605	8.558	125.788
SE	8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
ZN	8	56.506	5.779	51.131	69.381	2.043	452.050	33.393	10.227

*Standards

NBS Tomato Leaves Analysis Values		
AS	0.22	0.32
CD	3.0	
CU	10.0	12.0
PB	6.0	6.6
NI		
SE		
ZN	56.0	68.0

Table 2-E1.

Earthworm Tissue Analysis

OBS	ID	WEIGHT	VOLUME	AS	CD	CU	PB	NI	SE	ZN	WORM_IN	WORM_OUT	FINAL_WT	DRY_WT	RWET_WT	H2O_SOIL	LOCATION
1	AAEACW124[illegible]	[illegible]594	50	9.26	3.18	11.51	2.26	6.17	3.79	113.4	58	58	12.33	1.54	78	34	1
2	AAEACW1241R2	0.503	50	11.43	4.50	8.33	0.00	3.71	4.47	110.7	67	47	10.97	1.41	69	28	2
3	AAEACW1241R3	0.538	50	2.88	4.67	13.36	0.07	5.33	3.81	109.4	67	59	9.50	1.40	63	20	3
4	AAEACW1242R1	0.578	50	2.94	3.44	11.40	0.16	5.65	3.72	121.7	67	62	10.70	1.61	70	47	4
5	AAEACW1242R2	0.567	50	3.97	3.82	10.38	0.00	2.85	3.09	116.1	64	61	11.60	1.58	76	43	5
6	AAEACW1242R3	0.537	50	5.31	6.81	9.10	0.45	4.97	3.82	279.1	61	60	14.55	2.00	96	47	6
7	AAEACW1243R1	0.535	50	3.08	5.70	12.13	0.36	1.90	5.89	115.5	67	59	12.13	1.74	78	37	7
8	AAEACW1243R2	0.509	50	2.46	5.40	11.76	0.77	2.19	3.83	107.8	67	53	11.44	1.69	76	41	8
9	AAEACW1243R3	0.524	50	2.39	4.23	8.95	0.00	1.75	4.29	121.9	67	55	11.24	1.51	74	36	9
10	AAEACW1244R1	0.537	50	3.63	2.54	11.15	0.26	8.78	3.91	128.2	71	60	11.13	1.52	70	31	10
11	AAEACW1244R2	0.583	50	2.66	2.63	8.47	0.41	10.66	3.34	120.7	58	57	12.55	1.54	82	12	11
12	AAEACW1244R3	0.509	50	3.44	4.09	9.21	0.00	4.16	3.83	116.6	58	49	10.04	1.28	65	37	12
13	AAEACW1245R1	0.519	50	3.95	3.96	11.15	0.17	4.37	4.91	101.8	67	65	14.46	1.80	92	52	13
14	AAEACW1245R2	0.555	50	4.95	0.39	8.45	0.34	3.54	3.06	99.7	64	59	12.57	1.62	79	53	14
15	AAEACW1245R3	0.536	50	8.40	2.95	12.01	0.63	4.32	4.94	343.0	61	51	11.66	1.49	76	63	15
16	AAEACW1246R1	0.542	50	2.68	7.58	10.96	1.00	1.69	4.70	378.8	71	66	11.15	1.64	74	38	16
17	AAEACW1246R2	0.545	50	4.13	5.15	8.69	0.00	1.96	3.03	172.2	61	50	11.31	1.58	74	45	17
18	AAEACW1246R3	0.591	50	3.47	5.09	9.12	0.07	1.97	3.81	270.5	67	60	11.42	1.70	72	46	18
19	AAEACW16U1R1	0.320	25	44.92	0.30	25.37	0.00	0.73	2.11	105.2	71	46	7.57	1.09	50	62	19
20	AAEACW16U1R2	0.538	50	92.47	0.75	18.84	0.91	0.96	4.93	126.1	58	39	6.50	0.89	42	67	20
21	AAEACW16U1R3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	21
22	AAEACW16U2	0.559	50	17.44	1.37	25.83	0.00	1.01	3.85	125.0	58	41	6.32	0.85	40	41	22
23	AAEACW16U3	0.508	50	27.07	3.72	27.63	0.00	0.13	3.64	104.0	67	56	9.29	1.61	61	47	23
24	AAEACW16U4R1	0.524	50	114.03	2.48	43.97	6.85	0.41	4.29	123.0	71	71	12.81	1.74	81	47	24
25	AAEACW16U4R2	0.546	50	103.02	2.19	46.68	2.27	2.41	4.95	112.4	64	61	14.95	1.95	94	61	25
26	AAEACW16U4R3	0.531	50	145.48	3.29	69.94	19.00	1.73	4.24	118.2	61	61	15.40	2.00	98	66	26
27	AAEACW16V1R1	0.506	50	93.38	1.60	22.31	0.38	0.00	3.85	123.2	64	37	5.98	0.89	39	41	27
28	AAEACW16V1R2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	28
29	AAEACW16V1R3	0.579	50	77.29	1.00	17.34	7.24	1.67	3.20	115.5	61	34	6.05	0.93	38	69	29
30	AAEACW16V2	0.538	50	59.01	3.26	18.19	0.17	0.68	8.36	119.6	58	61	14.34	1.77	91	55	30
31	AAEACW16V3	0.596	50	87.67	5.40	34.29	3.00	0.78	3.44	105.5	67	63	15.95	2.14	103	63	31
32	AAEACW16V4R1	0.574	50	108.45	3.18	19.14	1.72	0.73	3.92	115.5	58	64	13.04	1.69	82	46	32
33	AAEACW16V4R2	0.519	50	95.86	2.14	22.52	0.66	0.71	3.37	123.0	61	62	16.19	1.96	104	66	33
34	AAEACW16V4R3	0.551	50	124.77	5.16	29.29	1.62	0.21	3.36	114.1	67	61	13.03	1.82	84	50	34
35	AAEACW16W1R1	0.522	50	53.16	1.49	13.67	0.65	0.41	3.54	122.3	67	38	6.07	0.99	39	55	35
36	AAEACW16W1R2	0.053	25	43.63	13.74	34.32	2.74	14.31	1.42	142.9	58	5	0.58	0.07	4	59	36
37	AAEACW16W1R3	0.545	50	77.52	1.90	22.73	3.19	1.04	3.39	141.9	58	41	5.87	0.84	38	54	37
38	AAEACW16W2	0.510	50	77.94	2.69	18.02	0.86	1.31	6.57	116.4	67	58	14.44	1.91	92	59	38
39	AAEACW16W3	0.517	50	29.01	3.97	21.54	0.66	0.32	3.00	109.0	64	68	13.40	1.86	87	70	39
40	AAEACW16W4R1	0.517	50	91.39	3.03	20.48	0.56	1.48	2.42	110.0	61	53	14.82	1.80	96	63	40
41	AAEACW16W4R2	0.532	50	140.51	2.21	14.92	2.14	0.59	4.61	115.3	58	54	15.14	1.82	98	66	41
42	AAEACW16W4R3	0.532	50	98.21	3.69	14.64	1.11	0.50	4.04	126.6	58	55	13.66	1.76	87	56	42
43	AAEACW16X1R1	0.278	25	24.73	1.95	17.33	0.07	2.37	2.97	126.5	58	17	2.48	0.33	16	48	43
44	AAEACW16X1R2	0.500	50	53.50	2.19	13.58	0.00	0.53	4.90	107.7	67	57	10.56	1.42	68	62	44
45	AAEACW16X1R3	0.504	50	45.14	1.14	11.09	0.18	0.33	3.67	118.8	58	52	8.61	1.11	55	57	45
46	AAEACW16X2	0.583	50	39.02	2.61	12.33	0.33	0.37	3.17	119.8	71	57	9.03	1.31	57	48	46
47	AAEACW16X3	0.546	50	150.64	4.62	17.29	1.63	2.69	3.75	108.7	67	53	13.85	1.74	89	72	47
48	AAEACW16X4R1	0.503	50	36.28	3.50	19.36	0.38	0.83	3.08	134.9	64	62	12.24	1.77	77	71	48
49	AAEACW16X4R2	0.590	50	40.25	2.48	24.81	19.22	1.38	4.15	120.1	71	66	11.33	1.53	72	69	49
50	AAEACW16X4R3	0.503	50	2.88	4.67	12.20	0.48	3.71	3.48	299.9	71	56	8.46	1.22	54	62	50
51	AAEACW16Y1R1	0.245	25	5.00	1.66	17.83	2.63	1.97	3.98	123.2	58	19	2.26	0.34	14	66	51
52	AAEACW16Y1R2	0.525	50	3.52	2.96	14.93	2.84	1.17	3.90	110.8	71	54	7.38	1.06	47	64	52
53	AAEACW16Y1R3	0.507	50	3.25	0.17	21.67	1.26	1.12	3.25	115.1	67	33	4.27	0.66	27	67	53
54	AAEACW16Y2	0.518	50	3.76	1.65	15.03	0.46	2.16	4.73	102.0	67	44	6.42	1.13	42	64	54

Table 2-E1.

(Continued)

OBS	ID	WEIGHT	VOLUME	AS	CD	CU	PB	NI	SE	ZN	WORM_IN	WORM_OUT	FINAL_WT	DRY_WT	RWET_WT	H2O_SOIL	LOCATION
55	AAEACW16Y3	0.514	50	6.13	4.67	12.53	4.26	3.24	5.16	125.2	67	63	14.69	1.97	96	66	55
56	AAEACW16Y4R1	0.500	50	3.10	3.93	12.48	19.88	2.53	4.70	108.4	61	52	9.32	1.42	59	66	56
57	AAEACW16Y4R2	0.508	50	2.85	1.98	11.30	0.00	0.82	2.66	111.9	64	65	10.40	1.59	67	60	57
58	AAEACW16Y4R3	0.520	50	2.21	2.63	9.78	5.37	2.82	2.98	213.2	71	60	9.11	1.34	59	64	58
59	AAEACW16Z1R1	0.587	50	2.64	2.74	11.05	0.00	1.56	2.13	400.9	64	64	10.32	1.51	65	46	59
60	AAEACW16Z1R2	0.522	50	4.31	2.60	13.67	1.03	9.32	4.12	110.8	64	52	9.72	1.41	64	50	60
61	AAEACW16Z1R3	0.541	50	2.96	4.93	15.23	3.59	8.44	3.79	112.4	64	59	9.40	1.42	62	42	61
62	AAEACW16Z2	0.561	50	5.26	2.11	11.03	1.76	3.86	3.65	102.2	67	59	12.86	1.73	81	55	62
63	AAEACW16Z3	0.502	50	5.88	1.78	9.84	1.57	4.42	5.28	113.2	61	57	11.93	1.54	79	57	63
64	AAEACW16Z4	0.564	50	3.28	2.24	6.10	0.43	4.82	3.63	111.4	58	59	13.17	1.68	84	50	64
65	AAEACW16Z5	0.542	50	3.41	2.06	14.92	1.37	4.18	4.52	114.1	67	60	12.65	1.78	82	53	65
66	AAEACW16Z6	0.598	50	2.59	2.43	12.27	1.57	3.04	4.43	112.6	64	59	13.11	1.74	83	53	66
67	AAEACW16Z7	0.512	50	27.83	1.89	13.84	7.01	0.52	2.64	111.3	64	68	10.89	1.54	69	40	67
68	ABEACW14Q1	0.556	50	22.03	2.90	62.12	5.65	2.10	3.69	132.8	67	57	14.38	1.97	95	18	68
69	ABEACW14R1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	69
70	ABEACW14S1	0.575	50	121.30	1.94	30.15	0.85	2.12	3.57	123.2	58	47	10.00	1.33	65	64	70
71	ABEACW15Q1	0.504	50	27.28	2.20	91.54	3.85	1.52	3.87	131.6	67	50	11.25	1.78	75	25	71
72	ABEACW15R1	0.524	50	26.24	6.69	159.23	1.03	1.18	3.15	121.9	91	66	6.14	1.04	40	28	72
73	ABEACW15S1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	73
74	BKEACW1161R1	0.639	50	2.74	5.80	11.95	1.47	6.60	2.90	123.7	71	61	10.65	1.42	68	32	74
75	BKEACW1161R2	0.512	50	3.03	3.05	13.06	0.18	4.23	3.22	126.7	71	53	9.11	1.29	58	43	75
76	BKEACW1161R3	0.504	50	3.08	3.31	10.49	0.28	5.39	4.07	122.7	58	51	9.48	1.10	60	43	76
77	BKEACW1162R1	0.519	50	2.02	5.39	9.42	1.43	2.63	3.95	116.3	67	48	7.06	1.18	47	44	77
78	BKEACW1162R2	0.530	50	3.30	3.51	7.15	0.00	4.56	3.30	120.5	58	54	10.01	1.41	65	42	78
79	BKEACW1162R3	0.581	50	3.01	4.35	10.31	0.15	2.61	4.04	117.6	58	48	10.12	1.38	65		79
80	BKEACW1331R1	0.524	50	3.91	3.97	11.81	1.32	2.51	5.25	122.8	67	62	11.44	1.72	74	19	80
81	BKEACW1331R2	0.521	50	2.98	5.16	13.12	0.00	2.91	3.55	99.5	67	59	9.48	1.31	63	15	81
82	BKEACW1331R3	0.517	50	3.19	2.85	14.68	.	8.64	3.87	116.8	64	60	9.25	1.35	59	16	82
83	BKEACW1332R1	0.556	50	4.41	4.34	14.10	5.83	4.35	4.05	113.0	64	41	6.60	0.94	41	7	83
84	BKEACW1332R2	0.551	50	7.71	1.64	12.86	0.44	3.75	6.44	119.5	67	52	10.16	1.47	67	11	84
85	BKEACW1332R3	0.523	50	5.64	3.86	10.68	1.51	10.26	7.93	116.3	61	51	10.00	1.39	66	14	85
86	BKEACW1333R1	0.528	50	2.94	2.16	9.92	0.00	1.26	2.75	106.7	71	56	9.83	1.39	63	14	86
87	BKEACW1333R2	0.532	50	4.23	2.90	9.56	0.08	1.16	4.79	125.7	71	64	10.30	1.13	65	20	87
88	BKEACW1333R3	0.506	50	4.64	3.54	9.07	0.00	2.11	15.81	124.3	61	58	14.29	1.76	92	27	88
89	BKEACW1334R1	0.522	50	0.86	8.73	7.74	4.96	5.87	3.54	109.9	67	61	14.45	1.88	93	13	89
90	BKEACW1334R2	0.552	50	1.72	8.25	8.58	5.60	5.74	3.71	150.1	58	58	13.87	1.79	90	11	90
91	BKEACW1334R3	0.508	50	1.67	7.59	8.64	2.64	4.76	3.05	124.5	67	73	13.54	1.77	87	11	91
92	BKEACW1335R1	0.631	50	1.82	4.68	8.78	0.86	3.67	2.61	123.4	71	67	13.39	1.64	87	9	92
93	BKEACW1335R2	0.618	50	2.02	4.86	10.42	2.17	4.48	3.32	130.0	71	59	13.99	1.81	92	10	93
94	BKEACW1335R3	0.572	50	1.84	6.39	9.77	1.12	3.88	2.19	159.7	71	62	13.99	1.78	90	12	94
95	BKEACW1336R1	0.554	50	1.81	9.94	9.55	2.51	5.81	3.43	121.6	67	61	16.70	2.16	109	21	95
96	BKEACW1336R2	0.524	50	1.43	11.84	9.23	4.94	5.95	2.19	124.7	71	62	13.54	1.81	88	.	96
97	BKEACW1336R3	0.507	50	1.28	7.31	9.74	4.71	5.75	3.75	120.0	64	62	14.22	1.84	91	16	97
98	BKEACW1337R1	0.537	50	4.38	2.42	11.71	0.45	3.01	4.56	156.1	71	60	10.64	1.45	69	24	98
99	BKEACW1337R2	0.504	50	5.65	3.81	10.59	0.28	0.23	6.05	162.4	71	65	10.27	1.41	67	22	99
100	BKEACW1337R3	0.594	50	9.93	3.99	7.72	0.07	3.23	8.84	121.8	58	59	11.36	1.51	73	35	100
101	BKEACW1338R1	0.501	50	4.09	3.53	9.86	0.08	2.13	2.10	110.5	71	60	12.93	1.69	85	20	101

Table 2-E1.

(Continued)

OBS	ID	WEIGHT	VOLUME	AS	CD	CU	PB	NI	SE	ZN	WORM_IN	WORM_OUT	FINAL_WT	DRY_WT	RWET_WT	H2O_SOIL	LOCATION
102	BKEACW1338R2	0.653	50	4.36	5.49	10.01	4.50	2.55	3.75	120.3	61	57	12.80	1.64	80	25	102
103	BKEACW1338R3	0.598	50	5.02	4.61	9.76	0.40	1.70	3.34	127.7	71	69	11.56	1.53	74	20	103
104	CPEACW2601	0.627	50	14.35	29.44	45.20	4.77	3.46	3.27	111.8	64	57	11.46	1.63	73	25	104
105	CPEACW27E1R1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	105
106	CPEACW27E1R2	0.522	50	2.78	7.77	1.39	0.56	1.76	11.97	111.8	58	53	8.58	1.21	56	30	106
107	CPEACW27E1R3	0.518	50	2.70	1.90	21.41	0.37	1.09	12.84	115.5	58	55	8.23	1.13	54	35	107
108	CPEACW27F1	0.560	50	8.48	25.99	21.14	1.50	1.82	6.16	336.3	64	49	8.35	1.24	55	21	108
109	CPEACW28F1R1	0.545	50	14.68	23.96	25.94	76.68	1.22	91.28	127.2	61	55	12.01	1.66	76	23	109
110	CPEACW28F1R2	0.522	50	4.69	22.71	12.24	23.93	1.85	11.97	123.3	67	51	9.87	1.41	63	24	110
111	CPEACW28F1R3	0.608	50	5.76	17.61	12.15	12.32	2.91	6.66	122.3	67	56	12.37	1.54	79	18	111
112	CPEACW29E1R1	0.508	50	1.67	0.93	91.31	2.05	4.86	88.09	140.5	58	27	4.31	0.62	28	21	112
113	CPEACW29E1R2	0.568	50	3.61	0.81	42.94	0.00	3.90	13.64	123.0	61	54	9.51	1.38	63	21	113
114	CPEACW29E1R3	0.521	50	3.17	12.58	25.79	1.90	4.93	22.55	120.6	58	45	8.30	1.20	54	24	114
115	CPEACW29E2	0.508	50	4.63	21.76	42.59	1.06	12.04	6.00	128.6	67	58	11.04	1.56	71	15	115
116	CPEACW29F1	.	.	.	.	.	.	.	.	.	61	2	0.28	0.05	2	26	116
117	CPEACW30E1	0.545	50	3.76	8.27	17.32	39.52	6.09	40.83	136.4	71	62	12.47	1.68	82	19	117
118	CPEACW30F1	0.525	50	3.90	3.66	12.55	2.55	5.46	10.00	119.7	67	43	5.76	0.98	37	23	118
119	CPEACW30F2	0.535	50	8.88	12.53	14.09	1.66	4.05	8.88	119.3	71	76	12.69	1.33	80	20	119
120	ESEACW13F2R1	0.501	50	5.09	4.04	7.96	3.17	3.53	4.49	114.5	61	57	10.73	1.57	68	13	120
121	ESEACW13F2R2	0.544	50	3.95	5.40	10.09	0.26	2.42	4.69	114.6	67	54	10.01	1.38	65	17	121
122	ESEACW13F2R3	0.532	50	8.93	5.57	13.42	0.83	2.19	8.93	128.5	61	54	9.97	1.34	65	19	122
123	ESEACW13F3R1	0.511	50	3.03	14.10	9.17	7.42	4.24	6.56	129.6	64	62	12.97	1.65	84	16	123
124	ESEACW13F3R2	0.539	50	5.66	11.14	16.68	2.86	3.93	5.66	131.4	67	63	12.44	1.63	78	14	124
125	ESEACW13F3R3	0.516	50	3.00	14.35	13.25	14.90	4.10	4.36	120.8	67	64	15.19	2.03	99	19	125
126	ESEACW13H1R1	0.504	50	3.67	4.48	11.98	0.18	1.92	4.27	125.7	67	59	9.92	1.44	64	15	126
127	ESEACW13H1R2	0.560	50	5.09	5.25	8.28	0.43	2.53	4.02	122.9	67	62	10.74	1.50	71	19	127
128	ESEACW13H1R3	0.618	50	4.94	4.05	12.60	5.89	2.86	7.69	115.7	61	59	11.71	1.59	76	22	128
129	ESEACW13H2	0.561	50	2.58	4.90	11.83	0.43	2.61	3.74	145.0	71	62	9.99	1.35	65	14	129
130	ESEACW13H3	0.670	50	1.42	9.56	7.74	5.58	5.85	3.51	116.8	64	67	12.85	1.66	83	17	130
131	ESEACW13J1	0.625	50	19.60	3.36	11.42	4.22	3.31	5.04	267.8	58	50	10.66	1.43	67	30	131
132	ESEACW13J2	0.534	50	2.72	5.24	15.71	80.51	2.09	5.34	144.6	67	56	9.48	1.37	62	18	132
133	ESEACW13J3	0.544	50	2.39	8.56	11.01	4.49	6.00	4.41	406.0	58	55	17.67	2.21	117	22	133
134	ESEACW13K1	0.654	50	4.51	4.14	11.68	3.20	4.00	2.68	160.3	64	54	9.68	1.34	64	14	134
135	ESEACW13K2	0.555	50	5.14	12.17	16.37	38.36	1.74	4.59	148.4	58	46	10.09	1.29	65	8	135
136	ESEACW13K3	0.508	50	2.46	7.69	16.51	26.75	6.23	4.43	156.5	67	62	15.42	2.19	98	17	136
137	ESEACW13L1	0.502	50	2.49	21.33	103.46	32.35	1.53	4.88	320.4	67	62	9.35	1.40	60	21	137
138	ESEACW13L2	0.537	50	2.70	11.28	11.06	5.85	5.34	2.33	128.9	71	65	13.85	1.73	90	32	138
139	ESEACW13L3	0.542	50	1.66	12.10	9.02	5.89	7.13	3.60	142.5	64	57	13.41	1.69	87	20	139
140	ESEACW14F1R1	0.532	50	4.23	3.70	9.56	2.80	3.23	5.73	124.7	67	66	11.22	1.60	71	20	140
141	ESEACW14F1R2	0.566	50	5.04	2.86	10.67	2.37	2.50	5.04	118.5	71	65	11.43	1.54	76	25	141
142	ESEACW14F1R3	0.529	50	8.51	3.05	9.24	3.86	3.24	5.77	194.4	58	45	10.84	1.31	71	28	142
143	Q1EACW11L1	0.633	50	2.76	8.94	14.44	0.14	4.53	4.82	110.4	61	56	12.53	1.58	81	21	143
144	Q1EACW12L1	0.586	50	1.62	8.46	11.75	4.33	4.12	4.69	373.5	61	62	13.46	1.71	86	15	144
145	Q1EACW12N1	0.576	50	4.25	11.64	27.41	85.23	2.20	3.91	196.8	61	49	8.13	1.25	52	20	145
146	Q1EACW12N2	0.520	50	9.42	4.31	10.65	1.52	4.36	5.38	161.1	64	50	9.47	1.38	60	34	146
147	Q1EACW12N3	0.526	50	3.04	7.41	9.48	0.00	7.07	4.85	122.3	61	59	11.32	1.49	74	15	147
148	Q1EACW13L4R1	0.589	50	19.95	3.54	12.46	12.72	3.08	7.05	151.7	67	57	11.10	1.52	73	25	148

Table 2-E1.

(Concluded)

OBS	ID	WEIGHT	VOLUME	AS	CD	CU	PB	NI	SE	N	WORM_IN	WORM_OUT	FINAL_WT	DRY_WT	RWET_WT	H2O_SOIL	LOCATION
149	Q1EACW13L4R2	0.506	50	15.32	3.77	7.39	8.38	3.59	11.36	131.1	67	60	13.78	2.11	87	30	149
150	Q1EACW13L4R3	0.520	50	9.13	9.34	13.05	3.06	1.86	5.87	134.3	64	66	10.56	1.51	69	22	150
151	Q1EACW13M1R1	0.529	50	18.43	4.58	11.04	7.45	1.64	7.09	153.8	61	59	12.56	1.62	82	29	151
152	Q1EACW13M1R2	0.612	50	11.85	5.89	10.27	9.79	2.72	4.17	197.5	58	62	11.54	1.52	76	25	152
153	Q1EACW13M1R3	0.523	50	10.99	11.10	13.84	2.37	2.23	4.68	169.9	67	54	11.12	1.59	71	22	153
154	K2EACW3P1	0.507	50	3.06	3.72	9.94	0.28	2.99	4.44	129.9	67	55	6.65	1.21	43	20	154
155	K2EACW3R1	0.535	50	5.33	13.10	13.06	8.30	3.21	3.83	139.8	67	63	12.72	1.79	82	51	155
156	K2EACW4N1R1	0.532	50	3.10	4.93	11.63	4.02	6.52	3.67	126.6	67	64	10.67	1.45	69	17	156
157	K2EACW4N1R2	0.502	50	4.68	3.61	12.53	0.48	2.52	4.08	196.9	71	65	10.67	1.38	68	13	157
158	K2EACW4N1R3	0.553	50	4.25	2.20	12.09	1.70	4.28	5.52	131.7	67	60	13.02	1.77	84	27	158
159	K2EACW4P1	0.581	50	1.72	6.25	9.96	10.14	4.85	3.70	115.1	64	62	10.78	1.46	70	29	159
160	K2EACW4Q1	0.510	50	3.04	13.35	22.53	12.04	3.95	4.22	212.5	71	55	9.82	1.41	65	44	160
161	K2EACW4R1	0.565	50	8.41	9.30	21.13	9.10	3.39	4.69	153.7	67	62	11.18	1.74	72	49	161
162	K2EACW5Q1	0.540	50	2.31	10.01	13.96	30.07	5.59	2.22	129.4	67	66	15.75	1.97	102	22	162
163	K2EACW5P1	0.554	50	3.88	3.00	10.45	0.34	1.74	4.42	150.5	61	50	8.05	1.25	52	30	163
164	K2EACW6Q1	0.557	50	2.69	9.62	12.90	22.51	5.15	4.13	131.7	67	57	14.95	1.98	98	12	164
165	K2EACW6P1	0.522	50	8.14	3.74	34.08	80.73	1.56	4.50	631.9	67	60	12.33	1.86	79	29	165
166	K2EACW6Q1	0.550	50	4.64	5.10	37.52	58.35	2.67	4.09	176.1	67	59	9.47	1.47	62	16	166
167	K2EACW6Q2	0.533	50	8.91	4.34	19.86	14.15	4.35	20.17	222.0	58	59	12.89	1.69	84	25	167
168	K2EACW8P1	0.596	50	10.91	10.41	49.90	51.33	1.79	4.78	165.9	64	65	11.54	1.65	74	28	168
169	K2EACW8P2	0.508	50	3.25	8.77	40.33	224.59	0.82	8.17	471.1	67	58	9.47	1.54	63	34	169
170	K2EACW8P3R1	0.515	50	3.40	21.86	35.90	5.51	0.81	4.17	181.3	67	62	9.33	1.41	62	17	170
171	K2EACW8P3R2	0.500	50	3.70	15.71	88.78	2.68	0.83	3.10	182.7	64	58	8.68	1 31	57	15	171
172	K2EACW8P3R3	0.518	50	3.57	21.73	70.83	91.87	2.06	4.92	261.3	61	51	7.30	1.14	48	22	172
173	K2EACW9Q1	0.507	50	2.86	11.25	13.78	64.77	4.86	4.64	135.8	67	59	17.13	2 30	111	19	173
174	K5EACW10P1	0.519	50	4.34	8.97	187.74	2.29	3.11	3.95	281.0	64	37	5.74	0.82	37	21	174
175	K5EACW10R1	0.628	50	17.12	24.69	63.91	14.08	5.84	1.19	190.8	61	61	10.27	1.57	67	36	175
176	K5EACW8R1	0.616	50	25.57	43.11	32.94	23.60	2.95	15.42	433.2	71	68	12.30	1.71	81	55	176
177	K5EACW8R2	0.543	50	17.96	53.69	22.91	7.62	3.07	8.75	152.7	67	55	10.09	1.51	63	58	177
178	K5EACW9Q1	0.537	50	8.38	22.92	82.94	5.66	3.20	7.36	179.4	61	53	9.61	1.54	62	40	178

Table 2-E2.

Initial Earthworm Tissue Content

OBS	ID	WEIGHT	VOLUME	AS	CD	CU	PB	NI	SE	ZN	DRY_WT
1	E-BKDG-1	0.570	50	1.14	1.55	10.94	0.00	0.82	3.42	120.79	2.30
2	E-BKDG-2	0.502	50	0.90	1.94	12.03	0.00	1.43	2.49	125.20	2.31
3	E-BKDG-3	0.531	50	0.85	1.28	10.05	0.55	0.88	2.92	144.73	2.20
4	E-BKDG-4	0.582	50	1.12	1.92	12.18	0.07	3.12	2.66	136.34	2.29
5	E-BKDG-5	0.506	50	0.89	2.49	9.07	0.28	1.71	2.47	119.27	2.27
6	E-BKDG-6	0.520	50	1.06	2.78	12.28	0.00	1.09	2.21	130.48	2.29

Table 2-E3.

Initial Earthworm Tissue Summary

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE	C.V
WEIGHT	6	0.535	0.033	0.502	0.582	0.014	3.211	0.001	6.256
VOLUME	6	50.000	0.000	50.000	50.000	0.000	300.000	0.000	0.000
AS	6	0.991	0.128	0.847	1.140	0.052	5.948	0.016	12.955
CD	6	1.995	0.561	1.282	2.781	0.229	11.971	0.315	28.129
CU	6	11.092	1.318	9.067	12.285	0.538	66.555	1.736	11.879
PB	6	0.149	0.222	0.000	0.546	0.091	0.892	0.049	149.559
NI	6	1.508	0.860	0.818	3.121	0.351	9.047	0.739	57.030
SE	6	2.696	0.425	2.212	3.421	0.174	16.175	0.181	15.777
ZN	6	129.468	9.784	119.269	144.727	3.994	776.805	95.730	7.557
DRY_WT	6	2.277	0.040	2.200	2.310	0.016	13.660	0.002	1.750

Table 2-E4.

Blank Analysis

OBS	ID	VOLUME	AS	CD	CU	PB	NI	SE	ZN
1	E-BLANK-1	50	0.01	0.00	0.01	0.01	0.00	0.01	0.1
2	E-BLANK-10	50	0.01	0.00	0.01	0.04	0.02	0.01	0.1
3	E-BLANK-11	50	0.01	0.00	0.01	0.01	0.07	0.01	0.1
4	E-BLANK-12	50	0.01	0.00	0.01	0.01	0.02	0.01	0.1
5	E-BLANK-13	50	0.01	0.00	0.01	0.01	0.02	0.01	0.7
6	E-BLANK-14	50	0.01	0.00	0.01	0.01	0.02	0.01	0.6
7	E-BLANK-15	50	0.01	0.00	0.01	0.00	0.01	0.01	0.3
8	E-BLANK-16	50	0.01	0.00	0.01	0.01	0.01	0.01	0.1
9	E-BLANK-17	50	0.01	0.00	0.01	0.01	0.01	0.01	0.1
10	E-BLANK-18	50	0.01	0.00	0.01	0.00	0.01	0.01	0.1
11	E-BLANK-19	50	0.01	0.00	0.01	0.01	0.01	0.01	0.5
12	E-BLANK-2	50	0.01	0.00	0.01	0.02	0.00	0.01	0.1
13	E-BLANK-20	50	0.01	0.00	0.01	0.01	0.01	0.01	0.1
14	E-BLANK-21	50	0.01	0.00	0.01	0.01	0.01	0.01	0.1
15	E-BLANK-3	50	0.01	0.00	0.01	0.01	0.00	0.01	0.1
16	E-BLANK-4	50	0.01	0.00	0.01	0.01	0.00	0.01	0.1
17	E-BLANK-5	50	0.01	0.00	0.01	0.01	0.00	0.01	0.1
18	E-BLANK-6	50	0.01	0.00	0.01	0.01	0.01	0.01	0.7
19	E-BLANK-7	50	0.01	0.00	0.01	0.01	0.00	0.01	0.2
20	E-BLANK-8	50	0.01	0.00	0.01	0.01	0.01	0.01	0.1
21	E-BLANK-9	50	0.01	0.00	0.01	0.01	0.01	0.01	0.1

Table 2-E5.

Blank Analysis Summary

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE	C.V
VOLUME	21	50.000	0.000	50.000	50.000	0.000	1050.000	0.000	0.000
AS	21	0.005	0.000	0.005	0.005	0.000	0.105	0.000	0.000
CD	21	0.001	0.000	0.000	0.002	0.000	0.019	0.000	55.566
CU	21	0.011	0.001	0.009	0.014	0.000	0.236	0.000	10.864
PB	21	0.008	0.008	0.003	0.041	0.002	0.172	0.000	98.178
NI	21	0.012	0.014	0.001	0.065	0.003	0.245	0.000	119.181
SE	21	0.005	0.000	0.005	0.005	0.000	0.105	0.000	0.000
ZN	21	0.213	0.213	0.061	0.698	0.047	4.476	0.046	100.114

Table 2-E6.

NBS Oyster Tissue Analysis

OBS	ID	WEIGHT	VOLUME	AS	CD	CU	PB	NI	SE	ZN
1	E-OYS-1	0.529	50	2.36	6.48	64.91	0.00	0.41	0.47	788.9
2	E-OYS-10	0.504	50	2.88	3.90	66.84	0.08	0.03	0.69	816.2
3	E-OYS-11	0.638	50	2.43	4.63	65.42	0.45	0.42	0.86	829.7
4	E-OYS-12	0.680	50	2.72	5.73	69.17	0.21	0.24	1.25	903.5
5	E-OYS-13	0.582	50	2.32	4.05	69.31	1.96	0.00	0.69	868.5
6	E-OYS-14	0.561	50	1.87	4.12	69.41	0.00	0.12	0.80	877.1
7	E-OYS-15	0.530	50	1.98	4.63	71.02	0.36	1.63	0.66	856.3
8	E-OYS-16	0.564	50	2.04	3.57	66.73	0.00	0.56	0.44	833.1
9	E-OYS-17	0.504	50	2.68	3.76	68.43	0.00	0.33	0.69	830.1
10	E-OYS-18	0.522	50	1.82	4.06	70.28	0.00	1.28	0.67	870.4
11	E-OYS-19	0.542	50	2.86	4.18	70.64	0.00	0.77	0.65	877.0
12	E-OYS-2	0.548	50	2.46	4.92	65.49	0.00	0.03	0.64	849.2
13	E-OYS-20	0.500	50	1.30	3.55	60.58	0.00	1.73	0.50	878.7
14	E-OYS-21	0.498	50	1.31	4.48	63.33	0.00	0.33	0.40	849.5
15	E-OYS-3	0.506	50	2.08	6.00	64.50	0.08	4.58	0.49	850.5
16	E-OYS-4	0.526	50	2.38	4.57	63.86	1.03	0.22	0.86	862.8
17	E-OYS-5	0.545	50	2.29	4.34	66.12	0.35	0.58	0.83	879.5
18	E-OYS-6	0.520	50	2.21	5.67	71.32	0.17	1.57	0.87	905.5
19	E-OYS-7	0.520	50	2.60	6.16	63.73	0.00	0.03	0.48	883.4
20	E-OYS-9	0.580	50	2.33	4.35	65.50	0.07	0.72	0.43	869.6

Table 2-E7.

NBS Oyster Tissue Analysis Summary*

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE	C. V.
WEIGHT	20	0. 545	0. 047	0. 498	0. 680	0. 010	10. 899	0. 002	8. 611
VOLUME	20	50. 000	0. 000	50. 000	50. 000	0. 000	1000. 000	0. 000	0. 000
AS	20	2. 245	0. 440	1. 300	2. 877	0. 098	44. 909	0. 194	19. 602
CD	20	4. 658	0. 885	3. 552	6. 476	0. 198	93. 157	0. 783	18 996
CU	20	66. 829	2. 991	60. 576	71. 323	0. 669	1336. 590	8. 948	4. 476
PB	20	0. 238	0. 476	0. 000	1. 959	0. 106	4. 753	0. 227	200. 333
NI	20	0. 780	1. 052	0. 000	4. 578	0. 235	15. 593	1. 106	134. 917
SE	20	0. 669	0. 206	0. 402	1. 250	0. 046	13. 376	0. 042	30. 795
ZN	20	858. 969	28 943	788. 941	905. 481	6. 472	17179. 379	837. 724	3. 370

*Standards

¶BS Oyster Tissue Analysis Values

AS	11.5	15.3
CD	3.1	3.9
CU	66.5	79.5
PB	.44	.52
NI	.84	1.22
SE	1.6	2.6
ZN	838.0	866.0

Table 2-E8

Manure Tissue Content

OBS	ID	WEIGHT	VOLUME	AS	CD	CU	PB	NI	SE	ZN	WORM_IN	WORM_OUT	FINAL_WT	DRY_WT	RWET_WT	H2O_SOIL
1	E-MAN-1	0.521	50	1.44	4.43	5.54	0.36	1.57	2.98	132.21	67	68	20.625	2.75	132	66.64
2	E-MAN-2	0.598	50	1.59	5.86	11.35	0.07	1.53	2.42	149.41	61	64	20.286	2.40	133	51.39
3	E-MAN-3	0.584	50	1.46	5.49	7.17	0.00	1.40	2.65	138.44	58	55	18.409	2.37	116	71.53
4	E-MAN-4	0.560	50	1.16	4.21	10.25	0.00	0.83	2.59	137.23	64	68	19.643	2.57	127	72.16
5	E-MAN-5	0.523	50	1.24	3.66	8.87	0.00	1.37	2.39	129.73	67	76	14.630	2.09	96	64.37
6	E-MAN-6	0.692	50	1.95	2.37	8.44	0.13	0.53	3.90	122.62	71	65	11.928	1.09	75	

Table 2-E9

Manure Tissue Summary

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN	SUM	VARIANCE	C V
WEIGHT	6	0.580	0.063	0.521	0.692	0.026	3.478	0.004	10.914
VOLUME	6	50.000	0.000	50.000	50.000	0.000	300.000	0.000	0.000
AS	6	1.473	0.281	1.161	1.951	0.115	8.838	0.079	19.049
CD	6	4.337	1.265	2.371	5.863	0.516	26.021	1.600	29.165
CU	6	8.603	2.086	5.543	11.351	0.852	51.617	4.353	24.252
PB	6	0.094	0.143	0.000	0.365	0.058	0.562	0.020	152.445
NI	6	1.205	0.424	0.530	1.567	0.173	7.231	0.180	35.157
SE	6	2.822	0.569	2.390	3.902	0.232	16.935	0.323	20.142
ZN	6	134.941	9.094	122.616	149.415	3.713	809.647	82.699	6.739
WORM_IN	6	64.667	4.676	58.000	71.000	1.909	388.000	21.867	7.231
WORM_OUT	6	66.000	6.841	55.000	76.000	2.793	396.000	46.800	10.365
FINAL_WT	6	17.587	3.527	11.928	20.625	1.440	105.521	12.437	20.053
DRY_WT	6	2.212	0.592	1.090	2.750	0.242	13.270	0.350	26.762
RWET_WT	6	113.167	23.233	75.000	133.000	9.485	679.000	539.767	20.530
H2O_SOIL	5	65.218	8.396	51.390	72.160	3.755	326.090	70.497	12.874

3.0 NATURAL RESOURCE EVALUATION

3.1 Introduction

A variety of studies were performed to characterize and evaluate the biotic resources in the study area, evaluate the impact of hazardous material contamination on those resources, and determine baseline conditions on the site in the event that restoration measures become necessary. The study area consists of a wetland zone, a transition zone, and a zone of upland vegetation. Most of the study area adjacent to Allied Chemical Corporation Bay Point Works and north of the Southern Pacific railroad tracks consists of salt or brackish tidal wetlands. Because of the complex nature of tidal wetlands, studies were designed to evaluate specific aspects of the wetland. Four studies in this area included a characterization of wetland plant communities, a determination of the abundance of and effects of contamination on soil macroinvertebrates, an evaluation of the habitat for rare and endangered wildlife species, and a general assessment of the functional value of the wetland in providing a variety of benefits, such as shoreline anchoring, sediment trapping, food chain support, fish habitat, and recreation.

The study area also includes a transition zone leading to a more upland zone of upland vegetation, primarily grassland, which occupies the higher elevations on both sides of the Southern Pacific railroad tracks. These zones were also studied to determine their quality as habitat for typical grassland wildlife species.

3.2 Wetland Assessment Using the FHWA Technique

Wetlands are dynamic and diverse systems providing a wide variety of benefits to man. Typically one thinks of fish and wildlife habitat functions when considering the importance of wetlands. This is not surprising since waterfowl and commercial fish production are largely associated with the quality and quantity of wetlands. However, there are many other functions that can be attributed to wetlands, including improvement of water quality, flood storage and desynchronization, ground-water discharge and recharge, food-chain support, and socioeconomic functions such as aesthetics and recreation.

The public interest review process for evaluation of wetland areas [Section 404(b)(1) of the Clean Water Act of 1977] requires assessment of many more wetland functions than just habitat. Evaluation is also required under Executive Order 11990 for any Federally funded project in wetlands. In both of these actions, many functions are attributed to wetlands and must be examined. Few techniques, however, have been developed which assess all wetland functions. A wetland evaluation procedure that does consider most known wetland functions has been developed for the Federal Highway Administration (FHWA) (Adamus 1983). This procedure is designed for use as a screening or rapid assessment mechanism to indicate general priorities for more detailed analysis. The FHWA technique incorporate office data, field data, and, when available, detailed quantitative data to indicate a high, moderate, or low probability that the wetland can provide a particular function. The probability ratings do not have statistical correlates but are also not merely relative values. The interpretation keys are quite rigorous for achieving a high or low probability that a particular function may occur for a particular wetland.

3.2.1 Methods

The FHWA technique, which evaluates 11 potential wetland functions, was used to provide a general assessment of the wetlands in the project area. In addition, a more detailed characterization and assessment of the plant and animal communities was accomplished by field sampling. The FHWA wetland evaluation was based primarily on available information and field observations made at a single point in time. Only limited information was available to assess the social significance of the wetland. A more thorough assessment could be accomplished if local priorities could be established. The evaluation resulted in the most comprehensive possible assessment with the available data; however, other information and additional field observations could add more definition and could possibly lead to slight changes in some ratings of functional significance. Thus, the FHWA technique assessment should be considered as a preliminary but meaningful assessment.

3.2.1.1 Office Data

Much of the information needed to implement the assessment was derived from aerial photos, maps, and other similar sources. Such information was used to define wetland configuration, drainage patterns, distribution of general vegetation types, and other factors that reflect the potential capability of the wetland to perform certain functions.

3.2.1.2 Field Data

Some information required to implement the assessment can only be obtained by direct field observation. Characterization of plant growth habit and species diversity, wildlife utilization, and water depth are examples of wetland characteristics estimated during a site visit on 27-30 August 1984. Site characteristics were determine from observations made by traversing the wetland. Reconnaissance of other areas of the wetland watershed was also performed at the time. Observations made during the plant and animal studies (Section 2.1) were also used.

3.2.1.3 Quantitative Data

Quantitative data reflecting spatial and temporal relationships (i.e., specific water quality parameters, stream velocities, and sediment characteristics) can be incorporated into the technique when available. Such data are not required to evaluate the wetland, but can be used to strengthen conclusions. Published and unpublished quantitative data as well as data generated from other studies conducted at the site (i.e., plant community characterization, macroinvertebrate sampling information, and wildlife studies) were incorporated into the assessment.

3.2.2 Definitions

Several basic terms must be defined to appropriately interpret results (Adamus 1983). Some of these terms are listed below.

Opportunity - the chance for a wetland to fulfill a particular function.

Effectiveness - the probability of a wetland being productive in maximizing the opportunity given it to fulfill a particular function.

Significance - the degree to which the performed function is valued by society, as partly reflected by its scarcity. It is not derived from the technical literature but is based on several factors including (1) official recognition of the wetland, (2) uses or demand for the wetland, (3) relative contribution or supply of the wetlands, and (4) availability of substitutes.

Functional-rating - the interaction of assigned opportunity and effectiveness probabilities.

Functional-significance - the interaction of assigned function rating and significance probabilities.

3.2.3 Results and Discussion

The technique requires the evaluator to answer specific questions about the physical, chemical, and biological characteristics of the wetland under study. Answers to questions found in the technique (Adamus 1983) are presented in Appendix 3-A. Results are summarized in Table 3-1. Figure 3-1 illustrates the wetland impact area* and basin.

Examination of the social significance of the wetland based on limited data indicated that the significance was high for many functions (Table 3-1). This high significance rating is not surprising based on concerns expressed by legal control placed on wetlands use in California, particularly in the San Francisco Bay area where tidal marsh acreage has declined by about 95% since early colonization in the area (Josselyn 1983). Onuf et al. (1978) indicated the social significance of these wetlands as follows, "The critical values of central and southern California coastal wetlands derive from their rarity rather than from any exceptional richness of the systems." The richness of many wetlands in the San Francisco Bay area has been largely diminished by human alterations.

In addition to examining the significance of the wetland, the biophysical characteristics were also examined to determine the functional rating. A brief analysis of the 11 functions is discussed in the following paragraphs.

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* See Adamus (1983) for definitions of terms.

Table 3-1

SUMMARY OF RESULTS FROM ANSWERS TO FHWA TECHNIQUE

NO SITE DOCUMENTION

PROJECT — NAVY

DATE — 07/04/85

FUNCTION	EFFECT	OPPORT	FUNC RATING	SIGNIF	FUNC SIG
GROUND WATER RECHARGE	LOW	LOW	LOW	HIGH	LOW
GROUND WATER DISCHARGE	LOW		LOW	HIGH	LOW
FLOOD STORAGE	HIGH	LOW	MOD	HIGH	HIGH
SHORELINE ANCHORING	HIGH	MOD	HIGH	HIGH	HIGH
SEDIMENT TRAPPING	HIGH	HIGH	HIGH	HIGH	HIGH
NUTRIENT RETENTION					
LONG - TERM	HIGH	MOD	HIGH	HIGH	HIGH
SEASONAL	MOD	MOD	MOD	HIGH	HIGH
FOOD CHAIN SUPPORT					
DOWNSTREAM	MOD		MOD	MOD	MOD
IN-BASIN	MOD		MOD	MOD	MOD
FISHERY HABITAT					
WARMWATER	MOD		MOD	MOD	MOD
COLDWATER	LOW		LOW	MOD	LOW
COLDW.RIVERINE	LOW		LOW	MOD	LOW
ANADROMOUS RIV	LOW		LOW	MOD	LOW
BASS, STRIPED	MOD		MOD	MOD	MOD
WILDLIFE HABITAT					
GENERAL DIVERSITY	MOD		MOD	HIGH	HIGH
WATERFOWL GROUP1	MOD		MOD	HIGH	HIGH
WATERFOWL GROUP7	HIGH		HIGH	HIGH	HIGH
HERON, GREAT BLUE	MOD		MOD	HIGH	HIGH
ACTIVE RECREATION					
SWIMMING	LOW		LOW	HIGH	LOW
BOAT LAUNCHING	MOD		MOD	HIGH	HIGH
POWER BOATING	LOW		LOW	HIGH	LOW
CANOEING	LOW		LOW	HIGH	LOW
SAILING	LOW		LOW	HIGH	LOW
PASSIVE RECREATION AND HERITAGE				MOD	MOD

Table 3-2

Answers to FHWA Technique Questions

PROJECT	FORM A WIA			BASIN		
QUESTION	X	W	D	X	W	D
1.1	N	N	N	N	N	N
1.2	N	N	N	N	N	N
1.3	Y	Y	Y	Y	Y	Y
1.3.1	Y	Y	N	N	N	N
2.1.1						
2.1.2						
2.2.1	Y	Y		N	N	
2.2.2	N	N		Y	Y	
3.1					N	
3.2					Y	
4.1	Y					
4.2	N					
5.1					N	
5.2					Y	
6.1		N				
6.2		Y				
7.1				N		
7.2				Y		
8.1					N	
8.2					Y	
9.1				N		
9.2				Y		
10.1						
10.2						
10.3						
10.4						
11.1	N					
11.2	Y					
12.1						
12.2						
13.1						
13.2						
14	N			N		
15.1	N					
15.2	N					
15.3	N					
15.4	N					
15.5	N					
15.6	Y					
15.7	N					
16	N					
17.1	N					
17.2						
18	N					
19	N					
20				Y		
21.1	N					
21.2	N					
21.3	N					
21.4	N					
21.5	Y					
21.6	N					
22.1	N	N		N	N	

PROJECT	FORM A WIA			BASIN		
QUESTION	X	W	D	X	W	D
22.1.1						
22.1.2						
22.1.3	N	N		N	N	
22.1.4	N	N		N	N	
22.1.5	N	N		N	N	
22.2	N	N		N	N	
22.2.1						
22.2.2	N	N		N	N	
22.2.3	N	N		N	N	
22.2.4	N	N		N	N	
22.2.5	N	N		N	N	
22.3	N	N		N	N	
22.3.1	N	N		N	N	
22.3.2	N	N		N	N	
22.3.3	N	N		N	N	
22.3.4	N	N		N	N	
22.4	Y	Y		Y	Y	
22.4.1	Y	Y		Y	Y	
22.4.2						
22.5	N	N		N	N	
22.6	N	N		N	N	
23.1	N			N		
23.2	N			N		
23.3	N			N		
23.4	N			N		
23.5	N			N		
23.6	N			N		
23.7	N			N		
23.8	Y			Y		
23.9	N			N		
24.1	N	N	N			
24.2	N	Y	N			
24.3	Y	N	Y			
24.4	N	N	N			
24.5	N	N	N			
24.6	N	N	N			
25.1						
25.2						
25.3						
26.1			N			N
26.2			N			N
26.3			N			N
26.4			N			N
26.5			N			N
26.6			N			N
26.7			N			N
26.8			N			N
26.9			Y			Y
26.10			N			N
26.11			N			N
27.1						
27.2						
28.1						

(Continued)

Table 3-2 (Continued)

PROJECT	FORM A WIA			BASIN		
QUESTION	X	W	D	X	W	D
28.2						
29						
30.1	N					
30.2	N					
31.1						
31.2						
32.1	N	N	N	N	N	N
32.2	Y	Y	Y	Y	Y	Y
32.3	N	Y	N	N	Y	N
32.4	N	N	N	N	N	N
32.5	N	N	N	N	N	N
32.6	N	N	N	N	N	N
32.7	N	N	N	N	N	N
32.8	N	N	N	N	N	N
33.1	N	N	N	N	N	N
33.2	Y	Y	Y	Y	Y	Y
33.3	Y	Y	Y	Y	Y	Y
33.4	Y	Y	Y	Y	Y	Y
33.5	Y	Y	Y	Y	Y	Y
33.6	Y	Y	Y	Y	Y	Y
33.7	Y	Y	Y	Y	Y	Y
33.8	N	N	N	N	N	N
34.1	Y	N	Y	Y	N	Y
34.2	N	Y	N	N	Y	N
34.3	N	N	N	N	N	N
34.4	N	N	N	N	N	N
34.5	N	N	N	N	N	N
34.6	N	N	N	N	N	N
34.7	N	N	N	N	N	N
34.8	N	N	N	N	N	N
35.1	Y	Y				
35.2.1				Y		
35.2.2				N		
35.2.3				N		
36	Y			Y		
37.1		N				
37.2			N			
38.1						
38.2						
39.1	N					
39.2						
39.3	N					
39.4	N					
39.5	Y					
39.6				N		
40						
41.1				N	N	N
41.1.1				N	N	N
41.1.2				N	N	N
41.1.3				N	N	N
41.2				N	N	N
41.2.1				N	N	N
41.2.2				N	N	N

PROJECT	FORM A WIA			BASIN		
QUESTION	X	W	D	X	W	D
41.2.3				N	N	N
41.3				Y	Y	Y
41.3.1				N	N	N
41.3.2				Y	Y	Y
41.3.3				N	N	N
41.4				N	N	N
42.1	Y	Y	Y			
42.2	N	N	N			
42.3	N	N	N			
43	Y	Y	Y	Y	Y	
44.1				N	N	
44.2				Y	Y	
45.1	N					
45.2	Y					
46.1	N					
46.2						
46.3	Y					
46.4	N					
47.1	N					
47.2	Y					
48.1	N	N				
48.2	N	N				
49.1	Y					
49.2	N					
50	Y	Y	Y			
51		Y				
52.1.1						
52.1.2						
52.2.1						
52.2.2						
53.1	N					
53.2	N					

(Continued)

Table 3-2 (Concluded)

PROJECT	
QUESTION	FORM B ANSWER
1.1	N
1.2	N
1.3	N
1.4	N
1.5	N
1.6	N
2	Y
3	
4	
5	
6	
7	
8	
9	Y
10	
11	
12	
13	
14	
15	
16	N
17	
18	
19	
20	
21	
22	
23	
24	
25	Y
26	Y
27	
28	Y
29	
30	
31	
32	Y
33	
34	Y
35	
36	
37	
38	
39	
40	Y
41	
42	
43	N
44	
45	
46	
47	
48	
49	N

PROJECT	
QUESTION	FORM B ANSWER
50	
51	
52	
53	
54	Y
55	
56	N
57	
58	
59	
60	
61	N
62	

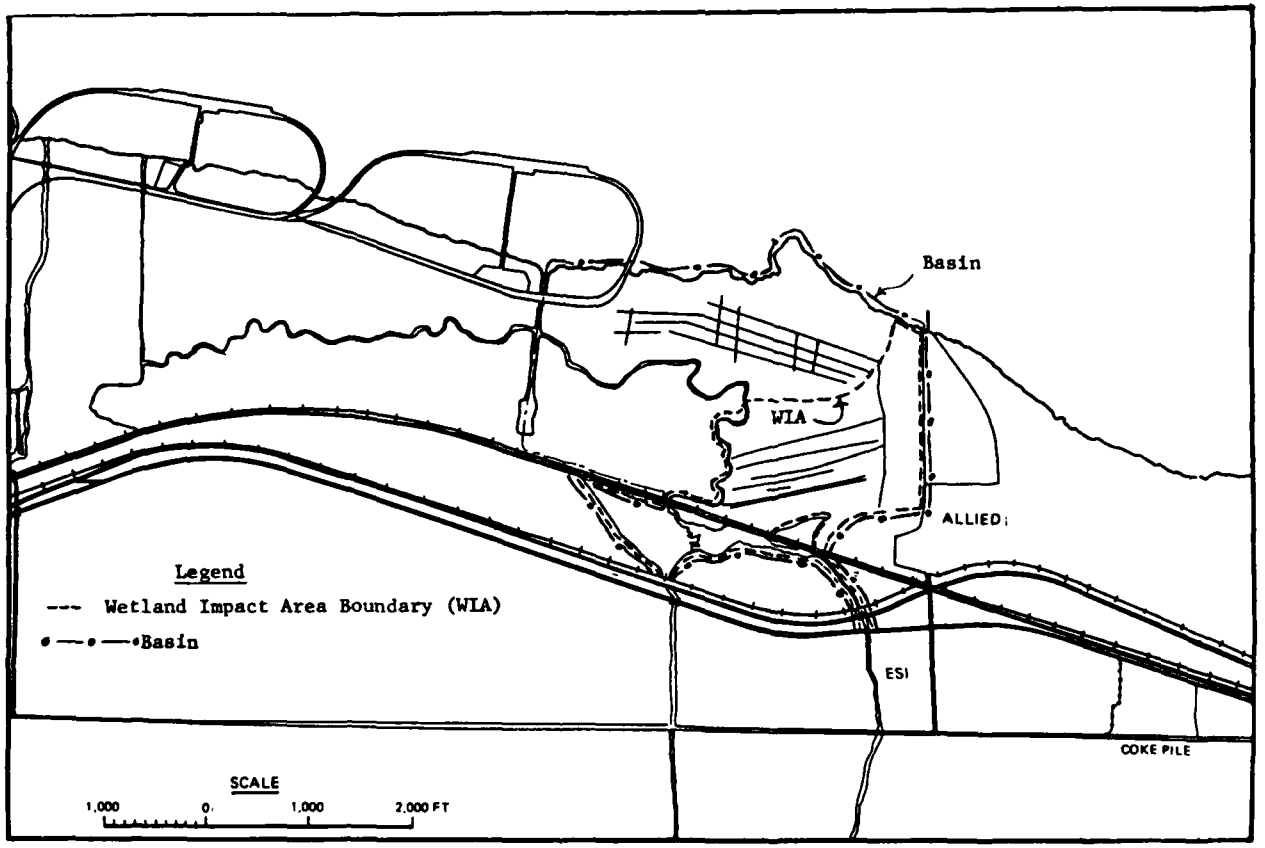


Figure 3-1. Location of wetland impact area and basin

Wildlife habitat is often considered an important function of wetlands and several detailed methods have been developed to assess this function. A general assessment of this function is provided. A higher resolution habitat assessment for selected wildlife species is provided in Section 3.5. A discussion of other wetland functions is also presented.

3.2.3.1 Wildlife Habitat

The FHWA technique provides a general assessment of the value of wetlands for wildlife habitat from several aspects: general wildlife diversity, harvested waterfowl, and wetland-dependent birds (excluding waterfowl). An evaluation was conducted for each category. Threatened and endangered species are not included in this assessment. See Section 3.5.

3.2.3.1.1 General Wildlife Diversity

Assessment of general wildlife diversity provides a measure of whether the annual total of wetland-dependent species recorded in the area is likely to be great (Adamus 1983). It implies that the wetland must support a diversity of species in winter as well as in summer. The evaluation indicated a moderate probability (Table 3-1) that the area supports a greater total annual diversity of wildlife species than might be supported by other wetlands of the same type in its ecoregion. The moderate potential (functional rating) for general wildlife diversity throughout most of the year is supported by the wetland physical characteristics, field observations made in August, and published reports of wildlife observations in the area (Jones and Stokes Associates, Inc. 1984; CH2M Hill 1976).

3.2.3.1.2 Harvested Waterfowl

California is a major wintering area for waterfowl using the Pacific Flyway. Suisun Marsh and the Sacramento and San Joaquin deltas provided important waterfowl habitat in California (Miller et al. 1975). Suisun Marsh does not, however, provide breeding habitat influential to the overall abundance of the Pacific Flyway waterfowl population. Breeding habitat is more important to the local population.

Waterfowl habitat requirements vary substantially among species and seasons. The technique stratifies waterfowl into nine groups, each having generally similar species requirements. The evaluator is required to select those groups most likely associated with the particular wetland being assessed. Two groups were evaluated in this study: (a) Group 1 (Table 3-1), which consists of dabbling ducks that prefer grassland wetland types, and (b) Group 7 (Table 3-1), which includes inland swans and geese.

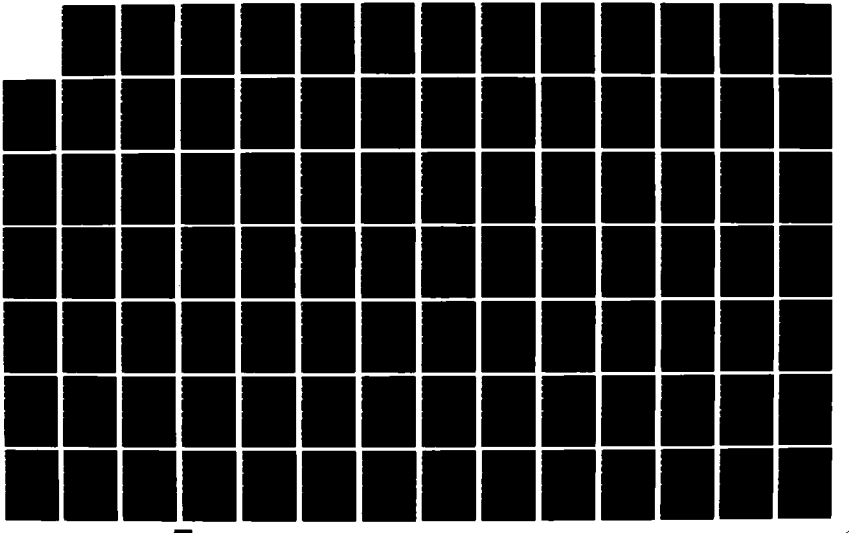
The evaluation indicated that there is a moderate probability (functional rating) the wetland is utilized by dabbing ducks such as mallards, pintails, gadwalls, and several species of teal. No waterfowl were observed at the census plot just east of the Pier 4 slough (Jones and Stokes, Inc. 1984) but mallards were observed in winter, summer, and spring at a census plot less than 1000 ft west of the Pier 4 slough. No waterfowl were observed in the wetland impact area (Figure 3-1) during the August 1984 field visit, but mallards were observed within the basin west of the Pier 4 slough. This difference in mallard occurrence may be a result of several factors including differences in sampling intensity, higher disturbance near the east end of the basin, few open-water ponds, differences in available food sources, effects of pollutants, or other unknown factors. No data were available to ascertain the reasons for the differences.

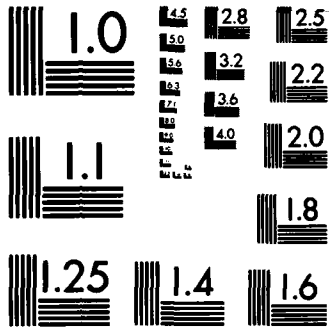
Evaluation of habitat characteristics for swans and geese indicated a high probability (functional rating) that the wetland is suitable habitat for these species. Surveys in the data east of the project area have recorded 250,000 geese at one time (CH2M Hill 1976). Nearly 90 percent of California's wintering swans have also been observed in the delta. However, none were observed in the basin during sampling or observations made in August 1984 (Jones and Stokes Associates, Inc. 1984). Aerial surveys conducted over Suisun Marsh during 1971 to 1976 indicate that geese are most abundant from November through January (California Department of Fish and Game Unpublished Data).

3.2.3.1.3 Wetland-dependent Birds (Except Waterfowl)

The FHWA technique provides a mechanism to assess the importance of the wetland to select species of birds dependent upon these areas during all or part of their annual activities. Habitat suitability was examined for the

AD-A165 127 REMEDIAL INVESTIGATION OF CONTAMINANT MOBILITY AT NAVAL 4/7
WEAPONS STATION C. (U) ARMY ENGINEER WATERWAYS
EXPERIMENT STATION VICKSBURG MS ENVIR C R LEE ET AL.
UNCLASSIFIED JAN 86 WES/MP/EL-86-2 F/G 6/6 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

great blue heron because this bird often uses tidal channels as feeding areas. It was also observed in Suisun Marsh (Jones and Stokes, Inc. 1984). The functional rating was moderate (Table 3-1).

3.2.3.2 Fishery Habitat

The FHWA technique provides two levels of analysis for assessing fishery habitat: (a) assessment of the functional group (i.e., warm-water or cold-water fishery with subcategories for riverine and anadromous species) and (b) assessment for particular species of concern. Assessment of the functional groups indicated a moderate probability that the area is regularly used by warm-water fish. The principal access point for fish species to enter the wetland impact area would be through the mosquito ditches which constrain dispersal. Water levels within the ditches were extremely shallow during observations made at low-water periods; therefore, fish habitat was restricted to the ditches and sloughs. The deeper tidal channels in the wetland basin were more desirable fish habitat because of greater availability and permanence of water, but water depth varies considerably with the changes in the tides. A few shallow ponds were observed scattered throughout the basin, but access by fish was limited. High water temperatures and low dissolved-oxygen levels in these shallow isolated ponds would also limit fish use.

Assessment of wetland use by particular warm-water species (e.g., striped bass) indicated a moderate probability that this species uses the wetland (Table 3-1). Fish use within the marsh is likely limited primarily to minnow-type species. The deeper channels would provide habitat for these fish as well as many larger fish.

3.2.3.3 Food-chain Support

Food-chain support pertains to use of nutrients by fish and aquatic invertebrates of commercial or sport value (Adamus and Stockwell 1983). Striped bass is the principal species of commercial or sport value according to discussions with several local residents. No invertebrate species were identified as commercially or recreationally valuable. The technique assesses both downstream and in-basin support; each is discussed below.

3.2.3.3.1 Downstream Transport and Utilization

Interchange of nutrients and primary productivity between the wetland and Suisun Bay downstream from the wetland is provided by a series of tidal channels and mosquito ditches. This and other factors influence downstream support for food-chain values. The evaluation indicated a moderate probability (functional rating) that the basin has significantly greater and more sustained net annual primary productivity than most unmanaged terrestrial systems. The probability is also moderate that organic matter produced by the wetland is more totally and evenly distributed among downstream animal users than for terrestrial systems.

3.2.3.3.2 In-basin Cycling and Food-chain Support

The probability is moderate (functional rating) that the wetland is critical to support some aquatic food chains within the wetland basin, due to: (a) the wetland having significantly higher sustained productivity than most unmanaged terrestrial or deepwater systems; or (b) the basin's ability to concentrate nutrients; and/or (c) the basin's ability to flush nutrients from the wetland into deepwater areas. The functional significance was moderate.

3.2.3.4 Ground-water Recharge

Ground-water recharge involves the movement of subsurface water or precipitation into the ground-water flow system (Adamus and Stockwell 1983). Movement is usually downward. This wetland function is influenced by hydroperiod, sediment type, wetland system, wetland position within the watershed, and several other factors (Adamus 1983). The wetland evaluation indicated a low probability that: (a) recharge to ground water exceeds ground-water discharge to the wetland on a net annual basis; and/or (b) the rate of recharge to the ground water exceeds the rate of recharge to the ground water from nearby terrestrial environments. The wetland occurs in an area where evaporation exceeds precipitation, so the opportunity for recharge is low.

3.2.2.5 Ground-water Discharge

Ground-water discharge involves the movement of ground water into surface water (Adamus and Stockwell 1983). Movement is usually upward and is often observed as springs. Factors that influence ground-water recharge into a wetland also influence ground-water discharge from a wetland. Several of these factors are listed above.

Evaluation of the wetland indicated a low probability (functional rating) that ground-water discharge to the wetland exceeds recharge to the ground water on a net annual basis. The functional significance was also considered low.

3.2.3.6 Flood Storage and Desynchronization

Flood storage is the process by which peak flows enter a wetland and are attenuated in their downslope movement (Adamus and Stockwell 1983). This process can be important in reducing downstream flooding.

The technique utilizes information derived primarily from field observations to assess flood storage. Therefore, the technique is less sensitive than if based on detailed studies. Results indicated a high probability that peak flows that reach the wetland are attenuated in their downslope journey. However, the opportunity to provide this function was considered to be low.

3.2.3.7 Shoreline Anchoring

Shoreline anchoring involves the stabilization of soil in shallow water or the water's edge by fibrous plant root systems (Adamus and Stockwell 1983). It may include long-term accretion of sediments and/or peat, along with shoreline progradation. Streambank and channel erosion were observed on the property. However, wetland vegetation appeared to provide an effective stabilizing mechanism, since most streambank erosion resulted from undercutting of the banks. Observations in the marsh indicated the presence of a dense root mass that retards erosion. The wetland evaluation indicated a high probability that the wetland is more effective at binding soil and/or dissipating erosive forces than fastlands adjacent to the wetland. There is also

a moderate probability that the wetland is exposed to appreciable erosive forces within the channels primarily because of tidal action.

3.2.3.8 Sediment Trapping

Sediment trapping is the process by which inorganic particulate matter of any size is retained or deposited within a wetland or its basin (Adamus and Stockwell 1983). Wetland vegetation on the property was very dense and, therefore, potentially very conducive to sediment trapping. The evaluation indicated a high probability that the wetland is effective in trapping and retaining appreciable amounts of inorganic sediments. The evaluation also indicated a high probability that appreciable amounts of inorganic sediments are carried into the wetland via runoff or surface flow. Turbidity of inflowing water would be greatest during high flow periods. This assessment, however, was constrained by a lack of inflow and outflow measurements of suspended solids.

3.2.3.9 Nutrient Retention

Nutrient retention is the storage of nutrients (primarily nitrogen and phosphorus) within the wetland substrate or vegetation (Adamus and Stockwell 1983). Several factors (i.e., hydroperiod, vegetation type, and current velocity) influence effectiveness of the wetland to perform this function. Assessment of nutrient retention was accomplished by considering both long-term and seasonal retention. Each is discussed in the following paragraphs.

3.2.3.9.1 Long-term Retention

Assessment of the potential effectiveness of the wetland to provide long-term retention of nutrients indicated a high probability that the wetland is more effective than most non-wetland environments for removing or retaining nutrients for long periods. However, limited water quality information was available to assess concentrations entering or leaving the wetland. There is a moderate probability that appreciable amounts (especially amounts of sufficient magnitude to cause downcurrent algal blooms) of nutrients are carried into the wetland.

3.2.3.9.2 Seasonal Retention

Evaluation indicated a moderate probability that the wetland is more efficient than most non-wetlands for temporarily retaining nutrients during the season in which nuisance algal blooms are most likely to occur, both down-current and in the wetland. The probability is also moderate that appreciable amounts of nutrients are likely to enter the wetland from channel or surface runoff.

3.2.3.10 Active Recreation

Active recreation, as used in the context of this evaluation, refers to recreation activities that are water dependent and that can occur either in an incidental or obligatory manner in wetlands (Adamus and Stockwell 1983). Activities assessed in this evaluation include swimming, boat launching, power boating, canoeing and kayaking, and sailing. The shallow character of the wetland, density of emergent vegetation, and limited access influence the recreational character of the wetland. The evaluation revealed a low probability that the wetland will be useful for the assessed recreational activities except boat launching, which was considered moderate.

3.2.3.11 Passive Recreation and Heritage

Passive recreation and heritage encompasses a wide variety of wetland uses including aesthetic enjoyment; nature study; open space; education; scientific study; preservation of rare, endangered, or endemic species; maintenance of the gene pool; protection of archaeologically or geologically unique features; and other uses (Adamus and Stockwell 1983). The evaluation procedure does not provide a mechanism for assessing physical attributes to determine the opportunity or effectiveness of the wetland to provide these uses. These functions primarily reflect local concerns and priorities (social significance) that are considered in the technique. Wetland significance for passive recreation and heritage was moderate, primarily because the wetland provides important habitat for several rare or endangered wildlife species (i.e., salt marsh harvest mouse). The wetland did not receive a higher rating

because of limited access. However, local concerns for declining acreages of wetlands in the San Francisco Bay area warrant a high level of importance.

3.2.4 Summary

Wetlands on the NWS Concord property are highly valuable for several hydrologic and water quality functions. They provide important shoreline anchoring and sediment trapping functions, both of which result in reduced discharge of suspended solids that may damage the fishery in Suisun Bay. The wetland was also assessed to be very effective in removing nutrients (primarily nitrogen and phosphorus), particularly over the long term. Based on this general assessment, however, the wetland provides only moderate value for most fish species because of limited deep water habitats. Waterfowl value was considered moderate to high in the basin. A more detailed assessment of the wildlife habitat value of the marsh is provided in Section 3.5 of this report.

3.2.5 References

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3.3 Characterization of Plant Communities

3.3.1 General Description of the Area

The wetlands under study are located on the south shore of Suisun Bay on NWS Concord. They are subjected to an average daily tidal flux of approximately 1.0 m. Suisun Bay waters are brackish-fresh in this area. Tidal flow reaches the area through canals, and most of the wetland surface is moistened during high tide (See Section 2.2.6.4). Drainage is to the north and west, with the northwest portion of the marsh being slightly lower in elevation. Water movement through the area is influenced by a number of east-west mosquito ditches. Adjacent upland areas are dominated by herbaceous vegetation, primarily grasses. The wetlands are bordered on the east by Allied Chemical Company. Fish and Wildlife Service indicated that Cordylanthus mollis subsp. moillis (soft bird's-beak) may occur on these areas of NWS Concord. This species is one for which Fish and Wildlife Service has sufficient biological information to support a proposal to list as endangered or threatened.

3.3.2 Methods

3.3.2.1 Selection of Sampling Areas

Two transects were established near the Allied Chemical Corporation Bay Point Works property. Transect I was established approximately 100 m west of the Allied Chemical Company waste lagoon dike on the east side of Parcel 572 on NWS Concord, and Transect II was located approximately 50 m east of the first transect (Figure 3-2). The starting point of both transects was located in the first wetland type (Salicornia) encountered beyond the uplands, and both transects extended northward to Suisun Bay. These two transects passed through the inspected area of the overflow of material from the adjacent Allied Chemical waste lagoon. Transect III was established in a remote reference area to the west of Parcel 571 (Figure 3-2). This wetland was separated from Suisun Bay by a service road, but it was connected to the bay by two large canals through which tidal waters passed. The transect extended from the fence on the south side of the service road (at telephone pole number 1623) southward for a distance of 315 m. Comparison of transects I and II to

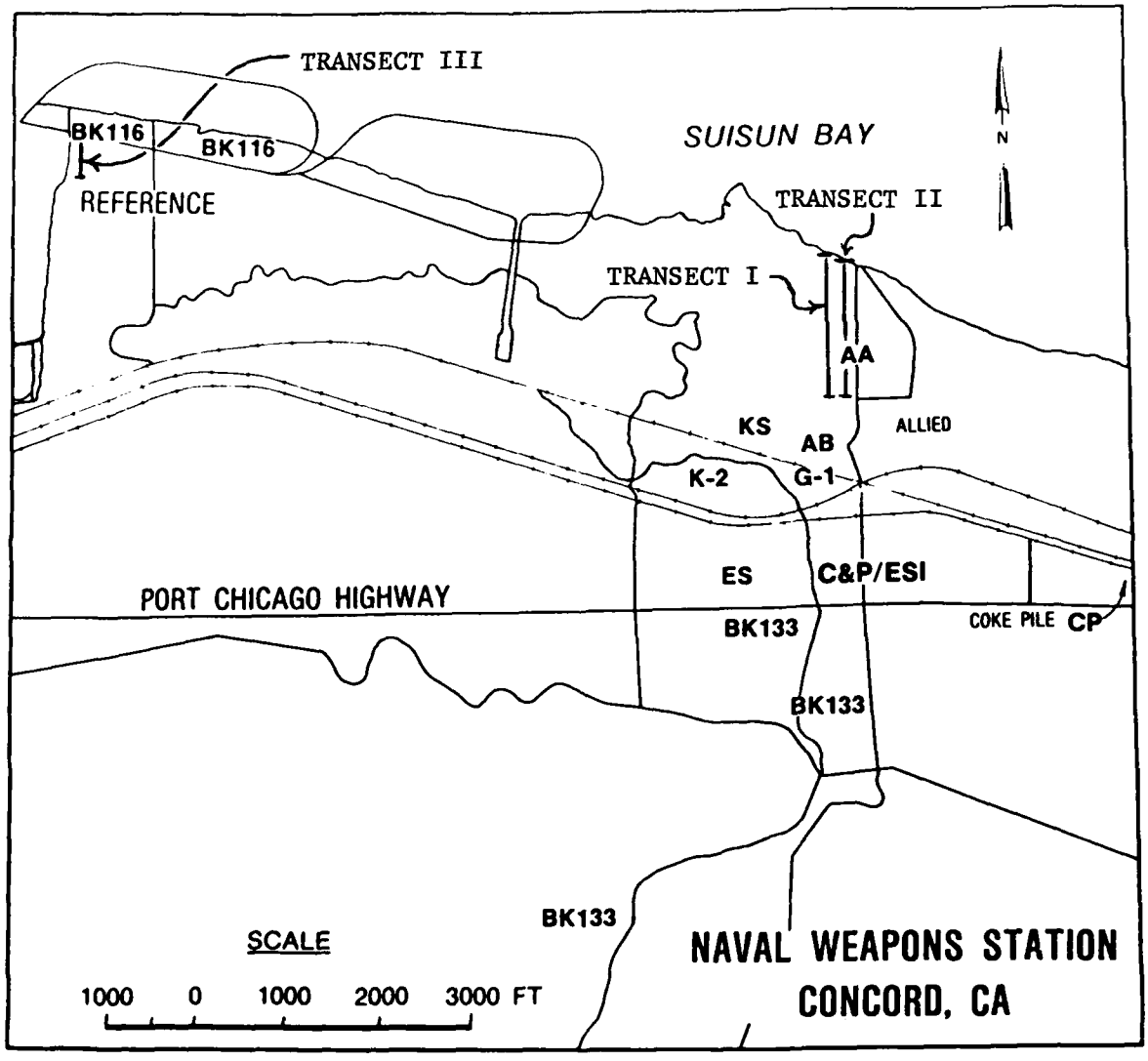

Figure 3-2. Location of three transects for plant community characterization

transect III indicated the impact of the overflow material on wetland plant communities.

3.3.2.2 Vegetation Sampling

3.3.2.2.1 Characterization of Community Types

A preliminary inspection of the area revealed six distinctive community types. All community types except the Scirpus californicus type* were characterized by applying the following procedure:

a. Ten randomly-located 1.0 m quadrats were sampled in each community type.

b. Percent cover of each species extending foliage into the quadrat was estimated using the following cover classes (Daubenmire 1968):

	Percent Cover	
Cover Class	Class Range	Midpoint of Class Range
1	0-5	2.5
2	6-25	15.0
3	26-50	37.5
4	51-75	63.5
5	76-95	85.0
6	96-100	98.0

c. Heights of each species having a cover class of 2 or greater were recorded in centimeters.

3.3.2.2.2 Transect Sampling

From the transect starting point, a 100-m tape was extended along the transect line. The first community type encountered and the height of the

* The Scirpus californicus community type was not characterized because it was not encountered along any of the three transects.

dominant species were recorded. The point at which the second community type began was recorded, as was community type and height of the dominant species. This procedure continued to the end of the transect at Suisun Bay. Any unvegetated areas were also recorded. The same procedure was used for the other two transects.

3.2.3.2 Data Analysis

3.3.2.3.1 Characterization of Communities Types

The following descriptive parameters were obtained from the field data for each community type:

a. Frequency (%) = Number of quadrats containing Species A/Total number of quadrats × 100

b. Relative Frequency (%) = Frequency of Species A/Total frequency for all species × 100

c. Relative Dominance (%) = Midpoints of cover class ranges for Species A/midpoints of cover class ranges for all species × 100

d. Importance Value = Relative Frequency + relative Dominance

e. Mean Plant Height = Height of Species A in all quadrats/Number of quadrats containing Species A

Species in each community type were ranked in order of decreasing importance values.

3.3.2.3.2 Transects

The percentage of each transect occupied by each community type was determined by summing the transect segments containing the community type and dividing by the total length of the transects. Height of each community type was also averaged and compared among transects.

3.3.3 Results

3.3.3.1 Community Types

Five discrete wetland community types were found to occur in the study area. (A sixth wetland community type, Scripus californicus, was observed in

the general area, but it did not occur in the area sampled.) The five types were characterized (Table 3-3) as follows:

3.3.3.1.1 Salicornia

This community type characteristically occurred at the highest wetland elevations and usually bordered the uplands. It was dominated by Salicornia virginica, with scattered forbs and grasses. In some areas, Distichlis spicata occurred as a co-dominant with Salicornia. This community type was the least diverse among the five community types characterized.

3.3.3.1.2 Distichlis

The Distichlis community type was dominated by Distichlis spicata, with Lepidium virginianum and Atriplex patula occurring as the most important sub-dominants. The Distichlis community type usually bordered the Salicornia community type at slightly lower elevations than Salicornia.

3.3.3.1.3 Scirpus

This community type was dominated by Scirpus robustus and/or Scirpus olneyi. In some areas, S. robustus was dominate, while S. olneyi dominated in other areas. In the sampled stand, these two species occurred as co-dominants, with Eleocharis parvula also being an important component of the community. This community type usually occurred at slightly lower elevations than the Distichlis community, and the area was either inundated or had saturated soils to the surface.

3.3.3.1.4 Juncus

The Juncus community type was dominated by Juncus bufonius, but Distichlis spicata was usually an important community component. Grindelia squarrosa was also an important species in this community type, especially in areas where slight disturbance (i.e. mosquito ditches) occurred. The Juncus community type usually was found in areas of deeper water than the Scirpus community type.

Table 3-3

Importance Value of Plant Species in Community Types Found in Marsh at the NWS Concord

Species	Community Type - Importance values				
	Salicornia	Distichlis	Juncus	Scirpus	Typha
Salicornia virginica	143.0	7.0	15.9	10.6	8.9
Unknown herb	23.1	-	-	-	-
Distichlis spicata	18.1	108.0	53.0	3.0	23.6
Festuca spp.	11.5	14.0	-	-	-
Cuscuta salina	4.3	-	-	-	10.1
Atriplex patula	-	24.0	3.2	5.3	6.8
Lepidium virginianum	-	23.0	21.0	-	-
Aster (large-flowered)	-	8.7	-	-	-
Polypogon monspeliensis	-	8.7	-	8.3	-
Eleocharis parvula	-	3.3	-	33.0	-
Scirpus robustus	-	3.3	-	43.0	24.2
Juncus bufonius	-	-	93.0	3.0	2.2
Grindelia squarrosa	-	-	13.9	-	13.2
Scirpus olneyi	-	-	-	77.0	-
Typha ssp.	-	-	-	16.8	76.5
Aster (small-flowered)	-	-	-	-	10.1
Pluchea purpurescens	-	-	-	-	8.9
Eleocharis aciculare	-	-	-	-	5.6
Polygonum spp.	-	-	-	-	4.4
Scirpus californicus	-	-	-	-	3.3
Rumex crispus	-	-	-	-	2.2

3.3.3.1.5 Typha

The Typha community was dominated by Typha spp.*, with Distichlis spicata and Scirpus robustus occurring in sub-dominants. Because Typha usually did not occur in extremely dense stands, there was sufficient subcanopy light penetration to allow other species to grow. Consequently, the Typha community type had the greatest species diversity. It occurred in the areas of deepest standing water.

3.3.3.2 Distribution of Community Types

The wetlands on NWS Concord consisted of a mosaic of community types. Although the community types were easily recognizable, most types were scattered throughout the area. Salicornia and/or Distichlis communities usually occurred immediately adjacent to the upland areas, but were also scattered throughout the wetlands in colonies of varying sizes. Juncus and Typha communities were usually confined to areas of deeper water nearer to Suisun Bay. Typha communities were scattered as small clumps throughout the wetland area in deepwater and along stream channels. The percentage of each transect occupied by each community type is shown in Table 3-4. The transect (Transect II) nearest the Allied Chemical property was dominated by Salicornia, while the Scirpus community dominated the other two transects. The Distichlis, Scirpus, Juncus community types occurred in all three transects, with the Scirpus community occurring in greatest abundance overall. The Typha community occurred in overall least abundance in each of the transects. A portion of the transect nearest the Allied Chemical property consisted of unvegetated areas, particularly within the first 400 m of the transect.

Heights of the plant communities (Table 3-5) generally did not vary appreciably among transects. However, the Scirpus community was significantly shorter in the transect nearest Allied Chemical waste lagoon than in the

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* Typha spp. refers to Typha angustifolia and Typha latifolia. These two species frequently hybridize, however the majority of Typha observed was T. angustifolia.

Table 3-4

Relative Occurrence of Wetland Plant Communities Along Three Transects in Marsh on NWS Concord

Community Type	Transect - Relative Occurrence, %*		
	II**	I	III
Salicornia	37	7	--
Distichlis	9	33	15
Scirpus	20	38	36
Juncus	27	14	34
Typha	--	7	14
Other (vegetated)	--	1	--
Other (bare mosquito ditch)	7	--	1

* Percent of transect dominated by community type.

** Transect II was located nearest to the eastern boundary of the NWS Concord property, approximately 50 m from the property boundary.

Table 3-5

Mean Heights of Dominant Species Along Transects

Community Type	Transect - Mean plant height, cm		
	II*	I	III
Salicornia	37	34	--
Distichlis	34	37	45
Scirpus	100	130	140
Juncus	108	113	108
Typha	--	135	184
Other (vegetated)	--	125	--
Other (bare mosquito ditch)	--	--	--

* Transect II was located nearest to the eastern boundary of the property approximately 50 m from the property boundary.

reference area, while the Typha community was significantly taller in the reference area (Transect III) than in the overflow impacted area (Transect I).

3.3.4 Discussion

3.3.4.1 Vegetation

The wetland community types present in the wetlands on the NWS Concord are not appreciably different from those found in other brackish marsh wetlands of the middle California area. Species composition was very similar to that found in other areas (Josselyn 1983). Under normal conditions, Salicornia occurs at higher elevations in the wetlands where soil salinities are high due to concentrations of salts in the soil by evaporation. Distichlis usually occurs in slightly more moist areas where soil salinities are slightly lower than those in Salicornia communities or Scripus robustus S. olenyi communities on the wetter sites. However, Juncus communities may border Distichlis when the change in elevation is abrupt. Juncus usually occurs in areas of slightly lower elevations than the Scirpus community. Typha normally occupies the areas of lowest elevation where soil moisture is high and salinities are low.

3.3.4.2 Factors Influencing Vegetational Pattern

Several factors combine to influence the observed vegetation pattern in the marsh at the NWS Concord. Each is discussed in the following paragraphs.

3.3.4.2.1 Water Depth

Typha, Scirpus, and Juncus communities generally occur at lower elevations than the Salicornia and Distichlis communities. Although not encountered in the sampling area, Scirpus californicus communities normally occur at the lowest elevations.

3.3.4.2.2 Salinities

Occurrence of plant communities in the marsh is influenced strongly by salinity levels, especially sediment salinities. At higher elevations where the soil surface is inundated less often and for shorter durations, evaporative processes concentrate salts in the sediments. These are areas where Salicornia and Distichlis communities occur. At lower elevations, Scirpus, Juncus, and Typha communities are predominant.

3.3.4.2.3 Disturbance

Human-induced activities have altered the marsh at the NWS Concord. The predominant altering activities are related to: (a) establishing and maintaining mosquito ditches and (b) overflow of materials into the marsh from a waste lagoon located on Allied Chemical property. These activities are discussed below.

3.3.4.2.4 Mosquito Ditches

In both the overflow impacted area and reference area, mosquito ditches extended in an east-west direction across the area. These mosquito ditches are 3 to 4 ft deep and approximately 3 ft wide. Excavated material was deposited in low berms on the edges of the ditches. The ditches serve as distribution channels for tidal waters and are filled daily. The slightly higher elevations along the berm favor species such as Grindelia squarrosa. Juncus bufonius stands often occurred adjacent to the ditches.

3.3.4.2.5 Overflow from Allied Chemical Company Waste Lagoons

On the extreme eastern side of the marsh, a portion of the marsh vegetation has been substantially impacted by the overflow of material from one of Allied Chemical's waste lagoons. As evidenced by data from Transect II (Table 3-4), several bare areas of varying widths were observed. The over flow materials had caused these areas to be slightly higher in elevation than prior to the overflow, which resulted in less frequent inundation and for shorter duration. More importantly, as salts from the overflow material

became concentrated on and in the soil, salt crystals were observed in barren areas. Most bare areas were completely devoid of vegetation, while decaying remnants of Salicornia were observed in others. There was evidence that salt-tolerant species (e.g., Distichlis spicata) were attempting to recolonize these areas, but recolonization was extremely slow.

3.3.4.3 Summary of Discussion

There were indications that soils in the overflow area near the dike of Allied Chemical waste lagoon were producing toxic effects on the plant species, especially in the unvegetated areas. Plant growth appeared stunted in some areas. This could possibly be indirectly related to water level and soil salinity. For example, stunted Typha occurred adjacent to Distichlis in some areas. Thus, the decreased frequency and duration of inundation as a result of the overflow spill material could be responsible for the stunted Typha. Abnormal Typha inflorescences were observed in some areas. These were quite small and very elongate. Although such abnormal morphological features could possible be induced by toxic hazardous materials from the overflow, it is also possible that these were the natural result of hybridization between Typha angustifolia and Typha latifolia. Such hybrids have been reported from the literature (Josselyn 1983).

3.3.5 Conclusions

The following conclusions were drawn:

a. Five plant community types* occurred in the marsh on the NWS Concord including:

(1) Salicornia

(2) Distichlis

(3) Scirpus

(4) Juncus

(5) Typha

b. The major natural influences on the distribution of vegetation types in the marsh were frequency and duration of inundation and soil salinity.

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* A sixth wetland community type, Scirpus californicus, was observed in the general area, but did not occur in the area sampled.

Distichlis and Salicornia occurred at higher elevations, while Typha, Scirpus, Juncus communities occurred in areas of deeper water.

c. Two man-induced factors have influenced the distribution of plant communities: (1) mosquito ditches and (2) overflow from Allied Chemical waste lagoon.

d. The principal effects of the overflow from the waste lagoon were slightly higher elevations and death and stunted growth of certain plant species.

3.3.6 References

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3.4 Characterization of the Macroinvertebrate Community

3.4.1 Materials and Methods

On 11 and 12 September 1984, a 100 (west to east) by 100 m grid was established within Site AA on Parcel 572 adjacent to the Allied Chemical waste lagoon dike (Figure 3-3). Using wooden stakes placed 10 m apart within the area, pairs of random numbers were used to establish the location of 40 coring sites. Sample locations were accepted or rejected to ensure that at least 10 samples were collected from each of the two dominant communities Distichlis and Scirpus. Cores (10 cm deep, 8.5 cm diameter) were removed from each location and kept in a cooler until processed. Sediment from each core was washed through a 35 standard sieve (0.5 mm) within 24 hr. The remaining materials retained by the sieve were preserved in 10 percent formalin and stained with Rose Bengal at the site. Two samples from the contaminated site were later discarded because of inadequate staining.

Salinity (measured as parts per thousand = o/oo) of interstitial water was determined (A/O Refractometer, accurate (± 0.5 o/oo)) by measuring the salinity of water which filled the hole after removal of the core.

On 12 and 13 September 1984, a 30 (north to south) by 100 m grid was established in a reference area approximately 7000 ft. to the west of Site AA

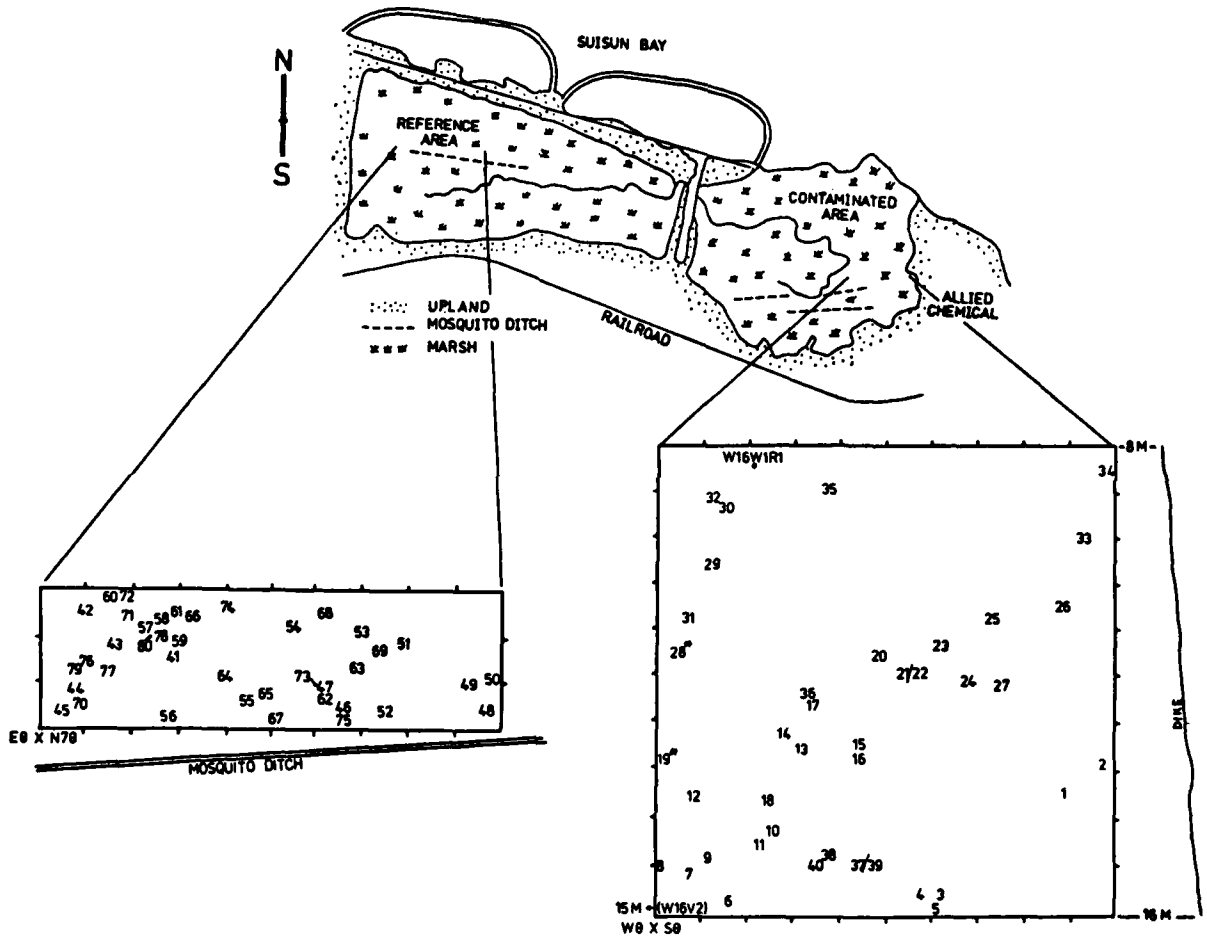

Figure 3-3. Location of field plots for soil macroinvertebrate characterization

(Figure 3-2). This area contained vegetation similar to that in Site AA and was considered far enough away from Site AA to have little impact from Site AA contamination. Forty cores were randomly collected and processed as described above. Salinity was determined as described above.

Fauna were separated from plant root/rhizome materials in the laboratory, identified to the lowest possible taxonomic level, and enumerated. Plant materials were dried at 103 C to a constant dried weight (± 0.05 g) for biomass determinations.

3.4.2 Statistical Analyses

Statistical comparisons were made with an analysis of variance procedure (ANOVA) from SAS package (SAS 1982). Numerical data (i.e., number of organisms) were transformed with a square-root function before analyses. Besides total number of organisms, only three species of oligochaetes were abundant enough for valid comparisons. Comparisons were made between Scirpus and Distichlis communities in both the reference and contaminated sites as well as between all cores from both sites.

Differences between communities at each site were also evaluated through ANOVA. When significant (alpha = 0.05) differences were found, communities were grouped following Duncan's Multiple Range Test (SAS 1982).

3.4.3 Results

3.4.3.1 Salinity

Salinity (Table 3-6) tended to be slightly higher within the reference area (range 15-35 o/oo) as compared to the contaminated site (range 8-36 o/oo), but no statistically significant differences were found. The location of the samples affected the salinity slightly with lower salinity occurring in samples collected on the western side of the contaminated area (Figure 3-4), although no trend was found in reference area.

Table 3-6

Comparison of Salinity by Community Type in Reference and Contaminated Areas

	Salinity, o/oo*					
	Reference Area			Contaminated Area		
Community Type	# Cores	Mean Salinity	Standard Deviation	# Cores	Mean Salinity	Standard Deviation
Distichlis spicata	14	27.2	6.10	11	17.6	6.8
Scirpus olneyi	10	25.5	5.88	14	17.8	7.3
Mixed	11	26.1	5.78	6	19.9	7.8
Salicornia**	--	--	--	6	25.0†	8.5
Juncus spp.**	5	26.5	5.61	--	--	--
Bare (no vegetation)	--	--	--	3	26.0††	--

* Dashed lines indicate that no samples were collected.
** Salicornia community rare in reference area; Juncus spp. community either rare or absent in contaminated area. Randomized experimental design did not place stations within these communities in those areas.
† Half the sites contained no water.
†† Only one site contained water.

3.4.3.2 Belowground Plant Biomass

Between 6.4 and 7.4 kg dry matter per square meter of plant materials mean standing stock (living and dead) were found in the top 10 cm of soil at the reference site (Table 3-7). Less of these materials were found in the contaminated communities, mean 0.9-4.9 kg dry matter m^2 (Table 3-7). When the Distichlis and Scirpus communities were compared with their respective counterparts, there was a statistically significant difference between sites (Table 3-8). Similarly the reference and contaminated sites were statistically different when vegetative type was not considered, i.e., all samples considered as a group (Table 3-8). Within the reference area, there were no statistical differences between vegetative communities while the biomass at one community in the contaminated site was significantly different from other communities (Table 3-9).

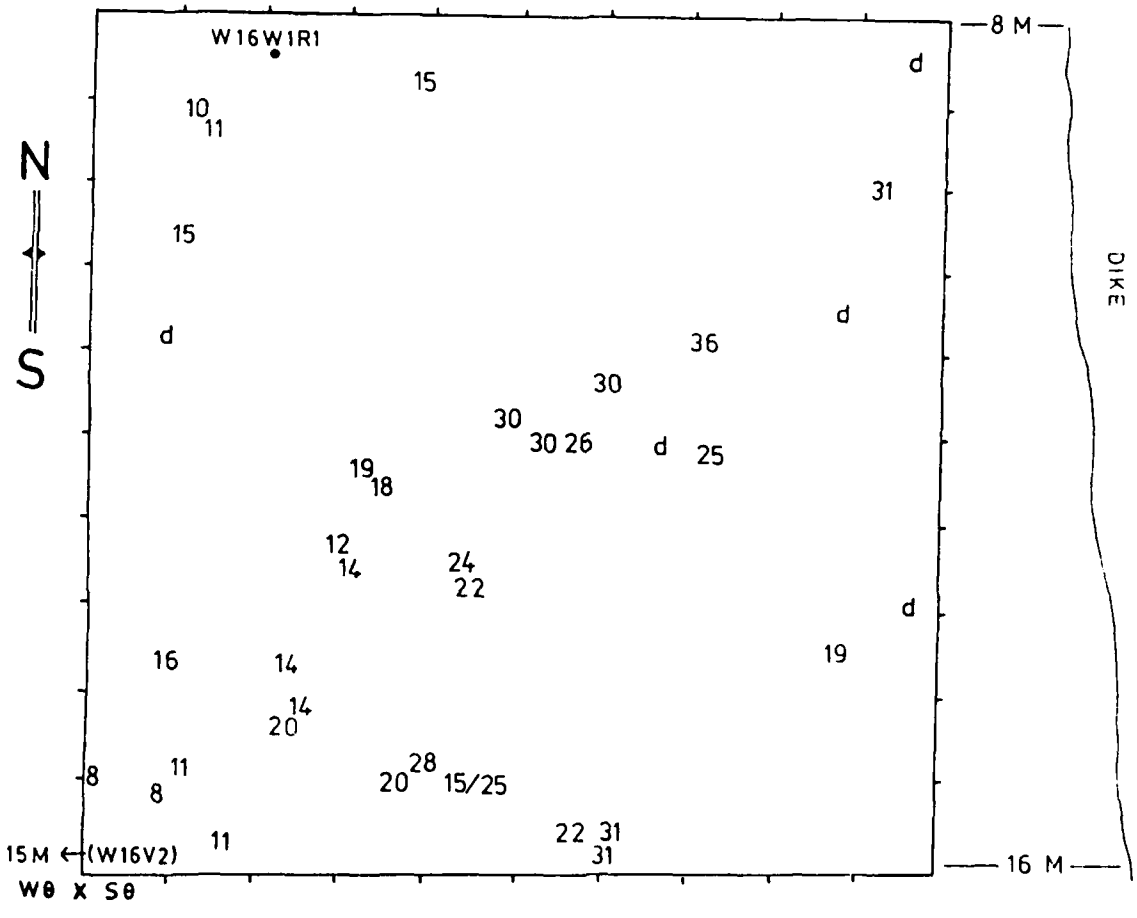

Figure 3-4. Salinity values (o/oo) for interstitial water within the 100 × 100 m grid at the contaminated area

Table 3-7

Comparison of Belowground Biomass by Community Type in Reference and Contaminated Areas

Plant Root/ Rhizome Community Type	Belowground Biomass, kg m^{-2}*					
	Reference Area			Contaminated Area		
	Sample Size	Mean	Standard Deviation	Sample Size	Mean	Standard Deviation
Scirpus	10	7.4	1.9	14	4.9	1.6
Distichlis	14	6.4	0.7	11	4.1	1.2
Mixed	11	6.8	0.8	5	3.4	2.0
Juncus	5	6.8	1.3	--	--	--
Salicornia	--	--	--	5	2.3	2.0
Bare	--	--	--	2	0.9	1.1
Polygonom	--	--	--	1	5.6	--

* Belowground plant tissue (living and dead) found in the surface 10 cm. Dashed lines indicate that no samples were taken.

Table 3-8

ANOVA Statistical Comparisons Between Contaminated and Reference Areas for Plant Biomass (Surface 10 cm of Soil)

Community	F	P > F
Scirpus	11.03	0.003*
Distichlis	32.39	0.0001**
All communities	11.17	0.0001**

* $P < 0.1$.
** $P < 0.001$.

Table 3-9

ANOVA* Statistical Comparisons of Root/Rhizome Biomass in Communities in the Reference and Contaminated Areas

		F	P > F
Reference Area			
Between communities		1.11	0.35
Contaminated Area		3.75	0.009**
Community	Group Designation**		
Scirpus	A		
Distichlis	A		
Mixed	AB		
Salicornia	AB		
Bare (no surface vegetation)	B		

* Where statistical differences existed, Duncan's Multiple Range Test was used to determine related groups at $\alpha = 0.05$ level of significance. Communities with no letters in common are statistically different. Only the bare areas are significantly different from vegetated areas.

** Significant at $P < 0.01$.

3.4.3.3 Infauna

At least 21 species of infauna were collected (Table 3-10) including four oligochaetes, one amphipod, three beetles, two chironomids, and a variety of other forms. Frequency of species occurrence in samples was low. In several cases, insect specimens were damaged during sampling and processing to the extent that identification required adult forms.

More total infauna were collected per core in the reference site (1568 m^2) than were collected in the contaminated site (352 m^2) (Table 3-11).

Table 3-10

List of Species Collected at the Contaminated and Reference Areas

Major Taxa		Species
Planaria		unidentified sp.
Nematoda		unidentified sp.
Oligochaeta	Tubificidae	*Quistadrilus multisetosus*
		Telematodrilus vejdovskyi
	Enchytraeidae	*Enchytraeus* c.f. *albidus* Henle
	Naididae	*Paranais litoralis* (Müller)
Polychaeta		Unidentified sp.
Gastropoda	Assimineiidae	*Assiminea californica* (Tryon)
	Terrestrial snails	sp. A
		sp. B
Amphipoda	Talitridae	*Orchestia* c.f. *traskiana* Stimpson
Collembola		unidentified sp.
Coleoptera		unidentified sp. A (larva)
		unidentified sp. B (larva)
Diptera	Chironomidae	Chironomid sp. A (larva)
		Chironomid sp. B (larva)
	Ceratopogonidae	*Culicoides* sp. (larva)
	Dolichopodidae	unidentified sp. (larva)
	Anthomyiidae	unidentified sp. (larva)
	Pupal case	unidentified sp.
Acarina	Mite	unidentified sp.

Table 3-11

Mean, Standard Deviation, Standard Error, and Range of Values for All Species Collected in All Communities at the Contaminated and Reference Areas

Species	Animals/m^2							
	Reference Area				Contaminated Area			
	Mean/m^2	Standard Deviation	Standard Error	Range	Mean/m^2	Standard Deviation	Standard Error	Range
Quistadrilus	405.7	582.1	88.2	0-1940.4	0.0	--	--	--
Telematodrilus	370.4	405.7	70.6	0-1234.8	88.2	229.3	35.3	0-882.0
Enchytraeus	35.3	70.6	17.6	0-352.8	4.6	35.3	5.7	0-176.4
Paranais	599.8	1199.5	194.0	0-6703.2	105.8	458.6	70.6	0-2822.4
Orchestia	105.8	247.0	35.3	0-1058.4	35.3	123.5	17.6	0-529.2
Assiminea	17.6	52.9	8.3	0-176.4	35.3	123.5	17.6	0-705.6
Gastropod sp. A	4.4	35.3	4.9	0-176.4	4.6	35.3	5.7	0-176.4
Gastropod sp. B	0.0	--	--	--	17.6	52.9	8.6	0-176.4
Polychaeta	4.4	35.3	4.9	0-176.4	4.6	35.3	5.7	0-176.4
Nematoda	17.6	70.6	17.6	0-352.8	0.0	--	--	--
Planaria	0.0	--	--	--	17.6	35.3	5.7	0-176.4
Anthomiidae	4.4	35.3	4.9	0-176.4	4.6	35.3	5.7	0-176.4
Coleoptera sp. A	4.4	35.3	4.9	0-176.4	0.0	--	--	--
Coleoptera sp. B	0.0	--	--	--	4.6	35.3	5.7	0-176.4
Coleoptera sp. C	0.0	--	--	--	17.6	70.6	17.6	0-352.8
Chironomidae sp. A	4.4	35.3	4.9	0-176.4	0.0	--	--	--
Chironomidae sp. B	4.4	35.3	4.9	0-176.4	0.0	--	--	--
Ceratopogonidae	17.6	35.3	4.9	0-176.4	4.6	35.3	5.7	0-176.4
Dolichopodidae	0.0	--	--	--	4.6	35.3	5.7	0-176.4
Collembola	17.6	35.3	4.9	0-176.4	0.0	--	--	--
Acarina	4.4	35.3	4.9	0-176.4	0.0	--	--	--
Diptera pupal case	0.0	--	--	--	4.6	35.3	5.7	0-176.4
Total	1570.0	1622.9	247.0	0-8643.6	352.8	599.8	105.8	176.4-2998.8

Differences were statistically significant (Table 3-12) whether infauna within individual plant communities at each site were examined or if infaunal cores among plant communities were pooled at each study site. Similarly, the three most abundant oligochaete species, all communities combined, were also significantly more abundant in the reference area (Table 3-12).

Small sample size and large variations between cores precluded statistical separation between reference and contaminated sites for at least some of the individual oligochaete species for Distichlis and Scirpus communities (Table 3-12). In every case, however, in both the Distichlis and Scirpus communities, the oligochaetes Quistadrilus multisetosus, Telematodrillus vejdovskyi, and Paranais litoralis were more abundant at the reference site (Tables 3-13 and 3-14).

When communities within the reference area were compared with one another, they were statistically inseparable for Q. multisetosus, T. vejdovskyi, and total organisms (Table 3-15). P. litoralis, however, was statistically more abundant in Scirpus (Table 3-15). No differences were detected among communities in the contaminated site (Table 3-15).

Statistical comparisons of animals in the mixed communities were not made because of the small sample size, but there were more total organisms in the reference area (mean = $2607/m^2$) than in the contaminated area mixed community (mean = $176/m^2$) (Table 3-16).

Macroinvertebrate taxa collected in the Juncus community are depicted in Table 3-17. The Juncus community was only recognized and sampled at the reference area.

Table 3-12

ANOVA Statistical Comparisons of Total Fauna and Three Dominant Oligochaete Species Between Contaminated and Reference Areas

	F	P > F
Total Fauna		
Scirpus communities	6.41	0.019*
Distichlis communities	5.91	0.023*
All communities combined	6.56	0.0001**
Quistadrilus		
Scirpus community	14.85	0.0009**
Distichlis community	3.04	0.094
All communities combined	3.99	0.0004**
Telematodrilus		
Scirpus community	1.60	0.219
Distichlis community	10.98	0.003**
All communities combined	3.66	0.0009**
Paranais		
Scirpus community	0.09	0.763
Distichlis community	2.80	0.107
All communities combined	2.92	0.005**

* Significant at $P < 0.05$.
** Significant at $P < 0.01$.
Note: Data were square-root transformed before analyses.

Table 3-13

Mean, Standard Deviation, Standard Error, and Range of Values for All Species Collected in the Scirpus Community

Species	Animals/m^2							
	Reference Area				Contaminated Area			
	Mean*/m^2	Standard Deviation	Standard Error	Range	Mean**/m^2	Standard Deviation	Standard Error	Range
Quistadrilus	617.4	723.2	229.3	0-1764.0	0.0	--	--	--
Telematodrilus	423.4	458.6	141.1	0-1234.8	229.3	335.2	88.2	0-882.0
Enchytraeus	52.9	88.2	35.3	0-176.4	17.6	52.9	17.6	0-176.4
Paranais	105.8	229.3	70.6	0-529.2	70.6	141.1	35.3	0-529.2
Orchestia	17.6	52.9	17.6	0-176.4	52.9	105.8	35.3	0-352.8
Assiminea	35.3	70.6	17.6	0-176.4	70.6	194.0	52.9	0-705.6
Polychaeta	17.6	52.9	17.6	0-176.4	17.6	52.9	17.6	0-176.4
Nematoda	35.3	105.8	35.3	0-352.8	0.0	--	--	--
Planaria	0.0	--	--	--	17.6	52.9	17.6	0-176.4
Anthomiidae	0.0	--	--	--	17.6	52.9	17.6	0-176.4
Coleoptera sp. C	0.0	--	--	--	35.3	105.8	35.3	0-352.8
Chironomidae sp. A	17.6	52.9	17.6	0-176.4	0.0	--	--	--
Ceratopogonidae	0.0	--	--	--	17.6	52.9	17.6	0-176.4
Collembola	35.3	70.6	17.6	0-176.4	0.0	--	--	--
Acarina	17.6	52.9	17.6	0-176.4	0.0	--	--	--
Diptera pupal case	0.0	--	--	--	17.6	52.9	17.6	0-176.4
Total	1375.9	1111.3	352.8	352.8-3351.6	529.2	511.6	141.1	0-1764.0

* n = 10.
** n = 14.

Table 3-14

Mean, Standard Deviation, Standard Error, and Range of Values for All Species Collected in the Distichlis Communities at the Contaminated and Reference Areas

Species	Animals/m^2							
	Reference Area				Contaminated Area			
	Mean*/m^2	Standard Deviation	Standard Error	Range	Mean**/m^2	Standard Deviation	Standard Error	Range
Quistadrilus	176.4	423.4	123.5	0-1587.6	0.0	--	--	--
Telematodrilus	194.0	264.6	70.6	0-882.0	0.0	--	--	--
Enchytraeus	17.6	52.9	17.6	0-176.4	0.0	--	--	--
Paranais	546.8	758.5	211.7	0-2469.6	264.6	846.7	264.6	0-2822.4
Orchestia	52.9	105.8	35.3	0-352.8	88.2	176.4	52.9	0-529.1
Assiminea	0.0	--	--	--	17.6	52.9	17.6	0-176.4
Gastropod sp. A	17.6	52.9	17.6	0-176.4	0.0	--	--	--
Gastropod sp. B	0.0	--	--	--	35.3	70.6	17.6	0-176.4
Nematoda	17.6	52.9	17.6	0-176.4	0.0	--	--	--
Planaria	0.0	--	--	--	17.6	52.9	17.6	0-176.4
Coleoptera sp. A	17.6	52.9	17.6	0-176.4	0.0	--	--	--
Coleoptera sp. B	0.0	--	--	--	17.6	52.9	17.6	0-176.4
Dolichopodidae	0.0	--	--	--	17.6	52.9	17.6	0-176.4
Total	1005.5	934.9	247.0	0-2822.4	441.0	899.6	282.2	0-2998.8

* n = 14.
** n = 11.

Table 3-15

ANOVA Statistical Comparisons of Fauna Between Communities at the Contaminated and Reference Areas

	F	P > F
Reference Site		
Between communities for *Quistadrilus*	1.46	0.242
Between communities for *Telematodrilus*	1.51	0.229
Between communities for *Paranais* sp.	2.92	0.047**
Between communities for total organisms	2.35	0.089
Community groups for *Paranais*		
Mixed A		
Distichlis AB		
Juncus AB		
Scirpus B		
Contaminated Site		
Between community for *Quistadrilus*	No animals collected	
Between community for *Telematodrilus*	2.16	0.084
Between community for *Paranais*	0.38	0.857
Between community for total organisms	2.21	0.077

* When differences were found ($P < 0.05$), a Duncan's Multiple Range Test was used to distinguish groups. Communities with no letters in common are significantly different from one another.

** Significant at $P < 0.05$.

Table 3-16

Mean, Standard Deviation, Standard Error, and Range of Values for All Species Collected in the Mixed Communities

Species	Animals/m^2							
	Reference Area				Contaminated Area			
	Mean*/m^2	Standard Deviation	Standard Error	Range	Mean**/m^2	Standard Deviation	Standard Error	Range
Quistadrilus	388.1	423.4	123.5	0-1411.2	0.0	--	--	--
Telematodrilus	564.5	458.6	141.1	0-1234.8	35.3	70.6	17.6	0-352.8
Enchytraeus	35.3	105.8	35.3	0-352.8	0.0	--	--	--
Paranais	1323.0	1975.7	599.8	0-6703.2	35.3	70.6	35.3	0-176.4
Orchestia	247.0	405.7	123.5	0-1058.4	0.0	--	--	--
Assiminea	0.0	--	--	--	35.3	70.6	35.3	0-176.4
Gastropod sp. A	0.0	--	--	--	35.3	70.6	35.3	0-176.4
Gastropod sp. B	0.0	--	--	--	35.3	70.6	35.3	0-176.4
Nematoda	35.3	70.6	17.6	0-176.4	0.0	--	--	--
Anthomiidae	17.6	52.9	17.6	0-176.4	0.0	--	--	--
Chironomidae sp. B	17.6	52.9	17.6	0-176.4	0.0	--	--	--
Ceratopogonidae	17.6	52.9	17.6	0-176.4	0.0	--	--	--
Total	2610.7	2452.0	740.9	352.8-8643.6	176.4	247.0	105.8	0-529.2

* n = 11.
** n = 5.

Table 3-17

Mean, Standard Deviation, Standard Error, and Range of Values for All Species Collected in the Juncus Community*

Species	Animals/m^2			
	Mean**/m^2	Standard Deviation	Standard Error	Range
Quistadrilus	599.8	882.0	388.1	0-1940.4
Telematodrilus	317.5	388.1	176.4	0-882.0
Enchytraeus	35.3	70.6	35.3	0-176.4
Paranais	141.1	141.1	70.6	0-352.8
Orchestia	105.8	229.3	105.8	0-529.2
Assiminea	35.3	70.6	35.3	0-176.4
Ceratopogonidae	35.3	70.6	35.3	0-176.4
Total	1270.1	705.6	317.5	0-2293.2

* This community was recognized and sampled only in the reference area.
** n = 5.

3.4.5 Appendix 3-A
Macroinvertebrate sample identification

Sample No.	Code
1	BCUNC0912841531SW87S26
2	BCUNC0912841523SW97S31
3	BCUNC0912841545CW62S04
4	BCUNC0912841549CW57S04
5	BCUNC0912841555CW61S02
6	BCUNC0912841602CW16S03
7	BCUNC0912841610DW07S09
8	BCUNC0912841616DW00S10
9	BCUNC0912841620CW11S12
10	BCUNC0912841628CW25S23
11	BCUNC0912841633CW23S15
12	BCUNC0912841638DW09S24
13	BCUNC0912841644CW31S35
14	BCUNC0912841648CW28S37
15	BCUNC0912841652MW43S36
16	BCUNC0912841659CW43S31
17	BCUNC0912841702DW34S42
18	BCUNC0912841709CW26S17
19	BCUNC0912841716MW01S31
20	BCUNC0912841724MW49S54
21	BCUNC0912841728MW53S50
22	BCUNC0912841731BW55S50
23	BCUNC0912841735PW61S57
24	BCUNC0912841739SW67S49
25	BCUNC0912841744MW72S62
26	BCUNC0912841749SW88S65
27	BCUNC0912841753MW75S48
28	BCUNC0912841758CW05S54
29	BCUNC0912841803CW11S74
30	BCUNC0912841807CW14S87
31	BCUNC0912841813DW08S62
32	BCUNC0912841817CW12S88
33	BCUNC0912841824SW93S80
34	BCUNC0912841827BW97S95
35	BCUNC0912841832DW38S90
36	BCUNC0912841840DW32S46
37	BCUNC0912841844DW43S10
38	BCUNC0912841847DW37S11
39	BCUNC0912841850DW44S10
40	BCUNC0912841854DW35S10
41	BCUNC0913841449DE29N85
42	BCUNC0913841455JE11N96
43	BCUNC0913841458DE17N87
44	BCUNC0913841502CE08N79
45	BCUNC0913841506ME05N74
46	BCUNC0913841512ME66N75
47	BCUNC0913841515ME62N79
48	BCUNC0913841518CE97N74
49	BCUNC0913841523ME93N80
50	BCUNC0913841525ME98N81
51	BCUNC0913841528ME79N89

52	BCUNC0913841533ME75N74
53	BCUNC0913841557ME70N91
54	BCUNC0913841604DE55N92
55	BCUNC0913841609DE45N76
56	BCUNC0913841611DE27N72
57	BCUNC0913841615CE23N91
58	BCUNC0913841618DE26N93
59	BCUNC0913841622DE31N88
60	BCUNC0913841625JE16N98
61	BCUNC0913841629DE29N94
62	BCUNC0913841633JE62N78
63	BCUNC0913841636DE69N92
64	BCUNC0913841639DE40N81
65	BCUNC0913841642DE49N77
66	BCUNC0913841644ME33N93
67	BCUNC0913841649JE51N72
68	BCUNC0913841652CE62N95
69	BCUNC0913841655DE74N87
70	BCUNC0913841702CE09N74
71	BCUNC0913841705DE19N95
72	BCUNC0913841708JE18N99
73	BCUNC0913841711ME60N79
74	BCUNC0913841714DE41N96
75	BCUNC0913841718ME66N72
76	BCUNC0913841723CE10N85
77	BCUNC0913841730CE15N82
78	BCUNC0913841734CE26N90
79	BCUNC0913841738CE08N83
80	BCUNC0913841742CE24N90

code legend:

BCUNC0912841531SW87S26

Column	Description
1-2	benthic core
3-5	Univ. of North Carolina
6-11	date
12-15	time
16-22	grid coordinates

3.4.4 Summary

Statistical differences do exist between contaminated and reference areas with respect to plant root biomass and macrobenthic organisms. Total root biomass and biomass within Distichlis and Scirpus communities were greater in the reference area. Total macroinvertebrate density was greater in the reference area and in the Distichlis and Scirpus communities within the reference area. Total densities of three species of oligochaetes were also greater in the reference area and in some of the plant communities between areas. The quantity and distribution of plant roots in the rhizosphere could greatly affect the numbers and diversity of fauna present.

3.4.5 Reference

SAS Institute, Inc. 1982. SAS User's Guide: Statistics. Cary, NC. 584 pp.

3.5 Wildlife Habitat Evaluation

3.5.1 Wildlife Species at NWS Concord

A recent natural resource inventory of the NWS Concord (Jones and Stokes Associates 1984) lists 120 species of birds, 18 mammals, and at least 13 reptiles and amphibians that were observed within the nine distinct habitat types that comprise the NWS Concord (see Appendix 3-A for list of species). The roughly 180-acre area under investigation for chemical contamination consists primarily of salt marsh, grassland, and a small freshwater marsh. More than 100 species of birds and mammals were seen in these same habitat types at various sites on the NWS Concord (Jones and Stokes Associates 1984) and, therefore, could come in contact with contaminated soil, water, vegetation, or food items. Many of these species are transients that range over a much wider area and might visit the site occasionally in their daily movements or as a stop-over during migration. Other species (i.e., salt marsh harvest mouse*, deer mouse, California vole, western harvest mouse, ornate shrew, raccoon, great blue heron, snowy egret, mallard, cinnamon teal, California black rail, sora rail, Virginia rail, northern harrier, ring-necked pheasant, marsh wren, red-winged blackbird, salt marsh yellowthroat, Suisun song sparrow, giant garter snake, Pacific gopher snake, and others) are seasonal or year-round residents of the area and therefore might be exposed to chemical contamination over extended periods of time.

Several rare and endangered wildlife species are known to be present on NWS Concord, with three reported from the contaminated area (Table 3-18). The salt marsh harvest mouse and the California least tern are listed as endangered by the US Fish and Wildlife Service (FWS) and the California Department of Fish and Game. The harvest mouse is a year-round resident of the salt marsh adjacent to the Allied Chemical Corporation Bay Point Works property, and the tern is known to nest at the Allied disposal ponds. The California black rail is listed as rare in California and is a candidate for Federal listing. It is a year-round resident of the salt marsh study area. Five additional rare or endangered species or candidates for listing (giant garter snake, bald eagle, California clapper rail, Suisun shrew, and salt

---

* See Appendix 3-B for scientific names.

Table 3-18

Rare and Endangered Wildlife Species at NWS* Concord

Species	Status**	Occurrence at NWS Concord
Salt marsh harvest mouse	FE,CE	Presence confirmed on contaminated area
California least tern	FE,CE	Presence confirmed on Allied Chemical property adjacent to contaminated area
California black rail	CR,X	Presence confirmed on contaminated area
Giant garter snake	CR	Presence likely on NWS
Bald eagle	FE,CE	Rare visitor to NWS and adjacent areas
California clapper rail	FE,CE	Presence possible on NWS in some years
Suisun shrew	X	Not known to be present on NWS; exists along north shore of Suisun Bay
Salt marsh yellowthroat	X	May be present on NWS; this subspecies of common yellowthroat is currently the subject of taxonomic and distributional studies by the FWS

*Information compiled from Jones and Stokes Associates (1984) and the Sacramento Endangered Species Office of FWS (letter from Gail C. Kobetich, Project Leader, dated 28 December 1984).

**FE - Listed as endangered by the US Fish and Wildlife Service.
CE - Listed as endangered by the Calif. Dept. of Fish and Game.
CR - Listed as rare by the Calif. Dept. of Fish and Game.
X - Candidate for listing by the US Fish and Wildlife Service.

marsh yellowthroat) are known to be present occasionally or are potential visitors to the marshes of NWS Concord.

3.5.2 Quality of the Study Area as Wildlife Habitat

A wildlife habitat evaluation was conducted in the area of suspected or confirmed chemical contamination (hereafter called the study area) adjacent to the Allied Chemical property. Habitat was selected as the basis for wildlife discussions because of its importance to the entire wildlife resource and because of its unifying nature (Roberts 1985). Separate evaluations were performed in the two major vegetation types in that area (grassland and salt marsh) and results are reported separately in the following sections.

3.5.2.1 Grassland Area

The habitat evaluation was conducted on the approximately 60-acre grassland study site adjacent to Allied Chemical property, and on two reference sites nearby. The study site was bounded on the east by Nichols Road and Allied Chemical Company property, on the south by the Amtrak railroad, and on the west by the drainage ditch passing under the trestles on the AT&SF and Southern Pacific railroads (Figure 3-5). The northern boundary was the interface between grassland and wetland vegetation, generally defined by the presence of pickleweed (Salicornia virginica) and saltgrass (Distichlis spicata) in the wetland area. One reference area with similar vegetation characteristics was established a few hundred yards southwest of the study site. It was bounded by the Southern Pacific and AT&SF railroads on the north, the Contra Costa Canal on the west, the Port Chicago highway on the south, and the fence line on the east. The second reference area was a grassland area (pasture) where cattle grazing was permitted. It was located across the Port Chicago highway from the first reference site and was bounded by the road on the north, the Contra Costa Canal on the east, the fence on the south, and the large grove of trees on the west.

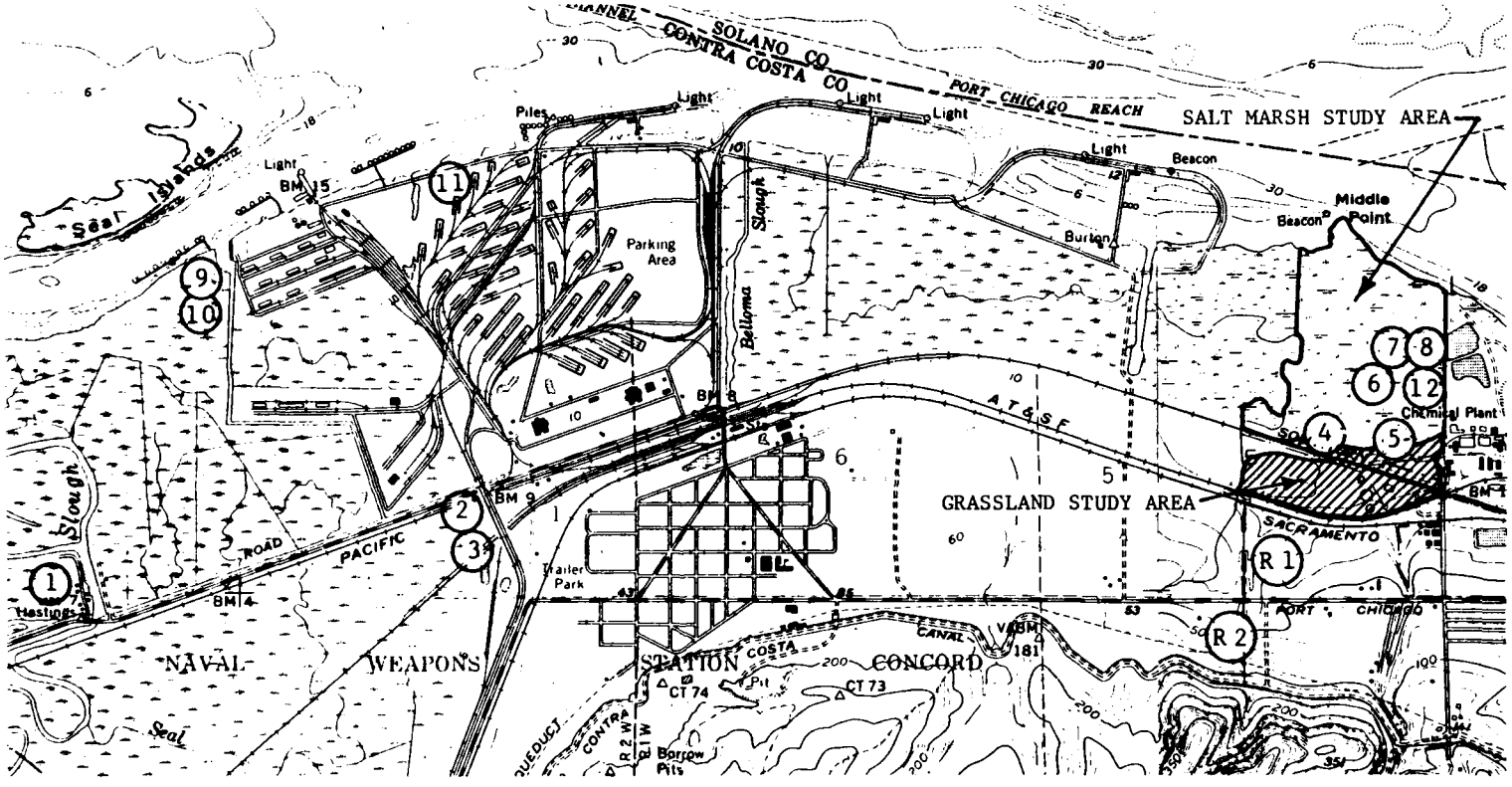

Figure 3-5. Map of NWS Concord showing study areas for the wildlife habitat evaluation. R1 and R2 indicate reference sites for the grassland evaluation. Plots 1 through 12 were used to evaluate salt marsh habitats for the salt marsh harvest mouse and California black rail

3.5.2.1.1 Methods

Habitat Suitability Index (HSI) models were used to determine the value of the sites as wildlife habitat. HSI models are components of the Habitat Evaluation Procedures (HEP) developed by U.S. Fish and Wildlife Service in conjunction with the Corps of Engineers and other Federal agencies. An HSI model rates habitat quality for individual species from 0 (unsuitable) to 1.0 (optimum). The models are based on the assumption that there is a linear relationship between the carrying capacity of the site for a species and a model's output or HSI. Variables included in HSI models are those factors that can be measured and that best explain the relationship between a species and its habitat.

Study areas were visited on 28 and 29 August 1984 to define site boundaries and to delineate vegetation cover types. After this visit and conversations with biologists from the Navy, California Department of Fish and Game, and FWS, three wildlife species were selected for the grassland habitat evaluation. These were the American kestrel, western meadowlark, and ring-necked pheasant.

The kestrel, meadowlark, and pheasant are all associated with grassland ecosystems and are known to exist on the NWS Concord. They provide a good overall assessment of the quality of the sites because their ecological requirements are somewhat different. The meadowlark is predominantly an insectivore, the pheasant predominantly a granivore, and the kestrel an opportunistic carnivore. The meadowlark and pheasant both nest in grassland areas; the kestrel nests in tree cavities but will use nest boxes and abandoned buildings. Collectively the variables in the habitat models for the three species reflect vegetation structure and diversity, and the juxtaposition of vegetation types. These elements are an integral part of quality in natural systems.

Habitat models were available from FWS for the kestrel (US Fish and Wildlife Service 1980) and from the Missouri Department of Conservation for the pheasant (Urich et al. 1983); they were used with only slight modification to the pheasant model. No model was found for the western meadowlark, although one was available for the eastern meadowlark (Schroeder and Sousa 1982). The two species have nearly identical habitat requirements, the only difference being that the western species tends to occupy drier sites. After

consultation with Richard L. Schroeder, the senior author of the eastern meadowlark model, the model was determined to be appropriate for use on NWS Concord without any modification. A list of variables in all the models is found in Table 3-19.

Habitat variables were measured at ten randomly selected sampling stations within the grassland study area. The site was first divided subjectively into areas of similar vegetation characteristics, then sampling stations were distributed in a stratified random arrangement. At each sampling station, habitat variables were measured at end of ten points located at 5-ft intervals along lines in each of the four cardinal compass directions, for a total of 40 sampling points per station. Data were averaged across all sampling stations to give an overall estimate of habitat suitability of the study area for each evaluation species. The two grassland reference areas had very uniform vegetation. Therefore only two sampling stations were established on each site.

Average values for each variable, the corresponding suitability indices (SIs), and the final HSIs for each of the three sites are found in Table 3-20. Copies of the models are included in Appendix 3-C. Vegetation measurements were taken at NWS Concord on 11-12 September 1984.

3.5.2.1.2 Results

HSI scores on the study area adjacent to Allied Chemical ranged from moderate for the pheasant to high for both the kestrel and meadowlark. Habitat suitability for the kestrel was optimum (HSI = 1.0). Grasslands of this type typically produce large numbers of prey animals (insects and small mammals) resulting in an abundant food base for the kestrel. This species has a feeding territory that averages 275 acres in size so the trees, fence posts, and power-line poles scattered over the site furnished an adequate number of perches for hunting.

Habitat quality for the meadowlark was slightly less than optimal (HSI = 0.89) on the study area due to the limited distribution of perch sites for this less wide-ranging species, and to the relatively tall herbaceous vegetation. The quality of the site for pheasants was relatively poor (HSI = 0.58) due to the lack of cultivated cropland that would serve as a

Table 3-19

Variables and Equations in the HSI Models for Western Meadowlark, American Kestrel, and Ring-necked Pheasant

Variable	Description	Equations For Calculating HSI
	Western Meadowlark	
1	% herbaceous cover	
2	% herbaceous cover that is grass	
3	Average height herbaceous cover	$HSI = (SI_1 \times SI_2 \times SI_3 \times SI_4)^{\frac{1}{4}} \times SI_5$
4	Distance to perch site	
5	% shrub cover	
	American Kestrel	
1	% herbaceous cover	$SI_{Food} = (SI_1 \times SI_2 \times SI_3)^{1/3}$
2	% herbaceous cover ≤ 30 cm tall	
3	Distance to perch site	$SI_{Reprod.} = SI_4 + SI_5$
4	Availability of trees ≥ 30 cm or a grove of trees within 1.6 km	HSI = lowest of SI_{Food} or $SI_{Reprod.}$
5	Availability of cliff ledges, earth banks, or abandoned buildings within 1.6 km	
	Ring-necked Pheasant	
1	% grassland within 810 ha	
2	% cropland within 810 ha	
3	Degree of grassland use (light, moderate, etc.)	
4	% cropland within 810 ha	
5	Extent of border (cover) around site	
6	% vegetative cover	$HSI = \frac{SI_1 + SI_2 + \ldots + SI_{13}}{10.5}$
7	Average height herbaceous cover	
8	% woody cover	
9	Species of grass present	
10	Grassland management practices	
11	Distance to winter cover	
12	Distance to cropland	
13	Distance to old field	

Table 3-20
HSI Values for the Grassland Study Site and Two Reference Areas, at NWS

Location	Variable	Value	SI	HSI
Study Site				
	Western Meadowlark			
	1	96.1%	1.0	
	2	96%	1.0	
	3	38.7 cm	0.91	
	4	34.9 m	0.87	
	5	0.2	1.0	0.89
	American Kestrel			
	1	96.1%	1.0	
	2	40.8%	1.0	
	3	<0.6 km	1.0	
	4	A	1.0	
	5	B	0.4	1.0
	Ring-necked Pheasant			
	1	25-75%	0.33	
	2	<40%	0.10	
	3	>75%	1.0	
	4	<10%	0.10	
	5	>50%	1.0	
	6	>60%	0.10	
	7	>43 cm	1.0	
	8	<5%	1.0	
	9	B	0.80	
	10	A	1.0	
	11	<0.40 km	1.0	
	12	>0.80 km	0.10	
	13	>0.8 km	0.10	0.58
Reference Area 1				
	Western Meadowlark			
	1	98.8%	1.0	
	2	98.7%	1.0	
	3	54.3 cm	0.52	
	4	--	1.0	
	5	0	1.0	0.72

(Continued)

Table 3-20 (Continued)

Location	Variable	Value	SI	HSI
Reference Area 1 (contd)				
		American Kestrel		
	1	98.8%	1.0	
	2	21.8%	0.55	
	3	<0.6 km	1.0	
	4	A	1.0	
	5	B	0.4	0.82
		Ring-necked Pheasant		
	1	25-75%	0.33	
	2	<40%	0.10	
	3	>75%	1.0	
	4	<10%	0.10	
	5	25-50%	0.33	
	6	>60%	0.10	
	7	>43 cm	1.0	
	8	<5%	1.0	
	9	B	0.8	
	10	A	1.0	
	11	<0.40 km	1.0	
	12	>0.80 km	0.10	
	13	>0.8 km	0.10	0.56
Reference Area 2				
		Western Meadowlark		
	1	97.5%	1.0	
	2	98.7%	1.0	
	3	16.3 cm	1.0	
	4	--	1.0	
	5	0	1.0	1.0
		American Kestrel		
	1	97.5%	1.0	
	2	100%	1.0	
	3	<0.6 km	1.0	
	4	A	1.0	
	5	B	0.4	1.0

(Continued)

Table 3-20 (Concluded)

Location	Variable	Value	SI	HSI
Reference Area 2 (contd)	Ring-necked Pheasant			
	1	25-75%	0.33	
	2	<40%	0.10	
	3	10-25%	0.40	
	4	<10%	0.10	
	5	<25%	0.10	
	6	50-60%	0.33	
	7	<23 cm	0.10	
	8	<5%	1.0	
	9	B	0.80	
	10	D	0.10	
	11	<0.40 km	1.0	
	12	>0.8 km	0.10	
	13	>0.8 km	0.10	0.38

source of winter food. Pheasants thrive in areas where grain crops such as corn, grassy areas for nesting, and dense escape cover are closely interspersed. Both nesting and escape cover were abundant on the site, but winter food was limiting.

The vegetation on the study area was not noticeably different from that on the first reference area. The bare area near the former kiln was the only noticeable impact that could be due to contamination, and it was too small (approximately 0.5 acre) to have a significant effect on the quality of the whole site.

HSI scores for the first reference area were similar to those for the study site. Habitat suitability for the meadowlark (HSI = 0.72) and kestrel (HSI = 0.82) were slightly lower due to the taller herbaceous layer.

The second reference area scored highly for both the meadowlark (HSI = 1.0) and kestrel (HSI = 1.0). The shorter grass that resulted from grazing provided more favorable conditions. Habitat suitability was lower for the pheasant (HSI = 0.38) because the short grass provided less cover.

Several wildlife species were observed on the grassland study area during the preliminary trip and during the sampling period. These included all three evaluation species plus the northern harrier, red-tailed hawk, rock dove, an unidentified swallow, loggerhead shrike, and house finch. The only mammal observed was the California ground squirrel. The individuals were seen on top of the pile of debris at the kiln site where they apparently inhabited burrows dug into the pile. Many other species known to use the grassland habitat were not observed during our brief visits, but they are listed in the natural-resource inventory by Jones and Stokes Associates (1984).

In addition to being moderate to high value for the evaluation species that typically inhabit grassland areas, the study site is also important as a refuge for marsh-dwelling wildlife during periods of exceptionally high tides. These species include the endangered salt marsh harvest mouse and rare California black rail, which are known to exist in the adjacent salt marsh, and the rare giant garter snake, which likely exists in the marsh.

3.5.2.2 Salt Marsh Area

The salt marsh study area was bounded on the north by Suisun Bay, on the east by the Allied Chemical property line, and on the south by the interface

with grassland vegetation. The western boundary was a line from the trestle on the Southern Pacific and AT&SF railroads due north to the naturally meandering creek, following the drainage generally east and north to be northeastermost bend of the creek, then along the line of the mosquito ditch to the shore of Suisun Bay (Figure 3-5). The total area was 121 acres.

3.5.2.2.1 Methods

The wildlife habitat evaluation for the salt marsh site focused on two species that of particular concern due to their endangered or rare status. These were the salt marsh harvest mouse and the California black rail, both of which are known to exist in the salt marsh adjacent to Allied Chemical Company property (Jones and Stokes Associates 1984, and observations during this study).

As with the grassland sites, the habitat evaluation on the salt marsh sites was performed with the aid of Habitat Suitability Index (HSI) models for the two evaluation species. There were no published models for the salt marsh harvest mouse or the California black rail; therefore, models were developed especially for this study according to standards published by the US Fish and Wildlife Service (1981). The HSI model for the salt marsh harvest mouse was based on habitat requirements described by Shellhammer (1982) and Shellhammer et al. (1984). The model for the California black rail was based on information in Evens and Page (1983). These models subsequently were tested and modified as described later.

3.5.2.2.1.1 Cover Map

A map of the vegetative cover in the salt marsh study area was developed to help identify study plots for the habitat evaluation and to simplify on-site sampling. However, the plant communities on this area were so complex--involving finely dissected, intergrading, and overlapping cover types due to variations in elevation, salinity, and frequency of disturbance--that it was not possible to develop a meaningful cover map for all community types in the entire marsh. Instead focus was placed on pickleweed (Salicornia virginica), a plant that is an important component of the habitat for salt marsh harvest mice and California black rails, and its distribution in the marsh was mapped

through a combination of computer-assisted evaluation of aerial photographs and site visits.

Transparencies of color infrared aerial photographs (scale 1:7200 taken 11 April 1985) were scanned by a Photomation System P-1700 (Optronics International, Inc.) through red, green, and blue filters, and again without any filter. The machine measured and recorded on computer tape the optical density of each 0.05 × 0.05 mm unit (pixel) of the photograph for each color. A computer was used to process the data and superimpose the four optical density measurements for each pixel. Using the locations and optical density values for several known patches of Salicornia, the computer then searched the entire marsh for pixels having the same color signatures. Results were produced as a shaded acetate overlay which, when superimposed on a base map of the marsh, showed the distribution of suspected Salicornia-containing plant communities. This computer-generated cover map was checked and modified during a visit to the site on 25-28 June 1985. Areas with Salicornia were located mainly on the periphery of the marsh, adjacent to the Allied Chemical property line and to the Southern Pacific and AT&SF railroad tracks (Figure 3-6).

3.5.2.2.1.2 Model Testing and Modification

Habitat suitability models for the salt marsh harvest mouse and California black rail were tested by applying the models on a series of study plots and comparing the resulting HSIs with subjective ratings of the same plots by experts on the habitat requirements of the two species. The test was performed between 25-28 June 1985 on 11 plots (Figure 3-5) whose boundaries were clearly marked on the ground with colored flagging. Jules Evens (Point Reyes Bird Observatory, Stinson Beach, CA), an expert on the California black rail, and Peter Sorensen (FWS, Endangered Species Office, Sacramento, CA), an expert on the salt marsh harvest mouse, were taken to each plot on 26 June and independently rated the sites on a scale from 0 (unsuitable) to 1.0 (optimal). The experts also provided written comments giving their reasons for the scores they gave to each plot.

From 26-28 June 1985, habitat variables potentially to be contained in the models were measured at sampling points located at 3-ft intervals along transects established at random within each study plot. HSI values calculated

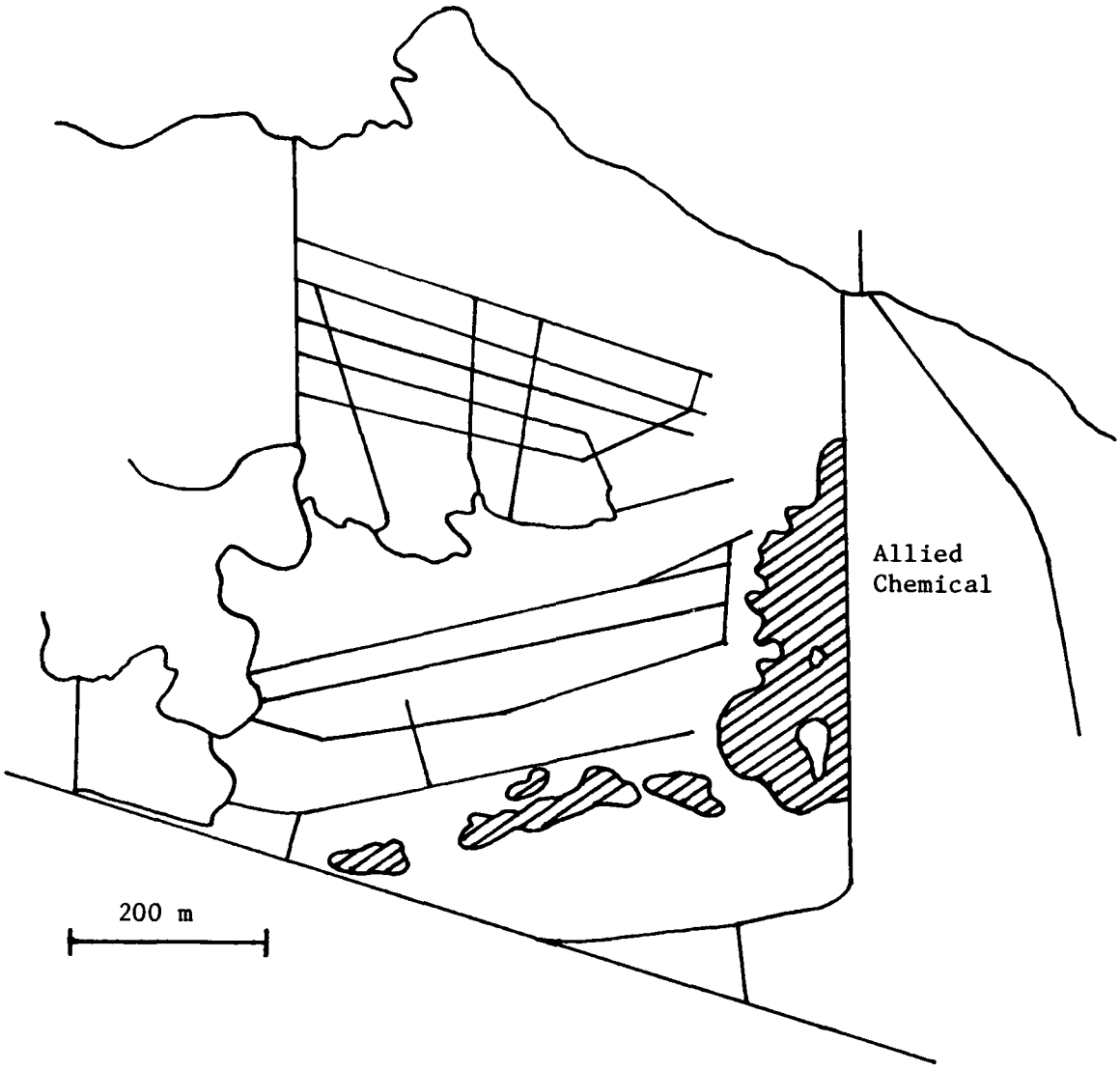

Figure 3-6. Approximate extent of Salicornia-containing plant communities in the salt marsh study area, NWS Concord

with the original models were then compared with the expert's ratings. Based on this comparison, statistical analysis, and further discussion with the experts, the models were modified until they reflected the habitat requirements of the two species more accurately. Final variables are listed in Table 3-21, and the complete models are included in Appendix 3-D.

3.5.2.2.2 Results

On the contaminated study area, habitat quality ratings by the species experts ranged from 0.10 to 0.50 for the salt marsh harvest mouse and from 0.05 to 0.70 for the California black rail (Table 3-22). On the same sites, the modified models predicted HSIs from 0.04 to 0.54 for the mouse and 0.16 to 0.73 for the rail. Therefore, habitat quality in different areas of the study marsh ranged from poor to moderate for the mouse and from poor to good for the rail. Over all plots, expert's ratings and HSI values were significantly correlated ($P < 0.01$; $r = 0.88$ for the salt marsh harvest mouse and $r = 0.91$ for the California black rail). Site 12 was not examined by the experts; however, the HSI models were applied there to provide a better indication of habitat conditions immediately adjacent to the Allied Chemical Company.

In general, salt marsh harvest mice require areas of dense and continuous cover within or immediately adjacent to areas subject to tidal inundation. They prefer high-marsh areas containing lush growth of pickleweed, but the lack of pickleweed can be offset by the presence of other plant species that provide suitable structure. Harvest mice avoid continuous stands of saltgrass (Distichlis spicata), bulrush (Scirpus sp.), or cattail (Typha sp.). A peripheral zone of dense cover at higher elevation is needed as a refuge during the highest tides.

Plots 4 and 5 in the study marsh received low ratings for salt marsh harvest mice because they were dominated by Distichlis and other grasses with little Salicornia or other suitable cover. These plots were at relatively high elevation and graded into upland vegetation. Plot 6 was located more centrally in the marsh outside the zone of Salicornia but was given an average rating because of its suitable structure and the plant diversity caused by the higher spoil piles along the bordering mosquito ditches. Plot 7 graded from a mixture of Salicornia and Scirpus at one end to almost continuous Distichlis at the other. Overall it received a below-average rating. The somewhat

Table 3-21

Variables in the HSI Models for the Salt Marsh Harvest Mouse and California Black Rail*

Salt Marsh Harvest Mouse	
Variable	
1	Percent plant cover
2	Average height of vegetation
3	Percent cover of *Salicornia*

California Black Rail	
Variable	
1	Percent cover of *Salicornia*
2	Average height of *Salicornia*
3	Soil moisture

* Complete models are in Appendix 3-D.

higher rating given to plot 8, located immediately adjacent to the dike along the Allied Chemical property line, was due mainly to its more continuous cover of *Salicornia*. However, the structure of the *Salicornia* was only average for harvest mice; the stand was short, sparse, and contained much dead material, perhaps due to high levels of chemical contamination. Its lack of vigor was further reflected by the presence of large amounts of dodder (*Cuscuta salina*), a plant parasite. The predicted HSI for plot 12 indicated average suitability for harvest mice due mainly to its moderate vegetation coverage and depth.

California black rails are more closely tied to tidal conditions and to *Salicornia* than are the mice. They prefer thick, lush growth of *Salicornia* that is relatively open underneath, allowing this 6-in. bird to move about freely. They are more common in areas where occasional tidal inundation or poor drainage result in damp soils and an abundance of invertebrates for food. Like the salt marsh harvest mouse, the black rail must have adequate escape cover peripheral to the marsh where it can find refuge from predators during the highest tides.

Table 3-22

Results of Habitat Evaluations of Salt Marsh Area, NWS Concord, for the Salt Marsh Harvest Mouse and California Black Rail

Plot Number	Experts' Scores		HSI Models	
	SMHM*	CBR**	SMHM	CBR
		Study Area		
4	0.10	--	0.04	--
5	0.20	0.05	0.09	0.16
6	0.40	0.30	0.40	0.15
7	0.30	0.50	0.28	0.48
8	0.50	0.70	0.54	0.73
12	--	--	0.50	0.64
		Reference Areas		
1	0.80	0.40	0.46	0.36
2	0.80	0.70	0.59	0.82
3	0.10	0.10	0.17	0.36
9	0.70	--	0.46	--
10	0.80	--	0.43	--
11	0.80	0.90	0.51	0.89

* Expert on the salt marsh harvest mouse was Peter Sorensen, FWS, Endangered Species Office, Sacramento, CA.

** Expert on the California black rail was Jules Evens, Point Reyes Bird Observatory, Stinson Beach, CA.

Plots 4, 9, and 10 had upland plant cover inappropriate for black rails; these sites were deleted from consideration in model testing. Plot 5 in the contaminated marsh adjacent to Allied Chemical was rated very poor for rails because of its dry soil, mainly grass cover, and very sparse Salicornia. Plot 6 received a slightly higher rating because of its damp soil and lush vegetation, but it lacked a significant component of Salicornia. Plot 7 contained good Salicornia cover at one end but was downgraded somewhat because of the abundance of Distichlis and the presence of bare areas. Plot 8 contained nearly continuous coverage of Salicornia but was downgraded due to its lack of vigor. Plot 12's above-average HSI score for black rails was due to its moderate coverage of Salicornia and good soil moisture.

3.5.3 Summary and Conclusions

More than 100 species of birds, mammals, reptiles, and amphibians are known to occupy the salt marsh, grassland, and freshwater marsh habitats of NWS Concord and, therefore, could potentially be exposed to hazardous material contamination. These include two Federally listed endangered species (salt marsh harvest mouse and California least tern) and one State-listed rare species (California black rail) that are known to exist on or immediately adjacent to the contaminated area. Five additional sensitive species (giant garter snake, bald eagle, California clapper rail, Suisun shrew, and salt marsh yellowthroat) are known to be present occasionally or are potential visitors to the NWS Concord.

An evaluation of the grassland portion of the contaminated study area--based on the western meadowlark, ring-necked pheasant, and American kestrel as evaluation species--indicated that the area is of moderate to high quality as habitat for wildlife. The physical structure of the vegetation did not differ appreciably from that of two nearby reference sites. With the exception of a 0.5-acre unvegetated area, there were no noticeable impacts of chemical contamination on the structure and distribution of vegetation on the grassland portion of the study site.

Habitat evaluation of the salt marsh study area focused on two rare or endangered wildlife species--the salt marsh harvest mouse and the California black rail. The evaluation was performed through a combination of HSI modeling and subjective ratings by experts on the habitat requirements of the

two species. Habitat quality on study plots in the contaminated marsh ranged from poor to moderate for the salt marsh harvest mouse and from poor to good for the California black rail.

Wildlife habitat evaluations were based primarily on the species composition and structure of the plant communities present in the contaminated area. They did not take into account the possible deleterious effects of heavy metals on reproduction, survival, and general well-being of the animals exposed to the site (see Section 4.4 on toxicological evaluation). The habitat evaluation indicated that the grassland portion of the study area and certain locations within the study marsh are of high value as wildlife habitat, particularly for rare and endangered species, and will continue to attract and expose wildlife species to heavy-metal contamination.

3.5.4 References

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3.5.5 Appendix 3-A. Species of Birds, Mammals, Reptiles, and Amphibians Present on NWS Concord.

Source: Jones and Stokes Associates (1984).

Table 3-A1

Bird Use of NWS Concord Habitat Types as Observed During 1982 Wildlife Surveys

SPECIES[1]	Salt marsh	Freshwater marsh	Grassland	Pond	Riparian habitat	Orchard and homestead	Oak woodland	Eucalyptus grove	Quarry
Eared grebe	RW[2]								
Western grebe	RW								
Pied-billed grebe	RW			RW					
Double-crested cormorant	RW								
Great blue heron	CP								
Great egret	CP								
Snowy egret	CP								
Black-crowned night-heron	I								
American bittern	CP	CP							
Mallard	CP	CP		CP					
American wigeon	CP								
Northern pintail	RW								
Green-winged teal	RW								
Cinnamon teal	CP								
Canvasback	RW								
Greater scaup	RW								
Common goldeneye	RW								
Bufflehead	RW								
Turkey vulture	RW		RW						
Black-shouldered kite	CP	RW	RW			CP		CP	
Sharp-shinned hawk						RW			
Cooper's hawk					RW	I			
Red-tailed hawk	RW		RW	CP	RW	RW	CP	CP	
Red-shouldered hawk			RW		I				
Golden eagle			I	RW			RW		
Bald eagle			I-T						
Northern harrier	CP	CP	CP			CP	I		
Prairie falcon			RW						
Merlin						RW			
American kestrel	CP		CP	CP	CP	CP	CP	CP	
California quail					CP		CP		CP
Ring-necked pheasant	CP		I	CP	CP	CP			
Virginia rail	CP	CP							
Sora	CP	CP							
California black rail	I								
American coot	CP			RW					
Killdeer	CP		I	CP					
Common snipe	RW		I						
Whimbrel	I								
Spotted sandpiper	RW								
Willet	RW	CP							
Greater yellowlegs	RW								
Long-billed dowitcher	RW								
Western sandpiper	RW								
American avocet	RW								
Black-necked stilt	RW								
Glaucous-winged gull	I								
Western gull	I								
Herring gull	I								
California gull	I								
Ring-billed gull	I								
Forster's tern	I								
Caspian tern	I								
Least tern	I								
Band-tailed pigeon					CP	I			
Rock dove					CP				
Mourning dove			I	CP	CP	CP	CP	CP	CP
Common barn-owl			I		I				
Western screech-owl					CP			I	
Great horned owl			I				I		
Burrowing owl			RW						
Short-eared owl	I		RW						
White-throated swift						I-T			
Anna's hummingbird	CP			CP	CP	CP	CP	CP	
Allen's hummingbird								CP	
Belted kingfisher	I								

Table 3-A1 (continued)

SPECIES[1]	Salt marsh	Freshwater marsh	Grassland	Pond	Riparian habitat	Orchard and homestead	Oak woodland	Eucalyptus grove	Quarry
Northern flicker	CP			CP	CP	CP	CP	CP	
Hairy woodpecker						CP			
Downy woodpecker					I	RW			
Nuttall's woodpecker				CP		CP	CP		
Western kingbird			I	CP	CP	CP	CP	CP	
Ash-throated flycatcher						I	I		
Black phoebe	CP			CP	CP	CP			
Say's phoebe			CP						
Violet-green swallow	I-T				I-T				
Tree swallow	I-T								
Northern rough-winged swallow	I-T								
Barn swallow	CP	CP			CP	CP			
Cliff swallow	CP	CP	CP	CP	CP	CP	CP		
Scrub jay			I	CP	CP	CP	CP	CP	CP
Common raven			I						
American crow			I						
Plain titmouse							CP		
Bushtit					CP	CP	CP		
Marsh wren	CP	CP							
Northern mockingbird				CP	CP	CP	CP	CP	CP
Sage thrasher			I						
American robin				CP	CP	CP	CP		
Varied thrush							CP		
Hermit thrush					I	CP	CP		
Western bluebird			CP				CP		
Ruby-crowned kinglet	CP				CP	CP	CP	CP	CP
Water pipit	I								
Cedar waxwing								CP	
Loggerhead shrike	CP		CP		CP	CP	CP	CP	CP
European starling			CP	CP	I	I	CP	CP	
Orange-crowned warbler							CP	CP	
Yellow-rumped warbler	CP		CP	CP	CP	CP	CP	CP	
Wilson's warbler					CP				
Common yellowthroat	CP	CP							
House sparrow					I	CP			
Western meadowlark	CP		CP	CP	CP	CP	CP	CP	CP
Red-winged blackbird	CP	CP	CP	CP	CP	I	CP	CP	
Hooded oriole							CP		
Northern oriole			I		CP	CP	CP	CP	
Brewer's blackbird		I	I	CP	CP				
Brown-headed cowbird			I					CP	
Western tanager					CP		CP	CP	
Purple finch			CP						
House finch	CP		CP	CP	CP	CP	CP	CP	
American goldfinch			I		I				
Lesser goldfinch			CP						
Brown towhee				CP	CP		CP		CP
Savannah sparrow	CP		CP	CP					
Vesper sparrow			CP	CP					
Lark sparrow			I		CP				
Dark-eyed junco			I	CP	CP	CP		CP	CP
White-crowned sparrow	CP	CP	I		CP	CP			CP
Golden-crowned sparrow	CP		I		CP			CP	CP
Suisun song sparrow	CP	CP							
TOTAL NUMBER OF SPECIES OBSERVED IN EACH HABITAT TYPE	69	15	43	28	42	37	33	25	12

[1] See Appendix 5 for scientific names of bird species.

[a] Codes for types of observations:
CP = bird census plot
RW = raptor and waterbird survey
I = incidental (including spotlight surveys)
I-T = incidental observation of transient bird over indicated habitat type; association with particular habitat is uncertain.

Table 3-A2

Mammal Use of NWS Concord Habitat Types as Observed During 1982 Wildlife Surveys

SPECIES[1]	HABITAT TYPES: Salt marsh	Freshwater marsh	Riparian habitat	Oak woodland	Orchard and homestead	Eucalyptus grove	Quarry	Grassland	Pond
Virginia opposum			SS[2]				SS		
Ornate shrew*	SMT								
Black-tailed jackrabbit*	I	I			I		I	SL	
California ground squirrel*								I	
Botta's pocket gopher*									I
Beaver	I								
Western harvest mouse	SMT				SMT	SMT		SMT	
Salt marsh harvest mouse*	SMT								
Deer mouse	SMT		SMT	SMT	PT	SMT		SMT	SMT
California vole*	SMT	SMT	SMT		SMT	SMT		PT	SMT
Muskrat*	I								
House mouse	SMT		SMT	SMT	SMT		SMT		SMT
Coyote	SS		SS	I				I	SS
Gray fox*	SS		SS		SS		SS	SL	SS
Raccoon	SS		SS		SS	SS	SS		SS
Striped skunk*	SS		SS				SS	SS	SS
Tule elk			I		I	I		I	I
Columbian black-tailed deer			I						SS

[1] Species are listed in phylogenetic order; scientific names are provided in Appendix 3.

[2] Codes for types of observations: SMT = small mammal trapping
PT = pitfall traps
SS = scent stations
SL = spotlight surveys
I = incidental observations

* Species previously reported at CNWS by Public Works Department, Engineering Division (1976).

Table 3-A4

Occurrence of Amphibian and Reptile Species in Habitat Types at NWS Concord

SPECIES[1]	HABITAT TYPES: Marshland, slough	Perennial pond (Cistern pond)	Seasonal pond	Riparian habitat	Oak woodland	Orchard	Eucalyptus grove	Oak savanna with rock outcrops	Quarry	Grassland
Salamanders										
California tiger salamander*		S[2]	S	P	P	U	U	S		P
Coast range newt		I	U	P						
Northern rough-skinned newt		P		U						
Ensatina				U	P	U	U			
California slender salamander				U	U	P	P	P		
Arboreal salamander				P	U	P	P			
Frogs and Toads										
Western spadefoot		P	P	P	P			U	U	P
California toad		S	S	S	P	P	P	P		U
Pacific treefrog		S	S	S						
Red-legged frog[3]		S**	U	U						
Bullfrog		S	U	S						
Turtles										
Western pond turtle*	S	P								
Lizards										
Northwestern fence lizard				I	S	I	S	S	S	S
Northern sagebrush lizard*								U	U	
California side-blotched lizard				P	I	P	U	I	I	I
California horned lizard					P			P	I	P
Western skink				P	U	P	P	P	U	P
Western whiptail									S	I
Alligator lizard		P			I	P	S		S	
California legless lizard*				P	P				U	
Snakes										
Pacific ringneck snake				P	P	U	U			
Sharp-tailed snake				I	P	P	U	U		U
Western yellow-bellied racer		S	U	I	P	P	P	I	P	I
San Joaquin coachwhip					P	P	P	I	I	P
Alameda striped racer*		U		U	U	U	U	U		
Pacific gopher snake	S	U	U	I	I	P	I	S	I	I
California kingsnake	I	I	U	I	I	P	P	I	I	P
Valley garter snake	I	S	I	I	P	P	P	P	P	P
Coast garter snake	P	I	P	I	P	P	P	P	P	P
Giant garter snake*	I	P								
Northern Pacific rattlesnake	P	P	U	I	I	P	P	I	S	I

[1] Scientific names of all species are given in Table 4-12.
* This species was a sensitive species for the present study; see discussion later in this chapter.
[2] Occurrence code: S = sighted during field surveys at CNWS
I = likely in indicated habitats
P = possible in indicated habitats
U = unlikely, although possible, in indicated habitats.
**Tadpoles of the red-legged frog introduced into the Cistern Pond in May 1982.

3.5.6 Appendix 3-B. Scientific Names of Animal Species Mentioned in Text

Common Name	Scientific Name
American Avocet	*Recurvirostra americana*
American Bittern	*Botaurus lentiginosus*
American Kestrel	*Falco sparverius*
Bald Eagle	*Haliaeetus leucocephalus*
Black-Shouldered Kite	*Elanus caeruleus*
California Black Rail	*Laterallus jamaicensis coturniculus*
California Clapper Rail	*Rallus longirostris obsoletus*
California Ground Squirrel	*Spermophilus beecheyi*
California Least Tern	*Sterna antillarum browni*
California Vole	*Microtus californicus*
Canvasback	*Aythya valisineria*
Cinnamon Teal	*Anas cyanoptera*
Common Merganser	*Mergus merganser*
Coturnix Quail (Japanese Quail)	*Coturnix japonica*
Deer Mouse	*Peromyscus maniculatus*
Eastern Meadowlark	*Sturnella magna*
European Starling	*Sturnus vulgaris*
Giant Garter Snake	*Thamnophis couchii gigas*
Gray Fox	*Urocyon cinereoargenteus*
Great Blue Heron	*Ardea herodias*
Greater Yellowlegs	*Tringa melanoleuca*
House Finch	*Carpodacus mexicanus*
Loggerhead Shrike	*Lanius ludovicianus*
Mallard	*Anas platyrhynchos*
Marsh Wren	*Cistothorus palustris*
Meadow Vole	*Microtus pennsylvanicus*
Mourning Dove	*Zenaida macroura*
Northern Harrier	*Circus cyaneus*
Ornate Shrew	*Sorex ornatus*
Pacific Gopher Snake	*Pituophis melanoleucus catenifer*
Raccoon	*Procyon lotor*

Common Name	Scientific Name
Red-Breasted Merganser	Mergus serrator
Red-Tailed Hawk	Buteo jamaicensis
Red-Winged Blackbird	Agelaius phoeniceus
Ring-Necked Pheasant	Phasianus colchicus
Rock Dove	Columba livia
Salt Marsh Harvest Mouse	Reithrodontomys raviventris
Salt Marsh Yellowthroat	Geothlypis trichas sinuosa
Snowy Egret	Egretta thula
Sora Rail	Porzana carolina
Suisun Shrew	Sorex sinuosus
Suisun Song Sparrow	Melospiza melodia maxillaris
Virginia Rail	Rallus limicola
Western Harvest Mouse	Reithrodontomys megalotis
Western Meadowlark	Sturnella neglecta
Western Sandpiper	Calidris mauri
Wood Duck	Aix sponsa

3.5.7 Appendix 3-C. Habitat Suitability Index (HSI) Models for Three Grassland Evaluation Species: American Kestrel, Western Meadowlark and Ring-necked Pheasant.

Sources of these models were US Fish and Wildlife Service (1980), Schroeder and Sousa (1982), and Urich et al. (1983), respectively. See text for details.

AMERICAN KESTREL

Species Narrative

General. The American kestrel (Falco sparverius) is a small raptor of open and semi-open country. The kestrel is a year-round resident in Indiana and a fairly common to uncommon summer resident (Keller et al. 1979).

Food Requirements. American kestrels generally hunt over open fields, consuming a large variety of insects, birds, small mammals, and some reptiles (Heintzelman 1964). Large insects, such as grasshoppers (Orthoptera), are taken in abundance during the summer months (McAtee 1935; Mech 1961; Smith et al. 1972). A study of nestling food habitats in Utah indicated that insects accounted for 80% of the prey individuals, but vertebrate prey accounted for over 96% of the prey biomass (Smith et al. 1972). Vertebrate prey becomes more important in fall and winter when insect populations decline (Breckenridge and Errington 1938; Craighead and Craighead 1956; Mech 1961).

Kestrels hunt from exposed perches such as trees, fence posts, or utility poles and lines, by hovering at 15 to 23 m (50 to 75 ft) above the ground, or by intercepting insects in flight (Roest 1957; Balgooyen 1976). Hunting perches averaged 6.8 m (22.3 ft) in height in California (Balgooyen 1976). Hunting habitat is characterized by low, open vegetation. Kestrels sometimes store excess food in grass clumps and trees for later use (Tordoff 1955).

Water Requirements. The kestrel can survive solely on the water contained in its food (Mueller 1973).

Cover Requirements. Kestrels are most commonly associated with open agricultural land and the ecotone between forest and grassland types (Bent 1938; Brown and Amadon 1968; Balgooyen 1976). Open areas provided foraging habitat while treelands satisfy nesting needs. Areas with greater than 11% tree or scrub cover hindered hunting activities in Illinois (Enderson 1960).

Male kestrels are more common in wooded, agricultural habitats during winter, while females choose more open, sparsely vegetated areas (Koplin 1973; Mills 1976).

Reproductive Requirements. Kestrels are secondary tree cavity nesters although nests may also be located in earthbanks, cliffs, buildings (Bent 1938; Roest 1957; Balgooyen 1976), and even in shallow scrapes on the ground (Richards 1970). Kestrels are dependent on cavities excavated by other

species, especially those of the common flicker (Colaptes auratus) (Balgooyen 1976).

Preferred nest sites in Oregon were 3.0 to 10.7 m (10 to 35 ft) above the ground (Roest 1957). Average nest height in California was 7.9 m (26 ft) above ground, ranging from 2.0 to 24.4 m (6.5 to 80 ft) (Balgooyen 1976). Minimum diameter of nesting trees in the Blue Mountains of Washington and Oregon is 30.5 cm (12 in) (Thomas et al. 1979). Kestrels return to the same nest areas in consecutive years, thus a reduction in suitable nest sites may limit populations (Craighead and Craighead 1956). A lack of nest sites is a limiting factor in kestrel reproduction (Hamerstorm et al. 1973). Kestrels will use nest boxes where suitable nest sites are lacking, and use of nest boxes can be an effective management tool. Nest boxes placed on old buildings were particularly attractive to kestrels.

Interspersion Requirements. Edge habitats between woodland and open land provide the necessary requirements for kestrels (Balgooyen 1976). Burned forest land in California was the most suitable kestrel habitat because it provided perches, food, nest sites and sparse woody vegetation. Home range size in Illinois was 2.2 to 2.4 km (1.4 go 1.5 mi) in diameter (Enderson 1960). Feeding territories may be limited to a prominent perch and a surrounding area with a radius of 0.2 km (0.125 mi) or less (Craighead and Craighead 1956). The average territory size in California was 109.4 hs (270 ac) (Balgooyen 1976), compared to the 129.6 ha (320 ac) size reported in Michigan by Craighead and Craighead (1956).

Special Considerations. Ingestion of prey contaminated with chlorinated hydrocarbon pesticides causes shell thinning and subsequent breakage of kestrel eggs (Lincer 1973).

Much of the kestrel's diet consists of insects and rodents that are generally considered harmful to man's agricultural interests (Fisher 1974). It is unlikely that kestrel needs would conflict with man's activities. Practices such as extensive cutting or flooding which reduce available nest sites, may reduce kestrel populations. Burned areas provided suitable short-term kestrel habitat. Depending on forest succession rates, such areas may remain suitable for 10 to 40 years following the burn (Balgooyen 1976).

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Habitat Suitability Index (HSI) Model for the American Kestrel

General Information

Species Information

Species:	American Kestrel (Falco sparverius)
Habitat Use Pattern:	Multi-cover type user
Status:	Resident
Cover Types:	Deciduous Forested Wetland (DFW), Deciduous Forest (DF), Cropland (C) Forbland (F)
Ecoregion:	2511
Model Type:	Uncalibrated Index Model. Earlier drafts of this model were critiqued by a kestrel expert. Specific review comments have been incorporated into this current draft.

Threshold Range Size. The amount of suitable habitat required to support a viable population of kestrels is not reported in the literature. It is estimated to be greater in size than the minimal home range size. If a suitable area is not large enough to support several pair of kestrels the HSI will equal 0.0.

Home Range Data. The minimum home range size (Hmin) needed to support a pair of American kestrels is estimated to be 0.4 km (0.25 mi) in diameter. Range size can be expanded to a maximum (Hmax) of 2.4 km (1.4 mi) in diameter.

Habitat Composition. Habitat composition information for species that are multi-cover type users is most useful when presented in terms of life requisite needs. Optimal life requisite composition may be determined by considering the composition of the habitat in terms of cover types and by considering what life requisites are provided by each cover type. Optimal life requisite composition for the kestrel is not reported in the literature. An estimation of the optimal percentages for the total area that provides life requisite support within the home range and the rational for each estimate is presented below.

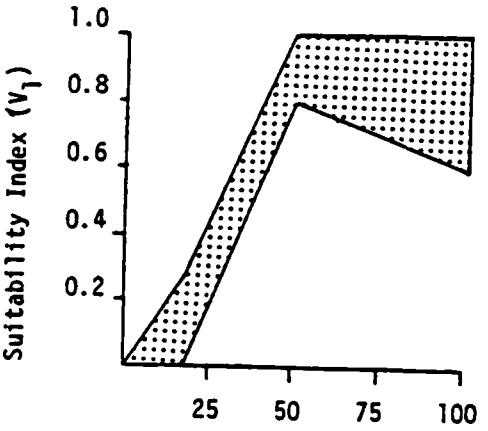
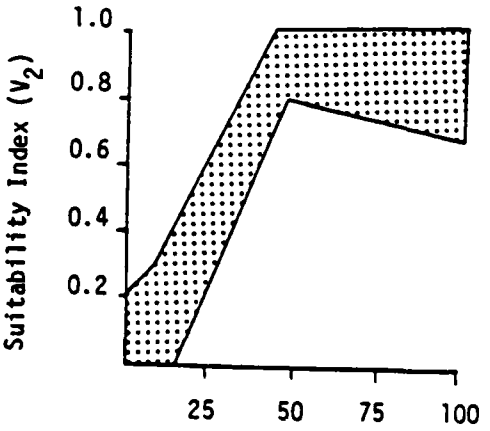
Life Requisite	Optimal Percentage Estimate
Food	60-80%
Reproduction	10-30%

Nest site availability can be limiting to kestrels, however nesting activities are usually concentrated toward a specific woodlot, nest tree, nest box, cliff, or old building. For this reason a low percent estimate for

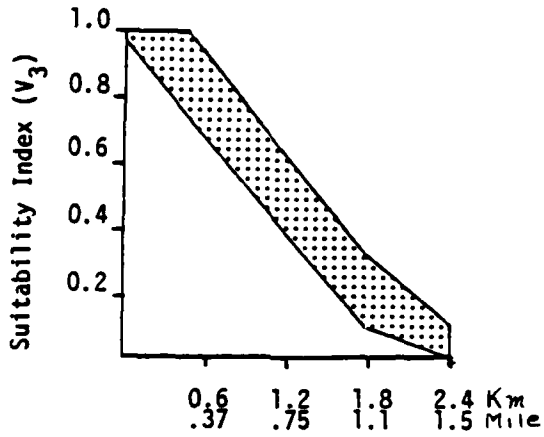
reproduction seems appropriate. Kestrels will hunt in several localities within their home range and thus a larger percent estimate for food is given.

Evaluation Criteria (by cover types)

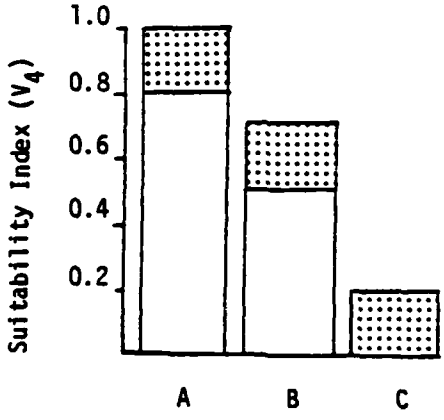
Food Value. Food value is related to the abundance and availability of suitable prey species inhabiting open terrain and the availability of suitable perch sites. It is assumed that if sufficient and suitable herbaceous cover is available within the home range of the kestrel then prey species will also be available.

Cover Type	Variable	Suitability Index Curve
F,	[V_1] % herbaceous canopy cover	
F,	[V_2] % herbaceous canopy ≤ 30 cm (12 in) tall.	

C.F, [V_3] Distance to nearest trees, forest edge, fence post or utility poles and lines.



C [V_4] Availability of fence rows, roadside ditches, and grassy-uncultivated areas.
A) Abundant
B) Moderate
C) Scarce - none



Food Value in forbland is a function of V_1, V_2, and V_3. All three variables are considered to be interactive. Compensations exist among the variables, except when any variable is equal to zero, in which case the entire life requisite value will also equal zero. The suggested function is:

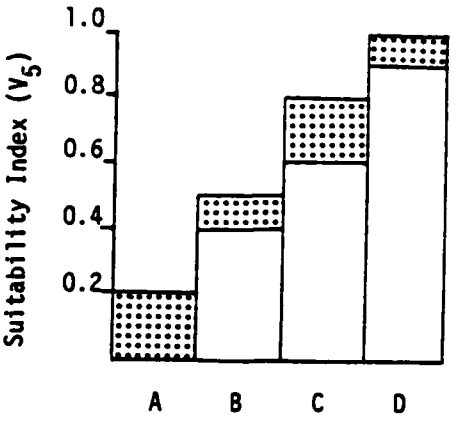
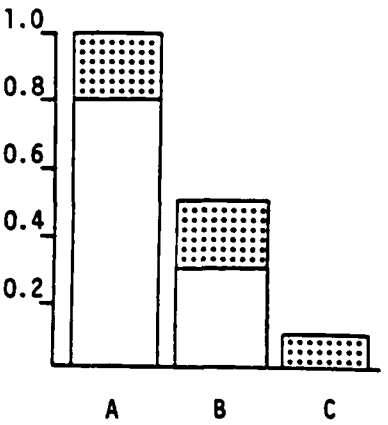
$$(V_1 \times V_2 \times V_3)^{1/3}$$

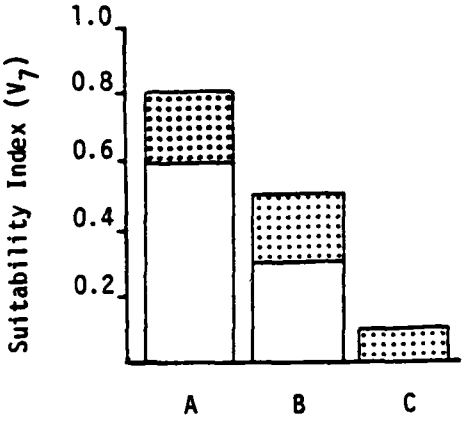
Food Value in cropland is a function of V_3 and V_4. Although cropland provides some food value it is not considered to have the potential to provide optimal food. For this reason the following function will prevent food value from exceeding a value of 0.5. V_3 and V_4 are interactive and compensations exist between them. The life requisite value will only equal zero if both variables are equal to zero.

$$0.5 \times \frac{V_3 + V_4}{2}$$

Water Value. Although kestrels regularly bathe in water, there is no information in the literature to suggest that water availability may be limiting to the American kestrel.

Reproductive Value. Reproductive value is related to certain woodland characteristics and/or the availability of suitable nesting sites.

Cover Type	Variable		Suitability Index Curve
DF, DFW	[V_5]	Overstory forest size class. A) Saplings (< 15 cm (6 in) dbh). B) Pole timber (> 15 cm (6 in) to 25 cm (10 in) dbh). C) Sawtimber (> 25 cm (10 in) to 50 cm (20 in) dbh). D) Mature trees (≥ 50 cm (20 in) dbh).	
F,C	[V_6]	Availability of large lone trees (≥ 30(12 in) dbh) or groves (≤ 0.4 ha (1 ac) in size) containing large trees within a diameter of 1.6 km (1 mi). A) Abundant (≥ 10 trees) B) Moderate (4 to 9 trees) C) Few to none (0 to 3 trees)	

F,C	[V_7]	Availability of cliff ledges, earth banks, or old abandoned buildings within 1.6 km (1.0 mi). A) Abundant B) Moderate to few C) Scarce to none	

Reproductive Value in deciduous forest, evergreen forest, and deciduous forested wetland is a function of V_5. It is assumed that if mature or sawtimber trees are prevalent that an adequate amount of suitable nesting cavities will naturally occur. Since only one variable can adequately assess the nesting suitability in a forest the reproductive value will equal to value of V_5.

Reproductive Value in forbland and cropland is a function of V_6 and V_7. V_6 and V_7 are not interactive. Either variable has the potential to independently provide optimal life requisite value.

$$V_6 + V_7$$

If the value of this function exceeds 1.0, the life requisite will equal 1.0.

Determination of the Habitat Suitability Index. The following is an abbreviated step by step discussion of HSI determination for multi-cover type species. More detailed information describing this process and an example application are included in this Handbook in the chapter entitle "Description of Species Narratives and HSI Models."

Step 1 - Determine Suitability Indices for each variable based on field data.

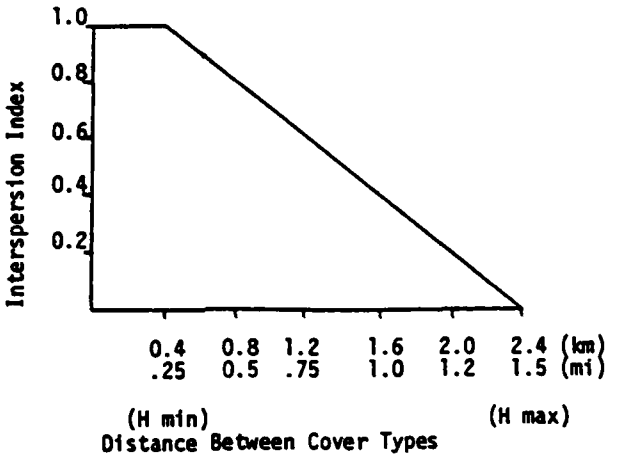
Step 2 - Compute Life Requisite Values for the indicated cover types using the suggested functions provided in the model.

Step 3 - Determine if all life requisites can be provided considering all cover types within the study area. If any life requisites are missing, the HSI will equal zero and no further evaluation is necessary.

Step 4 - Using the life requisite values computed in Step 2, the next step is to determine the spatial relationship of cover types providing various life requisites. Life requisite values may need to be adjusted to varying degrees depending on the distances separating them and how the distances compare with the species minimum and maximum home ranges. This step is accomplished as follows:

a) Determine the mean distance (measured from randomly selected points) from each cover type missing a life requisite to the edge of the next nearest cover type that provides the missing life requisite(s).

b) Incorporate the mean distance measurements from Step 4a into the x-axis of the home range-interspersion graph presented below. Determine where the mean distance measurement intercepts the graph and obtain the interspersion index by reading the corresponding value from the y-axis.



c) Multiply the interspersion index for each cover type determined in Step½4b by the life requisite value determined in Step 2. The products are the modified life requisite values.

Step 5 - Determine the relative abundance (in percent) of cover types used by the species within the study area, as follows:

$$\text{Relative Area for Cover Type A} = \frac{\text{Area of Cover Type A}}{\text{Total Area of all Cover Types used by the Species}} \times 100$$

Be certain that you consider only those cover types used by the species in determining relative area of cover types.

Step 6 - Determine the percent life requisite support provided by the available habitat as follows:

a) For each life requisite within each cover type, multiply the modified life requisite value(s) (Step 4c) by the relative area of that cover type (Step 5). The products equal the percent life requisite support provided by each cover type.

b) Sum the products from Step 6a for each life requisite. The total equals the percent life requisite support provided by the available habitat.

Step 7 - For each life requisite, divide the percent life requisite support (Step 6b) by the optimal percent life requisite estimate provided in the General Information section of the HSI Model (use the lower percentage where a range of percents are given as estimates for optimal life requisite percent). This yields the overall life requisite values for the entire study area.

Step 8 - The Habitat Suitability Index (HSI) is the lowest of the overall life requisite values.

Model Assumptions and Limitations. It is assumed in this model that adequacy of the prey base may be estimated by measuring structural habitat characteristics related to prey base. It is also assumed that cover requirements are satisfied by reproductive requirements. This model was constructed based upon habitat data for various regions of the United States. It is assumed this "general information" will be applicable in northwest Indiana.

The major limitation in this model is that optimal life requisite composition values and distances used in the interspersion graph are at best, estimates derived from both literature and expert opinion sources. The estimates presented may not be valid in every situation.

HABITAT SUITABILITY INDEX MODELS: EASTERN MEADOWLARK

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EASTERN MEADOWLARK (Sturnella magna)

HABITAT USE INFORMATION

General

The eastern meadowlark (Sturnella magna) is an omnivorous ground feeder (Willson 1974) that nests in open fields throughout the eastern and south-central United States (Robbins et al. 1966).

Food

Approximately 74% of the annual diet consists of animal matter and includes mainly beetles, grasshoppers, caterpillars, and occasionally flies, wasps, and spiders (Beal 1926, cited by Gross 1958). Crickets and grasshoppers comprise 26% of the annual diet, and beetles make up 25% of the annual diet. The remainder of the diet consists of vegetable matter, mainly grain and weed seeds. Seeds of smartweed (Polygonum spp.), ragweed (Ambrosia spp.), corn, wheat, rye, and oats are eaten in the winter months when insects are scarce (Gross 1958). Fruits, such as wild cherries (Prunus spp.), strawberries (Fragaria spp.), and blackberries (Rubus spp.), may also constitute a small percentage of the diet. During adverse winter weather, eastern meadowlarks have been observed to feed on road kills (Hubbard and Hubbard 1969).

Water

No data on drinking water requirements for the eastern meadowlark were located in the literature, although captive eastern meadowlarks do bathe in and drink free water (Gross 1958).

Cover

The eastern meadowlark is primarily found in grasslands, meadows, and pastures (Gross 1958). Meadowlarks inhabited old field successional stages in Georgia from 1 (grass-forb) to 15 years (grass-shrub) after the fields were no longer farmed (Johnston and Odum 1956). This species inhabited fields where

shrub coverage was less than 35%, regardless of grass cover in the area. Feeding and loafing cover areas in Missouri that had high use were characterized as grasslands with no forbs or scattered forbs present, while areas where forbs were dominant had little use (Skinner 1975). Maximum use was observed in grazed grasslands between 10 and 30 cm tall (4 and 12 inches), with scattered forbs present.

Reproduction

The preferred nesting habitat of the eastern meadowlark in Illinois was pasture, followed in descending order by hayfields, soilbank fields, winter wheat fields, idle areas, and fallow areas (Roseberry and Klimstra 1970). The density of nesting meadowlarks in pasters was inversely related to the intensity of grazing. Highest nesting densities occurred during the 2 years when pasters were not grazed, and numerous dead grass stems and vigorous stands of grass (fescue) were present. Nesting densities in haylands were highest in a mixed-grass hayfield. Use of alfalfa fields, wheat fields, and fallow areas for nesting was low because these areas lacked sufficient grassy cover to provide suitable nesting habitat. Idle areas were little used when shrubs and trees became abundant. The average height of nesting cover was 28 cm (15 inches), with the majority of nests located in cover 25 to 50 cm (10 to 20 inches) high. The presence of dead grass stems at ground level and the absence of woody vegetation or numerous shrubs in the immediate vicinity of the nest site seemed necessary for nesting.

Nests of the eastern meadowlark are built in shallow depressions and have a dome-shaped roof constructed of grass, frequently interwoven with clumps of grasses or weeds (Gross 1958). Elevated singing and lookout perches, such as telephone wires, electric power lines, mounds of earth, farm implements, or fence posts, are used by males.

Interspersion

Meadowlark territories in Wisconsin varied in size from 1.2 to 6.1 ha (3 to 15 acres) and were commonly 2.8 to 3.2 ha (7 to 8 acres) (Lanyon 1956). The average size of 15 territories in New York was 2.8 ha (7 acres) (Gross 1958).

Special Considerations

Domestic cats and dogs prey on the eggs and young of the eastern meadowlark, and close proximity of nesting sites to human habitations is undesirable (Lanyon 1957). Mowing and heavy grazing by livestock may destroy meadowlark nests (Roseberry and Klimstra 1970).

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This model was developed for application within the breeding range of the eastern meadowlark.

Season. This model was developed to evaluate the breeding season habitat of the eastern meadowlark.

Cover types. This model was developed to evaluate habitat quality in the following cover types: Pasture and Hayland (P/H); Grassland (G); and Forbland (F) (terminology follows that of U.S. Fish and Wildlife Service 1981).

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous habitat that is required before a species will occupy an area. Specific information on minimum areas required for eastern meadowlarks was not found in the literature. Based on home range data, it is assumed that a minimum of 1.2 ha (3.0 acres) of habitat must exist or the HSI will equal zero.

Verification level. Previous drafts of this model were reviewed by Fred Alsop, and his specific comments were incorporated into the current draft (Alsop, pers. comm.).

Model Description

Overview. This model considers the feeding and reproductive needs of the eastern meadowlark to determine overall habitat quality and assumes that these

two life requisites can be combined to assess habitat. It is assumed that cover needs are met by the feeding and reproductive habitat needs and that water will not be a limiting factor. All of the life requirements of the eastern meadowlark can be provided within each cover type in which it occurs.

The relationship between habitat variables, life requisites, cover types, and the HSI for the eastern meadowlark is illustrated in Figure 1.

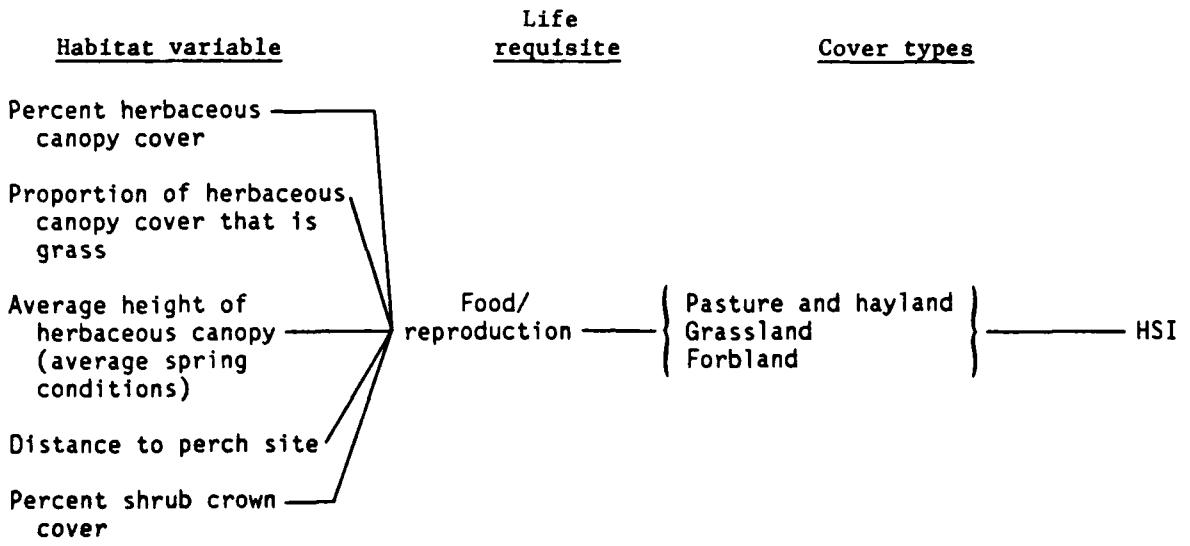


Figure 1. Relationships of habitat variables, life requisites, and cover types in the eastern meadowlark model.

The following sections provide a written documentation of the logic and assumptions used to interpret the habitat information for the eastern meadowlark in order to explain and justify the variables and equations that are used in the HSI model. Specifically, these sections cover the following: (1) identification of variables that will be used in the model; (2) definition and justification of the suitability levels of each variable; and (3) description of the assumed relationship between variables.

Food/reproduction component. Feeding and reproductive habitat suitability for the eastern meadowlark is related to the height and density of herbaceous vegetation, the abundance of grasses, the presence of shrubs, and the proximity of perch sites. Optimal habitats occur in herbaceous cover types dominated by grasses of moderate heights with low shrub densities and adequate numbers of perches. Meadowlarks prefer very dense vegetation, and optimal

herbaceous densities are assumed to occur at greater than 90% canopy cover. Suitability will decrease as the total herbaceous canopy cover decreases, and habitats will not be suitable at canopy covers of less than 20%. Data in the literature indicate that the best habitats are in grasslands with few forbs and that meadowlarks avoid areas where forbs are predominant. It is assumed that optimal conditions will exist when greater than 80% of the herbaceous cover is grass, that suitability will decrease as the relative percent of grass decreases, and that the habitat will not be suitable when less than 20% of the herbaceous cover is grass.

Data in the literature indicate that ideal vegetative heights for foraging and loafing are between approximately 10 and 30 cm (4 and 12 inches) and that the best heights for nesting are between 25 and 50 cm (10 and 20 inches). It is assumed that a large majority of the habitat should be suitable for foraging and loafing to have optimal habitat conditions. Therefore, it is assumed that the best habitats will have an average spring season canopy height of between 12.5 and 35 cm (5 and 14 inches). It is assumed that there will be enough variation in the actual canopy height so that there is a high likelihood of both suitable feeding and nesting heights being present if the average height falls within the range indicated. It is further assumed that, if the average height is less than 2.5 cm (1.0 inches) or greater than 76 cm (30 inches), no suitability will exist.

Ideal meadowlark habitats contain an abundance of perch sites, such as tall forbs, shrubs, trees, fences, or telephone wires. These perches can be within the cover type or on the periphery, such as a forest edge. It is assumed that optimal conditions exist when the average distance from random points in the cover type being evaluated to a suitable perch is less than 30 m (100 ft). This is equivalent to about four perches per 1.2 ha (3.0 acres), the minimum habitat area for the eastern meadowlark. It is assumed that suitability will decrease as the distance to perch sites increases to 60 m (200 ft), which is equal to about one perch site per 1.2 ha (3.0 acres). Some habitat suitability may exist even when there are no apparent perch sites, because of the adaptability of the meadowlark in selecting perches.

Suitability of the herbaceous component of the habitat is related to the total herbaceous cover, the relative grass cover, the height of herbaceous vegetation, and the proximity of perch sites. It is assumed that each variable exerts a major influence on overall habitat suitability. A habitat must

contain optimal levels of all variables to have maximum suitability. Low values of any one variable may be partially offset by higher values of the remaining variables. Habitats with low values for two or more of these variables will have low suitability levels.

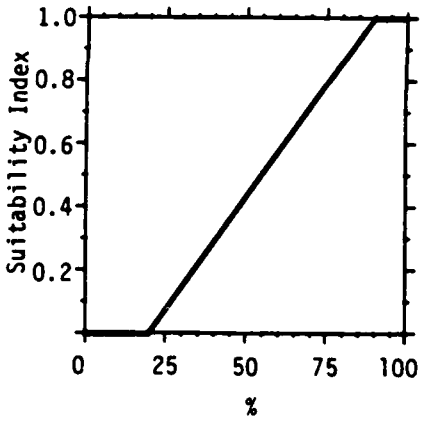
The presence of a moderate or dense shrub cover is a negative influence in meadowlark habitat selection. Optimal habitats contain less than 5% shrub canopy; suitability will decrease as shrub densities increase, and habitat will not be suitable at shrub densities greater than 35%.

Overall habitat suitability is related to the quality of the herbaceous component described above and the abundance of shrubs. It is assumed that, as shrub densities increase above 5%, the overall habitat value will decrease, regardless of the quality of the herbaceous component.

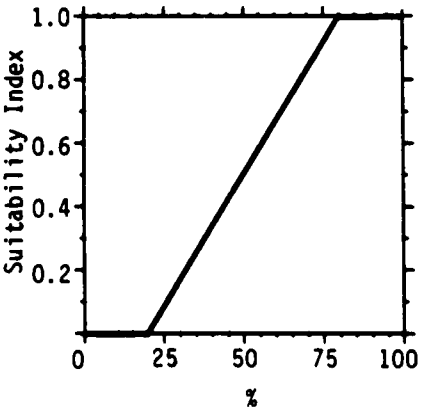
Model Relationships

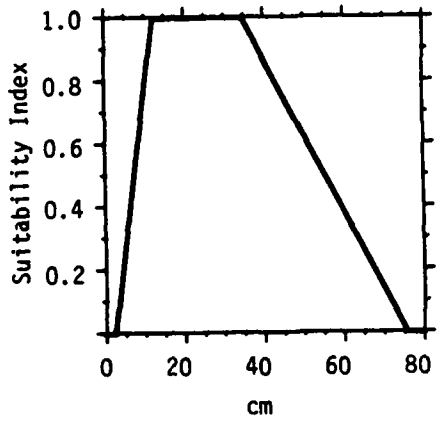
Suitability Index (SI) graphs for habitat variables. This section contains suitability index graphs that illustrate the habitat relationships described in the previous section.

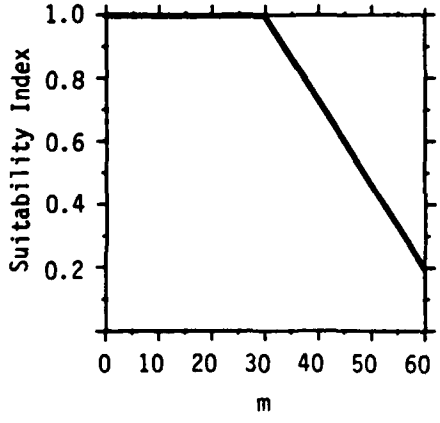
Cover Type	Variable	
P/H,G, F	V_1	Percent herbaceous canopy cover.

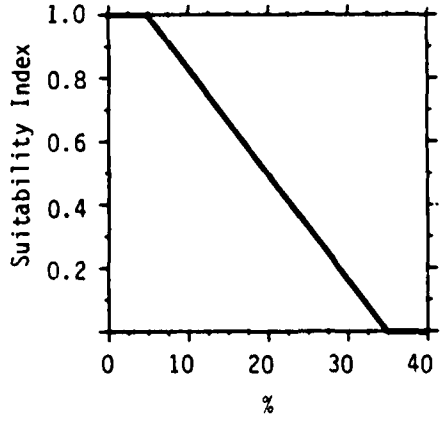


P/H,G, F	V_2	Proportion of herbaceous canopy cover that is grass.



P/H,G, F	V_3	Average height of herbaceous canopy (average spring conditions).	

P/H,G, F	V_4	Distance to perch site (such as tall forb, shrub, tree, fence, or telephone wires).	

P/H,G, F	V_5	Percent shrub crown cover.	

Equations. In order to determine life requisite values for the eastern meadowlark, the SI values for appropriate variables must be combined through the use of equations. A discussion and explanation of the assumed relationships between variables was included under Model Description, and the specific equation in this model was chosen to mimic these perceived biological relationships as closely as possible. Then suggested equation for obtaining the food/reproduction value is presented below.

Life requisite	Cover type	Equation
Food/Reproduction	P/H,G,F	$(V_1 \times V_2 \times V_3 \times V_4)^{1/2} \times V_5$

HSI determination. The HSI for the eastern meadowlark is equal to the life requisite value for food/reproduction.

Application of the Model

Definitions of variables and suggested field measurement techniques (Hays et al. 1981) are provided in Figure 2.

Variable (definition)		Cover types	Suggested techniques
V_1	Percent herbaceous canopy cover (the percent of the ground that is shaded by a vertical projection of all nonwoody vegetation).	P/H,G,F	Line intercept
V_2	Proportion of herbaceous canopy cover that is grass (the relative percent of all herbaceous cover that is comprised of grasses).	P/H,G,F	Line intercept
V_3	Average height of herbaceous canopy (average spring conditions) (the average vertical distance from the ground surface to the dominant height stratum of the herbaceous vegetative canopy during average spring conditions).	P/H,G,F	Line intercept, graduated rod
V_4	Distance to perch site (such as tall forb, shrub, tree, fence, or telephone wires) (the average distance from random points to the nearest suitable perch site, within or outside the boundaries of the cover type).	P/H,G,F	Pacing
V_5	Percent shrub crown cover (the percent of the ground that is shaded by a vertical projection of the canopies of woody vegetation less than 5 m (16.5 ft) in height.	P/H,G,F	Line intercept

Figure 2. Definitions of variables and suggested measurement techniques.

SOURCES OF OTHER MODELS

No other habitat models for the eastern meadowlark were identified.

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WILDLIFE HABITAT APPRAISAL GUIDE-MISSOURI

Landowner _____ Appraiser _____

Location _____ Date _____

Total Acres Appraised _____ County _____

RING-NECKED PHEASANT

Habitat Characteristics	Habitat Types: Cropland				Past/Hay				O'd Field		
Field No.											
Acres											
Percent Pasture/Hayland within 2 Mile Wide Circle (2000 Ac.)[1]											
1. 10-25% (200-500 Ac.)	10	10	10	10	10	10	10	10	10	10	10
2. 5-10% (100-200 Ac.)	5	5	5	5	5	5	5	5	5	5	5
3. <5% or 25-75% (<100 or 500-1500 Ac.)	3	3	3	3	3	3	3	3	3	3	3
4. >75% (>1500 Ac.)	1	1	1	1	1	1	1	1	1	1	1
Percent Cropland within 2 Mile Wide Circle (2000 Ac.)[1]											
1. 70-85% (1400-1700 Ac.)	10	10	10	10	10	10	10	10	10	10	10
2. 50-70% (1000-1400 Ac.)	7	7	7	7	7	7	7	7	7	7	7
3. >85% (>1700 Ac.)	5	5	5	5	5	5	5	5	5	5	5
4. 40-50% (800-1000 Ac.)	3	3	3	3	3	3	3	3	3	3	3
5. <40% (<800 Ac.)	1	1	1	1	1	1	1	1	1	1	1
Pasture/Hayland use within 2 Mile Wide Circle (2000Ac.)[2] Enter Percent Above Column											
1. >75% lightly to moderately used (>1500 Ac.)	10	10	10	10	10	10	10	10	10	10	10
2. 50-75% lightly to moderately used (1000-1500 Ac.)	8	8	8	8	8	8	8	8	8	8	8
3. 25-50% lightly to moderately used (500-1000 Ac.)	6	6	6	6	6	6	6	6	6	6	6
4. 10-25% lightly to moderately used (200-500 Ac.)	4	4	4	4	4	4	4	4	4	4	4
5. <10% lightly to moderately used (<200 Ac.)	1	1	1	1	1	1	1	1	1	1	1
Cropland Distribution within 2 Mile (2000 Ac.) Wide Circle (% cropland within 660' of past/hay)											
1. >75% (>1500 Ac.)	10	10	10	10	10	10	10	10	10	10	10
2. 50-75% (1000-1500 Ac.)	8	8	8	8	8	8	8	8	8	8	8
3. 25-50% (500-1000 Ac.)	6	6	6	6	6	6	6	6	6	6	6
4. 10-25% (200-500 Ac.)	4	4	4	4	4	4	4	4	4	4	4
5. <10% (<200 Ac.)	1	1	1	1	1	1	1	1	1	1	1
Border Extent											
1. Border around >50% of field	5	5	5	5	5	5	5	5			
2. Border around 25-50% of field	3	3	3	3	3	3	3	3			
3. Border around <25% of field	1	1	1	1	1	1	1	1			
Vegetative Cover (% Ground covered by herbaceous and shrub Canopy 6" - 18")											
1. 30-50%					5	5	5	5	5	5	5
2. 20-30% or 50-60%					3	3	3	3	3	3	3
3. <20% or >60%					1	1	1	1	1	1	1
Average Height of Herbaceous Vegetation (May 1-July 1)											
1. >17"					5	5	5	5	5	5	5
2. 9-17"					3	3	3	3	3	3	3
3. <9"					1	1	1	1	1	1	1
Woody Invasion (% Field occuring as trees, shrubs and vines)											
1. <5%					5	5	5	5	5	5	5
2. 5-15%					3	3	3	3	3	3	3
3. >15%					1	1	1	1	1	1	1
Grassland Composition											
1. Switchgrass or mixed warm season grass					10	10	10	10			
2. Alfalfa; bromegrass/alfalfa; or timothy/orchardgrass					8	8	8	8			
3. Mixed grasses and/or legumes;or bluegrass monotype					4	4	4	4			
4. Fescue monotype					1	1	1	1			
Grassland Management											
1. Grassland not mowed, grazed or flooded April 20-August 1					10	10	10	10			
2. Grassland not mowed, grazed or flooded before July 1					8	8	8	8			
3. Grassland lightly or moderately used April 20-August 1					4	4	4	4			
4. Grassland heavily used or flooded April 20-August 1					1	1	1	1			
Cropping Practices											
1. >4 ac. per 40 ac. food plot or unharvested grain	10	10	10	10							
2. 1-4 ac. per 40 ac. food plot or unharvested grain	7	7	7	7							
3. <1 ac. per 40 ac. food plot or unharvested grain	5	5	5	5							
4. Completely harvested little herbicide	3	3	3	3							
5. Completely harvested heavy herbicide	1	1	1	1							

Ring-necked Pheasant Habitat Planning Key O-Existing ●-Planned ●-Applied

Habitat Characteristics	Habitat Types: Cropland				Past/Hay				Old Field		
Crop Rotation											
1. Small grains-row crop-legume (Meadow)	5	5	5	5							
2. Small grains-row crop	3	3	3	3							
3. Continuous small grains or row crop	1	1	1	1							
Cropfield Management											
1. No fall tillage, residues undisturbed	10	10	10	10							
2. Chisel plowing once in fall	8	8	8	8							
3. Crop residues grazed, chopped or baled	6	6	6	6							
4. Fall discing; or with winter wheat	4	4	4	4							
5. Fall moldboard plowing	1	1	1	1							
Winter Cover (% field covered by dense woody or herbaceous cover)											
1. 30-50%									5	5	5
2. 20-30% or 50-60%									3	3	3
3. <20% or >60%									1	1	1
Distance to Winter Cover[1]											
1. < ¼ mi. ungrazed woodland or dense woody or herbaceous cover	10	10	10	10	10	10	10	10	10	10	10
2. ¼–½ mi. ungrazed woodland or dense woody or herbaceous cover	5	5	5	5	5	5	5	5	5	5	5
3. < ½ mi. grazed woodland or sparse woody or herbaceous cover	2	2	2	2	2	2	2	2	2	2	2
4. > ½ mi. to any woodland or woody or herbaceous cover	1	1	1	1	1	1	1	1	1	1	1
Distance to Pasture/Hayland											
1. < ¼ mi. light-moderate use, good plant diversity (Good plant diversity = grasses, forbs and legumes)	10	10	10	10					10	10	10
2. ¼–½ mi. light-moderate use, good plant diversity	8	8	8	8					8	8	8
3. < ¼ mi. light-moderate use, moderate plant diversity	6	6	6	6					6	6	6
4. ¼–½ mi. light-moderate use, moderate plant diversity	4	4	4	4					4	4	4
5. Heavy use; poor plant diversity; or > ½ mi. to pasture/hayland	1	1	1	1					1	1	1
Distance to Cropland or Food Plot											
1. < ¼ mi. No fall tillage					10	10	10	10	10	10	10
2. ¼–½ mi. No fall tillage					8	8	8	8	8	8	8
3. < ¼ mi. Fall disced or chiseled; or winter wheat					6	6	6	6	6	6	6
4. ¼–½ mi. Fall disced or chiseled; or winter wheat					4	4	4	4	4	4	4
5. > ½ mi. to cropfield or cropfield fall plowed					1	1	1	1	1	1	1
Distance to Old Field											
1. < ¼ mi.	5	5	5	5	5	5	5	5			
2. ¼–½ mi.	3	3	3	3	3	3	3	3			
3. > ½ mi.	1	1	1	1	1	1	1	1			
Existing Total											
Planned Total											
Applied Total											
Check Footnotes											
Maximum Possible Score	95	95	95	95	105	105	105	105	90	90	90
Existing Index											
Planned Index											
Applied Index											

Field No. _____ Code or Recommendation _____

Farm Habitat Index = $\frac{\Sigma(\text{Habitat Type Indexes} \times \text{Acres})}{\text{Total Acres Appraised}}$ = _____

Habitat Quality	Score Rating	0.75–1.0 Excellent	0.50–0.75 Good	0.25–0.50 Fair	0–0.25 Poor

NOTE:

1. If either Percent Cropland, Percent Pasture/Hayland or Distance to Winter Cover score 1, disregard other characteristics and enter .1 as Index.
2. If Pasture/Hayland Use in 2 Mile Wide Circle scores less than 10, multiply Index by Percent Pasture/Hayland Use.

Missouri Department of Conservation

U.S.D.A.
Soil Conservation Service
Columbia, Mo.

3.5.8 Appendix 3-D. Habitat Suitability Index (HSI) Models for the Salt Marsh Evaluation Species: Salt Marsh Harvest Mouse and California Black Rail.

These models were developed by Drs. James S. Wakeley and Thomas H. Roberts of the USACE Waterways Experiment Station from information in the literature, and were modified by them and Ms. L. J. O'Neil after review by species experts (see text for details).

HABITAT SUITABILITY INDEX (HSI) MODEL FOR THE SALT MARSH HARVEST MOUSE

3.5.8.1

Applicability

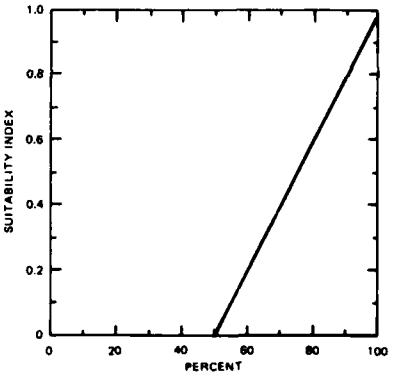
This model was developed to evaluate the year-round habitat needs of salt marsh harvest mice in the San Francisco Bay area. In general, salt marsh harvest mice prefer areas of Salicornia-dominated high salt marsh, adjacent to uplands. This model assumes that food, cover, and breeding sites are all found within the same general habitat type.

There is very little published information on the habitat requirements of salt marsh harvest mice. This model was developed from information given by Shellhammer et al. Recovery plan (US Fish and Wildlife Service 1984) and modified following field testing at NWS Concord in June 1985. (See Section 3.5 of this report)

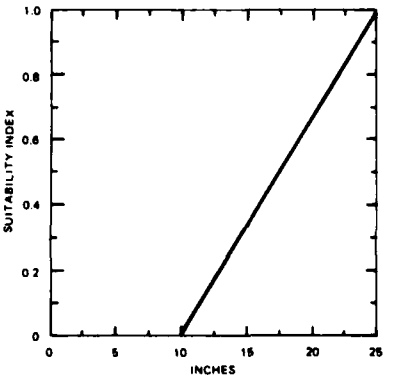
Salt marsh harvest mice require the presence of dense escape cover at higher elevations immediately adjacent to the marsh where they can find refuge from predators during the highest tides. This model was developed specifically for NWS Concord where escape cover was adequate at all study sites. If escape cover is absent, the final HSI should be multiplied by 0.5.

Model Variables

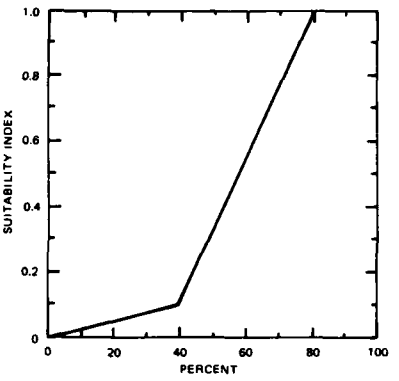
V1 Percent plant cover



V2 Average height of vegetation



V3 Percent coverage of Salicornia



Aggregation Equation

The Habitat Suitability Index (HSI) is assumed to be high if the coverage and height of the vegetation are adequate to provide suitable structure, and if the coverage of Salicornia is good. These two factors act in a compensatory manner. The overall HSI is calculated as:

$$HSI = [(S1 \times S2) + S3] / 2$$

Suggested Techniques

The following are suggested techniques for measuring habitat variables contained in the salt marsh harvest mouse HSI model.

V1 Point-intercept sampling along transects.

V2 Average of height measurements taken at intervals along transects. Measure to the tallest part of any plant within 2 inches of a rod placed at the sampling point.

V3 Point-intercept sampling along transects.

3.5.8.2

HABITAT SUITABILITY INDEX (HSI) MODEL FOR THE CALIFORNIA BLACK RAIL

Applicability

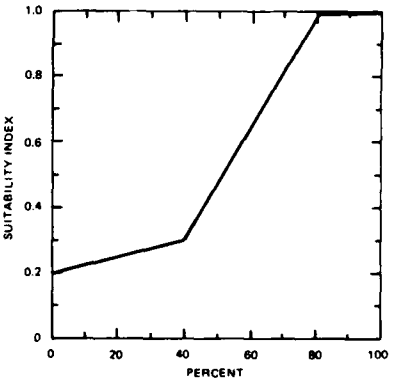
This model was developed to evaluate the year-round habitat needs of black rails in the San Francisco Bay area. In general, black rails inhabit areas of Salicornia-dominated high salt marsh, adjacent to uplands. This model assumes that food, cover, and nesting sites are all found within the same general habitat type. The suitability of any area that is not inundated by tides at least 7 times per year (or 0.1% of the year) is assumed to be 0.0 (based on a hydrologic survey of NWS Concord; see Section 2.2.6 of this report).

There is very little published information on the habitat requirements of California black rails. This model was developed from information given by Evens and Page (Unpubl. Rep. of the Marin Audubon Society, Mill Valley, CA, 1983) and modified following field testing at NWS Concord in June 1985 (see Section 3.5 of this report).

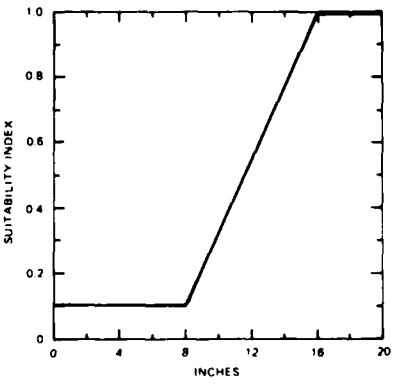
California black rails require the presence of dense escape cover at higher elevations immediately adjacent to the marsh where they can find refuge from predators during the highest tides. This model was developed specifically for NWS Concord where escape cover was adequate at all study sites. If escape cover is absent, the final HSI should be multiplied by 0.5.

Model Variables

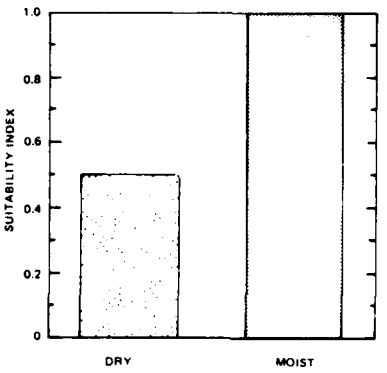
V1 Percent plant coverage of Salicornia



V2 Average height of Salicornia



V3 Average soil moisture conditions in spring and early summer



Aggregation Equation

The Habitat Suitability Index (HSI) is assumed to be high if the coverage and height of Salicornia are suitable. The highest quality sites maintain adequate soil moisture through frequent tidal innudation or poor drainage. The overall HSI is calculated as:

$$HSI = [(S1 + S2)/2] \times S3$$

Suggested Techniques

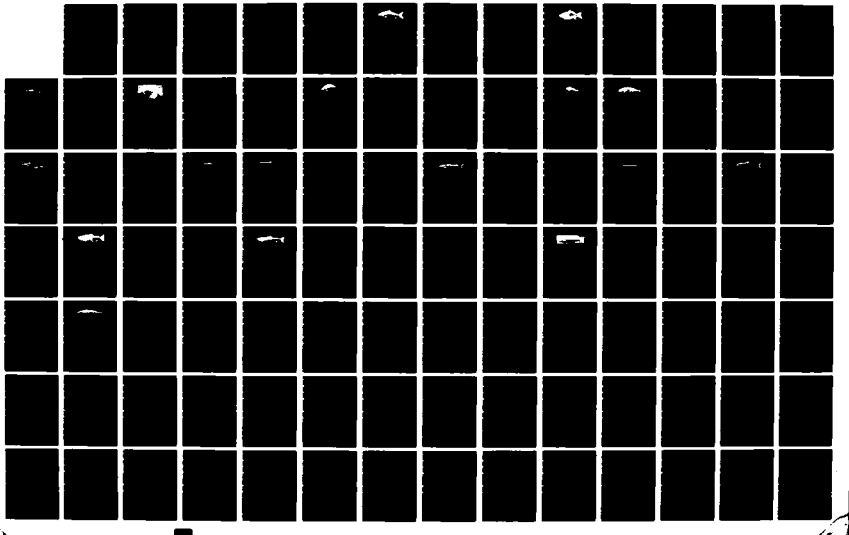
The following are suggested techniques for measuring habitat variables contained in the California black rail HSI model.

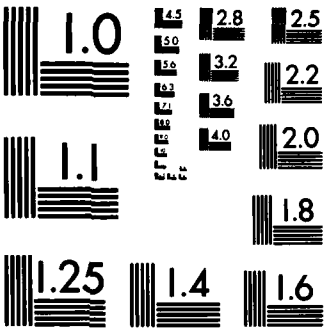
V1 Point-intercept sampling along transects.

V2 Average of height measurements taken at intervals along transects. Measure to the tallest part of any Salicornia plant within 2 inches of a rod placed at the sampling point. Skip points that do not contain Salicornia.

V3 Average moisture conditions during the breeding season in spring and early summer. Determined subjectively by examining soil from beneath or between plants.

AD-A165 127 REMEDIAL INVESTIGATION OF CONTAMINANT MOBILITY AT NAVAL 5/7
WEAPONS STATION C (U) ARMY ENGINEER WATERWAYS
EXPERIMENT STATION VICKSBURG MS ENVIR C R LEE ET AL.
UNCLASSIFIED JAN 86 WES/MP/EL-86-2 F/G 6/6 NL





3.5.9 Appendix 3-E A Synopsis of Life History and Habitat Requirements of Fishes, Benthic Macroinvertebrates and Zooplankton Inhabiting the Vicinity of the Naval Weapons Station Concord, California.

This appendix was prepared by Karen M. Saddler and John D. Lunz of the Coastal Ecology Group, Environmental Resources Division of the Environmental Laboratory, US Army Engineer Waterways Experiment Station.

3.5.9.1 Introduction

3.5.9.1.1 Purpose

This document contains life history and habitat information concerning species of fishes, benthic macroinvertebrates, and zooplankton with a documented occurrence in the vicinity of the NWS Concord. A report entitled, Initial Assessment Study Naval Weapons Station, Concord, California, prepared by Ecology and Environment, Inc., San Francisco, California, for the US Navy under Contract No. N62474-82-C-8272 provided the species occurrence information. Tables A-3 and A-4 of that report contain listings of benthic invertebrates and zooplankton, respectively, identified at NWS Concord; Table A-5 lists fish species identified in water adjacent to NWS Concord.

Information contained herein is intended to assist the fabrication of a more complete view of the wetland and aquatic habitats in and adjacent to the NWS Concord. It is the contention of the authors of this appendix that statements about the ecological impacts of physical-chemical alterations in the NWS Concord environment will be easier to understand and defend if the life histories and habitat requirements of NWS Concord fauna are known.

By itself this document has very little value to the preparation of defendable conclusions about habitat quality changes at and around NWS Concord. It should be used as a companion to other reports containing the results of physical, chemical, and biological field observations made at the NWS Concord by the US Army Engineer Waterways Experiment Station and its contractors. If hazardous substances contamination is found to be released into Suisun Bay in substantial amounts, then this information will be extremely useful for the evaluation of contaminant mobility into the fishery of the bay.

3.5.9.1.2 Information Sources

Information about fishes presented in Section 3.5.9.2 of this appendix was compiled from two sources: Lee et al. (1980) and Wydoski and Whitney (1979). Their untraditional identification as sources rather than references is an acknowledgement that life history and habitat information contained herein was extracted and compiled directly from these publications.

References cited by these sources are presented at the conclusion of Section 3.5.9.2. Information about benthic invertebrates and zooplankton presented in Section 3.5.9.3 was obtained from a much more dispersed and incomplete literature, which is cited in the more traditional "References" fashion at the conclusion of the section.

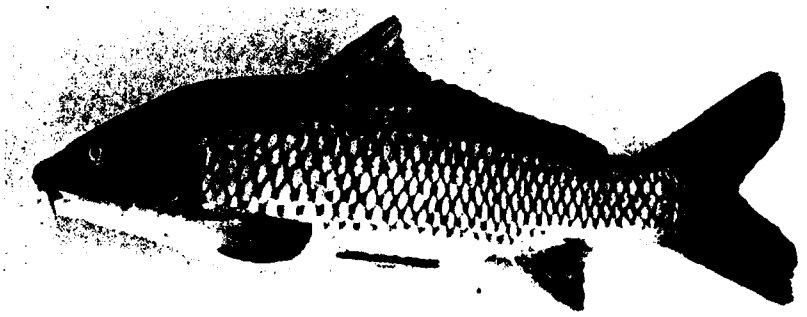
3.5.9.1.3 References

Lee, D. S., Gilbert, C. R., Hocutt, C. H., Jenkins, R. E., McAllister, D. E., and Stauffer, J. R., Jr. 1980. Atlas of North American Freshwater Fishes, North Carolina State Museum of Natural History, North Carolina State Museum of Natural History.

Wydoski, R. S., and Whitney, R. R. 1979. Inland Fishes of Washington, University of Washington Press, University of Washington Press.

3.5.9.2 Fishes

3.5.9.2.1 Species Summaries



Carp Cyprinus carpio Linnaeus

Distinguishing Characteristics

The carp is the only minnow with spines in the dorsal and anal fins and barbels at the side of the upper jaw. The goldfish has spines but no barbels. These spines are not true spines, but are fused and hardened soft rays.

Distribution

The carp is native to Asia. It was introduced throughout the United States, especially in the years after the Civil War.

Habits and Habitat

Carp generally inhabit the shallow areas of lakes and streams and are seldom found in water deeper than 100 ft. They are very tolerant of adverse conditions such as low dissolved oxygen, extreme variation in temperature, turbidity, and pollution. In California they have been found in brackish waters and near the freshwater tributaries to the Salton Sea. Generally, carp avoid swift current and prefer quiet water in areas of dense vegetation. The optimum water temperature is believed to be 70°F for this species.

Age and Growth

In the United States, the record weight is 55½ lb. The world record from Pretoria, South Africa, is 82 lb. In captivity carp have lived for 47 years, but the record for oldest fish in natural waters is 15 years.

	Age, yr - Average Total Length, in.										
Location	1	2	3	4	5	6	7	8	9	10	11
Ogden, Bay, Utah	6.8	12.9	20.4	25.0	27.1	28.2	28.5	28.4	...	...	...
Missouri											
Best growth	7.5	12.1	15.6	18.8	20.6	21.5	22.9	25.7	20.4	22.8	...
Poorest growth	4.9	9.7	13.1	14.9	16.0	17.0	18.3	19.3	19.4	...	...
Clear Lake, Iowa	8.6	18.6	24.0	27.4	29.7	31.2	...	...	...	...	...
Oahe Reservoir, S.D.	6.6	9.8	12.0	13.4	14.5	15.8	16.0	17.4	19.2	20.7	22.4

Reproduction

Carp move into shallow water (less than 4 ft deep) during the spring and summer and begin to spawn when water temperatures rise above 60°F (usually to 65-68°F). They sometimes spawn in water only 3 or 4 in. deep. Spawning occurs day and night with much activity and accompanied by considerable commotion. Carp are particularly active on warm days and frequently leap out of the water. Generally carp form small groups of 4 to 20 fish on the spawning areas, with one to several females and numerous males in the group. The female continues to move while spawning so that eggs are distributed over a large area. The adhesive eggs are spawned in groups of about 500. While males stay on the spawning grounds to spawn with other females, females leave as soon as they finish depositing their eggs. Males usually become sexually mature when age 2, while females are about 3. Carp egg production is usually high; estimates range from 36,000 to over 2,000,000 per fish, depending on the size of the fish. The eggs hatch in a short time in the warm water (about 4 days at 71°F). Within a few days after hatching, the yolk sac is absorbed and the fry can be found in shallow water in large schools. The young move into deeper water as they grow.

Food

In a study of Oklahoma waters (Summerfelt et al. 1971), zooplankton was more important in the diet of small carp (19.2 percent by volume) than in the diet of large carp (5.0 percent). Young carp ate more cladocerans and adults more copepods. Adult carp contained more plant material in their alimentary tracts (35.9 percent by volume) than small carp (15.5 percent). The foods eaten included algae, plant fragments, seeds, zooplankton, midges, caddisflies, clams, animal fragments, and miscellaneous organic and inorganic matter. Terrestrial insects and fish rarely occurred in stomachs. No fish eggs were eaten. In Oklahoma, carp probably compete for food with young game fish, carpsuckers, and largemouth and smallmouth buffalo.

Remarks

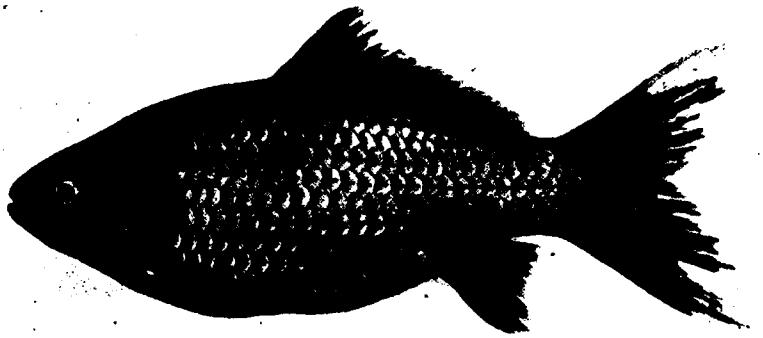
In the early days, the United States Bureau of Fisheries transported fish across the United States in railroad cars. The carp was billed as the greatest food fish ever, and every homesteader wanted carp in his ponds, lakes, and streams. The age of rail travel was near its peak, and it was natural that people would take advantage of the latest technology to further the "progress" of the country. Today money is being spent to remove carp where they compete

with game fish. In 1955 an estimated 1.5 million carp were killed with a fish-toxicant at Malheur Lake, Oregon, because of the damage they were causing to waterfowl foods. Control methods, such as the application of fish toxicants, are costly and are often only a temporary solution because of the high reproductive potential of carp. A small commercial fishery for carp existed on the Washington side of the Columbia River in the late 1930s. The harvest--126,705 pounds in 1937, 90,785 in 1938, and 104,487 pounds in 1939--was sold at markets in Portland and Seattle, primarily to people of Oriental and Jewish backgrounds to whom the fish has religious and cultural significance. At about the same time, carp taken in a small commercial fishery in Moses Lake were processed into dry meal and sold as fish food. Today a commercial fishery is operating in Moses Lake, Banks Lake, and Sprague Lake, and in the Columbia River. The peak catch was in 1969, when 1,267,000 pounds were taken; the catch in 1977 was 131,550 pounds. With the shortage of fish meal in the world markets, carp may supply a small portion of the meal needed in the United States.

Carp are under utilized by sportsmen. In an effort to correct various misconceptions about carp, the Nebraska Game and Parks Commission (1972) published a pamphlet describing ways to fish for carp and how to dress and prepare them for the table. Actually, carp are sporty on light tackle and are palatable. Smoked carp is considered a delicacy by many people. In Washington, carp can be taken by the conventional rod and reel, by spearing, and by bow and arrow. Whole-kernel corn makes good bait.

Source

Wydoski and Whitney (1979).



Goldfish Carassius auratus (Linnaeus)

Distinguishing Characteristics

This is the only minnow with spines in the dorsal and anal fins, and no barbels on the upper jaw. The closely related carp has barbels. In the wild, goldfish often revert to olive-green coloration because the brightly colored ones are soon eaten by predators such as birds or fish.

Distribution

The goldfish was originally native to eastern Asia. It has been widely introduced into many waters in the United States.

Habits and Habitat

Goldfish live well in ponds, even in cold water. Jumpoff Joe Lake in eastern Washington State has a complete ice cover during the winter, but nevertheless has an abundant population of goldfish. Generally goldfish reproduce if aquatic vegetation is available. Goldfish appear to establish themselves most successfully in small ponds or lakes with a large littoral zone where abundant aquatic vegetation is found.

Age and Growth

Goldfish have been reported to live for 25 years in captivity. This species has been reported to reach 18 in. in length and a weight of 3 lb in the wild state.

Reproduction

Spawning in the US generally occurs from around April, when the water reaches 55°-60°F, to August. The fish congregate in shallow marshy areas and spawn much as the carp do. Breeding males have tubercles on their gill covers and on the front of the pectoral fins. Breeding females lack the tubercles and become quite robust with developing eggs prior to spawning. Although egg production is related to the size of the female, an average of 14,000 eggs per

female has been reported for fish in India. Small goldfish in natural waters in the United States probably produce between 500 and 2,000 eggs. The eggs adhere to the vegetation and hatch in 8 to 10 days at water temperatures of 60 to 70°F or 2 to 3 days at 80 to 90°F.

Food

Young goldfish feed on microscopic plants and animals. Older fish appear to be omnivorous and opportunistic in their food habits, consuming all kinds of invertebrates and aquatic vegetation.

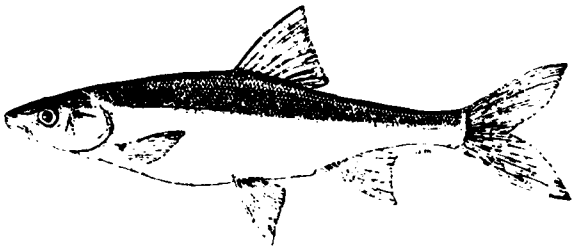
Remarks

The distribution of goldfish is subject to constant change because people thoughtlessly discard goldfish into various waters. We say thoughtlessly because they have not considered the possible harmful effects on native fish. The goldfish (and the same applies to any other fish that might be planted illegally) can spawn and increase in numbers to the point where they would crowd out the native fish. Jumpoff Joe Lake in eastern Washington is an example. Goldfish could also carry diseases or parasites and are commonly viewed as undesirable fish. Once established, goldfish are difficult to eradicate, even with fish toxicants such as rotenone. It is illegal to introduce exotic fish, including goldfish, into the waters of most states.

Goldfish in the wild have little economic benefit because they furnish no angling; furthermore, they may compete with native game fishes for food and space, although young goldfish may be used as a forage species by game fish. A fair commercial fishery (about 200,000 lb annually) exists in Sandusky Bay of western Lake Erie. These fish are sold in Chinese markets in Chicago and New York. Goldfish have been raised for use as bait and, of course, for sale as aquarium fish.

Source

Wydoski and Whitney (1979).



Sacramento blackfish Orthodon microlepidotus (Ayres)

Type Locality

San Francisco Market, but probably caught in lower Sacramento River (Ayres 1854).

Systematics

Monotypic and very distinctive from other endemic minnows. Hybridizes with Lavinia exilicauda and Gila bicolor. Coad (1976) considered Orthodon most closely related to Gila.

Distribution and Habitat

Warm, eutrophic backwaters, sloughs, lakes (including Clear Lake, Lake County, Calif.), and reservoirs of Sacramento-San Joaquin drainage, including Pajaro-Salinas system and lower Russian River. Absent from Pit River system, but possibly established through introductions in Truckee Meadows area of Nevada and Carmel River of southern California.

Adult Size

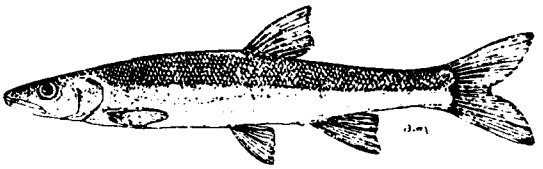
250-450 mm SL.

Biology

Feeds on phytoplankton and detritus. Life history summarized in Moyle (1976). Important commercial species in California with considerable potential for aquaculture.

Source

Lee et al. (1980).



Sacramento squawfish Ptychocheilus grandis (Ayres)

Type Locality

San Francisco Market but fish probably from lower Sacramento River, Calif. (Ayres 1854).

Systematics

Closely related to P. umpqua of Umpqua River, Oreg., and P. oregonensis of Columbia River drainage.

Adult Size

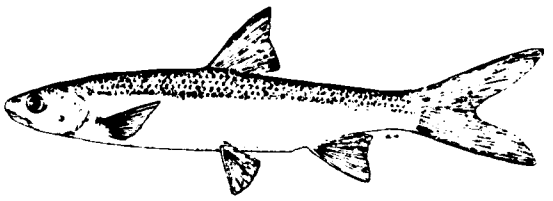
200-600 mm SL, 1150 mm SL maximum.

Biology

Piscivorous when larger than 150 mm SL. Life history (Moyle 1976) similar to P. oregoneniss. Dettman and Li (in press) indicate that under natural conditions, it has little impact on trout populations.

Source

Lee et al. (1980).



Splittail Pogonichthys macrolepidotus (Ayres)

Type Locality

San Francisco Market, but probably caught in Sacramento River, Calif., or its estuary (Ayres 1854).

Systematics

See P. ciscoides. The genus is very different from other California endemic cyprinids (Avise and Ayala 1976).

Distribution and Habitat

Formerly distributed in lakes and rivers of floor of great Central Valley, California, but now confined to Sacramento-San Joaquin Delta region and lower Sacramento River, up to Red Bluff Diversion Dam.

Adult Size

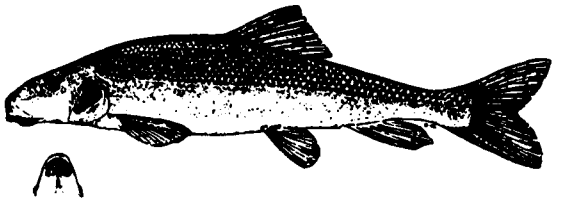
200-400 mm SL.

Biology

Benthic invertebrate feeder. Some information on life history in Moyle (1976). Life history studied by Caywood (1976).

Source

Lee et al. (1980).



Sacramento sucker Catostomus occidentalis Ayres

Type Locality

San Francisco Fish Market, but probably from Sacramento River (Ayres 1854).

Systematics

Subgenus Catostomus. Four poorly defined subspecies described: C. o. occidentalis from Sacramento and San Joaquin river drainages; C. o. mniotiltus from Pajaro and Salinas rivers; C. o humboldtianus from north coastal drainages; and C.o. lacusanserinus from Goose Lake, Modoc County, Calif. (Snyder 1914, Fowler 1913). Validity of all subspecies questionable.

Distribution and Habitat

Widespread in streams and reservoirs of Sacramento-San Joaquin drainage and adjacent Pacific drainages, California-Oregon. Adults require deep pools and are most abundant in clear cool streams at moderate elevations (200 to 600 m).

Adult Size

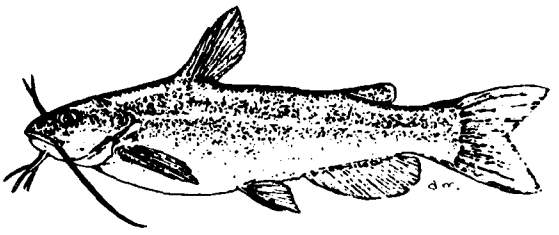
200-500 mm SL.

Biology

Feeds on detritus, algae, and small invertebrates. Life history similar to other large Catostomus (Moyle 1976).

Source

Lee et al. (1980).



White catfish Ictalurus catus (Linnaeus)

Type Locality

"Northern part of America" (Linnaeus 1758).

Systematics

No definitive study; no subspecies recognized. Phylogenetic relationships to other ictalurids presented by Taylor (1969).

Distribution and Habitat

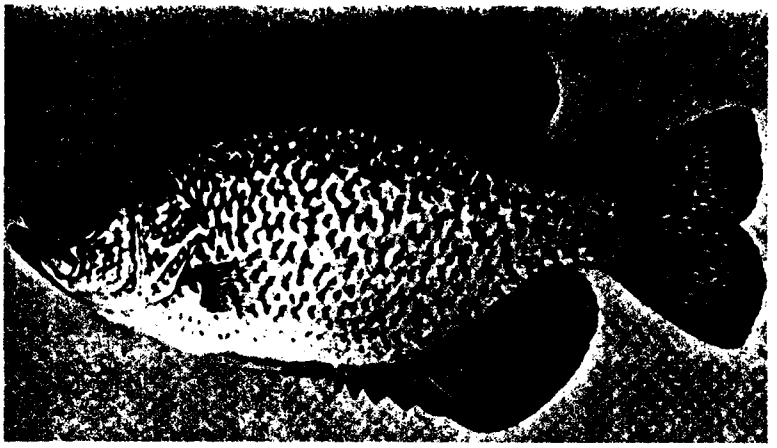
Native to the Atlantic coastal states from Florida to New York; widely introduced outside native range. Characteristic of rivers and ponds. Common.

Biology

Breder and Rosen (1966) and Smith (1979) described spawning.

Source

Lee et al. (1980).



Black Crappie Pomoxis nigromaculatus (Lesueur)

Distinguishing Characteristics

The black crappie has a compressed body with anal and dorsal fins of about equal size. The base of the dorsal fin is longer in the black crappie than in the white crappie. Black crappie usually have 7 to 8 dorsal spines, whereas white crappie usually have 5 or 6.

Distribution

Black crappie were originally found from eastern North Dakota and southeastern Manitoba east to southern Quebec and Vermont, southeast to North Carolina (absent from the Atlantic coastal areas), south to Florida, west to eastern Texas, and north to eastern South Dakota. The species was successfully introduced into California in 1908 and was first introduced into lakes near Spokane, Washington, in 1890 and 1892. It is now found north into British Columbia--possibly from transplants from Washington.

Habits and Habitat

The black crappie is generally found in clear water of large streams or in reservoirs and medium-sized lakes. It prefers dense aquatic vegetation over bottoms of sand, muck, or organic debris. The black crappie generally inhabits colder waters than does the white crappie. It feeds most actively in spring, when it is found in weedy areas usually less than 10 ft deep.

During summer it moves into deeper water and does not seem to be as available to anglers as in the spring. Black crappie apparently move about somewhat and do not remain in one location. In one study on a reservoir, black crappie moved an average distance of 5.4 miles.

Age and Growth

Black crappie of both sexes grow at about the same rate. The world record black crappie weighed 5 lb. Fish up to 9 years of age have been reported, but they usually do not live beyond 5 years. Although 10-in. crappie are considered a good size for Washington, specimens weighing 4-3/4 lb have been taken. In Oregon farm ponds, black crappie reach a length of 7 to 9 in. in 3 years.

	Age, yr - Average Total Length, in.								
Location	1	2	3	4	5	6	7	8	9
Ohio, average	2.2	4.7	6.3	7.8	9.2	9.9	11.5	11.9	...
Utah, average	2.5	6.0	8.0	9.0	10.0	11.0	12.0	14.0	...
Oklahoma, average	3.1	6.3	8.2	9.9	11.6	13.5	15.2	...	...
Montana	3.0	6.0	8.0	9.0	10.0	11.0	...	...	...
Lake St. Clair, Wash.	...	...	9.3	9.8	10.6	...	...	...	...
Lake Washington Wash.	3.1	6.0	8.0	9.1	9.9	10.6	11.1	11.7	11.8

Reproduction

Crappie usually reach maturity when 2 to 3 years old and 7 to 8 in. long. Faster growing individuals may mature at an earlier age. However, crappies, like many other species of centrarchids, may become stunted due to overcrowding and spawn at a much smaller size. They spawn in spring, during May or early June in most of the range, when water temperatures reach 58 to

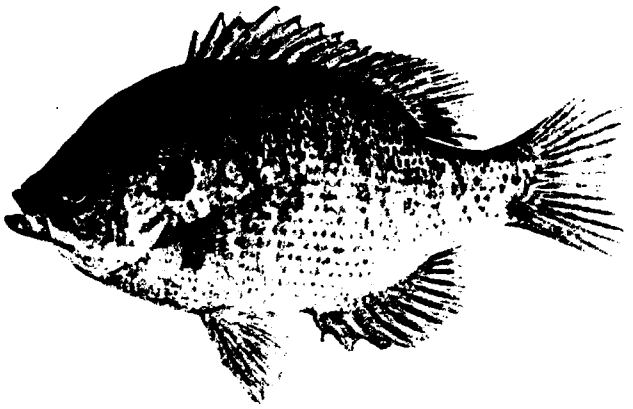
64°F. Males dig a shallow depression in soft mud bottoms, at a depth usually less than 8 ft. Females produce 11,000 to 188,000 eggs, depending on their size. After spawning, the male guards the nest very aggressively until the fry leave the site. In Lake Washington, males can be recognized rather easily during the spawning season because they become much darker than females.

Food

Young crappie feed principally on zooplankton. As they grow, they feed increasingly on small larval aquatic insects. Large fish generally depend on fishes for food. Good growth usually is an indicator that forage fishes are available. In California more than 85 percent of the diet of black crappie longer than 8 in. was reported to be fish. Of the fishes eaten, 50 percent were threadfin shad that had been introduced as forage and juvenile striped bass were 22 percent by volume. Other prey species included American shad, chinook salmon, pond smelt, goldfish, and bluegills.

Source

Wydoski and Whitney (1979).



Bluegill Lepomis macrochirus Rafinesque

Distinguishing Characteristics

The bluegill and pumpkinseed are sunfishes with compressed bodies and small mouths. The bluegill has a dark spot at the posterior base of the dorsal fin (absent in the pumpkinseed) which may be difficult to see in small specimens. As the common name indicates, the bluegill has a black to blue-black spot at the posterior edge of the opercle. In the pumpkinseed the posterior extension of the opercle is orange to red. Finally, the gillrakers on the first arch of the bluegill are long and slender, whereas those of the pumpkinseed are stubby.

Distribution

The original distribution of the bluegill was from Minnesota and southern Ontario eastward to the Atlantic states, south to Georgia, and west to Texas and northeastern Mexico. It has been widely introduced into various parts of the United States. This species was first introduced in 1890 into Loon Lake and Lake Colville in Washington and into California in 1908. It is now widely distributed in the western states including many warm-water lakes in Washington.

Habits and Habitat

Bluegill usually inhabit warm shallow lakes with rooted vegetation. They have adapted well, however, to some California reservoirs in which the water fluctuates and rooted vegetation is absent. They travel in small loose schools while feeding, particularly in early morning or in the evening. Because they feed by sight, they feed primarily during daylight. They grow fastest in water temperatures between 60 and 80°F and can survive temperatures up to 85°F. During mid-day bluegill go to deeper waters of shallow lakes or beneath the shade of trees or brush. The young remain in shallow water during the summer. High turbidity is probably detrimental to successful reproduction and good growth.

Age and Growth

Bluegill easily become stunted in some lakes, particularly in waters that are infertile or have dense vegetation. This sunfish has a rather long life span and grows well in most parts of the United States. The largest bluegill on record is a 15-in. specimen that weighed 4 lb 12 oz, taken from Ketona Lake, Ala. Bluegill up to 2 lb have been taken in Washington. However, a fish weighing 1 lb would be considered large.

	Age, yr - Average Total Length, in.								
Location	1	2	3	4	5	6	7	8	9
Buckeye Lake, Ohio	1.6	2.9	4.1	5.2	6.0	7.1	7.4	7.7	8.4
Illinois lakes	1.3	3.5	4.9	6.0	6.8	8.0	8.2	8.0	...
Indiana lakes	1.5	3.0	4.8	6.5	7.4	8.1	9.2	8.9	...
Wisconsin									
Northern	2.1	3.8	5.0	5.7	6.5	7.1	7.6	8.1	...
Southern	4.9	5.5	6.3	7.0	7.7	8.5	8.8	...	...
Clear Lake, Iowa	2.4	4.2	5.6	6.2	7.8	8.2	...	...	...
Montana	1.5	2.5	4.0	5.0	6.0	...	...	...	...
Folsom Lake, Calif*	1.4	3.1	4.8	7.0	7.9	8.7	...	...	...

*Fork lengths.

Reproduction

Generally, bluegill mature when 2 or 3 years old. However, maturity appears to be related to growth, and the fastest growing fish mature sooner than fish that grow slowly.

Bluegill spawn in the spring when the water temperature is approximately 67°F. Spawning begins in April in Alabama waters, early May in Ohio, late May in Illinois and Wisconsin, and early June in Michigan. In Wisconsin, spawning continues from late May to early August and peaks in June. Males generally form hollows for nests in a sandy bottom in shallow water. The number of eggs produced by a female varies from 23,600 to 49,400 and depends on her size. As many as 68,815 fry have been collected from a single nest. This number indicates that several females may spawn with one male. After spawning, the male vigorously protects the nest and keeps the eggs clean and aerated by fanning them with his fins. After hatching, the fry are protected for several days by the male. Newly hatched bluegill are about 0.1 in. long.

Food

Bluegill fry eat zooplankton--principally crustaceans such as copepods and cladocerans. As they increase in size, they eat increasing proportions of various aquatic insects. Other foods include molluscs, small crayfish, amphipods, and fish eggs. Terrestrial insects such as grasshoppers are sometimes important in the diet. During summer, bluegill may eat plants such as algae and higher rooted plants. They continue to feed in winter (sometimes can easily be taken by angling through the ice), but the consumption of food decreases drastically when water temperatures drop below 55°F.

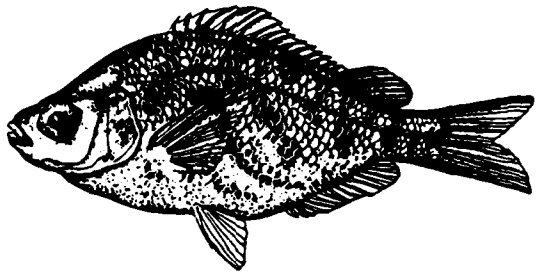
Remarks

Because of its fine table quality, good fighting ability, and ease of capture, the bluegill is eagerly sought by anglers in certain parts of the United States. It can easily be taken on flies, and it can provide excellent sport on light tackle. In some midwestern and eastern states, the bluegill is one of the top sport fish in terms of numbers taken. Stunting (slow growth because of high population density) has been a major problem in managing bluegill, particularly in small lakes such as farm ponds. Using large predators,

seining the shallows to remove the abundant young, intensive angling and harvest of fish, and the use of chemicals to kill the eggs in nests are some techniques that have been used to produce good growth and large sizes in bluegill populations.

Source

Wydoski and Whitney (1979).



Tule perch Hysterocarpus traski Gibbons

Type Locality

Sacramento River, Calif. (Gibbons 1854).

Systematics

Monotypic. Only exclusively freshwater embiotocid. Hopkirk (1973) described three subspecies: H.t. layunae from Russian River, H.t. pomo from Clear Lake, and H.t. traski from Sacramento Valley.

Distribution and Habitat

Abundant in low elevation sections of Sacramento River and major tributaries, Calif., including Pit River up to Pit Falls. Also abundant in Clear Lake, Lake County, Calif., and Russian River. Extinct in Pajaro-Salinas drainage and San Joaquin River system.

Adult Size

100-150 mm SL.

Biology

Livebearer, each female giving birth to 20-80 young. Juveniles may be sexually mature a few weeks after birth. Feeds on both benthic and planktonic invertebrates and lives up to seven years. (Moyle 1976).

Source

Lee et al. (1980).

Prickly Sculpin Cottus asper Richardson

Distinguishing Characteristics

As the common name suggests, the body of this species is covered with many prickles. Specimens from brackish water usually have fewer than those from fresh water. Sometimes the prickles are restricted to a patch under the pectoral fin. This species has well-developed palatine teeth, a single pore at the tip of the chin, a dark spot at the posterior part of the first dorsal fin, and 15 to 19 anal rays.

Distribution

The prickly sculpin occurs from Ventura River, Calif., to Seward, Alaska (including Vancouver Island, British Columbia), and along the Pacific slope of North America.

Habits and Habitat

The prickly sculpin typically inhabits the pools and quiet water areas of large coastal streams, but also lives along the shores of lakes. It is able to tolerate salt water very well and is abundant in estuaries. In Yaquina Bay, Oreg., it has been found in salinities of 24 parts per thousand and may tolerate higher salinities than other typically freshwater species in the family. The prickly sculpin generally is found on bottoms of sand, gravel, or rubble. Although most sculpins are commonly near or in cover, the prickly sculpin appears to depend on its protective coloration for concealment and is often in open areas. Small specimens are generally in vegetated areas in shallow water. During winter, prickly sculpin go into deeper water and live under cover of rocks, logs, and debris. They avoid the fast-water areas of streams and are seldom taken in small streams. They usually are in water with a temperature of 50 to 64°F, but have been found at water temperatures as high as 82°F.

Age and Growth

In Conner Creek, Wash., most prickly sculpins collected were age 2 or younger. No fish over 5 years old were collected. The largest fish was 5.9 in. in length, weighed 2.4 oz, and was 5 years old. In 1966 young-of-the-year prickly sculpin were about 0.6 in. long in early June, 0.8 in. by late June, 1.4 in. by late August, and 1.6 in. by the middle of October. In Oregon the prickly sculpin was found to have the following average standard lengths (inches) at each year of life: age 1, 1.8; age 2,2.1; age 3, 2.8; age 4, 3.3; age 5, 4.5; and age 7, 5.2. In British Columbia this species may reach a size of about 12 in., but most are less than 6 in.

Reproduction

The peak of spawning in Washington occurs during April and May. In Conner Creek, Wash., females with mature eggs have been collected as early as late February until late May. In British Columbia this species may spawn from mid-February to June. Among experimentally reared prickly sculpin eggs only 50 percent survived at 59°F and none at 64°F. Nests are usually under rocks and logs in areas with slow water velocities (about 1 cu ft per sec or less). This species apparently also spawns under man-made materials such as cans, car bodies, discarded mufflers or tailpipes, and sheet metal. The yellow to orange eggs are adhesive and slightly more than 1 mm in diameter. A male may spawn with several females in his nest site.

Prickly sculpin mature as early as 2 years of age, although some may not spawn until 4 years old. Mature females 3.7 to 6.9 in. have been collected from several localities in Washington. The number of eggs produced ranged from 280 for a 3.7-in. female to 7,410 for a 6.9-in. female. The average number of eggs for each age is as follows: age 3, 956; age 4, 1,734; age 5, 2,158; age 6, 4,020, and age 7, 5,190. In Oregon a 2.4-in. female may contain 584 eggs and a 6.3-in. female 10,980.

Food

The young of the prickly sculpin are pelagic for 30 to 35 days. They feed on plankton and aquatic insect larvae. The larger fish feed on benthic organisms such as crustaceans and immature aquatic insects. The predominant food items in Conner Creek, Wash., are amphipods, isopods, and midges. The prickly sculpin feeds on fish eggs and small fishes when they are available. Because it reaches a relatively large size, it may eat more fish than other

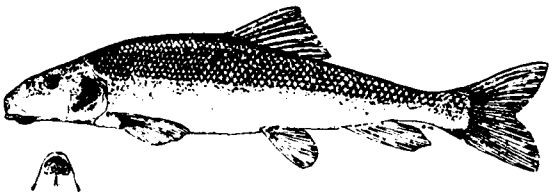
sculpins because it is better able to capture and swallow them. The small fishes eaten by the prickly sculpin include its own young and those of sticklebacks, but sometimes also the young of salmon and trout.

Remarks

This sculpin is readily caught on baited hooks, and many youngsters fishing the tributary streams of Lake Washington, Wash., have probably caught it. Electrofishing surveys in Lake Washington have revealed that this is the most abundant forage fish along the shallow shores. In terms of occurrence and percentage of total volume, the prickly sculpin was the most important food item eaten by largemouth bass in Lake Washington, where it was also found in stomachs of cutthroat trout, northern squawfish, and yellow perch.

Source

Wydoski and Whitney (1979).



Western sucker Catostomus occidentalis Ayres

Type Locality

San Francisco Fish Market, but probably from Sacramento River (Ayres 1854).

Systematics

Subgenus Catostomus. Four poorly defined subspecies described: C.o. occidentalis from Sacramento and San Joaquin river drainages; C.o. mniotiltus from Pajaro and Salinas rivers; C.o. humboldtianus from north coastal drainages; and C.o. lacusanserinus from Goose Lake, Modoc County, Calif. (Snyder 1914, 1908, and Fowler 1913). Validity of all subspecies questionable.

Distribution and Habitat

Widespread in streams and reservoirs of Sacramento-San Joaquin drainage and adjacent Pacific drainages, California-Oregon. Adults require deep pools and are most abundant in clear cool streams at moderate elevations (200 to 600 m).

Adult Size

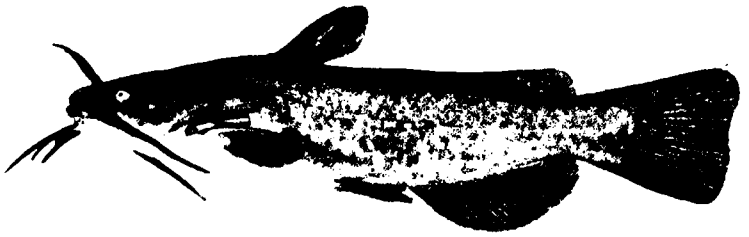
200-500 mm SL.

Biology

Feeds on detritus, algae, and small invertebrates. Life history similar to other large Catostomus (Moyle 1976).

Source

Lee et al. (1980).



Brown Bullhead Ictalurus nebulosus (Lesueur)

Distinguishing Characteristics

Both the brown bullhead and the black bullhead have pigmented chin barbels that easily distinguish them from the yellow bullhead, which has unpigmented chin barbels. The spines in the pectoral fins of the brown bullhead have rather strong serrations on the posterior edge; the serrations are absent or weak in the black bullhead. Also, the brown bullhead lacks the jet black membranes like those present between fin rays in the black bullhead.

Distribution

The original range was from Nova Scotia south to Florida, west to Louisiana, northwest to North Dakota and Saskatchewan, and east to Nova Scotia. Introduced as early as 1874 in the central valley of California, the brown bullhead is recorded as established in Washington in 1882 and 1883 and is the most common bullhead in Washington.

Habits and Habitat

This species inhabits warmwater ponds, lakes, sloughs, and sluggish areas in streams. Adults are usually in deeper water along the shoreline of lakes, but move into shallow, weedy areas to feed and spawn. They prefer shallow bays in large lakes, such as Lake Washington, Wash. Brown bullhead are tolerant of high temperatures (up to 97°F) and low dissolved oxygen (0.2 part per million). In Lake Washington, tagged bullheads have been recaptured only near the tagging location. In Folsom Lake, California, tagged bullheads moved an average of 1.7 miles from the tagging site before they were recaptured by anglers; the longest distance traveled was 16.2 miles.

Age and Growth

The brown bullhead generally grows rapidly although growth rates vary

Location	Age, yr - Average Total Length, in.						
	1	2	3	4	5	6	7
Little River, Md.	3.5	7.0	10.1	12.2	14.0	...	...
Monocracy River, Md.	5.7	8.0	9.3	...	...	...	...
Lake Butte des Morts, Wisc.*	...	6.0	7.5	9.4	10.4	...	...
Ten Mile Lake, Oreg.	4.4	8.0	9.8	10.6	10.8	11.3	...
Lake Washington, Wash.							
Males	2.7	5.0	8.0	10.4	11.7	12.9	13.9
Females	2.7	4.7	7.8	9.78	11.0	11.5	11.7

*Lengths at capture; not back-calculation of growth

somewhat in different locations. In Lake Washington, bullhead weighing over 2 lb have been taken in experimental nets. The life span is rather short--seldom more than 5 years.

Reproduction

Brown bullheads mature when 3 years old. They spawn from April through June, when the water temperature is about 70°F. They dig a circular depression about 1 ft in diameter in the mud or sand or among plants on the bottom. The fish choose nesting areas in dense vegetation, shaded areas, or near objects such as logs or stumps. The nest is in shallow water, a few inches to several feet deep. Females deposit cream-colored eggs about 0.1 in. in diameter. Egg production of females 8 to 13 in. long varies from 2,000 to 13,000, depending on the size of the female. The nest is guarded by the male, or sometimes by both sexes, until the young are several weeks old. The eggs hatch in 5 days at a water temperature of 77°F, and in 7 days at 69°F. The young are about one-fourth in. long at hatching and are yellowish in color. As soon as the yolk sac is absorbed (5 to 10 days), the young begin to move about as a school and feed. Toward the end of summer, the schools disperse and the fish begin to move into deeper water.

Food

Brown bullheads feed on the bottom, primarily at night--although they also feed on dark, cloudy days, particularly in turbid water. The young feed primarily on zooplankton and midge larvae. Larger fish feed on items such as insect larvae, molluscs, worms. Adults feed on many food items such as insect larvae, molluscs, worms, leeches, terrestrial insects, algae, other aquatic

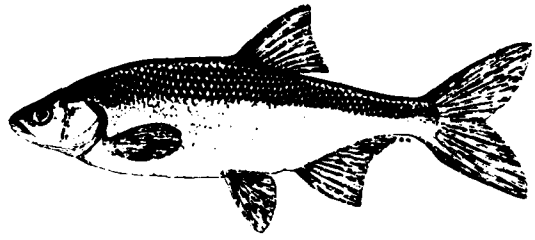
plants, and fishes. Midges form a substantial part of the brown bullhead diet. Although the diet of brown bullhead in a pond in Ontario, Canada, included large quantities of invertebrates, fishes predominated--especially pumpkinseed (55 percent of volume) and golden shiner (15 percent).

Remarks

Although this species is abundant in many lakes in Washington, only a limited sport fishery exists. In general, brown bullhead are taken most often in lakes near population centers where it is unnecessary to travel far to fish. The University of Washington Arboretum has a rather intensive fishery for this species in the spring. Still-fishing on the bottom with bait such as worms or shrimp is effective for bullhead. Usually the catch per angler hour is highest at twilight or immediately after dark.

Source

Wydoski and Whitney (1979).



Hitch Lavinia exilicauda Baird and Girard

Type Locality

Sacramento River, Calif. (Baird and Girard 1854).

Systematics

Three subspecies have been recognized: L.e. chi from Clear Lake, L.e. exilicauda from Sacramento and San Joaquin drainage, and L. e. harengus from Pajaro and Salinas drainages (Hopkirk 1973). Hybridizes with L. symmetricus, Orthodon microlepidotus, and Gila crassicauds.

Distribution and Habitat

Characteristic of warm low-elevation lakes, sloughs, backwaters, and ponds, Sacramento and San Joaquin rivers; Clear Lake, Lake County, Calif.; and ponds and slow-moving waters of Pajaro and Salinas rivers. Also abundant in some reservoirs.

Adult Size

200-300 mm SL.

Biology

Pelagic zooplankton feeder. Spawns in spring in streams or shallow waters of lakes. Life history summarized in Moyle (1976).

Source

Lee et al. (1980).

Pacific Lamprey Entosphenus tridentatus (Gairdner)

Distinguishing Characteristics

Adult lampreys can be identified by the arrangement of the teeth in the suckerlike mouth. In the Pacific lamprey, the large supraoral lamina has 3 cups, the lateral teeth are in 4 pairs, and the posterior teeth are parallel to the margins of the mouth, more or less continuous with the lateral teeth. Females have a well-developed ventral fin fold, but the males have none. To identify the larvae or ammocoetes of Pacific lamprey, check for a dark line of pigment above and below the tip of the tail.

Distribution

The Pacific lamprey is found in coastal streams from southern California to the Gulf of Alaska. It is apparently rare north of the Alaska peninsula. This lamprey has also been taken off the coast of Japan, as far south at the Yuhutu River, Hokkaido, but is not known to spawn there. In Washington this species is found in most large coastal rivers and occurs inland in the Columbia, Snake, and Yakima river systems. It has been reported to ascend the Snake River inland into Idaho in rather large numbers.

Habits and Habitat

The adults are parasitic on fish in the Pacific Ocean while the ammocoetes (larvae) are filter feeders that inhabit the fine silt deposits in backwaters and quiet eddies of streams. Lamprey apparently travel great distances at sea. Upon reaching maturity, the adults enter fresh water in the late spring and early summer to spawn. They can even pass barriers by slowly ascending the walls of dams by clinging to them with their suckerlike mouths. Newly metamorphosed individuals migrate from their parent stream to the Pacific Ocean from March to July, with a peak in April and June.

Age and Growth

Adults may reach a length of 30 in. and a weight of about 1 lb. A small lamprey 5.5 in. long was found on a 12-lb chinook salmon off the Oregon coast. This lamprey did not leave a scar when it was removed. However, it may not have begun to feed, as its length was almost identical with that of a newly metamorphosed lamprey (5.4 in.) taken in Lake Washington.

It is not known for certain how long Pacific lamprey live in fresh water. However, they are 5 to 6 years old when they transform from the ammocoete stage in British Columbia, where they reach the following mean lengths (inches) during their larval existence: age 0, 0.7; age 1, 1.5; age 2, 2.1; age 3, 2.7; age 4, 3.1; and age 5, 3.8. Landlocked Pacific lampreys (7.6-8.5 in. long) in the parasitic phase have been reported in California and British Columbia.

Reproduction

Spawning occurs during June and July in nests that are formed as depressions in the small gravel of riffles. The males arrive first on the spawning areas. However, both sexes participate in digging the shallow nest that may be up to 2 ft in diameter. The small eggs (about 1 mm in diameter) are oval and hatch in 2 or 3 weeks depending upon water temperature. The mean number of eggs produced by a female is about 34,000 but can be as many as 106,000 for a 16-in. female. The adults die after spawning; lamprey larvae or ammocoetes remain in the stream environment up to 6 years before migrating to the Pacific Ocean.

Food

The ammocoetes does not have eyes or teeth, and its mouth is enclosed by a hoodlike flap that is used to filter microscopic plants and animals from the water. After metamorphosing into the adult parasitic phase, Pacific lamprey feed on the body fluids of various species of fish. Parasitic lamprey use their suckerlike mouths to attach to a fish, rasp an opening into the fish's body with their sharp teeth, and suck the body fluids and blood for their nourishment. Lamprey produce an anticoagulant that prevents clotting of the host's blood. The parasitic phase (probably 12 to 20 months) and feeding habits, though not well known for this species, may be similar to those of the sea lamprey, which have been described in detail by Lennon (1954).

Remarks

Between 1943 and 1949, the Willamette River in Oregon supported a commercial fishery for this lamprey. The average annual harvest was 23,179 lb, which probably amounted to 10 to 20 percent of the total run. The harvest was taken to a reduction plant, where the vitamin-rich oil was extracted and the meal was sold for livestock or poultry food or fertilizer. In earlier days, Northwest Indians processed lamprey for food by smoking, sun drying, and salting. Today they are used by fishermen as bait for white sturgeon in the Columbia and Fraser river systems. Lamprey ammocoetes reportedly have been used as trout bait in British Columbia.

The importance of lamprey predation in the Pacific Ocean has not been clearly evaluated, although biologists have suspected there might be significant effects on some fish populations because of experience with the closely related sea lamprey in the Great Lakes, where it is clear that lake trout and other fishes were reduced in abundance. But not many fish from the Pacific Ocean are observed to have lamprey scars, unlike the Great Lakes where large numbers of fish have been observed with scars. Perhaps an explanation of these observations is that fish weakened from parasitism by lampreys would be consumed quickly by the large predators or scavengers that inhabit the Pacific Ocean but are not found in the Great Lakes. Each year, however, lamprey-scarred salmon are observed in rivers of the Pacific Northwest, even as far inland as Idaho. Scott and Crossman (1973) reported that up to 20 percent of the coho salmon examined in British Columbia had scars from the Pacific lamprey.

Although lampreys are not generally considered predators of mammals, scars have been found on whales. For example, between 25 and 89 percent of finback, sei, blue, humpback, and sperm whales examined off the coast of British Columbia contained the scars of the Pacific lamprey (Pike 1951).

Source

Wydoski and Whitney (1979).

White Sturgeon Acipenser transmontanus Richardson

Distinguishing Characteristics

The white sturgeon has a short rounded snout with 4 barbels that are closer to the end of the snout than to the mouth. This species has more lateral bony scutes (38-48) than the green sturgeon (28-30) and has 4 to 8 scutes arranged in two rows between the pelvic and anal fins compared to 1 to 4 scutes in one or two rows for the green sturgeon, which is the only other sturgeon in Washington State.

Distribution

In marine and fresh waters of rivers along the Pacific coast from Monterey, California, to Cook Inlet in northwestern Alaska. In Washington, white sturgeon are found in the Columbia River, Snake River, Grays Harbor, Willapa Bay, Puget Sound, and Lake Washington.

Habits and Habitat

In the Columbia and Snake rivers, white sturgeon are found in the deeper holes. Although sturgeon are bottom dwellers, they have been reported to leap occasionally from the water. These fish are frequently found in localized holes in the river that are well known to sturgeon fishermen. In the water below the spillway at Bonneville Dam, little activity of the sturgeon is observed when the spillway has been closed for a time. When the gates are opened and closed, however, sturgeon have been observed to leap out of the water. Most activity near the surface apparently occurs in spring. During fall and winter, the commercial and sport catch of sturgeon is low, but even then occasional spurts of activity occur. Fishermen say that these fish are most active and bite better after the river has begun to rise and becomes turbid. Sturgeon tagged in San Pablo Bay, Calif., have been recaptured as far as 60 miles upstream, and one traveled some 660 miles to the mouth of the

Columbia. Nearly 4,000 were tagged in the Columbia in 1947-50. Most were captured close to the tagging location, and two fish were taken four times each by sportsmen within a few months. A number of white sturgeon were captured at the mouth of the Columbia, some 100 miles downstream from the tagging locality. One migrated at least 200 miles to the Naselle River, Willapa Bay, Washington. This was the only reported recapture of a tagged fish outside the Columbia River system. Sturgeon in the Columbia appear to migrate upstream during fall and downstream in late winter and spring.

White sturgeon that were tracked with radio transmitter in the Columbia River were inactive in mid-winter but exhibited movements in summer and early fall. These fish occupied shallower waters in summer when water temperatures were warm (63°-64°F) and deeper pool areas in winter (Haynes et al. 1978).

Age and Growth

The white sturgeon is the largest fish found in the fresh waters of North America. Specimens have been reported to reach a length of 20 ft and a weight of 1,800 lb. In the Columbia River, white sturgeon reach the minimum legal length of 36 in. when they are 8 to 9 years old. This species is long lived. One fish from the Columbia was determined to be 82 years old. One large female sturgeon from the Columbia River, 12½ ft long, weighed 1,285 lb and contained 125 lb of eggs.

	Age, yr - Average Fork Length, in.							
Location	1	5	10	15	20	25	30	82
Columbia River, Oreg.	11	26	48	64	70	75	92	127
San Pablo Bay, Calif.	21	32	46	57	70	80	95	

Reproduction

Males may mature at 9 years of age and females at 13 to 16 years. Spawning occurs in the Columbia River from May through July when water temperatures are between 48° and 63°F. A 95.5-lb female contained 1.7 million eggs, but larger fish may produce up to 3 million. In California, sturgeon larvae have been captured in the San Joaquin Delta between the middle of April and late May when water temperatures ranged from 57° to 72°F. Larvae shorter than 0.7 in. still had yolk sacs; when the larvae were about 0.9 in. long, they had barbels and an appearance similar to that of the larger fish.

Food

The stomachs of small white sturgeon in California have been found to contain primarily mysid shrimp and amphipods. Larger sturgeon feed on a variety of organisms such as crustaceans (shrimp, crab, isopods, amphipods), annelid worms, mollusks (clams, mussels, snails), and fish (salmon, striped bass, starry flounder, gobies, herring). In the Columbia River, this species has been reported to feed on clams, crayfish, smelt, large suckers, squawfish, sockeye salmon, and adult Pacific lampreys; one stomach even contained a house cat.

Remarks

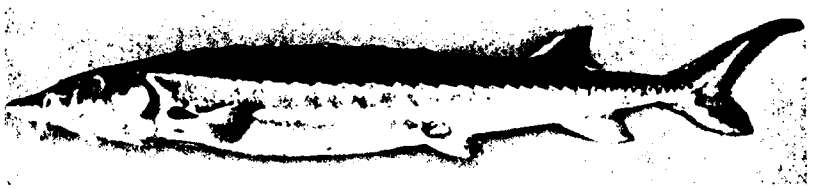
During the 1800s, white sturgeon were in great demand for their caviar and smoked flesh. Today there is less demand for sturgeon, although they are still taken commercially in Washington and Oregon. White sturgeon, occasionally taken in salmon nets, may be kept during the open salmon season. In addition, there is a local commercial fishery specifically for sturgeon in the Grays Harbor and Willapa Bay region of Washington.

Experience has shown that fishing can soon reduce populations of long-lived fishes such as the sturgeon. Regulations that provide protection for sturgeon stocks can be effective. The California Department of Fish and Game noted that their sturgeon stocks were becoming depleted and adjusted their regulations, including total closure, during 1901-54. The regulations since 1954 have provided some protection for the species as shown by a ten-fold increase in the estimated population between 1954 and 1967.

White sturgeon from the Columbia River have been intensively studied by Ivan Donaldson, a former biologist with the US Army Corps of Engineers at the Bonneville Dam, to whom we are indebted for most of the information on that species from the Columbia River.

Source

Wydoski and Whitney (1979).



Green Sturgeon Acipenser medirostris Ayres

Distinguishing Characteristics

The snout of the green sturgeon is long and narrow and has 4 barbels that are equidistant between the mouth and the snout or closer to the mouth. See Distinguishing Characteristics under the white sturgeon for differences between the two species.

Distribution

Along the Pacific coast and its tributaries from Los Angeles to southeastern Alaska; also in Asia (North Japan, Korea, and Sakhalin).

Habits and Habitat

The habits and life history of this species are unknown, but probably similar to those of the white sturgeon. It is much less abundant than the white sturgeon, although it can be locally abundant.

Green sturgeon are found most often in marine waters, but are also taken seasonally in the lower reaches of coastal rivers. For example, this species was captured easily (10-15 per hr) with experimental gillnets in the Yaquina River near Toledo, Oregon, during September 1968. Some specimens have been reported 140 miles inland in the Columbia River. Tagging studies have indicated that green sturgeon move large distances, and, therefore, there may be considerable mixing of populations along the Pacific coast. Of twenty-five green sturgeon tagged in San Pablo Bay, Calif., three were recovered in Oregon waters: one in Winchester Bay along the southern Oregon coast and the other two near the mouth of the Columbia.

Age and Growth

Little is known about the age and growth of the green sturgeon, but they are somewhat smaller than the white sturgeon. The largest green sturgeon reported was 7 ft long and weighed 350 lb. Most green sturgeon landed in

Washington and Oregon are less than 50 lb and probably most that are seen along the North American coast weigh between 50 and 100 lb.

Reproduction

Little is known. Scott and Crossman (1973) reported that green sturgeon are captured in nets during the late summer and early fall in the lower Fraser River, which may indicate a migration into fresh water to spawn in the spring. They also stated that this species is believed to spawn from the middle of June to the middle of July in the Datta River, USSR.

Food

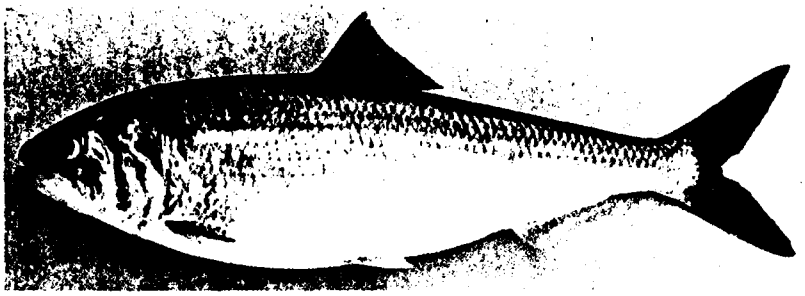
The ventral, protrusible, suckerlike mouth of the green sturgeon is adapted for feeding mainly on the bottom. Like the white sturgeon, this species probably feeds on a variety of invertebrates and fishes while in the Pacific Ocean. Juveniles captured in shallow water (3-8 ft deep) in late June through August in the San Joaquin River, California, had fed mainly on amphipods and mysid shrimp. Other invertebrates are also eaten.

Remarks

The flesh of green sturgeon is believed to be inferior to that of the white sturgeon. In earlier days green sturgeon caught in the Columbia River were either killed or thrown back by commercial fishermen. Now small numbers are taken commercially, primarily from the mouth of the Columbia River and rom Willapa Bay. The sport fishery is apparently negligible in Washington.

Source

Wydoski and Whitney (1979).



American Shad Alosa sapidissima (Wilson)

Distinguishing Characteristics

The American shad is the only member of the herring family that is found in the fresh waters of the Pacific coast. It can easily be distinguished from other fish in the fresh waters of Washington by the sawlike serrated edge along the midline of the belly. A longitudinal row of dark spots (3-23) at the shoulder is concealed by the scales. These spots are very apparent, however, when the fish is handled and the deciduous scales are lost.

Distribution

The American shad was introduced into our waters from its native Atlantic coast. It was first planted in the Sacramento River, California, in 1871, but soon spread to other waters along the Pacific coast, including the Columbia River (1876-77). Later (1885-86), shad were planted into the Columbia River as well. It is generally believed, however, that the original introduction was responsible for the distribution of the shad along the Pacific coast. Today the American shad is found from San Pedro, California, northward to southeastern Alaska. Extremely large runs occur in the Columbia, and shad occur in the lower reaches of the Snake River. Elsewhere in Washington (Chehalis and Willapa rivers), the runs are relatively small.

Habits and Habitat

The shad is an anadromous fish like the salmon and steelhead. Spawning runs occur in many coastal rivers. Ordinarily, juvenile shad spend their first summer of life in the river where they are spawned and move out to sea in the late fall. Shad mature after 3 or 4 years at sea, when they return to their home stream to spawn. Some adults stray into other rivers to spawn, as has been demonstrated by their rapid spread after introduction along the

Pacific coast. Nothing is known about their movements or habits while they are growing in the Pacific Ocean.

Age and Growth

While in fresh water, American shad grow to lengths of 4 to 5 in. by the time they migrate to sea. Mature adults may reach a length of 2½ ft and a weight of 15 lb. The maximum size of adult shad from the Columbia River is about 8 lb. Female shad from the Camas-Washougal fishery on the Columbia range from 17 to 22 in. in length and weigh 3.5 to 5 lb. Male shad from this fishery are 16 to 19.5 in. long and weigh 2.5 to 4 lb.

Reproduction

Male American shad first mature at 3 years of age, and females at 4. Spawning runs occur when the water temperatures of the rivers are near 60° to 65°F. In the Columbia River, these temperatures occur sometime between June and August. Peak spawning occurs before June 25 in Willamette River Slough and between July 20 and August 5 at Bonneville Dam and upstream. The peak varies slightly from year to year, depending upon water temperature and flow. Spawning groups consist of a female accompanied by one to several males. During spawning the adults swim near the surface, often with their backs out of water. A large female may produce up to 300,000 eggs. The small semibouyant eggs are laid in the open water of the rivers, primarily at night, and are carried downstream as they develop. The fry hatch in 7 to 10 days and remain in the river during the first summer of life. Adult survival after spawning varies with the latitude; the further north, the higher the survival rate.

Food

The shad is a plankton feeder. While in fresh water, the juveniles first feed on microscopic animals and later on aquatic insects. While they are at sea, the shad strain small animals such as the mysid shrimp from the sea with their gill rakers. Normally, mature shad do not feed while on their spawning migration. However, this might be due to the absence of food items of the right size, since they readily strike small lures and flies. One feeding fish was taken from Lake Washington, Wash., where freshwater mysid shrimp are abundant.

Remarks

Nobody knows the role of the shad in the ecosystem of Pacific waters, fresh or marine. Do the juveniles use the same food in the river that might

be available for species such as salmon or trout? Do shad compete with other species while they are growing in the ocean?

The shad provides good sport on light tackle. Its mouth is soft and hooks tear loose easily, so the fish must be played gently. Good lures are the shad dart, which is a small 1/8-oz jig, or a gold No. 2 hook with red beads strung above it. Some fishermen claim good success with small spoons and spinners or even wet flies. The flesh of the American shad is rich in flavor, but somewhat bony. Some people consider baked shad a delicacy. However, the shad roe is the most valued part of the fish.

Source

Wydoski and Whitney (1979).

Chinook Salmon Oncorhynchus tshawytscha (Walbaum)

Distinguishing Characteristics

The chinook or king salmon is most often confused with the coho salmon. See the preceding description for distinctions between the two species.

Distribution

The chinook salmon is found along the Pacific coast from the Ventura River in southern California to Point Hope, Alaska. It is also found in northeast Asia, from the Anadyr River south to Hokkaido, Japan. Spawning adults are found in most of the larger streams of the Upper and Lower Columbia River drainage, coastal drainage, and Puget Sound drainage.

Habits and Habitat

Juvenile chinook salmon spend about a year in fresh water before smolting and migrating to the Pacific Ocean. Feeding fish generally remain in the ocean from 3 to 4 years (range, 2-8 years) before they mature and return to their parent streams to spawn.

Columbia River fall chinook salmon move to the north in their seaward migration. The main body of fish shows up in the commercial troll fishery off the Washington coast. Chinook from the Sacramento-San Joaquin River System in California for the most part contribute to the fisheries from the California coast northward to the central Washington coast. Chinook from the coastal streams of Oregon and Washington also migrate northward. Most of the catch (about 75 percent) is off British Columbia and southeastern Alaska.

In the Elk and Sixes rivers along the southern Oregon coast, juvenile fall chinook move downstream out of the spawning areas from March through June. In the intertidal area of the Sixes River, juveniles hold territories during the ebb tide but tend to school during the flood tide. It is believed that this behavior helps to regulate the numbers of juvenile salmon to the

limit of the carrying capacity of the stream. In Idaho, juvenile chinook were observed on the bottom and near the surface in quiet water at night and at all depths during the day. In flowing waters they occupied feeding positions near the bottom, but most fish moved no more than about 18 in. once they took a position.

Age and Growth

This is the largest of the five Pacific salmon species, which explains why it is sometimes referred to as "king salmon." When mature, the chinook salmon averages about 36 in. in length (range, 16-60) and weighs about 22 lb (range, 2½-125).

Reproduction

Length of time spent in the Pacific Ocean varies from 2 to 8 years. Adults begin to ascend coastal streams in late May and early June. The principal spawning months are July through September. Fish from the early run are referred to as spring chinook and spawn in late summer. Fall chinook migrate up the streams in August and September when water temperatures are between 42° and 58°F and spawn as soon as the spawning grounds are reached. Spawning behavior is similar to that of the other salmons (see description under pink salmon). Redd-building behavior and redd development have been summarized in detail for Columbia River chinook salmon by Burner (1951). All adults die after spawning.

Average egg production by a female is 5,000 (range, 2,250-7,750). The eggs hatch in about 2 months, depending on water temperature. The young remain in the gravel 2 to 3 weeks after hatching. Juveniles remain in fresh water from a few days to 3 years. Usually, juvenile fall chinook feed for a short time and then migrate to the ocean, whereas most juvenile spring chinook remain in the stream for one year before migrating. Some individuals may stay in fresh water for longer periods of time before going to sea, especially in systems with lakes, such as the Lake Washington, Wash., system. The young are territorial and aggressive in the stream riffles, but not to the extent characteristic of juvenile coho salmon.

Food

Young chinook salmon feed upon small invertebrates in fresh and salt water. In fresh water the summer food is composed primarily of aquatic insect larvae and terrestrial insects. In salt water they feed on small crustaceans and other bottom forms. In one Oregon study, maturing chinook were found to

feed mostly upon fish (93 percent by weight) such as herring, anchovies, pilchard, sand lance, rockfish, and ratfish. The rest of the food consisted of assorted invertebrates such as crab larvae, euphausids, and shrimp.

Remarks

Overall, chinook salmon are the least abundant of the five species in the Pacific coast states. Nevertheless, this species is rather important to the economy of the United States. Annual commercial landings in 1963-1967 averaged about 315 million lb, with a value of about $68 million. The average annual commercial catch for Washington at that time was about 440,000 fish, while the growing annual sport catch was about 200,000 fish. In 1977 the commercial catch was about 800,000 fish and the sport catch 370,000.

Chinook salmon are most abundant in large streams. As a result they have suffered most from the construction of dams. Hatchery programs are beginning to be successful in increasing the size of the spawning runs.

A chinook salmon population is landlocked in Lake Cushman and completes its entire life cycle in fresh water. Elsewhere they have survived in smaller freshwater lakes but were not able to reproduce. Plants in the Great Lakes, however, have resulted in a large sport fishery.

Source

Wydoski and Whitney (1979).

Rainbow Trout and Steelhead Salmo gairdneri Richardson

Distinguishing Characteristics

Rainbow trout and steelhead (the sea-run form of rainbow trout) lack the red-orange "slash marks" on the underside of the lower jaw and the basilbranchial (hyoid) teeth behind the tongue that are usually present in cutthroat trout. Rainbow trout usually have 11 or 12 (range, 10-13) rays in the dorsal fin, and typically 10 rays in the pelvic fin. The rainbow trout has fewer than 150 scales along the lateral line as compared with 150 to 180 in the cutthroat trout. The name "rainbow" comes from the reddish stripe which is often, but not always, present along the side. Steelhead are uniformly silvery until they darken toward spawning time.

Distribution

The original range of the rainbow trout and the steelhead was from northern Mexico to southeastern Alaska, and inland to the tributaries of the upper Columbia River, to Hell's Canyon Dam on the Snake River and the Clearwater and Salmon rivers in Idaho. Human activities have eliminated the anadromous form south of the San Francisco. In western Washington both forms are present in most drainages of Puget Sound, coastal streams, and the lower Columbia River. East of the Cascade Mountains, they are found in tributaries of the Columbia drainage such as the Entiat, Okanogan, and Yakima rivers, and tributaries of the Snake River such as the Grande Ronde River. The nonmigratory or inland strain of the rainbow trout now is widely distributed in lakes and streams of the Northwest and other parts of the United States that are suitable, thanks to the extensive planting of this popular sport fish.

Habits and Habitat

Rainbow trout prefer cool water, less than 70°F, with plenty of oxygen, although they can survive from 32°F up to 80°F. In lakes where surface waters

warm above 70°F in the summer, trout will move to deeper, cooler water if the oxygen content is sufficient there. The rainbow is tolerant of a wide range of salinities.

Steelhead commence life in streams pure as rain water and after a year or two migrate into sea water. The migratory urge is hereditary. Some stocks have few or no individuals that will migrate to sea.

Age and Growth

The growth of rainbow trout varies greatly, depending upon conditions such as water temperature, water chemistry, and food supply. Water chemistry is affected by the geological characteristics of the area. Growth is slower in western Washington, which has higher rainfall, lower temperature, and less fertile water than eastern Washington, where the rainfall is less, allowing accumulation of nutrients, higher temperatures increasing the activity of fish, and more fertile waters increasing the food supply. Generally, limestone or sandstone in a drainage will produce more fertile trout water than granite or lava. The growth of steelhead increases dramatically when they move into salt water.

Steelhead juveniles begin to migrate to sea when 1 year old (3.1-18.1 percent), but most (72.2-90.9 percent) stay in fresh water for 2 years, and a few (2.0-9.2 percent) stay 3 years. They occupy riffle areas in summer, and pools during the other seasons. Generally they are associated with the stream bottom. Seaward migration depends on such factors as fish size and time of year. In Washington the migratory fish (called smolts) usually move to the sea during April through June, with a peak about mid-April. In Minter Creek, Washington, 91 percent of the migrating fish studies were 5.1 to 7.3 in. in fork length. Somewhere in their range, however, juvenile steelhead will be migrating to sea during each month of the year. The stocking location, time of stocking, and size of hatchery fish all have a bearing on survival of adults. In a California study, age at seaward migration of hatchery-reared juvenile steelhead had a profound effect on the survival of adults. In a California study, age at seaward migration of hatchery-reared juvenile steelhead had a profound effect on the survival to adulthood: age 1 at migration, 2.5 percent survival; age 2, 6 percent; and age 3, 18 percent. Probably the larger wild fish also have better survival rates than the smaller ones.

Location	Age, yr - Average Total Length, in.							
	1	2	3	4	5	6	7	8
Nonanadromous								
Ross Lake, Wash.	4.8	10.5	13.6	15.1	16.0	...	...	...
Tributaries to Ross Lake	5.0	6.4	7.4	7.8	9.2	...	...	...
Chester Morse Lake, Wash.	3.9	7.5	12.1	15.7	17.5	18.5	19.3	20.0
Pyramid Lake, Alberta	2.4	5.3	7.5	9.3	11.6	14.8	17.9	...
Okanogan Lake, British Columbia	4.5	12.0	17.0	22.5	28.0	...	...	...
Snake River, Idaho	5.1	10.3	13.8	18.4	19.2	...	...	...
Fish Lake, Utah	2.9	7.5	12.4	15.4	17.6	...	...	...
Steelhead								
Green River, Wash.	3.5	6.5	8.7	...	...	...	...	...
	...	...	+	18.5	25.7	29.7	...	...
Willamette System, Oreg.								
Streams	3.6	5.7	7.5	12.1	...	...	...	...
Reservoirs	-	8.6	11.4	12.0	...	...	...	...
Salt water	...	...	19.5	27.1	31.0	...	...	...
Waddell Creek, Calif.	-	15.4	(22.7)	...	...	...	...	...
	-	+	25.6	...	...	...	...	...
	-	-	18.4	(24.3)	...	...	...	...
	-	-	+	26.8	...	...	...	...
	-	-	-	21.8	(25.7)	...	...	...
	-	-	-	+	27.4	...	...	...
Vancouver Island, British Columbia	?	5.5	6.3	7.1	...	...	...	...
	...	...	+	26.4	31.5	...	...	...

Notes:

- Fish were in the streams as juveniles.

+ Fish were in salt water.

() Lengths of fish returning to streams for second spawning.

Virtually nothing is known about steelhead migrations or habits in the ocean.

Reproduction

The rainbow trout normally spawns in the spring from February to June, depending on the water temperature and location. There is also a fall spawning stock. The fish mature at age 1 to 5, depending on their growth rate, but most mature at 3. The rainbow needs running water to succeed in spawning. Populations in lakes move into tributaries to spawns. As many of our lakes do not have suitable tributaries, the populations must be maintained by plants from hatcheries. Most adult steelhead ascend spawning streams in December to February (winter run). In some streams there is a smaller summer run in August and September. In large rivers such as the Columbia where they have long distances to migrate, some steelhead probably migrate upstream every month of the year, but the summer run is larger than the winter run in the Columbia.

Spawning by winter-run steelhead occurs in early spring within a month or two after the fish arrive in the home stream. Summer-run fish also spawn in the spring, but are in fresh water for a longer period of time (up to 6 months). Spawning behavior is similar to that of salmon. The female digs a redd, successively digging, spawning, and resting as she moves upstream. The redd covers up to 6½ sq yd of bottom. The eggs are covered with several inches to a foot of gravel. Eggs spawned first are usually covered with the most gravel.

Not all adult rainbow or steelhead die after spawning. Those steelhead that survive usually return to sea in a short time. The number of eggs per female varies from 200 to 9,000 and is dependent on the size of the female and the strain or stock of fish. Certain stocks, such as the Donaldson trout developed by Professor Lauren Donaldson at the University of Washington College of Fisheries, have been selectively bred for numerous generations to produce rapid-growth rainbow that produce large numbers of eggs. One of those females produced more than 27,000 eggs (Ging 1973). Steelhead from the Alsea River, Oregon, produce an average of 3,438 eggs (range, 2,000-5,000) for fish 21.7 to 30.7 in. in fork length. The eggs hatch in bout 50 days when water temperature is 50°F. Although up to 95 percent of the eggs are fertilized, only about 65 to 85 percent survive the embryonic stage. The principal loss of developing eggs is probably due to suffocation by silt. The fry, or alevins,

emerge somewhat later and remain in the peripheral waters of pools until they become large enough to maintain themselves in the current of riffles.

Food

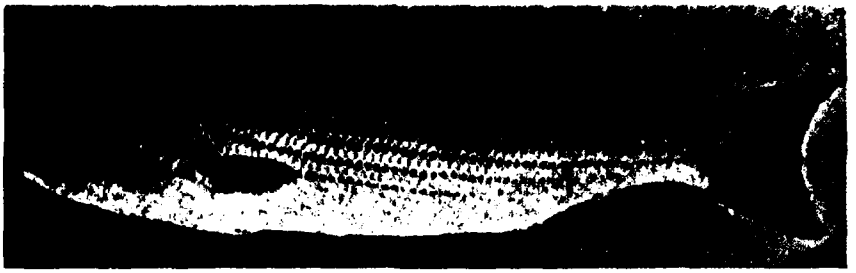
Rainbow trout and juvenile steelhead feed primarily on foods that are associated with the bottom; examples are aquatic insects (Diptera, mayflies, stoneflies, and beetle larvae), amphipods, aquatic worms, and fish eggs. Occasionally they eat small fish. The diet changes seasonally, depending on fluctuations in the availability of food items. In the ocean, steelhead eat crustaceans such as amphipods as well as squid, herring, and other fishes.

Remarks

The steelhead is one of the most highly regarded game fishes in the Northwest as indicated by the State Legislature's designation of it as Washington's state fish. The management program for this species has increased the size of the runs in some rivers. Fisheries for rainbow trout are heavily dependent on hatchery stocking of lakes and to a lesser extent streams. The cost of putting a hatchery-reared rainbow in the creel varies, depending on feed costs and other local conditions. In California streams in 1966, it cost 74 cents to put a trout in the creel by planting fingerlings, and only 24 cents for catchables (Burns 1966). In Washington we believe the situation is the same in streams, but opposite in lakes where there is heavy fishing pressure that produces an annual turnover in the trout population.

Source

Wydoski and Whitney (1979).



Striped Bass Morone saxatilis (Walbaum)

Distinguishing Characteristics

The striped bass has 2 separate dorsal fins, slivery sides with numerous dark longitudinal stripes or lines (hence the common name), and 3 spines in the anal fin. The coloration is the most distinctive characteristic and should readily identify the species.

Distribution

The original range of this species was on the Atlantic coast from the St. Lawrence River, Canada, to the St. Johns River, Florida. It also occurs in streams long the Gulf of Mexico from western Florida to Lake Pontchartrain, Louisiana.

The striped bass was introduced into upper San Francisco Bay in 1879. It extended its range northward to Coos Bay, Oregon, by 1914 and by 1928 had become sufficiently abundant there to support a commercial fishery. The Fish Commission of Oregon included this species in its commercial code in 1931. In 1936 a single specimen was taken in a gill net about 5 miles below Bonneville Dam on the Columbia River. Today the range along the Pacific coast extends from 25 miles south of the Mexican border to Grays Harbor, Washington. Striped bass are plentiful in San Francisco Bay, Calif., and in the Umpqua River, Oreg.

Habits and Habitat

Striped bass remain in small schools of feeding groups during the first year. By the end of the first summer, the fish travel in large schools. During the summer feeding migrations, the large schools occur near the surface in tributaries, estuaries, and the ocean. The fish move into the estuaries and fresh water in the fall and remain there over the winter. It is generally

accepted that subpopulations or races occur in the striped bass. For example, little exchange occurs between the southern race from the San Francisco Bay region and the more northerly race in Coos Bay and the Coquille and Umpqua rivers in Oregon.

Age and Growth

Striped bass may attain a weight of 125 lb and an age of 40 years. The females grow faster and reach an older age than do males. The largest male on record weighed about 40 lb. Growth rate of striped bass in the first 9 years of life appears remarkably similar for fish from the Atlantic and Pacific coasts. Between 1930 and 1957-58, the growth in length for striped bass from California waters increased approximately 10 percent. The growth of established landlocked populations is faster than that of marine populations.

	Age, yr - Average Total Length, in.								
Location	1	2	3	4	5	6	7	8	9
Millerton Lake, Calif.	5.2	11.8	16.8	21.9	26.6	30.4	34.2	...	...
Sacramento-San Joaquin Delta, Calif.	4.1	9.8	15.3	19.6	22.9	25.7	27.9	29.9	32.3
Coos Bay, Oreg.	...	...	14.5	19.0	22.7	25.0	27.3	28.8	30.0
Atlantic coast	4.9	9.3	14.4	17.7	20.9	24.0	27.0	29.5	32.3

Reproduction

Striped bass are reported to spawn from April through June, when the water temperatures are 50° to 73°F. In California, spawning in 1963-64 began when the water temperature was about 58°F, but the peak occurred when the water was at 61° to 69°F.

The fish move far upstream to spawn. In California most spawning occurs 70 to 160 miles upstream from the junction of the Sacramento and San Joaquin rivers. Males mature at 2 or more years of age, and females mature at 4 or more years. A few or many males accompany the female during the spawning act, when they move vigorously through the water with much splashing. The semibuoyant eggs are broadcast loosely into the water and are kept suspended by the currents and eddies as they are carried downstream. A 3-lb female produces about 14,000 eggs, and a 50-lb female about 5 million. The eggs hatch in about 2 days at 64°F, or 3 days at 60°F. The larvae transform into young fish

resembling the adults in 3 to 4 weeks, at which time they have reached the head of tidewater. Juvenile bass continue downstream into the estuaries early in their second summer, when they are about 6 in. long.

Food

Larval striped bass feed on zooplankton and switch to various invertebrates as they grow. In California, juvenile bass feed largely on mysid shrimp (Neomysis) and an amphipod (Corophium), but also eat fishes; as subadults, they feed largely on fishes among which threadfin shad and small striped bass are the most important. Among other fish species eaten are American shad, herring, smelt, carp, and chinook salmon. The diet of adult striped bass is similar to that of subadult fish.

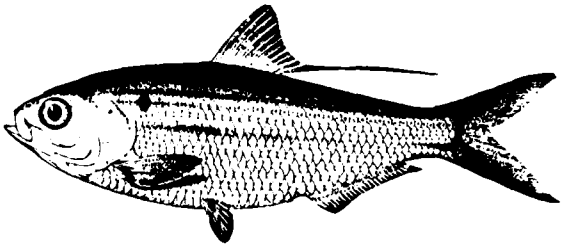
Remarks

The voracious appetite of the striped bass and its excellent fighting ability make it a choice game fish, and its high-quality white flesh makes it excellent for the table. On the Pacific coast, the average annual sport catch is about 3 million fish, of which California accounts for almost two-thirds and Oregon the remainder (very few are taken in Washington). Between 1920 and 1930, up to a million pounds of striped bass were harvested commercially along the Pacific coast. Since the early 1930s, striped bass have been taken only incidentally in the commercial fisheries for other species during April through June; the annual harvest is now 100,000 lb.

Landlocked populations of striped bass have been established in three reservoirs: Santee-Cooper Reservoir, S. C.; Kerr Reservoir, Va.-N. C.; and Millerton Lake, Calif. Although attempts have been made elsewhere, the results were not encouraging. In places where landlocked populations have become established, the catch per angler is low. Because the size of the fish produced in these waters has been large, however, these fish may add a significant quality fishery.

Source

Wydoski and Whitney (1979).



Threadfin shad Dorosoma petenense (Gunther)

Type Locality

Lake Peten, Guatemala (Gunther 1866)

Systematics

Subgenus Signalosa (Nelson and Rothman 1973). Three subspecies of doubtful distinction described: D. p. atchafalayae, D. p. vanhyningi, and D. p. atchafalayae, D. cepedianum (Minckley and Krumholz 1960). Synonymies listed by Miller (1964). Genus Dorosoma in Mem. Sears Found.

Distribution and Habitat

Natural range from Ohio River of Kentucky and southern in west and south to Oklahoma, Texas, and Florida, along coast of Gulf of Mexico to northern Guatemala and Belize (Miller 1964). Widely introduced as forage species, making accurate delineation of natural range difficult. Minckley and Krumholz (1960) discussed recent invasion of Ohio River and summarized early introductions. Habitat similar to D. cepedianum: lakes, ponds, larger rivers, estuaries, and reservoirs. Often in swifter flowing waters (e.g., bases of spillways) than that species. Introduced into California in 1955; subsequently moved north to Yaquina Bay, Oreg. (Krygier et al. 1973) via marine migration.

Adult Size

75-175 mm TL; maximum 220 mm TL (Guatemala), 178 mm TL (United States).

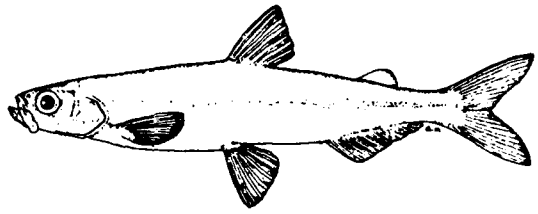
Biology

Popular forage species widely introduced in warm United States waters. Northern distribution limited by low tolerance of cold temperatures, 7-14°C (Hubbs 1951, Pflieger 1975). Spawning may occur at less than a year in open 21°C waters over plants and other objects (Miller 1964). Johnson (1970),

reported on reproduction, growth, and population dynamics. Feeds on plankton. Length-weight relationships summarized in Carlander (1969). Hoffman (1967) listed parasites.

Source

Lee et al. (1980).



Delta smelt Hypomesus transpacificus McAllister

Type Locality

Lower Joaquin River between Three Mile Slough and False River, Calif. (McAllister 1963).

Systematics

Closely related to H. olidus. McAllister (1963) divided H. transpacificus into H. t. transpacificus of California and H. t. nipponensis of Japan. Klyukanov (1975) considered the two to be distinct species.

Distribution and Habitat

Hypomesus t. transpacificus is confined to Sacramento-San Joaquin Delta region in larger channels where water is fresh to brackish. Hypomesus t. nipponensis has been successfully introduced into a number of California reservoirs.

Adult Size

55-70 mm SL, 120 mm SL maximum.

Biology

Apparently lives only one year and dies after spawning. Mildwater feeder on copepods and opossum shrimp. Neomysis. Life history summarized in Moyle (1976).

Source

Lee et al. (1980).

Three-Spine Stickleback Gasterosteus aculeatus Linnaeus

Distinguishing Characteristics

This species is easily identified by prominent and separated spines in the dorsal fin (the third spine at the front edge of the soft dorsal fin is much smaller than the other two), pelvic fins modified into prominent spines, and sides without scales but with few to many bony plates. The freshwater form has fewer lateral plates than the marine form.

Distribution

One of the most widespread fishes in the world, the three-spine stickleback is found in North America, Europe, and Asia. In North America it is found in the Pacific Ocean and coastal waters from Baja California to St. Lawrence Island, Alaska, and in the Atlantic Ocean and coastal waters from Chesapeake Bay northward to the Hudson Bay region, including the Lake Ontario basin.

Habits and Habitat

This species is found in marine and freshwater habitats. The marine form has many lateral plates and lives primarily in shallow bays and estuaries, but some populations are found over deep water. In the marine environment the stickleback is primarily pelagic. It has been found up to five hundred miles from land in the Gulf of Alaska. The freshwater populations are usually close to the bottom in streams and lakes, often closely associated with aquatic vegetation. Large schools of sticklebacks are a common sight, except during the spring breeding season when males are territorial. Breeding males have a strong homing instinct and return to their nest if captured and displaced from the site.

Age and Growth

Freshwater sticklebacks may live to a maximum of 3 years. Their life span varies in different waters. In Alaska they live for 2 to 3 years, whereas in Washington it appears that about 90 percent of the fish live only 1 year and the rest for a second year. The fish apparently die shortly after breeding. In Karluk Lake, Alaska, sticklebacks were reported to have the following average fork lengths (inches) at different ages: young of the year, 1.5; age 1, 2.2; age 2, 2.1; age 3, 2.4; and age 4,3.0.

Reproduction

Freshwater forms spawn from May through July and sometimes into August. Marine forms usually enter fresh water to spawn in early June. The male builds a nest of algae and debris that is stuck together with a glue-like fluid from its kidneys. The nests are built in vegetation and on the bottom. Courtship behavior is very elaborate. When a female enters the territory of a male, he courts her with a zigzag dance. The female responds with a head-up sign of acceptance. The male then entices the female to the nest by pointing at the entrance and turning on his side. Once the female has entered, the male prods her at the base of the tail, stimulating her into laying her eggs. The female leaves the nest after spawning, and the male enters and fertilizes the eggs. The male follows this same behavior with several females and collects several clutches of eggs. He then guards the nest and aerates the eggs by fanning them with his large pectoral fins. Females from freshwater populations produce 100 to 150 eggs each and those from marine populations produce 250 to 350 eggs. The eggs hatch in about 7 days, at about 64°F. The male continues to guard the young for a short time until the school disperses. Males may then build another nest and repeat the cycle. Most three-spine sticklebacks die shortly after spawning, but some age 1 fish may survive.

Food

Consists largely of zooplankton and aquatic insect larvae. Sticklebacks collected from the pelagic zone contain primarily zooplankton such as copepods, cladocerans, and ostracods, and those from the benthic zone contain primarily bottom organisms such as aquatic insect larvae (e.g., stoneflies, midges, and caddisflies), snails, terrestrial insects, and small worms. During the breeding season, males guarding nests steal and eat the eggs of other males near their territory. In addition, schooling sticklebacks (those that

have not matured) divert the attention of nesting males and eat all the eggs.

Remarks

Three-spine sticklebacks are small and are good prey for piscivorous fishes. Coastal cutthroat trout feed to a large extent on sticklebacks in marine and fresh waters. In Wapato Lake, Washington, sticklebacks have come to be of great scientific interest because of work suggesting that the behavior of certain groups may be closely related to environmental characteristics. The number of bony lateral plates varies among freshwater populations and this trait appears to be inherited. Somehow it is linked to behavior patterns that affect the vulnerability of sticklebacks to predation by fish. The result is that sticklebacks with certain plate counts are much more abundant where predatory fishes are found, and those with other plate counts are more abundant in lakes where predatory fishes are absent.

Source

Wydoski and Whitney (1979).

3.5.9.2.2 Selected References

3.5.9.2.2.1 From the Source Wydoski and Whitney (1979)

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CONTENTS

3.5.9.3 Species Summaries

3.5.9.3.1 Benthic Macroinvertebrates and Zooplankton

Phylum: Annelida

Neanthes succinea Frey and Leuckart 1847

Habitat: Sandy mud to muddy sediments of bays (Smith and Carlton 1980).

Feeding: Filtering, discretely motile, jawed and pumping (Coull 1978).

Life Cycle: Reproductive behavior is epitoky (posterior sexual part develops from the anterior sexless part) or heteronereids (Gosner 1971).

Streblospio benedicti Webster 1879.

Habitat: Mudflats of estuaries and tributaries (Smith and Carlton 1980).

Feeding: Surface deposit feeding, discretely motile, tentaculate (Coull 1978).

Life Cycle:

Polydora uncata

Habitat: Subtidal or mudflats of estuaries and bays or sandflats and sandy mud sediments of bays (Smith and Carlton 1980).

Feeding: Surface deposit feeding sessile, tentaculate (Coull 1978).

Life Cycle:

Phylum: Arthropoda

Corophium spinicore Stimpson, 1857 (Shoemaker 1949)

Habitat: Tube builder attaching to debris on mud bottom (Smith and Carlton 1980).

Feeding: Filter feeder; strains fine detritus through filter setae on the gnathopods, the feeding current being provided by the pleopeds (Barnes 1980).

Life Cycle:

Protis californica

Habitat:

Feeding:

Life Cycle:

Pontharpinia obtusidens

Habitat:

Feeding:

Life Cycle:

Corophium acherusicum Costa, 1857 (Shoemaker 1949).

Habitat: Tube builder attaching to debris on mud bottom and tube builder attaching tube to algae, especially on harbor pilings; introduced (Smith and Carlton 1980).

Feeding: Filter feeder; strains fine detritus through filter setae on the gnathopods, the feeding current being provided by the pleopods. (Barnes 1980).

Life Cycle:

Synidotea laticauda Benedict, 1897.

Habitat: San Francisco Bay only; on hydroids, fouled pilings, etc. (Smith and Carlton 1980).

Feeding:

Life Cycle:

Corophium insidiosum Crawford, 1937. (Shoemaker 1949).

Habitat: Tube builder attaching to debris on mud bottom, estuaries, harbor pilings, introduced (Smith and Carlton 1980).

Feeding: Filter feeder; strains fine detritus through filter setae on the gnathopods, the feeding current being provided by the pleopods (Barnes 1980).

Life Cycle:

Acartia clausi Giesbrecht

Habitat: A calanoid copepod found most frequently in bank water and bank water mixed with coastal water (Brenning and Fadschild 1979). A psychrophilic species. (Moraitou-Apostolopoulou and Verriopoulos, 1980).

Feeding: Filter-feeding which is a behavioral process under sensory control. These copepods are able to distinguish between enriched and nonenriched food particles (Poulet and Marsot 1978). Also herbivorous (White 1979).

Life Cycle: Eggs are subcutaneous. Unfavorable environmental conditions such as low temperature, low O_2 concentration and darkness can inhibit these eggs from hatching within the natural sea bottom mud (Uye 1980). Undergoes a molting pattern termed isochronal development (Miller et al. 1977).

Eurytemora affinis

Habitat: A calanoid copepod characterized as being part of the littoral zooplankton of the estuarine (Roddie et al., 1984).

Feeding: A filter-feeding omnivore that possesses effective filtering mechanisms for small-sized particles (Schnack 1981). Feeds on the green alga Namochloris sp. (Barthel 1983) and planktonic bacteria (Boak and Goulder 1983).

Life Cycle: Resting eggs and nauplii (Johnson 1979). Females are dimorphic; some have "wings" and others do not. Possibly shared a common ancestry with the marine genus Temora (Heron and Damkaer 1976).

Neomysis awatschensis (Brandt)

Habitat: A mysid shrimp commonly encountered in marine, brackish, and fresh waters (Smith and Carlton 1980).

Feeding: Filter feeders and scavengers (Smith and Carlton 1980).

Life Cycle: The sexes are externally dimorphic and separate. The female has rudimentary abdominal appendages and 2 or 3 pairs of oostegites forming a brood pouch (Gosner 1971).

Phylum: Mollusca

Corbicula fluminea Muller

Habitat: Widely encountered on bay and ocean beaches as discarded fish bait. Abundant in freshwater canals and irrigation channels, and large aggregations have locally clogged canal systems and water pipes. Also attach to substrate by cementation or abyssus (Smith and Carlton 1980).

Feeding: Shallow to deep burrowing or free-living in faunal burrowers or nestlers or epifaunal (Smith and Carlton 1980).

Life Cycle: Involves hermaphroditic reproduction. Incubation of fertilized eggs done in specialized marsupial areas of the exhalant bronchial cavity of the inner demibranches. Benthic juveniles sometimes called a pedivelinger (Sinclair and Isom 1966).

Macoma inconspicua

Habitat: In silt to sand of bays uncommon. (Smith and Carlton 1980).

Feeding: Deposit feeding (Barnes 1980). Very deep burrower when tide is not in, body moves backward and forward as they dig so the cutting action of the shell can assist in burrowing (Walls 1982).

Life Cycle:

Mya arenaria Linnaeus, 1758.

Habitat: Soft-shelled or long-necked clam; found in mud and sand of bays, burrowing to 30 cm. deep; introduced from the Atlantic coast (MacNeil 1965).

Feeding: Thin-shelled burrowers with well-developed siphons, with one or no cardinal teeth (Barnes 1980).

Life Cycle:

Petricola pholadiformis Lamarck, 1818.

Habitat: Burrowing in mud; introduced from Atlantic coast (Smith and Carlton 1980). Intertidal. Borer of soft rock and shales. The tunneling habit arose from a nestling mode of life. They have the ability to enlarge the crevice they inhabit (Barnes 1980).

Feeding: Rock borer (Barnes 1980).

Life Cycle:

3.5.9.3.2 References

3.5.9.3.2.1 Literature Cited

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3.6 Summary of Natural Resource Evaluation

The wetland at NWS Concord is a complex mosaic of five community types dominated by Salicornia, Distichlis, Scirpus, Juncus, and Typha. The distribution of vegetation types has been influenced by frequency and duration of inundation, soil salinity, mosquito ditches, and overflow from an Allied Chemical waste lagoon. The overflow from the waste lagoon resulted in slightly higher elevations and death and stunted growth of certain plant species near the lagoon dike. The number and diversity of soil invertebrates in the wetland were significantly reduced in the overflow impacted area near the waste lagoon dike when compared to the reference area 7,000 ft to the west of the impacted area. Wetlands on the NWS Concord are highly valuable for several hydrologic and water quality functions. The wetlands provide important shoreline anchoring and sediment trapping function, both of which result in reduced discharge of suspended solids that may damage the fishery in Suisun Bay. The wetland is very effective in retaining nutrients (primarily nitrogen and phosphorus) particularly over the long term. The wetland provides only moderate value for most fish species because of limited deep water habitats. The wildlife habitat evaluation indicated that the grassland portion of the study area and certain locations within the study wetland are of high value as wildlife habitat, particularly for rare and endangered species. These areas will continue to attract and expose wildlife species to toxic metal contamination.

4.0 PUBLIC HEALTH AND ENVIRONMENTAL CONCERNS

This section reports the evaluation of the types and degrees of potential hazards to public health, welfare, or the environment that may result from the release of hazardous substances from a facility. CERCLA Section 101(a) defines facility as "(b) any site or area where a hazardous substance has been deposited, stored, disposed of, or placed, or otherwise come to be located." Pollutant or contaminant is defined in CERCLA Section 104(a)(2) as "any element, substance, compound or mixture...which after release into the environment and upon exposure, ingestion, inhalation, or assimilation into any organism either directly from the environment or indirectly by ingestion through food chains, will or may reasonably be anticipated to cause death, disease, behavioral abnormalities, cancer, genetic mutation, physiological malfunctions (including malfunctions in reproduction) or physical deformation, in such organisms or their offspring."

The factors that describe the extent of the impacts of a release or a potential release of a hazardous substance will be evaluated in this section. In addition, the hazardous substances present at NWS Concord, the concentrations found, the migration potentials of the hazardous substances in various environmental media, and their threat to the environment and public health will be evaluated. The factors to be discussed in this evaluation are:

4.1 Contaminants found at the site

4.2 Factors affecting migration

4.3 Environmental fate of contaminants

4.4 Exposure and toxicological evaluation

4.5 Importance of contaminated areas to Suisun Bay ecosystem

Reference will be made to various sections of this remedial investigation where specific data and information have already been presented and discussed.

4.1 Contaminants Found at the Site

Soil sample analyses (Sections 2.1.2.1 and 2.2.1) indicated that many of the metals were found to be present in concentrations in excess of values found in remote reference sites or in concentrations statistically greater than surrounding sample sites or in excess of soil concentrations established for the maximum allowable sewage sludge application (MASSA). Arsenic,

cadmium, lead, selenium, zinc, and copper were found in soil concentrations in excess of the criteria described above. The frequency and location of these metal concentrations in soil sample sites have been shown in Figures 2-3 to 2-8 and Figures 2-59 to 2-64.

4.2 Factors Affecting Migration

Pathways for migration of contaminants have been shown in Figure 1-3 and include migration from soil to ground water, surface water, or the atmosphere; migration from ground water to surface water or surface water to ground water; erosion of soil; migration from surface water to the atmosphere; tracking by humans or animals; and uptake by plants and animals. Of these pathways, the primary concerns for contaminant migration at NWS Concord are migration from soil to surface water during erosion of soil, soil to the atmosphere as dust, tracking by humans or animals, and uptake by plants and animals.

4.2.1 Soil to Surface Water

The hydrologic evaluation (Section 2.2.6) indicated that contaminants adsorbed to soil in Nichols Creek adjacent to C+P/ESI can migrate during rainfall runoff and erosion of soil downstream into K-2 and through a culvert into KS. In addition, contaminated soil from barren areas in AA, AB, KS, and K-2 can migrate during rainfall runoff into drainage ditches or further downstream in the K-2 area. Tidal gauge data and historical tide data indicated that tidal inundation will enhance further migration of contaminated soil through the wetland drainage ditches toward the canal and ultimately into Suisun Bay. In addition, contaminated soil on the surface of wetland areas will be remobilized during tidal scouring and especially by wave action during extreme high tides.

4.2.2 Soil to the Atmosphere

Wind erosion of contaminated soil has been described in Section 2.2.6.6.5 and does occur on barren areas in the KS area on parcel 572 and has potential to occur on barren areas in AA, AB, and K-2 areas. Data on air sampling and chemical analysis are not available; however, the potential for wind erosion

of fine-textured contaminated soil from barren areas in a high energy wind environment such as that described in Section 2.2.6.6.5 at NWS Concord is high enough to warrant consideration of corrective action.

4.2.3 Tracking by Humans and Animals

Soil data indicated contaminants were predominantly located at the soil surface of the contaminated areas at NWS Concord and will be accessible to humans and animals walking over the site. Consequently, contaminants adsorbed to shoes, clothes, and animal feet and skin will be tracked and dispersed across the site and potentially off site. In addition, foot traffic on the barren contaminated surface soil during dry periods will produce dust which can be inhaled by the human or animal walking over the soil. This migration requires consideration of corrective action.

4.2.4 Uptake of Plants and Animals

The biological test results in Sections 2.1.2 and 2.2.2 through 2.2.4 indicate that certain contaminants can migrate into plants and animals at certain sample sites. The fact that plants and animals took up contaminants indicates migration of these contaminants into the environment and especially into the food chains associated with NWS Concord. Bioassay plants accumulated Cd, Zn, and Cu under flooded wet soil conditions, and these same metals plus Pb and Se under the drier upland soil conditions. Bioassay clams accumulated Pb and Cd in a few specific areas. Earthworms accumulated As, Cd, Pb, Se, and Cu in specific contaminated areas on NWS Concord. This migration has long-range impacts on food chains and the wildlife that are associated with NWS Concord.

4.3 Environmental Fate of Contaminants

The potential for contaminants at NWS Concord to migrate and adversely impact human health or the environment is dependent upon the environmental fate of each substance. The fate of a contaminant in the environment is a function of the behavior of the contaminant under conditions associated with natural surroundings. Environmental fate is usually described in terms of a

contaminant's mobility and persistence. Mobility is a measure of the degree that a contaminant will move in the environment subject to natural transport processes. Persistence is a measure of the time required for a contaminant to react and degrade via natural processes operating under local environmental conditions.

4.3.1 Mobility of Contaminants

Mobility of contaminants can occur by (1) the contaminant adsorbing to soil particles and being transported along with the soil particle in surface runoff, (2) the contaminant becoming soluble and dissolving in water, or (3) the contaminant being absorbed into a plant or animal from the soil.

Soil analysis data indicated the distribution of contaminants at NWS Concord resulting from the mobility of contaminants by soil particle transport in surface runoff. Figures 2-59 through 2-65 graphically show the location of the accumulation of contaminants.

The clam bioassay data indicated the locations of mobility of contaminants as soluble forms. Metals such as Zn, Cd, Pb, Cu, and Ni are less mobile under wet or flooded soil environments because of the formation of insoluble compounds such as sulfides and insoluble organic complexes. Few specific sample sites in K-2 and G-1 were observed (Figures 2-66 through 2-68). These data suggest a low solubility of metals appeared to be occurring at the time of the clam bioassay test.

Plant and earthworm bioassay tests were used to indicate the potential mobility of contaminants from soil into plants and soil invertebrates. Test results did show a high potential for certain contaminants such as As, Pb, Cd, and Se to be absorbed and accumulated in plants and earthworms at certain sample sites (Figures 2-69 through 2-79). Mobility of Zn, Cd, and Pb is generally observed more under drier upland soil conditions than under flooded wet soil conditions.

4.3.2 Persistence of Contaminants

The metals observed at NWS Concord are very persistent in the environment. Past discharges of As, Pb, Cd, Se, Cu, Zn, and Ni on NWS Concord properties are still present and observed in the soil analysis. Each of these

contaminants readily adsorbs to soil particles and forms insoluble compounds under wetland conditions that are subject to transport during soil or wind erosion and will persist for many years. Biological effects from these contaminants can be chronic and will occur slowly over a long period of time.

4.4 Exposure and Toxicological Evaluation

4.4.1 Introduction

An investigation of heavy metal contamination on and adjacent to Parcels 571, 572, 573, 574, 575, 576, 579D, and 581 on the NWS Concord has revealed elevated concentrations of heavy metals in the area including arsenic (As), cadmium (Cd), lead (Pb), selenium (Se), zinc (Zn), copper (Cu), and nickel (Ni). Field evaluation and plant and animal bioassay data indicate that these heavy metals are mobile and are probably entering the food chain. Of particular interest from a toxicological perspective are the relatively more toxic heavy metals (i.e., As, Cd, Pb) and the potential impact of these metals on wildlife and especially endangered or rare species of birds and mammals that occupy NWS Concord. The potential impact of Se at NWS Concord is of critical concern because of its widespread toxic effects on wildlife at the Kesterson National Wildlife Refuge in the San Joaquin Valley (U.S.D.I. 1984). Movement of all of these metals into the food chain is important from an environmental perspective.

The contaminated area at NWS Concord provides both terrestrial and aquatic (freshwater and salt marsh) habitats (Parcels 571 and 572 have been designated as part of a Wetland Preserve in a Memorandum of Understanding between the Navy and U.S. Fish & Wildlife Service executed 1 Feb., 1984) for a variety of plant and animal species (Appendix 3-A), some of which are rare or endangered. Such species include the salt marsh harvest mouse (Reithrodontomys raviventris halicoetes) and the California black rail (Laterallus jamaicensis conturniculus), which are confirmed as inhabiting the contaminated site and are, therefore, exposed to the on-site heavy metal contamination. The California least tern (Sterna antillarum browni) has been identified in the area of NWS Concord and seen on the adjacent Allied Chemical Corporation Bay Point Works dike. The giant garter snake (Thamnophis couchii gigas) and salt marsh yellowthroat (Geothlypis trichas Sinuosa) are likely present at NWS Concord.

The California clapper rail (Rallus longirostris obsoletus) inhabits the larger Suisun Bay ecosystem and could periodically utilize the contaminated sites. Also seen in the area, although rarely, are bald eagles (Haliaeetus leucocephalus). The Suisun shrew (Sorex sinuosus) could possibly be found at NWS Concord.

The salt marsh harvest mouse, California least tern, California clapper rail, and bald eagle are all listed as endangered by the U.S. Fish & Wildlife Service, U.S. Dept. of the Interior. The Suisun shrew, California black rail, and salt marsh yellowthroat are candidates for listing by the U.S. Fish & Wildlife Service as endangered. The giant garter snake is listed as rare by the California Department of Fish & Game as is the California black rail. Therefore, two federally listed endangered species (i.e., salt marsh harvest mouse and California least tern) and one state listed rare species (i.e. California black rail) are known to exist on or immediately adjacent to the contaminated site. In addition, more than 100 other species of birds, mammals, reptiles, and amphibians are known to occupy the salt marsh, grassland, and freshwater marsh habitats of NWS Concord. These species can be subject to exposure to elevated concentrations of toxic metals.

Toxic heavy metals are known to cause damage or death in individuals and probably impact populations of wildlife including both mammalian (Luckey and Venugopal 1976) and avian species (Bellrose 1959, Anderson 1975, Kendall and Scanlon 1979, Kendall 1980, Kendall and Scanlon 1981a, Kendall and Scanlon 1982, Kendall and Scanlon 1985). Such metals have entered the food chain at NWS Concord. Food-chain contamination with toxic heavy metals poses a health hazard to many species of birds and mammals and other wildlife. A toxicological evaluation is necessary to determine the risk to the health of wildlife being exposed to toxic heavy metals, particularly those species which are listed as rare or endangered.

Wildlife toxicology, which develops and uses ecological and related acute and chronic toxicological information concerning the organism(s) being studied, will be used to quantify the risk to wildlife health and safety. Wildlife toxicology may be defined as the study of the effects of environmental toxins, such as heavy metals, on wildlife species, as related to their well-being behavior, general health, and reproduction (Kendall 1982).

A state of well-being implies, for instance, that there is no substantial increase in the probability of being preyed upon. A state of good general

health means that the organism(s) can maintain homeostasis (relatively stable physiological conditions) and, therefore, can survive in a variety of environmental situations. Since the reproductive process in birds and mammals is often very sensitive to the influence of chemical contaminants such as heavy metals in the environment, it will be accorded careful consideration (Kendall 1982).

The term "wildlife" usually pertains to vertebrate animals living in a natural, undomesticated state, although there are no clear taxonomic guidelines for defining the word. Here, emphasis will be on those species of wildlife, particularly birds and mammals which are rare or endangered or from which social or economic benefits, in terms of hunting and fishing, sources of food, nature photography, or aesthetic pleasures, may be derived. This emphasis is in line with the concept that the most often mentioned species of wildlife are those that provide benefits (or detriments) to human society. This is not meant to say, however, that other species are not equally important components of the ecosystem (Kendall 1982).

The metals Pb, Cd, Se, and As, in that order, will be individually discussed in the context of contamination at NWS Concord. Multi-element exposure will be considered. These contamination levels will then be put into perspective as related to potential impacts on wildlife at NWS Concord based on the current toxicological literature. Zinc and copper concentrations are also highly elevated at NWS Concord, but for the purpose of the present discussion the toxicological significance of these metals to wildlife are not considered as great as other metals in the area. The emphasis will be placed on the relatively more hazardous metals Pb and Cd, and also on Se and As. All metal data from NWS Concord are reported on a dry-weight basis unless otherwise noted. For purposes of discussion, micrograms per gram is equivalent to milligrams per kilogram.

4.4.2 Analysis of Lead Contamination

Soil analyses of Pb in contaminated areas (i.e. the KS area on Parcel 572, the K-2 area on Parcel 573 and 574, the G-1 area on Parcel 575, the ES area on Parcel 579D, and the CP area on Parcel 581) showed levels up to 7000 mg/kg (Figure 2-5). Eight areas indicated Pb values in excess (Table 2-2) of the MASSA limits (511 mg/kg). These sites should be restricted

from agricultural land use. Lead contamination at these sites could pose a hazard in regard to food-chain contamination in wildlife. These sites could pose a hazard to humans from inhalation of lead-contaminated dust in employees at the Allied Chemical Corporation Bay Point works site or to personnel that enter the hazardous substance contaminated area. Background levels of lead for cropland soils are 11 mg/kg. Bioaccumulation data (Table 2-10) indicated certain lead-contaminated sites in the K-2 area on Parcels 573 and 574 and the KS on Parcel 572 have earthworms with average tissue Pb concentrations of 34.7 mg/kg (minimum = 0.3 and maximum = 224.6) and 10.7 mg/kg (minimum = 2.3 and maximum = 23.6), respectively. These levels were considerably higher than the average Pb concentration of 1.7 mg/kg in earthworms in the more remote reference areas. Site G-1 on Parcel 575 averaged 12.3 mg/kg Pb in earthworms while sites ES on Parcel 579D and CP on Parcel 581 showed average levels of 11 and 12.1 mg/kg earthworm Pb, respectively. It should be noted, however, that maximum values of Pb in earthworms were excessive and were 85.2, 80.5 and 76.7 mg/kg in earthworms from sites G-1, ES, and CP, respectively.

A regression analysis ($r = 0.64$) of earthworm tissue Pb on soil Pb indicated an important relationship: soil concentrations of Pb, when elevated, would result in increased lead in earthworm tissue (Figure 2-83). The acute toxic effect of lead does not appear to be a critical factor for earthworms at NWS Concord. Therefore, earthworms will survive in lead-contaminated soil but will bioaccumulate Pb allowing for an enhanced potential for lead to be passed up into the food chain. It should be noted, however, that a macroinvertebrate community study (i.e., in site AA on Parcel 572) did reveal decreased species diversity and abundance in the contaminated versus remote reference sites. The study demonstrated that invertebrate species were so impacted on site that the food resource base in the area could be greatly reduced.

The total plant uptake of Pb by Typha ranged from below 1 mg to in excess of 55 mg of Pb (Figure 2-27). Lead content of field-collected Typha tissue ranged from below 1 mg/kg to an excess of 54 mg/kg (Figure 2-19). Earthworm tissue Pb also regressed ($r = 0.72$) well on Typha Pb (Figure 2-86). The sites where plant Pb (Figure 2-43) was elevated were at CP on Parcel 581 (approximately 60 $\mu g/g$) and KS on Parcel 572 (approximately 25 mg/kg) where the soil concentration of Pb was over 4,000 mg/kg. These data are consistent with data reported by Hess and Blanchar (1976, 1977) showing that in soil situations where metal contents are elevated, it is possible that chemical forms of

soluble Pb can easily become available for plant absorption. Lead (Figure 2-12) has been identified as moving into the surface waters of the stream in the KS area on Parcel 572 and the G-1 area on Parcel 575 as measured by clam bioassay. Clam tissue indicated levels of lead in the KS area on Parcel 572 and the G-1 area of Parcel 575 of up to approximately 9 mg/kg. The remote reference sites indicated Pb concentrations in clam tissue of approximately 1.0 mg/kg and below. These data indicate that there is a potential for lead to be mobile in surface waters in certain areas and to contaminate aquatic food chains as well as terrestrial food chains.

4.4.3 Toxicological Evaluation of Lead Contamination

4.4.3.1 Background

Considerable information is available noting that elevated concentrations of Pb in the soil have resulted in increased Pb concentrations in the tissues of rodents which exist in those habitats. This suggests that the salt marsh harvest mouse and related rodent species at NWS Concord (Table 3-A2) may become contaminated with Pb. Scanlon et al. (1983) have shown that pine voles (Microtus pinetorium) had elevated Pb concentrations in their carcasses when trapped from Virginia orchards with a history of use of Pb arsenate. Pine voles are a herbivorous species low in the food chain, probably not too dissimilar from the herbivorous nature of the salt marsh harvest mouse. Adult pine voles that were collected from abandoned orchards had total mean body Pb (µg/g) concentrations of 40.67 (±3.48 S.E.) µg/g as compared to an average of 19.50 (±2.7, S.E.) in juveniles. Elevated levels of body Pb, when concentrated in field voles (Microtus agrestis) in Wales (average 42.8 - 45.3 µg/g, wet weight (w.w.), body Pb) resulted in lead-induced renal inclusions and renal edema indicating kidney disease (as reported in Clark 1979).

Scanlon (1979) reported on Pb concentrations (µg/g, dry weight (d.w.)) in small mammals and on Pb concentrations in soils (µg/g, d.w.) from roadside areas which ranged from 19.9 to 109.7 µg/g. Soil from control areas had a mean Pb content of 7.8 µg/g. Short-tailed shrew (Blarina brevicauda) trapped from Pb contaminated habitats of roadsides had mean body Pb concentrations up to 34.8 (±9.5, S.E.) µg/g, d.w. The short-tailed shrew is a carnivorous

species consuming a great deal of earthworms in their diet. Even the white-footed mouse (Peromyscus leucopus), predominantly a herbivorous species, averaged 15.6 (±1.2, S.E.) µg/g, d.w., body Pb when trapped from roadside environments. Their body Pb was reduced to about 5.0 - 7.6 µg/g in control areas away from highway traffic. In any case, carnivorous species appear to heavily bioaccumulate Pb when living in Pb-contaminated areas by eating such food resources as earthworms. As determined in the present NWS Concord evaluation, earthworms can have high concentrations of Pb in their tissues. This suggests that any species of mammal (i.e., the Ornate shrew or Suisun shrew) consuming a substantial portion of earthworms or other soft-bodied soil invertebrate in its diet would heavily bioconcentrate Pb. In addition, even herbivorous species such as pine voles and white-footed mice living in Pb-contaminated areas will bioaccumulate Pb from such habitats. Therefore, this strongly suggests that the salt marsh harvest mouse would bioaccumulate Pb from living in Pb-contaminated zones which, in fact, contain up to 7,000 µg/g soil Pb in some areas at NWS Concord. Getz et al. (1977) have also shown Pb concentrations were higher in small mammals living in areas that contain Pb-contaminated roadside environments. They substantiated that even herbiborous species such as Peromyscus contained significantly higher concentrations of body Pb in more contaminated lead habitats than in background areas. Considerable evidence is available to predict the bioaccumulation of Pb in salt marsh harvest mice in the contaminated areas of NWS Concord.

The salt marsh harvest mouse is a species restricted to the salt and brackish water marshes adjoining San Francisco Bay and its tributaries (Shellhammer 1982). Fisler (1965) has reported that salt marsh harvest mice eat primarily green vegetation in addition to seeds. They are capable of drinking salt water, brackish water, and fresh water. Therefore, in the contaminated habitats of NWS Concord, there is a possibility of exposure to Pb primarily through ingestion of contaminated vegetation and also potentially through ingestion by drinking Pb-contaminated water. Exposure to elevated concentrations of Pb can be toxic to the hematopoetic, excretory, and nervous systems of animals (Goyer and Rhyne 1973). Ingested Pb is of particular significance as a chelating agent on serum enzyme systems (Luckey and Venugopal 1976). In the heme pathway, delta-aminolevulinic acid dehydratase (ALAD) is extremely sensitive to Pb. Mouw et al. (1975) found significant decreases in ALAD enzyme activity in urban rats (Rattus norvegicus) with blood Pb concentrations

of 0.4 - 1.0 µg/g. Lead has been demonstrated to be extremely deleterious to heme biosynthesis (the oxygen-carrying component of red blood cells) in rats and in humans (Chisholm 1971).

Mouw et al. (1975) found that urban rats (N = 17) with elevated renal Pb, greater than 15 µg/g, w.w., had intranuclear inclusions in kidney cells. In addition, excess kidney weight was identified relating kidney disease. Lead is very toxic to kidney structure and function in mammalian systems (Luckey and Venugopal 1976). Cells of the proximal convoluted tubules are most severely affected including the formation of intranuclear inclusion bodies of tubular lining cells and functional as well as ultrastructural changes in mitochondria. These symptoms are manifested by aminociduria (excess amino acids in urine), glycosuria (urinary excretion of carbohydrates), and hyperphosphaturia (excess excretion of phosphates in urine) (Goyer and Rhyne 1973).

4.4.3.2 Lead and the Salt Marsh Harvest Mouse

To evaluate potential Pb exposure and hazard to salt marsh harvest mice, a preliminary risk analysis is required. Limited data are available on the ecology of the salt marsh harvest mouse. The salt marsh harvest mouse will eat about a third of its body weight per day of seeds, fruits, and greens. This species has a small home range of approximately 0.4 hectares (1 acre) (Caras 1967). The weight of the salt marsh harvest mouse has been reported to be from 7.6 to 14.5 g with an estimated average weight of 11.05 g. Therefore, harvest mice would be expected to eat approximately 3.64 g (w.w) of food per day. As an example of a Pb-contaminated food resource, field-collected Typha tissue at NWS Concord had in excess of 54 µg/g (d.w.) Pb concentration in some areas. This would be equivalent to approximately 5.4 µg/g, w.w. (assuming plants are 90 percent water, C. R. Lee 1985, personal communication). Other native vegetation in these areas can potentially contain lead at these contents or more. If similar contaminated vegetation (perhaps up to 54 µg/g lead concentrations) was consumed then harvest mice would ingest 19.29 µg lead/day. Thus, the daily exposure of salt marsh harvest mice to lead alone in the contaminated areas could be upwards of 1.75 µg lead/g body weight.

White-footed mice (Peromyscus leucopus) that were collected adjacent to the Baltimore-Washington parkway averaged 4.91 µg/g (w.w.) total body burden of Pb (white-footed mice eat approximately 4.29 g (w.w.) food per day which

translated to about a 2.1 µg/g Pb exposure rate) (Clark 1979). These values are similar to the potential exposure patterns to Pb in salt marsh harvest mice. Odenbro and Kihlstrom (1977, as reported in Clark 1979) reported that laboratory mice that received from 1.5 - 3.0 µg/g Pb exposure experienced reproductive impairment.

In rodents collected near a metalliferous mine site in Wales, renal edema occurred in field mice (Apodemus sylvaticus) that averaged 8.6 µg/g (w.w.) total body burden of Pb. Levels of exposure of 2.4 to 9.0 µg/g Pb in horses, cattle, sheep, and dogs have resulted in fatalities, reproductive impairment, convulsive seizures, and anorexia (reported in Clark 1979). The exposure is further complicated on the NWS Concord site by virtue of the fact that not only Pb but Cd and other heavy metals are present. Such metals can be both ingested and probably inhaled via contaminated dust. Der et al. (1976) have reported exposure of only 25 µg Pb plus 25 µg Cd per day for 70 days in 300-g rats (0.176 µg/g for both Pb and Cd together via intraperitoneal injection) resulted in cessation of spermatogenesis in the seminiferous tubules. The potential ramifications to salt marsh harvest mice of multi-element exposure is an important consideration at NWS Concord. In any case, considerable evidence exists that relate the fact that salt marsh harvest mice living in Pb-contaminated zones will most likely have elevated Pb concentrations in their tissues which could place them at risk for developing aberrations in blood tissue and renal lesions and even reproductive impairment. Other animals such as the Ornate shrew (Sorex ornatus), the Suisun shrew, and California vole (Microtus californicus) will probably be bioaccumulating significant quantities of Pb and probably other heavy metals and contribute these metals to food web contamination, particularly in the upper predators in the food chain such as the black-shouldered kite (Elanus caeruleus), red-tailed hawk (Buteo jamaicensis), and others.

4.4.3.3 Lead and the California Black Rail

Extensive evidence also exists showing that Pb exposure in avian species can result in disease, particularly in the kidneys and cardiovascular system (Kendall and Scanlon 1981a, Kendall and Scanlon 1982, Kendall et al. 1983). Of particular interest at NWS Concord is the presence of rare avian species, such as the California black rail which is known to occupy the site. There is

evidence to show that avian species occupying Pb contaminated sites will have elevated Pb concentrations in their bodies (Siegfried et al. 1972, Kendall and Scanlon 1979). Available evidence strongly suggests that Pb exposure in black rails could be of toxicological importance.

The black rail is a secretive small bird with a total adult length of approximately 12.7 to 15.2 cm (Todd 1977). These birds probably weigh no more than 100 to 120 grams (Page 1985, personal communication). To consider potential risk of Pb exposure to black rails, potential food consumption levels must be evaluated. The average daily food consumption by adult bobwhite quail (Colinus virginianus) is 15.0 g (approximately 8 percent of their body weight) (Kendall 1985, personal communication). Kenaga (1973) also reported bobwhites to consume 8.8 percent of their body weight per day in seeds and grains. Such data are consistent with Pasquier (1977) noting that land birds weighing 100 to 1,000 grams will eat material equaling 5 to 9 percent of their own body weight per day. Therefore, one would speculate that, on the average, 8 percent of a black rail's body weight of food would be ingested per day for a bird that probably weighs no more than 110 g (birds at the lower range of body weight, such as 100 g, tend to ingest food at a greater percentage of their body weight). Kenaga (1973) reported that Dunlin (Erolia alpina) weighing 114 g ingest 8.9 g of food per day (8.5 percent of body weight)--close to the 8 percent value generated for black rails. Eight percent of 110 g is 8.8 g, which should be close to the daily food-ingestion rate in black rails. The birds, as noted in Wilbur and Tomlinson (1976), are omnivorous and show food preference predominantly for invertebrates such as horse mussels, clams, and shore crabs and insects, but also eat Spartina seeds. Their foraging for food includes carnivorous strategies, but also herbivorous strategies. At NWS Concord, earthworms were shown to bioaccumulate significant quantities of Pb in their tissue and averaged 34.7 µg/g in site K-2 on Parcels 573 and 574. The maximum concentration of Pb in earthworm tissue reached 224.6 µg/g. In any case, earthworms and other soil invertebrates are probably concentrating substantial quantities of Pb which will contribute to Pb exposure in black rails and other species which eat invertebrate organisms at NWS Concord (i.e., American bittern, California least tern, black-shouldered kite, and American kestrel). Taking the average Pb tissue content of 34.7 µg/g (d.w.) in earthworms (with approximately 77 percent water, and with a weight of approximately 2 g) in site K2 on Parcels 573 and 574 would convert to 7.98 µg/g, w.w. and

would mean 15.96 µg Pb would be ingested by a bird, for instance, eating an earthworm. If a black rail were to consume 8.8 g of earthworms or other similarly Pb-contaminated invertebrates per day, this would mean that approximately 70.22 µg of Pb could be ingested during a daily period of the black rail. A daily exposure pattern of Pb in black rails of approximately 0.64 µg/g body weight would be indicated (black rails would be exposed to Pb at 4.13 µg Pb/g body weight if they ingested earthworms with reported higher concentrations of Pb of 224.6 µg/g, d.w. (or 51.7 µg/g, w.w.). Edens et al. (1976) found a significant drop in egg production by Japanese quail (Coturnix coturnix japonica) in treatment groups of 10 µg/g dietary Pb daily (female Coturnix average 240 g and consume 18 g food/day, 7.5 percent body weight; Ringer 1985, personal communication). Assuming dry and fresh weight of dietary mash rations are similar, this will mean 0.75 µg Pb exposure/gram body weight. Also, it was noted that lower body weight trends were evidenced in lead-dosed Japanese quail.

Lead can probably be ingested by wildlife in the water at NWS Concord although fresh surface water data for lead are not available. Ringed turtle doves (Streptopelia risoria) that ingested Pb in the water at the rate of 100 µg/ml tended to have lower spermatozoan counts in the seminiferous tubules than controls related to potential impacts on reproduction (Kendall and Scanlon 1981b). Evidence does exist that Pb exposure can disturb reproductive processes in birds (Kendall 1980). As was mentioned earlier, in a report by Der et al. (1976), the interaction of Pb and Cd can even further affect reproductive processes in rats and probably in birds as well. Such interactive exposures would be occurring at NWS Concord due to multi-element contamination in the area.

Kendall and Scanlon (1981b) reported on Pb contamination in ringed turtle doves receiving 0 to 100 µg/ml Pb in their drinking water for 2 weeks prior to pairing and throughout the breeding cycle. Body burdens of Pb increased in doves with associated reductions in testes weights and spermatozoan numbers. Progeny of Pb-treated parents had higher concentrations of Pb in their bodies than control birds. Juvenile birds that receive Pb-contaminated food from their parents can readily build up Pb concentrations in rapidly developing bodies (Kendall and Scanlon 1981b). Such data are important to evaluate in that black rails could be breeding in the contaminated area.

In addition to impacts on the reproductive process, Pb exposure in avian species can result in damage to renal tissue. Ringed turtle doves that ingested Pb acetate in their drinking water for 90 days at the rate of 100 µg/ml exhibited kidneys with ultrastructural aberrations. These birds had Pb intranuclear inclusion bodies and deterioration of tubular cells in kidneys along with apparent reduction of mitochondrial numbers in the tubular cells (Kendall and Scanlon 1981). Mourning doves (Zenaida macroura) that had elevated Pb exposure in the form of lead shot ingestion exhibited severe kidney and liver pathology (Kendall et al. 1983). Of particular interest is the fact that Pb ingestion under conditions of cold exposure (i.e., a stressful condition) resulted in significantly enhanced mortality in ringed turtle doves compared to birds that ingested Pb and were maintained at normal temperature (Kendall and Scanlon 1985). These results strongly suggest an enhanced degree of risk for black rails being exposed to Pb and living in the wild at the same time being subjected to a variety of environmental stresses (i.e. temperature, level of nutrition, and reproduction).

As in mammals, birds appear to be quite sensitive to Pb exposure in the form of deleterious effects in blood delta-ALAD activity and other blood characteristics (i.e., hemoglobin). Kendall and Scanlon (1982) reported that rock doves (Columba livia) taken from urban areas had significant depressions in ALAD enzyme activity associated with increased body burdens of Pb (particularly the concentration of Pb in the liver). One would speculate that birds and mammals occupying urban habitats have no higher and probably a lesser degree of Pb exposure than to what currently exists in some areas at NWS Concord (upwards of 7,000 µg/g in the soil). As has been addressed in the present discussion, toxic effects of Pb are often seen in animals inhabiting Pb-contaminated environments. From a quantitative level, an elevated amount of Pb exposure in both mammalian and avian species probably exist at NWS Concord, enough to be resulting in toxicological lesions. The ultimate response at the population level cannot be evaluated with data available for populations of wildlife on site. The evidence suggests that at the individual level the potential exists for enhanced stress to individuals to be manifested in, for instance, impaired reproductive performance. Many of the studies on the toxicology of Pb exposure which have produced this evidence have been completed only in the laboratory. In the field, additional stressors other than Pb exposure, including nutritional, climatic and reproductive stress, could enhance

the toxic effects of Pb. Also, there are multi-element exposure situations which can probably modify and often increase the hazard to animals existing in those environments.

4.4.4 Analysis of Cadmium Contamination

Soil Cd ranged from near detectable limits to more than 80 mg/kg (Figure 2-4). The remote reference areas, sites BK, had the lowest soil Cd, generally about 0.2 mg/kg, considered to be a median background concentration for agricultural soils (Table 2-2). Sites KS on Parcel 572, K-2 on Parcels 573 and 574, G-1 on Parcel 575, ES on Parcel 579D, CP on Parcel 581, and AA on Parcel 572 had elevated levels of Cd which exceeded MASSA limits (i.e. 2.7 mg/kg) for Cd on agricultural cropland (Table 2-2). These data indicate these sites would be restricted against agricultural land use. Cadmium concentrations in earthworm tissue averaged 30.7 mg/kg (maximum = 53.7 and minimum = 9.0) and 13.6 mg/kg (maximum = 29.4 and minimum = 0.8 mg/kg) in the KS area on Parcel 572 and the CP area on Parcel 581, respectively. The KS area had the highest soil concentration of Cd and likewise had earthworms with the highest tissue Cd levels. A regression analysis ($r = 0.38$) indicated that log earthworm tissue Cd tended to increase as the log of the level of soil Cd increased (Figure 2-81). The remote reference sites had earthworms with tissue Cd averaging 5.0 mg/kg (Table 2-10).

The greenhouse upland plant analysis also indicated that cadmium had the capacity to move into plant tissue in excess of an established critical content of 8 mg/kg (Figure 2-42) and observations of plant Cd exceeded levels (15 mg/kg) that would result in a 10-percent plant-yield reduction. Cadmium ranged up to 28 mg/kg from the CP area on Parcel 581 in the upland plant bioassay. From the KS area on Parcel 572, values ranged in excess of 40 mg/kg. These data indicate that a high potential for substantial movement of Cd from upland soil into plants is underway. Earthworm tissue Cd regressed ($r = 0.77$) on greenhouse plant tissue (Figure 2-88) revealed a strong relationship indicating definite bioavailability of Cd in soils at NWS Concord and high potential for movement into the food chain.

A greenhouse flooded soil plant analysis showed that Cd in plant tissue ranged in excess of 7 mg/kg from site K-2 on Parcel 574 (Fig. 2-35). The field-collected Typha tissue indicated as much as 1.6 mg/kg Cd from site

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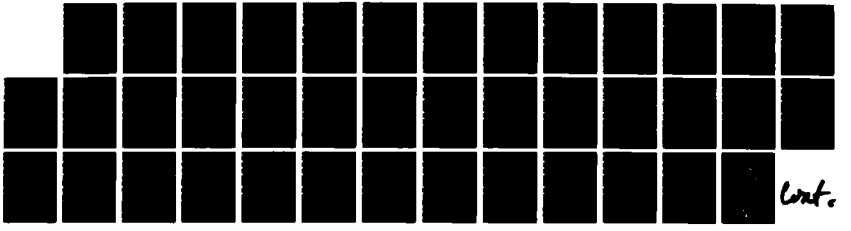
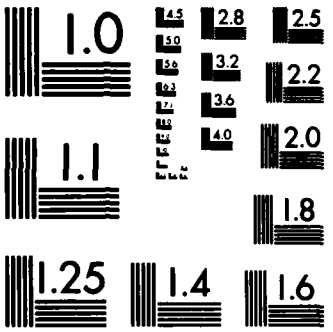




area on Parcel 574 (Figure 2-18). The AA area on Parcel 572 the G-1 area on Parcel 575, and the K-2 area on Parcels 573 and 574 also contain elevated concentrations of 1 mg/kg or more of Cd in Typha tissue. The total plant uptake of Cd by Typha exceeded 1.5 mg in the K-2 area on Parcels 573 and 574 (Figure 2-26). Movement of Cd into aquatic habitats was demonstrated by the clam bioassay with Corbicula fluminea. Cadmium on site exhibited mobility into animals in aquatic areas. Clam tissue Cd contents were elevated above 1.2 mg/kg at the G-1 area on Parcel 575 and the AA area on Parcel 572. Clam tissue analyses indicated a maximum of 2.7 mg/kg Cd in clams from the AA site on Parcel 572. Cadmium concentrations generally ranged below 1.0 mg/kg in clam tissue from remote reference sites BK. These data indicate a potential exists for Cd to be mobile in surface waters in certain areas and contaminate aquatic food chains as well as terrestrial food chains.

4.4.5 Toxicological Evaluation of Cadmium Contamination

4.4.5.1 Background

In the vicinity of a primary Pb/Zn smelter at Avonmouth, England, Cd concentrations were elevated in soil, vegetation, and animals. Martin and Coughtrey (1976) reported concentrations of Cd in the topsoil of 42 µg/g from a contaminated area and 2 µg/g Cd in a relatively unpolluted control area. The remote reference sites, sites BK, had soil Cd concentrations at approximately 0.2 µg/g considered to be median background concentrations (Table 2.2 and 2B-1) whereas more contaminated areas at NWS Concord (i.e. site KS on Parcel 572) had Cd concentrations in excess of 80 µg/g. In England, various species of slugs and earthworms greatly bioaccumulated Cd from contaminated zones with earthworms containing an average of five times the concentration of Cd in the contaminated area versus the control area (Martin and Coughtry 1976). At NWS Concord, an average background level of Cd in earthworms was 5 µg/g, approximately six times below the average in earthworms at the contaminated area (30.7 µg/g, area KS). Martin and Coughtrey (1976) reported on two specimens of sparrow hawks (Accipiter nisus) collected from a contaminated and a rural area. These predacious birds ingest a great deal of invertebrate material in their diet. The right kidney of the sparrow hawk collected from the contaminated area contained in excess of 66.6 µg/g Cd, as compared to 3.7 µg/g from

the right kidney of the sparrow hawk collected from the more remote area. Such buildup of Cd in the tissues of both avian and mammalian species is not unusual because chronic storage of Cd in vivo is encouraged by the presence of the Cd-binding protein, metallothionein. Metallothinonein binds cadmium in the liver and kidney, and Cd in the metallothionein pool turns over very slowly. Metallothioneins have also been found in other tissue (Kagi and Vallee 1961). Martin and Coughtrey (1976) showed ranges of Cd concentrations in living plant material from 6 to 25 µg/g; in herbivores such as wood lice, slugs, and snails from 29 to 171 µg/g; and in a carnivore (thrush Turdus philomelos) kidney of 387 µg/g. These data indicate strong tendencies for food chain bioaccumulation that has been demonstrated at NWS Concord by both plant and earthworm bioassay data. Earthworms showed a strong tendency to bioaccumulate Cd, exhibiting an average of 30.7 µg/g tissue Cd from site KS on Parcel 572. The greenhouse upland plant analysis also showed that Cd had the capacity to move into plant tissue ranging up to 28.8 µg/g (site CP on Parcel 581) whereas sites KS on Parcel 572 had plant bioassay values in excess of 40 µg/g. It is clear from studies, such as reported by Martin and Coughtrey (1976), that strong evidence exists that there is substantial partitioning of Cd into living tissue as one moves up the food chain. Consequently, there is strong probability that many birds and mammals would be receiving significant exposure to Cd via food-chain contamination at NWS Concord.

The upland plant bioassay tissue indicated in excess of 40 ug/g Cd from site KS on Parcel 572 as discussed above. Salt marsh harvest mice would be expected to consume approximately 3.64 grams, w.w., of food per day (assume plants are 90 percent water, C. R. Lee 1985, personal communication). Thus, if the animal were consuming plant tissue contaminated with 20 to 40 µg/g, d.w., Cd in either upland or area adjacent to wetland areas such as KS on Parcel 572 at NWS Concord, the contribution to Cd exposure in harvest mice would be substantial. A potential exposure of 40 µg/g d.w. (4.0 µg/g, w.w.) in plant tissue would represent a potential ingestion of approximately 14.56 µg Cd which could be ingested per day per harvest mouse. This would indicate an approximate daily exposure of 1.3 µg Cd/g body weight in the mouse. Cadmium, once ingested, can cause extensive amount of damage in the vertebrate system. In addition, this heavy metal is extremely persistent over time. Cadmium damages the liver, kidney, ovary, testes, intestine, lung, heart, and bone. Cadmium causes renal dysfunction (Itokawa et al. 1978, Lauwerys et al. 1979,

Kazantzis 1979, Bonner et al. 1980, Nogawa et al. 1980), interferes with absorption and utilization of essential trace elements (Weber and Reid 1974, Hamilton and Valberg 1974, Hamilton and Smith 1978, Petering et al. 1979, Chertok et al. 1981), inhibits enzymes (Johnson and Walker 1970, Kench and Gubb 19701, Sugawara and Sugawara 1975, Schnell 1978, Dresner et al. 1982), interferes with the immune system (Koller et al. 1975, Nelson et al. 1982), induces tumors (Guthrie 1964), causes hypertension (Perry et al. 1979, Kopp et al. 1982), disrupts spermatogenesis (Parizek 1957, Fowler et al. 1982), and damages nerve fibers (Gabbiani et al. 1967, Weiss 1978).

4.4.5.2 Cadmium and the Salt Marsh Harvest Mouse

Gale (1979) reported on the toxic effects of Cd in the developing hamster embryo. Cadmium was injected into hamsters on the eighth gestation day, and these animals were sacrificed on the fifteenth day of gestation. Pregnant hamsters that received Cd injections at a dose of 2 μg/g had eye and brain defects in young. Also observed was a 27-percent rate of external defects as compared to controls of the defects included abnormal tails, edema, cleft lips, and limb defects. This discussion demonstrates that ingestion of Cd by the salt marsh harvest mouse during its breeding period may result in defects. Although injection of Cd certainly could increase the rapidity in allowing access of Cd to the sensitive embryo, ingestion still can result in significant Cd loading. This is accentuated by the fact that multi-element exposure between Pb and Cd can have even more pronounced toxicological effects on reproduction as has been discussed earlier (Der et al. 1976).

4.4.5.3 Cadmium and the California Black Rail

Cadmium can affect embryogenesis and cause teratological effects in avian systems as well (King et al. 1978). King et al. (1978) have reported that Cd acetate injected into eggs of white leghorn chickens, at the rate of 0.03 mg/egg, caused a 30.9-percent abnormality rate in surviving embryos. The most common malformations occurred in the liver and the cardiovascular system with edema totaling over a 90-percent response rate. Embryolethality, embryotoxicity, and congenital abnormalities have all been reported in avian embryos associated with Cd exposure. Dietary exposure to Cd does not usually

result in significant quantities of Cd being passed into the egg in the avian system. However, it does appear that during Cd exposure (40 µg/g dietary) sufficient quantities of Cd can be passed to the egg and be toxic to the embryo (Yancey 1983). One would be quite suspect of Cd contamination occurring at NWS Concord, particularly in those species of birds consuming invertebrates in the area. Such species would probably include the California black rail. White and Finley (1978a) have demonstrated that Cd concentrations in the diet of birds lead to elevated concentrations of Cd in vivo particularly in the liver and kidney. Of particular importance here is the fact that with exposure to Cd via the diet in birds, exposed birds will accumulate this metal in their tissues over time. Such was the case with mallard ducks (Anas platyrhynchos) fed Cd in their diets (White and Finley 1978b). White and Finley (1978b) showed that pathological changes in the kidney and testes were highly related to the concentration of Cd in the diet and the duration of exposure. Animals receiving Cd in their diet at 200 µg/g had a very high incidence of kidney lesions and testicular necrosis. Even at exposure levels as low as 20 µg/g, some changes in the testes and kidney pathology were noted.

The effect of Cd or Pb in surface waters on obligate aquatic food chains most likely would be limited to the lower trophic levels (plankton, filter-feeders). However, there is no substantial evidence for either Cd or Pb biomagnification in water-breathing animals (Kay 1984). The potential impact of Cd or Pb entering aquatic food chains is restricted to air-breathing animals (mammals, birds, etc.) which feed on invertebrates such as clams, which have been shown to bioconcentrate these metals in certain sample sites in G-1 and ES areas of NWS Concord.

4.4.6 Analysis of Selenium Contamination

Soil analyses indicated elevated concentrations of up to approximately 140 mg/kg Se at the CP site on Parcel 581. Selenium concentrations were elevated in bioassays with upland plants and earthworms at the CP site on Parcel 581. Significant bioaccumulation was indicated in earthworms. Earthworm bioassays showed an average level of 23.9 mg/kg (maximum = 91.3 and minimum 3.3) Se in the tissue of earthworms from the CP site on Parcel 581 (Table 2-10). This is substantially above the average level of 0.4 mg/kg in the remote reference areas, sites BK. Also, in the upland plant bioassay on

the CP site on Parcel 581, Se concentrations in the plant tissue exceeded 11 mg/kg (Figure 2-45). Earthworm tissue concentration of Se regressed ($r = 0.72$) on greenhouse plant tissue Se indicating a strong correlation (Figure 2-89) and that bioavailability of Se from the soil is quite apparent. There is a strong relationship between soil Se and earthworm tissue. A regression analysis ($r = 0.86$) of earthworm tissue Se on soil Se concentrations indicated bioavailability of Se from the soil into earthworms (Figure 2-84). These data strongly suggest that the presence of Se in the soil at NWS Concord is a problem because it can be transferred into both earthworms and plants and subsequently be transported into the food chain. Evaluation of Figure 2-13 indicates that the Se does not appear to be moving into the aquatic ecosystem by virtue of the similar values of Se concentration in clam tissue from the various aquatic areas at NWS Concord. However, in the upland ecosystems in the CP area of Parcel 581, the soil is contaminated with Se and the potential for a significant amount of bioaccumulation exist.

4.4.7 Toxicological Evaluation of Selenium Contamination

A synthesis of the information on Se contamination at NWS Concord, particularly at the CP site on Parcel 581, indicates elevated concentrations of Se with movement of this metal into the food chain. Selenium has gained a great deal of attention in the western states due to the widespread toxic effects of Se currently being encountered at the Kesterson National Wildlife Refuge in the San Joaquin Valley of California (U.S.D.I. 1984). Selenium is considered an essential element. Diets deficient in Se cause liver necrosis in rats and multiple organ necrosis in mice. In birds, Se deficiencies can include muscle myopathies (Hammon and Belisles 1980). However, as represented by wildlife poisoning from Se in the Kesterson area, elevated exposure to Se can result in severe toxicoses. Although the mechanism(s) of the toxic effects of Se is not well understood, it appears that Se may have the ability to interchange with sulfur in certain tissues, particularly in the nails and hooves of animals. In addition, Se as selenate may have an effect on many sulfhydryl enzymes (Hammond and Belisles 1980).

The addition of sodium selenite in the diet of chickens was toxic in terms of the hatchability of fertile eggs at exposure to 5 μg/g of Se. Additional experiments revealed that diets containing 7 and 9 μg/g of Se resulted

in decreases in egg weights and hatchability (Ort and Latshaw 1978). This is consistent with the supposition by Lakin (1973) that Se in concentrations of 4 μg/g or more in the diet is toxic to animals. In a historical perspective, in the 1930s, certain soils in the western plains in the United States were found to produce vegetation, including wheat, that was toxic to animals because of the Se content of the crops. Selenium is required in the diet of animals at a minimum level of 0.04 μg/g and is beneficial at 2.1 μg/g. At levels above 4 μg/g, it becomes toxic to animals. Accumulation of Se in biological systems may be illustrated by Se content of marine fishmeal which is approximately 2 μg/g being 50,000-fold higher than the Se content of seawater (Lakin 1973). As evidenced at NWS Concord, Se is mobile (being accumulated in earthworms and plant tissues). Extensive consumption of plant tissue containing up to 11 μg/g Se content could be hazardous to some species of animals that occupy habitats associated with the CP area on Parcel 581 (e.g., shrews, mice, hawks, owls, etc.). In addition, extensive foraging on earthworms showing a Se concentration of 23.9 μg/g in their tissue could also contribute heavily to Se exposure and the toxic effects of Se in the CP area on Parcel 581.

Although there is a limited amount of information, apparently the major portion of Se in plants is present in an organic form, selenomethionine (Allaway et al. 1967 as reported in Osman and Latshaw 1976). Selenium in natural food sources occurs in organic forms (seleno amino acids) rather than as a mineral. Most dietary intake occurs from the ingestion of plant foods although some fish and certain seafoods contain high levels of Se. Organic Se compounds such as selenomethinonine can be directly incorporated into the tissues and accumulate to fairly high levels (Scott 1973). It has been reported that the half-life of Se in mammalian systems is fairly short, probably from 1 to 2 days (Weissman et al. 1983). However, young mammals may have enhanced sensitivity to the Se due to increased retention of Se in their body tissues as compared to adults. In any case, relatively speaking to Cd and Pb, Se is not as persistent in mammalian or avian tissues.

Animals consuming forage bearing 5 to 10 μg/g Se for long periods of time can develop selenosis. Chronic Se poisoning, as probably would be the case at NWS Concord, if poisoning occurred, is seen in three forms: (1) blind staggers (caused by water soluble organic Se compounds); (2) alkali disease (caused by ingestion of plants in which Se is bound into proteins and is

relatively insoluble in water); and (3) chronic selenosis (produced experimentally with selenate or selenite.

Several Se derivatives have been injected into 4-day-old chick embryos for teratological evaluation. Teratological effects have been produced, especially with the injection of sodium selenite or selenomethionein. Common deformities included under development of the beak, abnormal development of the feet and legs, fusing or webbing of the two outside toes, and in extreme cases the foot was fused into one large toe (Palmer et al. 1973). Similar deformities have been observed at the Kesterson area in American coots (Fulica americana), which have had nests containing deformed young in a substantial percentage of the population (Ohlendorf 1984; Hoffman 1984, personal communication; and U.S.D.I. 1984).

The biological testing of Se (bioassay results) at NWS Concord indicates that potential exposure of avian species and resulting teratogenic effects of Se ingestion in breeding birds raises serious concern. Severe teratological effects in birds exposed to Se have been observed at the Kesterson National Wildlife Refuge in California (U.S.D.I. 1984).

4.4.8 Analysis of Arsenic Contamination

Arsenic was detected in concentrations up to 2,500 mg/kg on the AA area on Parcel 572 at NWS Concord (Figure 2-3). Other contaminated sites included the AB area on Parcel 572, the G-1 area on Parcel 575, the K-2 area on Parcel 574, the KS area on Parcel 572, and the CP area on Parcel 581 with elevated concentrations compared to remote reference sites (BK). Earthworm bioassay analyses indicated that, even though this As was adsorbed to the soil, it had a capacity to move into earthworm tissue. A regression analysis ($r = 0.76$) of the natural log of earthworm tissue of As on the natural log of soil As indicated a strong relationship (Figure 2-80) between the increase in that as soil content of As and the increase in earthworm tissue content of As. Arsenic concentrations in tissues of earthworms from sites AA and AB on Parcel 572, the two most contaminated sites, averaged 36.3 mg/kg (minimum = 0.9 and maximum = 150.6) and 49.2 mg/kg (minimum = 22.3 and maximum = 121.3), respectively (Table 2-10). These As levels in earthworms were substantially higher than the 3.5 mg/kg average (minimum = 0.9 and maximum = 9.9) at remote reference sites BK.

Plant tissue analyses for As indicated that field-collected Typha ranged up to approximately 1.4 mg/kg (Figure 2-17). Total uptake of As by Typha ranged from below 0.25 and up to approximately 1.5 mg (Figure 2-25). The greenhouse flooded soil plant analysis indicated that As accumulated up to 27 mg/kg in plant bioassays from the AA site on Parcel 572 (Figure 2-34). In the greenhouse upland soil plant analysis As was shown to accumulate to only 1.5 mg/kg at the CP area on Parcel 581 (Figure 2-41). These plant data indicate that little As is taken up in plants in the upland site but in the aquatic areas uptake of As is much greater. This is consistent with data from Folsom et al. (1981) showing that As was much more available under flooded soil redox conditions being reduced than under oxidized soil redox conditions. Overall, these data indicate movement of As into plants occupying relatively wet habitats and in soil-dwelling organisms in contaminated areas. Also, high plant and earthworm toxicity was observed in the AA area on Parcel 572 (Figures 2-69 and 2-75, respectively). Plant and earthworm bioassays illustrate significant bioaccumulation and potential for significant exposure to As in many species of animals in the food web.

4.4.9 Toxicological Evaluation of Arsenic

Arsenic exists not generally as a free element but more generally in various oxidation states. Arsenic is widely distributed in the earth's crust and exists mostly in the pentavalent form in soil while that added to the environment is often in the trivalent form (Hammond and Belisles 1980). Compounds of As may be absorbed after ingestion or by inhalation. Generally speaking, trivalent As compounds are more toxic to mammals than pentavalent compounds. Arsenic forms tend to be rapidly excreted by the kidneys of mammals and probably do not accumulate. However, arsenites bind to tissue proteins and are concentrated in the leukocytes. Accumulation has been observed in the body primarily in the liver, muscle, hair, nails, and skin perhaps because of the availability of sulfhydryl groups for binding. Excretion occurs through urine and in feces via the bile (Hammond and Belisles 1980). Data from NWS Concord indicate that As has the capacity to move into the food chain, particularly into earthworm species and into plants grown in wetland conditions. These data strongly support the potential exposure to As in a number of avian and mammalian species occupying the area. Although data from NWS Concord do not

indicate the various species of As present in the soil, up to 2,500 mg/kg total As probably would have significant quantities of various species (i.e. trivalent forms) known to be toxic to both wildlife and humans. Once ingested, As at the biochemical level, particularly in the trivalent form, can interfere directly with enzyme action. Arsenic/sulfur bonding can occur in enzymes with two groups that are important often times in enzyme functioning. Webb (1966) reported on 78 different enzyme systems from a number of species of animals that are inhibited by trivalent As at concentrations between 0.1 and 10.0 micromolar. Particularly sensitive were those oxidative enzyme systems such as pyruvate oxidase, delta amino acid oxidase, liver choline oxidase, and glucose oxidase. Therefore, As can be associated with toxic effects to energy metabolism in cells.

It appears that inorganic arsenicals in both the trivalent and pentavalent state can act as mutagenic substances causing chromosomal aberrations, and point mutations. Decreases in DNA synthesis and DNA repair have also been reported (Rossman et al. 1977). There is little doubt, at least from a clinical point of view, that exposures to As compounds can result in tumor development (Casarett 1975). This is probably associated with the ability of As to introduce chromosomal aberrations or point mutations. Cancers which have resulted from exposure to As usually involve the skin, ethmoid bone structure, and the lung. In human occupations which involve the inhalation of As, there are clearly both potential acute and chronic effects including cancer (Vallee et al. 1960). Chronic exposure of avian and mammalian wildlife populations to As at NWS Concord could result in tumor formation. One should also be concerned about the development of tumors in humans (i.e., at Allied Chemical) in those individuals that could be exposed to As in the area. As has been earlier noted, soil concentrations in the AA area of Parcel 572 had As concentrations up to 2,500 µg/g. Although the AA area might be expected to receive limited human utilization, therefore limited exposure to As, if some activities did require persons to be in that area frequently, substantial exposure could occur. Dust from exposed areas would increase potential for cancer in humans and other organisms. Arsenic is a well-documented tumorogenic agent; in addition, it can also act as a teratogenic poison in mice and in birds. Hood and Bishop (1972) showed that intraperitoneal injections of As salts in mice resulted in fetal deaths, resorption, and short jaws among the fetuses. Arsenates are thought to be reduced in vivo to arsenites, and it is the

trivalent form which is thought to be most active. A dose of 25 µg/g sodium arsenate caused no effect but a level of 10 µg/g sodium arsenite was noted to cause embryotoxicity and teratogenic effects in mice (Hood and Bishop 1972). A dose level of 45 µg/g sodium arsenate did result in significant increases in fetal anomalies, resorptions or deaths in mice. It has been reported that, in the early developmental stages of the chick embryo, As 3^+ has a higher lethal effect whereas a higher teratongenic effect is seen with As 5^+ (Peterkova and Puzanova 1976). Arsenic does not have the bioaccumulative potential which Pb and Cd have at NWS Concord; however, it can pose a threat to breeding birds and mammals, particularly in regards to reproductive disturbances. This threat raises serious concern for endangered and rare species at NWS Concord.

4.4.10 Summary of Toxicological Evaluation

Toxicological evaluation of heavy metal contamination at NWS Concord indicates that a variety of heavy metals including Pb, Cd, Se, and As are mobile and are moving into both plant and animal tissue and are probably contaminating animal food chains. This area on NWS Concord provides habitat for rare and endangered species that are being exposed to toxic heavy metals in their feeding habits. Considerable evidence demonstrates that the animals, both birds and mammals, that exist in environments contaminated with heavy metals generally build up elevated concentrations of these metals in their bodies. They probably do this by ingestion of these materials through the food chain, drinking contaminated water or by inhalation. In any case, a high potential exists at NWS Concord for the contamination of species higher on the food chain, such as in carnivorous birds and mammals, with toxic heavy metals. These toxic heavy metals, particularly Pb and Cd, are extremely persistent. They do not break down as do even the most persistent organic contaminants in the environment, such as polychorinated biphenyls. Therefore, the environment will not recover naturally in a short period of time. If left to recover naturally, it will probably have to weather away the problem over a long period of time, perhaps over decades. Also, because these metals (in particular, Pb and Cd) have long half-lives, once they are incorporated into avian and mammalian tissues, they are retained quite long. The toxicological manifestations of these metals in vivo are quite varied and include disruptions in energy metabolism, renal function, central nervous system effects, and

reproductive toxicity. The latter is probably of crucial importance in the NWS Concord area particularly as related to the salt marsh harvest mouse. Since the reproductive process in mammals is sensitive to toxic heavy metal exposure, the potential exists for impact on the ability of the population (i.e., harvest mice) to sustain itself without actually killing outright one individual animal.

Without question, areas at NWS Concord are heavily contaminated compared to acceptable levels of metals in both soil and biological tissue and from evaluation of these data the information suggests associated toxicological impacts. From a toxicological perspective, the contamination present is a long-term chronic problem. In addition, evidence exists that plant toxicity (death) in the contaminated area could reduce available habitat for animals such as the salt marsh harvest mouse and California black rail which occupy the area. The food base has probably been damaged by the fact that a substantial number of invertebrates have been killed by the contamination as evidenced by the reduction in diversity and abundance of soil macroinvertebrates in the contaminated site versus a remote reference site. Therefore, in addition to the potential toxicological impact, the area has suffered a reduction of habitat quality and a reduction of the food base for many species or birds and mammals that occupy this area.

4.5 Importance of Contaminated Areas to Suisun Bay Ecosystem

The wetland area at NWS Concord is important to Suisun Bay since it directly mediates what will be discharged into the bay from the surrounding watershed drainage. The wetland will function as flood storage and desychronization, sediment trapping, nutrient retention both long term and seasonally, and food-chain support. The terrestrial area at NWS Concord is important as a source of nutrients for the wetland area and as habitat for wildlife associated with the bay ecosystem. Contamination of either or both the wetland and terrestrial areas can result in contamination of food chains associated with each area. The most significant factor about the wetland and terrestrial areas is that these areas are important habitat for several rare or endangered species. The amount of habitat for these species has dwindled over the years. Consequently, these areas are among the very few remaining to support these

rare or endangered species. Contamination of these important habitat areas could seriously threaten these rare or endangered species.

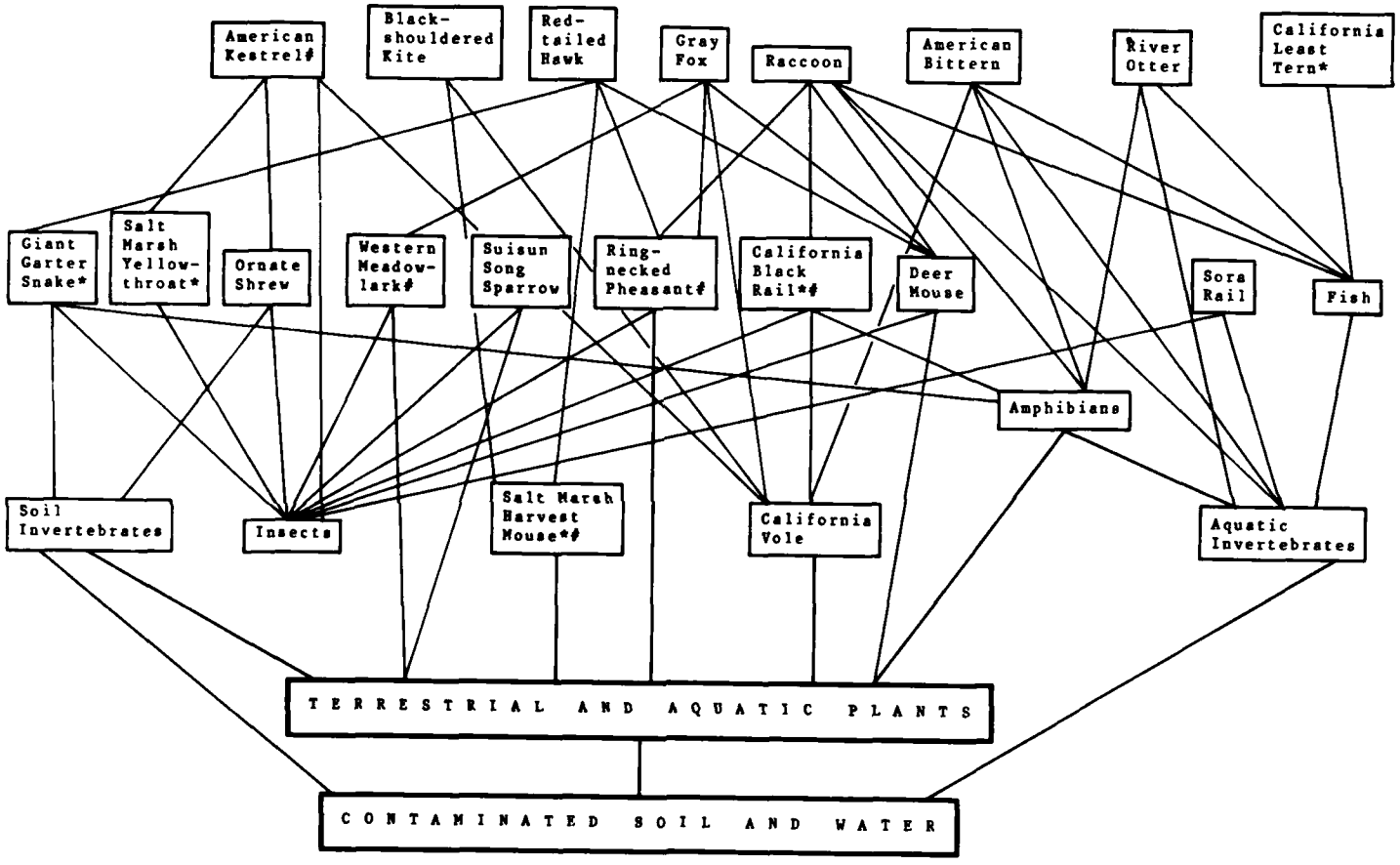
4.5.1 Food Webs

4.5.1.1 Wetland and Terrestrial

The food web associated with the wetland and terrestrial areas at NWS Concord is shown in Figure 4-1. The components of the food web were reported in previous surveys and literature for the NWS Concord and the Suisun Bay ecosystem. The rare and endangered species are indicated by an asterisk. Contaminants have been shown to have a high potential to bioaccumulate in plants and soil-dwelling organisms exposed to contaminated soil. The potential for these contaminants to move through the food web and adversely impact the rare and endangered species was discussed in Section 4.4 and found to be of serious concern.

4.5.1.2 Aquatic

The food web associated with the aquatic areas at NWS Concord and Suisun Bay is shown in Figure 4-2. The components of the food web have been reported by Ecology and Environment Inc. (1983). Contaminants have been shown to move into marsh plants and to some extent into clams (mollusks). The plant bioassay indicated a high potential for plant uptake of As, Cd, Pb, Zn, and Cu from contaminated soil. These plants will eventually become the food (detritus) for the aquatic food web. The clam bioassay indicated a moderate potential for aquatic organisms to bioaccumulate Pb, Cd, and Zn from surface waters in contact with certain contaminated sites in the K-2 area of Parcels 573 and 574, the G-1 area of Parcel 575, and the ES area of Parcel 579D. The potential for these contaminants to move through the food web and result in adverse impacts was discussed in Section 4.4 and found to be of a low potential at the present time. Continued migration of contaminated soil from barren areas will increase this potential for aquatic organisms to be exposed to soil adsorbed contaminants. A synopsis of life history and habitat requirements for fishes, benthic macroinvertebrates, and zooplankton inhabiting the vicinity of NWS Concord is presented in Appendix 3.5.9 for further information and reference.



* denotes rare or endangered species or candidates for listing
\# denotes species used in the habitat evaluation

Figure 4-1. Simplified food web associated with wetland and terrestrial areas at NWS Concord

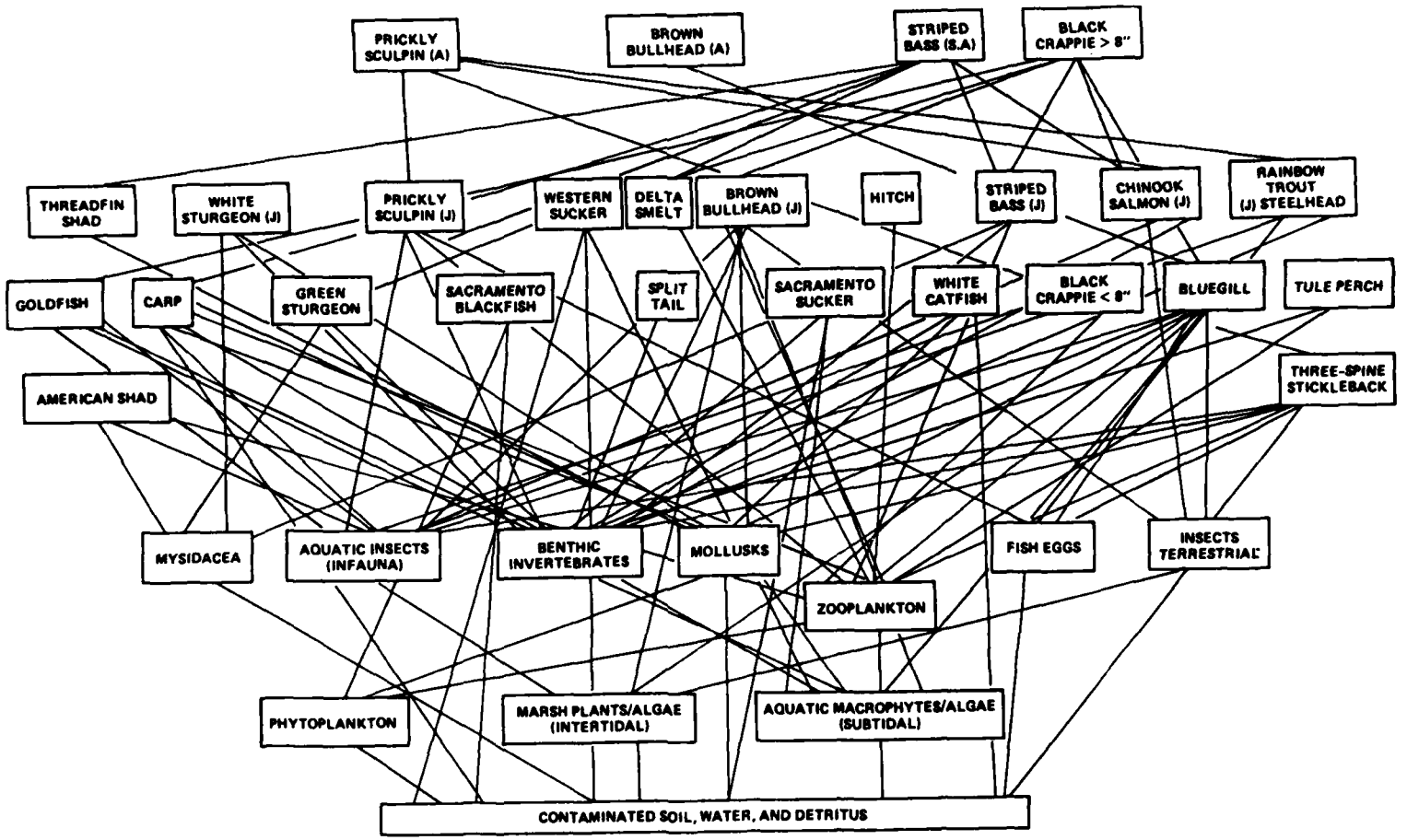


Figure 4-2. Food web scheme for aquatic areas of Suisun Bay marsh estuarine system

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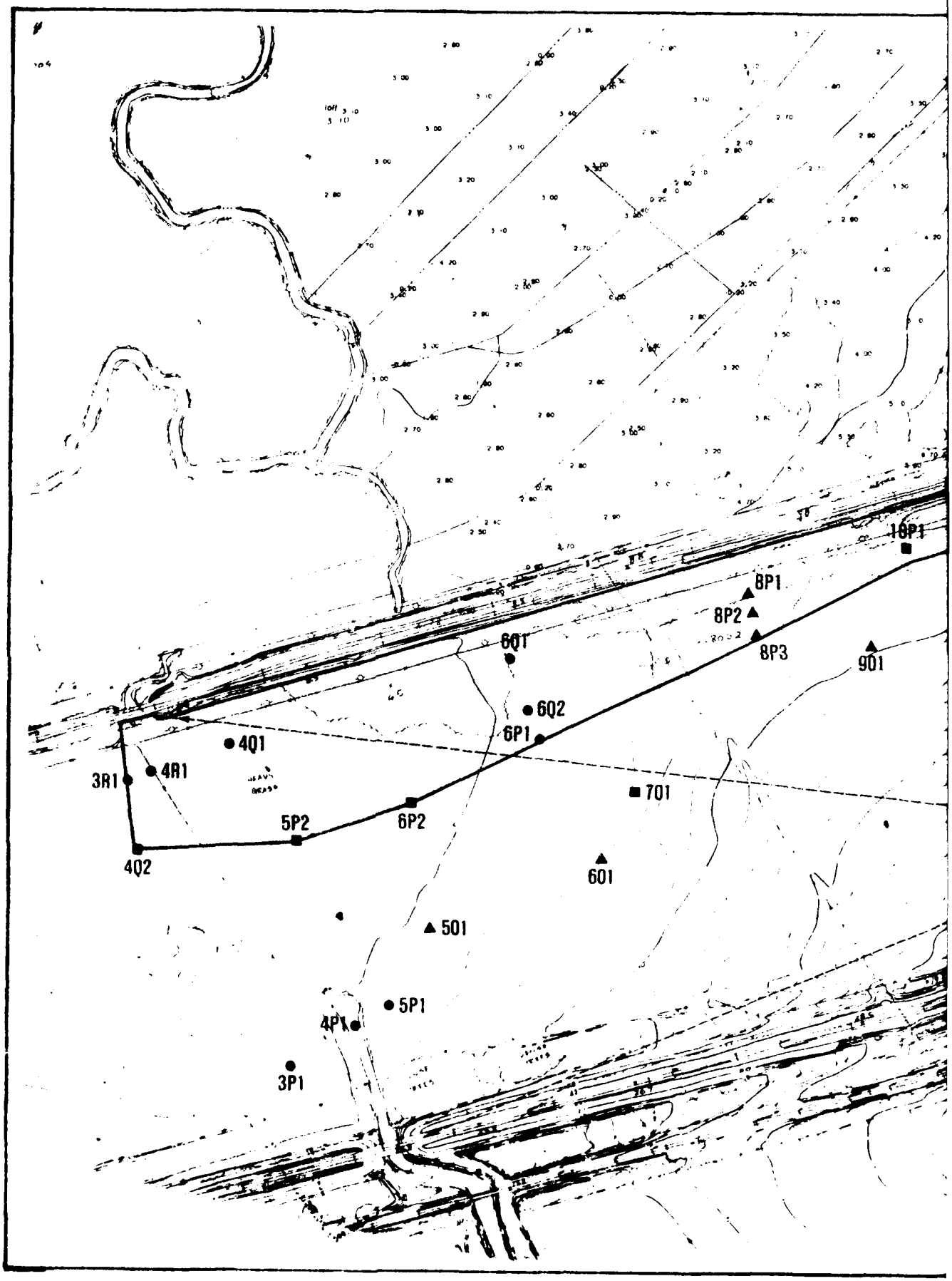
5.0 TOTAL CONTAMINATED AREA REQUIRING CORRECTIVE ACTION

The total area of contamination combining every sampling site that showed metal contents statistically above surrounding sample sites and above a critical value in soils, plants, and earthworms was shown in Figure 2-90. A detailed toxicological evaluation indicated that these concentrations can have substantial impact on endangered species and the ecosystem in general. The estimated acres associated with this contamination according to each parcel is listed below:

Area	Acres Impacted
ES (Parcel 579D)	1.41
(Parcel 576)	0.63
G-1 (Parcel 575)1.60	1.60
K-2 (Parcels 573 and 574)	6.56
KS (of Parcel 572)	8.15
AA + AB (of Parcel 572)	23.35(+6.08)
CP (Parcel 581)	2.57(+0.93)
Canal near Pier 4 (Parcel 571)	2.43
TOTAL CONTAMINATION	46.70(+7.01)

Acres in parentheses are areas just outside those sampling sites that exceeded criteria and in between the next sampling site that was below criteria. Detailed topographic maps showing the areas of contamination are presented in Figures 5-1, 5-2, and 5-3. These impacted areas will be the subject of a feasibility report and a natural resource damage assessment. Sampling sites survey data are shown in Appendix 5-A.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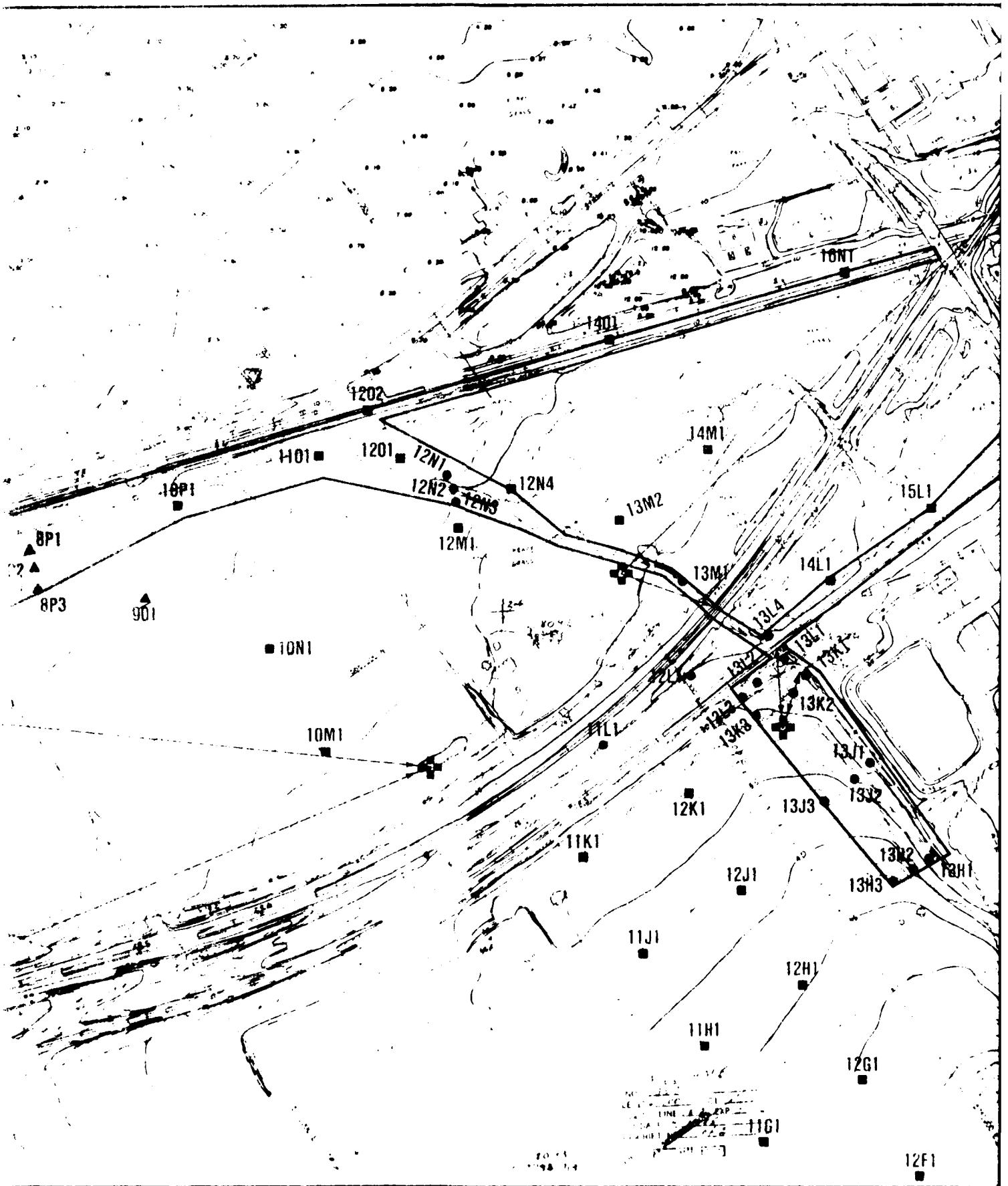
4P1
3P1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1201
H01
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12N2
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12N4
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15L1
18P1
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13M1
14L1
8P3
901
13L4
10N1
13K2
10M1
11L1
13K3
13J1
13J2
12K1
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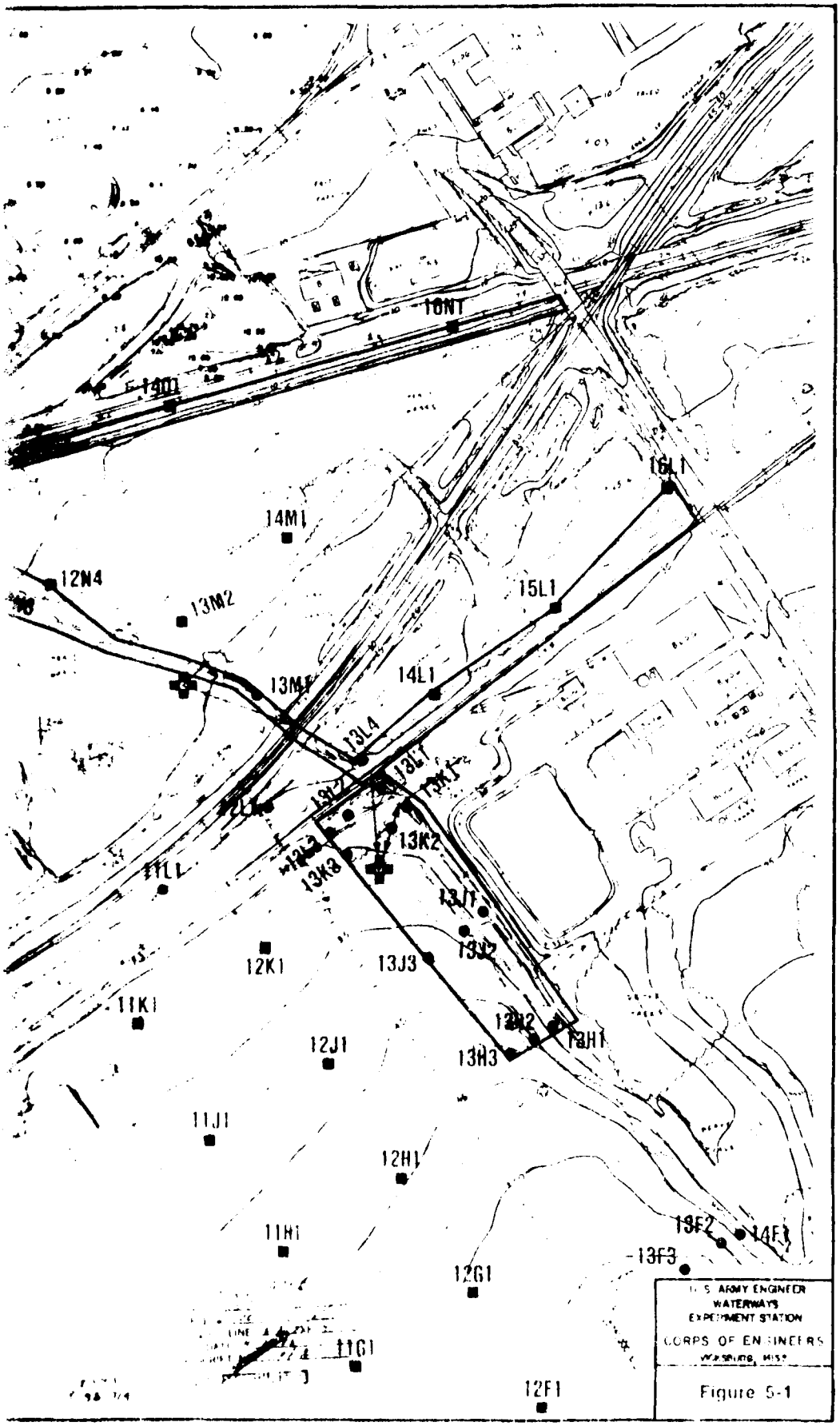
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14L1
13L4
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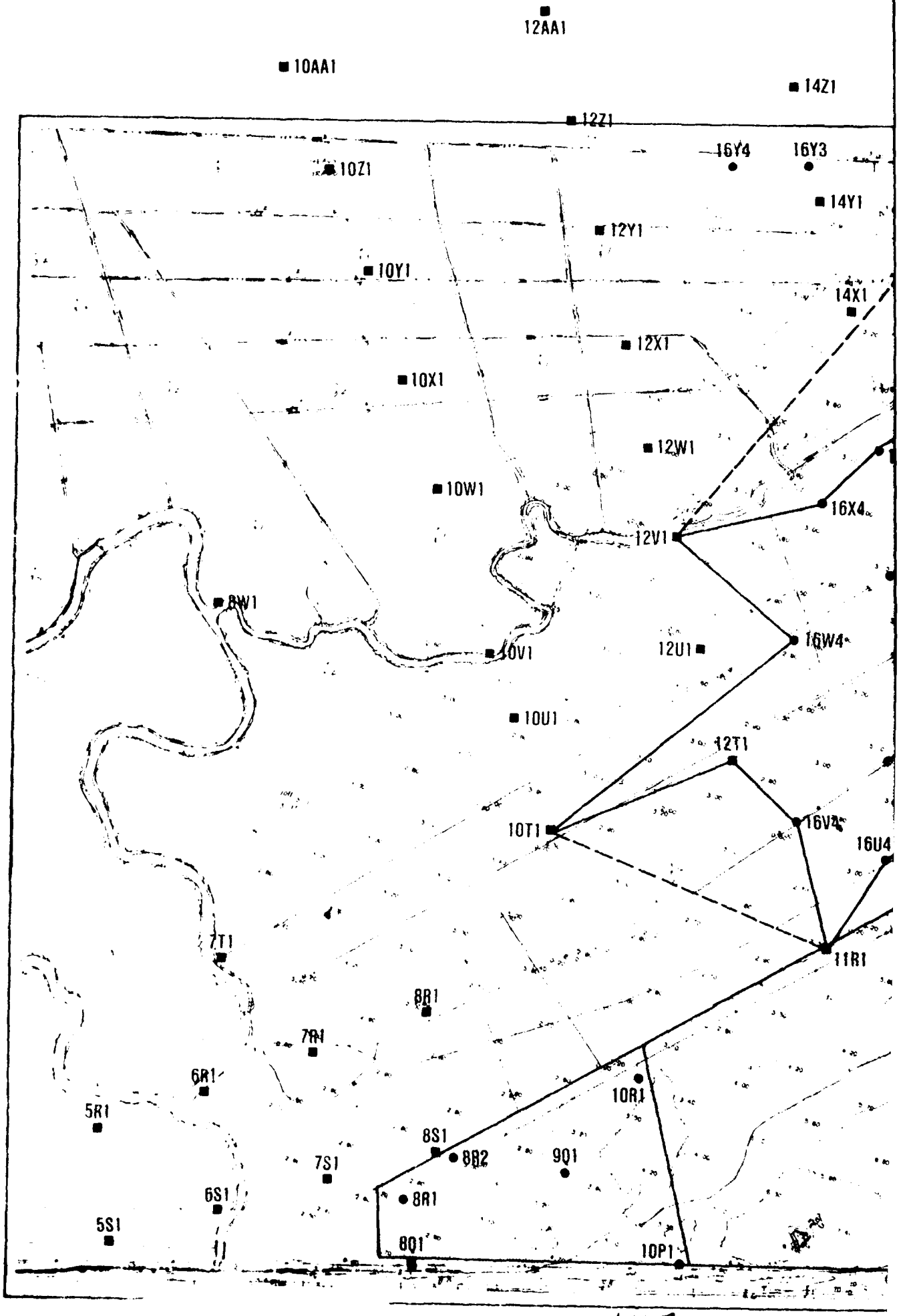
11L1
13J1
13J2
12K1
13J3
11K1
12J1
13H3
11J1
12H1
11H1
13F2
14F1
13F3
12G1
11G1
12F1
U.S. ARMY ENGINEER
WATERWAYS
EXPERIMENT STATION
CORPS OF ENGINEERS
Figure 5-1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12W1
10W1
16X4
12V1
8W1
16W4
10V1
12U1
10U1
12T1
16V4
10T1
16U4
11R1
7T1
8R1
7R1
6R1
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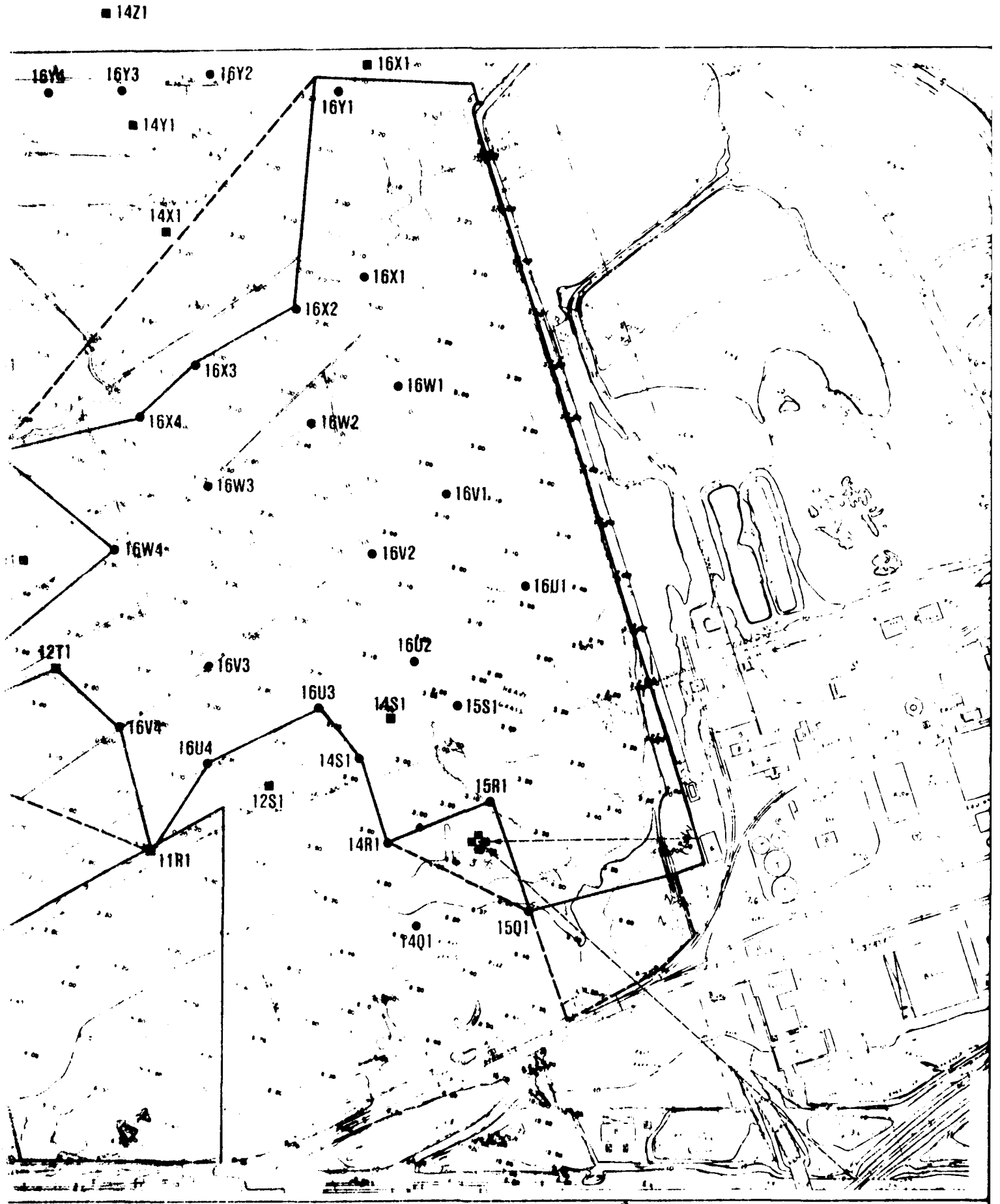
8R2
9Q1
7S1
6S1
8R1
5S1
8Q1
10P1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16W2
16W3
16V1
16W4
16V2
16U1
12T1
16V3
16U2
16U3
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16V4
16U4
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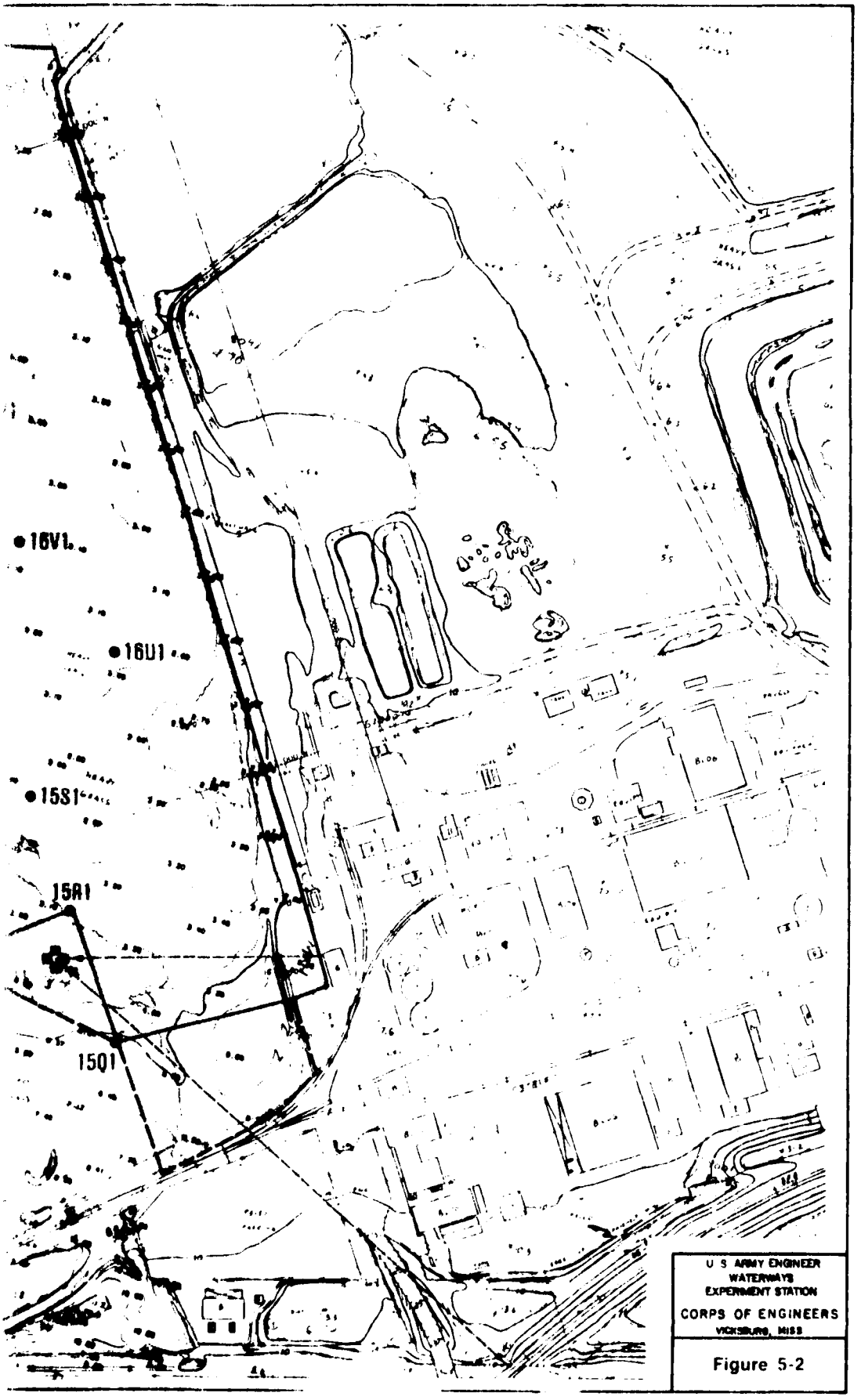
16V1
16U1
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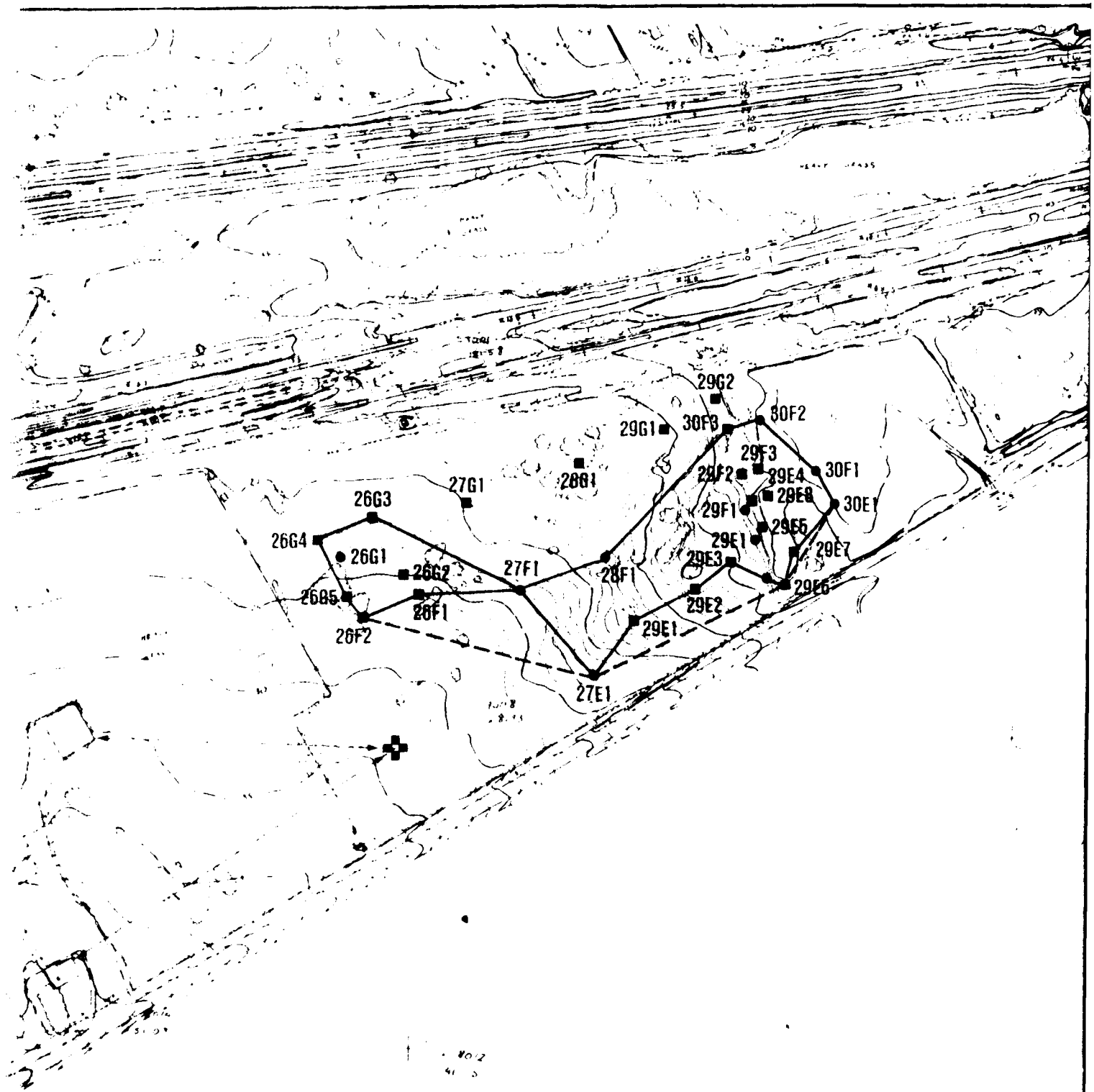
15R1
15Q1
U S ARMY ENGINEER
WATERWAYS
EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MISS

Figure 5-2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29E1
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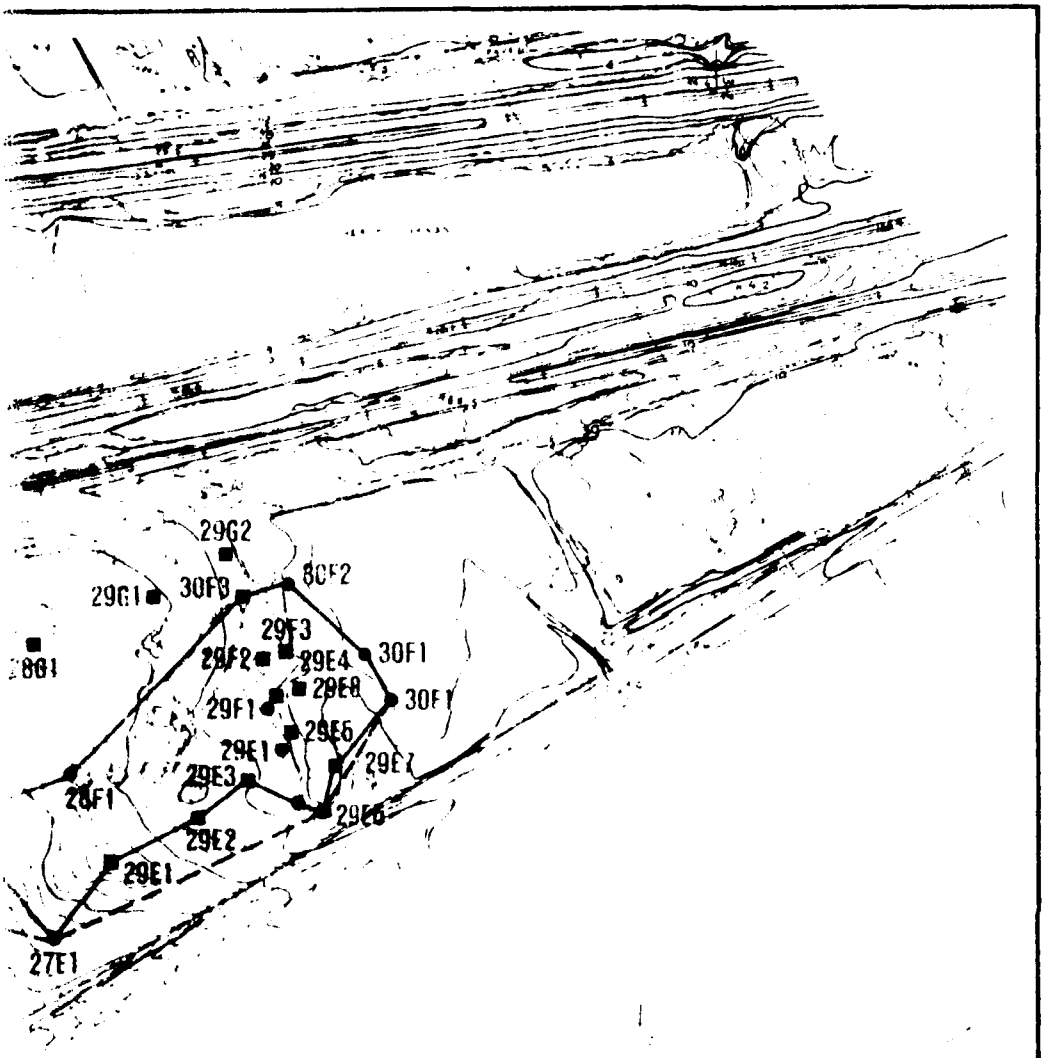

U S ARMY ENGINEER WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
VICKSBURG, MISS
Figure 5-3

Appendix 5-A. Sampling Sites, Survey Data

I. Siting point 1. NW corner of red brick building in Allied grounds, along side the fence next Navy property
403.98 ft., 120-deg. 25'

2. NE corner of RR bridge where two RR tracks and a road intersect just south of Allied property
931.27 ft., 161-deg, 44'

AA SITE, JULY 84 SAMPLING

	Sample number	Distance	Bearing
1.	16U1	469	40 deg 57'
2.	16U2	345	10 51
3.	16U3	378	340 12
4.	16U4	513	316 26
5.	16V1	629	24 59
6.	16V2	552	10 02
7.	16V3	584	332 52
8.	16V4	686	317 39
9.	16W1	837	20 17
10.	16W2	816	08 23
11.	16W3	810	352 33
12.	16W4	846	338 52
13.	16X1	1046	18 45
14.	16X2	1020	11 29
15.	16X3	1007	359 24
16.	16X4	984	351 27
17.	16Y1	1386	19 47
18.	16Y2	1479	11 07
19.	16Y3	1510	5 00
20.	16Y4	1570	0 30
21.	16Z1	1824	20 30
22.	16Z2	2044	7 32
23.	16Z4	2355	359 38
24.	16Z5	2840	351 58
25.	16Z6	2570	347 43
26.	16Z7	2792	338 20

AA Site, Feb. 85 sampling,

27.	10BB1	2387	346 14
28.	10AA1	2201	344 26
29.	10Z1	2018	342 18
30.	10Y1	1843	339 30
31.	10X1	1678	335 47
32.	10W1	1520	331 20
33.	10V1(STREAM)	1302	322 43
34.	10U1	1220	318 27
35.	10T1	1107	310 21
36.	12BB1	2171	357 43
37.	12AA1	1980	355 54
38.	12Z1	1794	353 44
39.	12Y1	1609	350 56
40.	12X1	1433	347 23
41.	12W1	1264	343 09

42.	12V1	1123	339 10
43.	12U1	972	331 54
44.	12T1	830	322 28
45.	12S1	392	314 60
46.	8W1(STREAM)	1782	319 10
47.	14AA1	1848	6 44
48.	14Z1	1649	6 05
49.	14Y1	1445	4 27
50.	14X1	1243	3 11
51.	16Y1	1625	21 13
52.	16X1	1425	22 10
53.	11R1	598	298 29
54.	14S1	273	354 36
55.	5S1	1943	283 54
56.	6S1	1742	283 56
57.	7S1	1540	283 51
58.	8S1	1343	283 30
59.	5R1	1919	289 50
60.	6R1	1719	290 48
61.	7R1	1521	292 15
62.	8R1	1313	294 25
63.	7T1(STREAM)	1670	298 45

AB SITE, JULY 84, Same siting point as the AA site

64.	14Q1	190	245 54
65.	15Q1	158	175 08
66.	14R1	164	298 48
67.	15R1	73	48 25
68.	14S1	262	334 37
69.	15S1	247	21 50

KS SITE, July 84 sampling, same siting point as the AA site

70.	8R1	1421	281 06
71.	9Q1	1136	278 47
72.	10R1	960	285 11
73.	10P1	1029	266 12
74.	8R2	1317	282 57

KS SITE, FEB 85 SAMPLING, SAME SITING POINT AS THE AA SITE

75.	8Q1	1446	276 35

II. K2 SITE,

Siting Point: 1. NE Corner of upper tressel near Q high security area
1349.34 ft 268-deg. 58'
2. SE Corner of tressel near Q area and closest to bay
1707.93 ft 297-deg. 22'

K2 SITE, JULY 84 SAMPLING

76.	6P1	1064	299 13
77.	6Q1	1141	305 29
78.	6Q2	1093	301 28
79.	5P1	1336	278 30
80.	4P1	1399	277 41
81.	3P1	1520	276 10
82.	4R1	1706	294 24
83.	4Q1	1579	296 24
84.	3R1	1742	293 52

K2 SITE, FEB 85 SAMPLING

85.	4Q2	1724	289 59

86.	5P2	1461	290 25
87.	6P2	1270	293 05
88.	7O1	901	294 59

III. G-1 SITE, SITING POINT COORDINATES

1. SE Corner of RR bridge used for the AA site
   936 ft. 61-deg. 21'

2. Northern most culverts for SI Creek to pass under
   RR tracks 179 ft. 124-deg. 14'

G-1 SITE(D-1), JULY 84 SAMPLING

89.	13M1	112	111 43
90.	12N3	320	308 02
91.	12N1	356	314 29
92.	12N2	332	311 40

G-1 SITE, FEB 85 SAMPLING

93.	13M2	96	14 35
94.	14M1	269	50 37
95.	12M1	300	300 39
96.	12N4	248	323 10
97.	12O1	440	312 28
98.	12O2	535	317 41
99.	11O1	573	306 16
100.	14O1	412	12 36
101.	16N1	668	52 10
102.	10P1	794	293 49
103.	10N1	636	272 59
104.	10M1	610	254 03

IV. ES AND G-1 SITES WITH SITING POINT

1. NW Corner of SI boundry fence
   117 ft. 34-deg. 46'
2. Mid point of culvert nearest SI plant
   144 ft. 09-deg. 06'

ES and G-1 site, JULY 84 SAMPLING

105.	14F1	759	147 45
106.	13H1	346	144 26
107.	13J1	167	125 18
108.	13K1	102	37 33
109.	13L1	127	14 02
110.	13K3	53	305 51
111.	13J3	150	163 09
112.	13H3	334	157 06
113.	13F3	745	155 07
114.	13F2	748	150 14
115.	13H2	339	150 05
116.	13J2	156	138 09
117.	13K2	65	30 41
118.	13L2	94	343 10
119.	13L3	102	320 11
120.	13L4	165	04 44
121.	12L1	191	312 31
122.	11L1	313	277 57

ES AND G-1 SITE, FEB 85 SAMPLING

123.	14L1	272	30 45
124.	15L1	468	46 51
125.	16L1	708	50 02

126.	12K1	204	249 03
127.	11K1	427	250 22
128.	12J1	297	207 04
129.	11J1	472	225 22
130.	12H1	458	188 35
131.	11H1	580	207 07
132.	12G1	638	180 09
133.	11G1	731	195 36
134.	12F1	828	175 27
135.	11F1	897	187 55

V. CP SITE SITING POINT

1. SW Corner of tin building just west of CP site
   490 ft. 281-deg. 37'
2. NW Corner of red brick building west of CP site and along the main road
   631 ft. 246-deg. 37'

CP SITE, JULY 84 SAMPLING

136.	27F1	330	48 30
137.	26G1	324	353 31
138.	27E1	350	80 09
139.	28F1	467	57 42
140.	29F1	695	65 41
141.	29E1	687	69 57
142.	29E2	673	75 23
143.	30F1	829	66 51
144.	30F2	807	58 03
145.	30E1	829	71 06

CP SITE, FEB 85 SAMPLING

146.	29F2	726	61 36
147.	29F3	752	62 20
148.	29E4	712	65 13
149.	29E8	742	66 00
150.	29E7	733	73 56
151.	29E5	704	69 12
152.	29E6	697	77 24
153.	29E3	632	71 00
154.	29E2	559	72 03
155.	29E1	446	71 37
156.	26G2	284	12 35
157.	26G3	379	04 00
158.	26G4	362	348 58
159.	26G5	256	352 07
160.	26F1	254	18 31
161.	26F2	220	354 55
162.	27G1	416	25 51
163.	28G1	555	42 33
164.	29G1	684	49 59
165.	29G2	779	52 29
166.	30F3	756	56 01

6.0 CONCLUSIONS

This remedial investigation indicates the following conclusions:

a. Substantial contamination has occurred as a result of the release of hazardous substances onto Parcels 572, 573, 574, 575, 576, 579D, and 581 at NWS Concord.

b. Hazardous substances such as arsenic, cadmium, lead, selenium, zinc, and copper are present in surface soil on certain portions of these parcels at concentrations that are statistically greater than other sampled sites and are in excess of established acceptable levels.

c. Results of plant and earthworm bioassay tests indicate a high potential for mobility of arsenic, cadmium, lead, and selenium into plants and soil-dwelling animals.

d. Field-collected plant samples from Parcel 575(G1) and Parcel 574(K2) indicate native plants are contaminated with cadmium, lead, and zinc.

e. Clam bioassay tests in the field indicate that there is a moderate potential for cadmium, lead, and zinc to move into surface waters at a limited number of sampling locations (Parcels 576 and 575).

f. The hydrological evaluation indicates that the low permeability of the soils on these parcels minimizes the potential for ground-water contamination. However, storm events and high tides have resulted in the movement of hazardous materials in surface waters across the wetland surface and into mosquito-control drainage ditches. Ten-year high tides completely inundate the entire wetland area as well as backing up into Parcel 573 (K2 site). Predicted 25- year storm events would wash contaminated sediment from Nichols Creek on Parcels 579D, 576, and 575 over the stream embankment and through an existing culvert onto Parcel 572 (at the KS site).

g. A comprehensive natural resource evaluation indicated the wetland areas have moderate to high functional values for wildlife habitat, food-chain support, flood storage, shoreline anchorage, sediment trapping, nutrient retention, and passive recreation and heritage. A lower potential value was determined for fishery habitat, ground-water recharge or discharge, and active recreation. The macroinvertebrate community study indicates contamination from the overflow of the Allied Chemical Corporation Bay Point Works's waste lagoon onto Parcel 572 resulted in a significantly lower number and diversity of species in the contaminated wetland site in comparison to a reference site. The habitat evaluation study indicated a moderate to high potential value and that wildlife are attracted to the contaminated site and consequently are exposed to the hazardous substances.

h. The toxicological evaluation indicates that lead, cadmium, selenium, and arsenic are probably contaminating animal food chains and that high potential exists for the contamination of species higher in the food chain, such as carnivorous birds and mammals. This area on NWS Concord provides habitat for rare or endangered species which are being exposed to toxic metals in their

feeding habits. The contamination present at NWS Concord is of a persistent nature and will cause chronic problems to inhabitants of the area.

7.0 RECOMMENDATIONS

The following recommendations are made as a result of this remedial investigation:

a. Remedial action is required for certain areas on Parcels 572, 573, 574, 575, 576, 579D, and 581 as delineated in Figure 2-90. A feasibility study will define the appropriate remedial action.

b. Additional soil samples should be taken beyond the areas sampled in this remedial investigation on Parcels 571, 572, 576, and 581. Soil contamination was found to the extent of the sampling locations. Consequently, the soil beyond these sites requires sampling and testing.

c. Ground-water samples should be collected from well 02N01W04Q01 located between the Chemical and Pigment Company holding pond and the Sacramento Northern Railroad right of way.

d. An assessment of natural resource damage should be prepared regarding hazardous substance contamination on Parcels 571, 572, 573, 574, 575, 576, 579D and 581 at NWS Concord.

AD-A165 127 REMEDIAL INVESTIGATION OF CONTAMINANT MOBILITY AT NAVAL WEAPONS STATION C..(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS ENVIR.. C R LEE ET AL. 7/9

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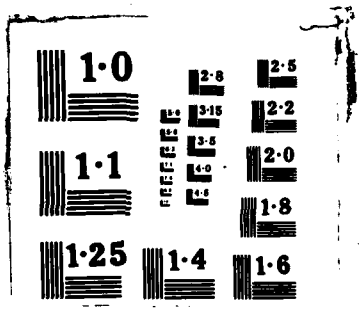
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SUPPLEMENTARY

INFORMATION

DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
P.O. BOX 631
VICKSBURG, MISSISSIPPI 39180-0631

REPLY TO ATTENTION OF
WESES-R

23 May 1986

Errata Sheet

No. 1

REMEDIAL INVESTIGATION OF CONTAMINANT MOBILITY AT NAVAL WEAPONS STATION, CONCORD, CALIFORNIA

Final Report

Miscellaneous Paper EL-86-2

January 1986

1. Page 123, Figure 2-60:

   Replace this page with the inclosed, corrected page.

2. Page 186:

   After the third reference entry on this page, insert the following:

   Holnigren, G. G. S., Meyer, M. W., Daniels, R. B., Chaney, R. L., and Kubota, J. 1985. "Cadmium, Lead, Zinc, Copper, and Nickel in Agricultural Soils of the United States," Journal of Environmental Quality (in press).

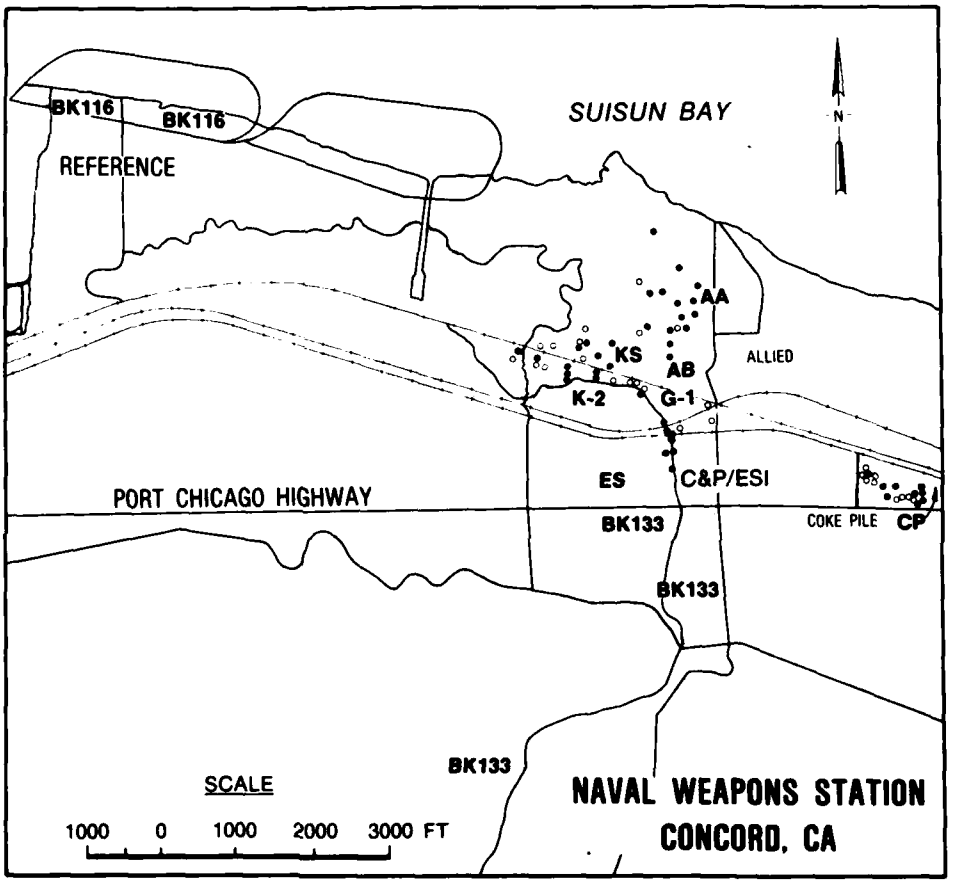

Figure 2-60. Distribution of soil cadmium concentrations in excess of 2.7 mg/kg. Solid circles were WES collected samples, open circles were Brown and Caldwell collected samples


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