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U.S. ARMY
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— COMMITTED TO PROTECTION OF THE ENVIRONMENT —

COMPREHENSIVE MONITORING PROGRAM

Contract Number DAAA15-87-C-0095

FINAL BIOTA ANNUAL REPORT FOR 1989

JUNE 1990

Version 2.0

Volume I

R.L. STOLLAR & ASSOCIATES, INC.
Harding Lawson Associates
Ebasco Services Incorporated
DataChem, Inc.
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Midwest Research Institute

ROCKY MOUNTAIN ARSENAL • COMMERCE CITY, COLORADO • 80022-2180

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Prepared by:

R. L. STOLLAR & ASSOCIATES INC.
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U. S. ARMY PROGRAM MANAGER FOR
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TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF FIGURES

VOLUME I

VOLUME II

• SPECIES CODES AND NAMES

ACRI = Grasshopper
ANDI = Blue winged Teal
ANPL = Mallard
AQCH = Golden Eagle
ATCU = Burrowing Owl
BRTE = Cheatgrass
BUJA = Red-tailed Hawk
BURE = Ferruginous Hawk
BUSW = Swainson's Hawk
BUVI = Great Horned Owl
CEDE = Coontail
CHVO = Killdeer
COLE = Ground Beetle
CYLU = Black-tailed Prairie Dog
ESLU = Northern Pike
EUCY = Brewer's Blackbird
FASP = American Kestrel
FUAM = American Coot
HALE = Bald Eagle
HEAN = Sunflower
ICME/ICNE = Black and Brown Bullhead
ICPU = Channel Catfish
KOIR = Kochia
LEMA = Bluegill
LASE = Prickly Lettuce
MISA = Largemouth Bass
ODHE = Mule Deer
OLIG = Earthworm
PEMA = Deer Mouse
PHCO = Pheasant
PIME = Bull Snake
PIPI = Black-billed Magpie
PLAN = Plankton
POND = American Pondweed
POPE = Sego Pondweed
SPTR = Thirteen-lined Ground Squirrel
STNE = Western Meadowlark
STVU = Starling
SYAU = Desert Cottontail
TATA = Badger
TUMI = American Robin
ZEMA = Mourning Dove

• TROPHIC GROUPS

Terrestrial Groups

TPPR = Terrestrial Primary Producers
THER = Terrestrial Herbivores
TOMN = Terrestrial Omnivores
TCAR = Terrestrial Carnivores
TDET = Terrestrial Detritivores

Aquatic Groups

APPR = Aquatic Primary Producers
APCO = Aquatic Primary Consumers
AWCO = Aquatic Water Column Omnivores
APCA = Aquatic Primary Carnivores
ATCA = Aquatic Top Carnivores
ABFO = Aquatic Bottom Feeding Omnivores

• OTHERS

ANOVA = Analysis of variance
ARMY = U.S. Army
BCRL = below lower certified reporting limit
BCCL = College Lake Control Area
BCML = McKay Reservoir Control Area
BCRM-1 = Control Site 1 on RMA
BCSP = Sawhill Ponds Control Area
BCTL = Trilby Lateral Control Area
BCTR = Tamarack Ranch Control Area
BCWP = Walden Ponds Control Area
BCWR = Wellington Wildlife Refuge Control Area
BS1-3 = Staked Site 3 in BSA 1
BS12-C25 = Collection location in BSA 12, outside a staked site, in Section 25
BURM-30 = Collection location outside a BSA, on RMA, in Section 30
BDMS = Biota Data Management System
BSA = Biota Study Area
BSA1 = Most of Section 36 (Basin A)
BSA2 = Portions of Section 26 and 35 (Basin C and Basin F)
BSA3 = Portions of Section 35 and 2 (Sand Creek Lateral)
BSA4 = Portions of Section 35 and 2 (South Plants)
BSA5 = Portions of Section 3, 2, 1, 6, 11, 12 (RMA Lakes)
C = Control
CARS = Contamination Assessment Reports
CDOW = Colorado Division of Wildlife
CMP = Comprehensive Monitoring Program
cm/yr = centimeters per year
CPS-1 = Radian's Contour Plotting System 1
CRL = Certified Reporting Limit
DBCP = dibromochloropropane
DDE = dichlorodiphenylethane
DDT = dichlorodiphenyl trichloroethane
EBASCO = Ebasco Environmental Services Inc.
EC = electrical conductivity
ECD = Electron Capture Detection
ESE = Environmental Science and Engineering
°F = Fahrenheit
F = Far
FS = feasibility study
ft = foot
FY = Fiscal Year
g = grams
GC = Gas Chromotography

geometric mean = U.S. Fish & Wildlife Service geometric mean
GPC = Gel Permeation Chromatograph
GT = greater than
ha = hectare
HASP = Health and Safety Plan
HEP = Habitat Evaluation Procedure
in = inches
IRDMS - Installation Restoration Data Management System
Kd = soil/water partition coefficient
Koc = percent of organic carbon
Kow = octanol/water partition coefficient
KWT = Kruskal-Wallis Test
LC50 = chemical concentration at which 50% of test organisms expire
µg/g = microgram per gram
µl = microliter
m = meter
MKE = Morrison-Knudsen Engineers
mi = miles
mph = miles per hour
MRI = Midwest Research Institute
msl = mean sea level
N = Near
NAS = National Academy of Sciences - National Academy of Engineering
NCP = national Contingency Plan
NOAA = National Oceanic and Atmospheric Administration
NP = North Plants
NRDA = national resource damage assessment
OCP = organochlorine pesticide
OVA = organic vapor analyzer
PMRMA = Program Manager RMA
PPE = personal protective equipment
ppb = parts per billion
QA/QC = Quality Assurance/Quality Control
RI = remedial investigation
RIC = RMA Resource Information Center
RI/FS = remedial investigation/feasibility study
RMA = Rocky Mountain Arsenal
RPD = relative percent difference
SARS = RMA Study Area Report
SCBA = self-contained breathing apparatus
SCS = U.S.D.A. Soil Conservation Service
Shell - Shell Chemical Company
teratogens = chemicals that cause embryonic defects
TSP = trisodium phosphate
TSY = Toxic Storage Yard
UCRL = Upper Certified Reporting Limit
USAEWES = U.S. Army Engineers Waterways Experiment Station
USATHAMA = U.S. Army Toxic and Hazardous Materials Agency
USDI = U.S. Department of the Interior
USEPA = U.S. Environmental Protection Agency
USFWS = U.S. Fish and Wildlife Service

EXECUTIVE SUMMARY

The Biota CMP is designed to provide both continued and long-term monitoring of contaminants in biota at RMA. The results of the 1989 Biota Monitoring Program provide further documentation of contaminant concentrations in biota at the Arsenal as they currently exist and how they compare to concentrations observed in ecologically similar control areas.

The 1989 Biota Monitoring Program involved an intentional sampling program in which selected terrestrial and aquatic species were collected from designated study areas, delineated to include the major foci of known contamination on RMA as well as uncontaminated areas. Within each study area, relatively sedentary species were collected from specific sites. More mobile species were collected as close to contamination foci, within each study area, as was possible. When dead animals were encountered, these "fortuitous samples" were also collected for potential analysis. All of the tissues from intentional samples were analyzed for seven target analytes (aldrin, dieldrin, endrin, DDE, DDT, mercury, and arsenic). Some analyses for specific analytes were omitted for certain fortuitous samples.

The seven contaminants selected for monitoring were among the 22 chemicals previously detected in RMA biota and were selected based on their ability to negatively impact biota, including: carcinogenicity, ability to cause developmental abnormalities, solubility in water, leachability, and solubility in lipids.

The study areas for terrestrial species were as follows:

- o BSA1 - encompasses Basin A
- o BSA2 - encompasses Basins B, C, D, E, F, and adjacent areas
- o BSA3 - encompasses Sand Creek Lateral corridor
- o BSA4 - encompasses South Plants
- o BSA5 - encompasses uplands around Lower Lakes
- o BSA11 - Toxic Storage Yard
- o BSA12 - North Plants
- o BSA13 - Administration Building

The study areas for aquatic species were as follows:

- o BSA6 - Lake Mary
- o BSA7 - Ladora Lake
- o BSA8 - Lower Derby Lake
- o BSA9 - Rod & Gun Club Pond
- o BSA10 - Upper Derby Lake

During the selection of species for monitoring, emphasis was given to species that are part of food webs and chemical pathways leading directly to humans, higher level carnivores, or to threatened or endangered species. Other criteria included distribution on RMA, home range relative to RMA, ability of population to support collection, and existence of other historical contaminant data. The specific life stages and seasons for sampling were chosen to maximize the detection of contaminants and the exposure of the collected individual to the RMA environment.

Summary of Results

Dieldrin was the most ubiquitous of the seven target analytes detected in samples of terrestrial species collected in 1989. It was detected in at least one analyzed sample of every terrestrial species. It was also detected in all terrestrial study areas except in the peripheral area of the RMA where sample sizes were small. No other organochlorine pesticide (OCP) was detected at frequencies close to that of dieldrin, or with such geographic or taxonomic breadth. Compared to the 65 percent detection rate of dieldrin in terrestrial samples collected on RMA, aldrin was detected in 4.2 percent of the samples, endrin in 11 percent, DDT in 5.9 percent, DDE in 6.4 percent, arsenic in 19 percent, and mercury in 8.0 percent. Dieldrin was detected in 3.8 percent of the terrestrial control samples. Aldrin, endrin, and DDE were not detected in the control samples; while DDT, arsenic, and mercury were detected in 1.9 percent, 10 percent, and 3.6 percent of the control samples, respectively.

Dieldrin was also the most frequently detected analyte in aquatic biota. It was detected in 86 percent of the aquatic study area samples. In particular, dieldrin was found in all vertebrate species sampled. DDE, with reportable concentrations in 41 percent of the aquatic samples analyzed, was the next most frequently detected OCP. Endrin was detected in 8.9 percent, DDT in 3.6 percent, aldrin in 1.8 percent, mercury in 53 percent, and arsenic in 19 percent of the aquatic samples. DDE was the only OCP detected in samples from aquatic control areas, being found in 18 percent of those samples.

Arsenic was detected more frequently in samples from control areas (22 percent) than in samples from RMA study areas (19 percent). Mercury was detected in 42 percent of the samples from control areas.

Sedentary terrestrial biota, most indicative of local target analyte presence, included cheatgrass, earthworms, ground beetles, and deer mice. Earthworms, in particular, provided good evidence of local sources of all target analytes. Additionally, earthworms provided the greatest percentage of samples with reportable concentrations of arsenic (100 percent) and mercury (71 percent).

Black-tailed prairie dogs and deer mice had the highest percentage of reportable concentrations for dieldrin. Deer mouse samples recorded the maximum program concentrations of aldrin, DDT, DDE, and mercury. Mourning doves and ring-necked pheasants were the best terrestrial avian indicators of target analyte presence. Mourning doves were particularly good indicators of endrin.

In aquatic systems, killdeer was the best overall indicator of target analyte presence. Mallards were also good indicators. Killdeer were more effective as aquatic indicator species of DDE, DDT, and endrin presence than any other aquatic species, while mallards had the greatest detections for dieldrin and the only aquatic detection of aldrin. Largemouth bass were effective indicators of the target analytes, including mercury, with generally higher frequencies and concentrations of this analyte compared to the other fish species. Arsenic was detected only in aquatic plants and plankton on RMA. The highest concentration was found in a sample of sego pondweed.

1.0 INTRODUCTION

1.1 Site Background

In 1942, an area just northeast of Denver, Colorado (Figure 1.1-1), was set aside as the Rocky Mountain Arsenal (RMA) for use by the U.S. Army (Army). During World War II and afterwards, the Army used RMA for the manufacturing and demilitarization of incendiary munitions and chemical ordnance. Munitions filling operations ceased in 1969, at which time Army activity at RMA primarily involved demilitarization; today the Army's sole mission at RMA is to effect a Superfund cleanup. The RMA currently occupies approximately 27 square miles.

Beginning in 1947, portions of RMA were leased to Julius Hyman Company and then to Shell Chemical Company (Shell), as well as several smaller lessees. From 1947 to 1982, these lessees used RMA facilities to manufacture industrial chemicals including chlorinated benzenes, naphthalene, and fused caustic. Several pesticides, a nematocide, and herbicides were also manufactured, including: aldrin, dieldrin, chlordane, dibromochloropropane (DBCP), dichlorodiphenyl trichloroethane (DDT), azodrin, parathion, and atrazine.

Over the years, manufacturing facilities were built in two primary areas: South Plants in the northern half of Sections 1 and 2, and North Plants in Section 25. Other major facilities are the Toxic Storage Yard in Section 31 and an Administration/Barracks Complex in Section 35. In addition, a series of impoundments for cooling water, collectively known as the Lower Lakes, were constructed or enhanced in the southern half of Sections 1 and 2, and a series of basins for discharged waste liquid were constructed in Sections 26, 35, and 36. These primary areas of facility construction are shown on Figure 1.1-2.

The various uses of the land resulted in the introduction of contaminants to the abiotic (physical) environment (air, surface water, ground water, and soil) at RMA through such activities as burial or surface disposal of solid wastes, and discharge of wastewaters and industrial fluids to basins from chemical and sanitary sewer systems. Industrial wastes and industrial products that were not manufactured to specification were commonly disposed of in shallow trenches at depths of less than 10 feet (ft). Munitions were destroyed and disposed in trenches and on the ground surface. Wastewaters generated by Army and private industrial processes in the South Plants and North Plants areas were, at various times throughout the history of RMA operations, discharged to a series

of unlined evaporation and holding basins (Basins A through E) and to asphalt-lined Basin F. Chemical and sanitary sewers that transported wastes from industrial areas to the basins leaked contaminants both to vadose-zone soils and into ground water through direct or indirect hydraulic communication between the surface and the water table. Further, ditch systems that transported cooling water and surface-water drainage from the South Plants manufacturing complex flowed to the interconnecting Lower Lakes (Lake Mary, Upper Derby Lake, Lower Derby Lake, Ladora Lake) or to the Sand Creek Lateral. It has been shown that this surface-water drainage has transported contaminants downstream from several sources in South Plants.

1.2 Nature and Extent of the Impact on Biota

As summarized in the previous section, unintentional spills and discharges of contaminated wastes have occurred throughout the history of RMA. Some of the waste products or their derivatives then entered RMA biota, primarily through interactions between water, soil, plants (primary producers), herbivores (primary consumers), and carnivores (secondary consumers). This process has affected several species of biota present on RMA to a degree that varies with their geographic location, specific food web membership, trophic level, life span, movement patterns, reproductive frequency, and physiology.

Initially observed impacts of RMA contamination on biota were related to water, which has been found to be a major exposure route in aquatic food webs (ESE, 1989). Therefore, studies of biota contamination have focused upon the wastewater effluent and surface-water systems in portions of Sections 1, 2, 26, 35, and 36, which are attractive to wildlife. Impact on wildlife in these areas has tended to be more concentrated than in other areas on RMA. Contaminants in these areas include semivolatile and volatile organic chemicals, such as: solvents, pesticides and herbicides, inorganic salts, Army chemical agents and resultant degradation products, and several heavy metals. Depending upon contaminant location, vertical and areal extent, and concentration, exposure has led to varying degrees of impact on biota.

1.3 Synopsis of Previous Biota Investigations

The following is a brief synopsis of the Literature Summarization given in the Comprehensive Monitoring Program (CMP) Biota Technical Plan (Stollar et al., 1988). It is presented here to provide perspective to the results of this report.

In the early 1950s, initial cases of on-post wildlife mortality and off-post agricultural damage were reported. In 1952, a substantial number of on-post waterfowl deaths and severe off-post crop damage were reported. Following several accidental releases of caustics into the lakes in the late 1940s and early 1950s, fisheries declined and may have been absent altogether (Hyman, 1953a). These incidents prompted many studies and research projects designed to investigate the causes and consequences of these incidents (Sciple, 1952; Jensen, 1955; Finley, 1959). The information gathered linked the mortality and crop damage to contamination on or emanating from RMA. Early studies revealed the presence of aldrin, dieldrin, and other organochlorine pesticides in the waters of the Derby Lakes and Ladora Lake in concentrations up to 2,400 parts per million (ppm) (Sheldon et al., 1963). These chemicals were also found in the tissues of game fish and migratory waterfowl.

During the following decades, RMA biologists and contractors developed study plans for surveys of vegetation, amphibians, reptiles, fish, diurnal invertebrates, birds, and mammals to ascertain population size, assess habitat conditions, and determine patterns of relationships among different life forms and trophic levels. A number of chemical spills and resultant fish mortality incidents in the Lower Lakes of RMA in the 1960s triggered a series of phytotoxicity studies, chemical contamination investigations, and a wildlife census. Species lists of most major vertebrate animal groups, vascular plants, miscellaneous invertebrates and some insect orders were also compiled. Concentrations of aldrin, dieldrin, endrin, dichlorodiphenylethane (DDE), and other organochlorine pesticides (OCPs), as well as high concentrations of trace metals (copper, mercury, cadmium, and arsenic), continued to be detected in lake waters and sediments, soils, and animal tissues.

Several studies were conducted in support of on-post contamination assessments and restoration planning programs that began in the 1970s. It was during the mid-1970s that the first comprehensive baseline surveys were conducted (Thorne et al., 1979). Some of these studies had a

toxicological or ecological emphasis, while others were conducted in support of the proposed Stapleton Airport expansion onto RMA property and county-wide wildlife habitat planning (Williams, 1981; Parsons and ESI, 1983). These studies revealed that plants were better indicators of disturbance and related environmental stress than animals, although waterfowl tended to possess the highest concentrations of contaminants. OCPs were also detected in the eggs of American kestrels (Falco sparverius) and some waterfowl species, and were related to a decrease in nesting success (DeWeese et al., 1982; McEwen et al., 1985).

Finally, more recent and ongoing studies initiated in the early to mid-1980s, have been conducted under the Remedial Investigation/Feasibility Study (RI/FS). The Biota RI studies were performed by Environmental Science and Engineering (ESE) with additional data input from Morrison-Knudsen Engineers (MKE). These studies provided preremediation data to determine: (1) the nature and extent of the contamination; (2) the necessity for and proposed extent of remedial action; and (3) an analysis of food chain contamination and bioaccumulation. These studies provide a baseline for the data reported in this 1989 Biota Annual Report prepared under the Biota CMP.

During the RI, tissues of species from terrestrial and aquatic ecosystems were analyzed for seven contaminants: aldrin, dieldrin, endrin, DDE, DDT, arsenic, and mercury. The tissues were collected from on- and off-post control areas and from areas of presumed contamination within RMA. Sampled species were selected to represent varying trophic levels, exposure pathways, important components of regional ecosystems, and/or economical concerns; also considered was their degree of interaction with species of special, state, or federal concern.

Analysis of tissues from the RI program revealed all of the seven target analytes in one or more of the species investigated (ESE, 1989). Dieldrin and arsenic were detected in both species of plants studied, field bindweed (Convolvulus arvensis) and annual sunflower (Helianthus annuus). Endrin

was detected only in the sunflower. All analytes except aldrin, DDE and DDT were detected in both invertebrate species (grasshoppers and earthworms). Aldrin was detected only in grasshoppers and DDE and DDT were not detected in either invertebrate group. Among the seven aquatic species studied, only plankton and aquatic macrophytes evidenced arsenic. Four of the five fish species contained various combinations of mercury, aldrin, dieldrin and/or DDE. The largemouth bass, Micropterus salmoides, contained all four of these analytes. The black bullhead, Ictalurus melas, contained mercury, dieldrin and DDE. The bluegill, Lepomis macrochirus, and northern pike, Esox lucius, contained mercury and dieldrin. The fathead minnow, Pimephales promelas, did not evidence any of the target analytes. Five raptor (golden eagle, Aquila chrysaetos; red-tailed hawk, Buteo jamaicensis; ferruginous hawk, Buteo regalis; American kestrel, and great horned owl, Bubo viginianus), two terrestrial bird species (ring-necked pheasant, Phasianus colchicus; mourning dove, Zenaidura macroura) and several waterfowl species (mallard, Anas platyrhynchos; blue-winged teal, A. discors; redhead, Aythya americana; and American coot, Fulica americana) contained varying concentrations of dieldrin, DDE, arsenic, and mercury. Scattered concentrations of organochlorine pesticides were detected in the tissues of three species of large and medium-sized mammals (black-tailed prairie dogs, Cynomys ludovicianus; cottontails, Sylvilagus spp.; and mule deer, Odocoileus hemionus). The Biota RI report (ESE, 1989) concluded that dieldrin concentrations increased progressively from lower trophic levels (plants and insects) to higher levels (raptors and mammals), supporting the evidence of bioaccumulation of dieldrin and other analytes within the RMA food web. Results from 1986 and 1987 aquatic studies reported in the Biota RI (ESE, 1989) indicated bioaccumulation of organochlorine pesticides and mercury through aquatic food chains as well.

Following completion of the Biota RI, a program to provide ongoing monitoring of ground water, surface water, air, and biota was implemented. This CMP was to provide ongoing monitoring of the various media through time, and a vehicle to reevaluate, validate, and complement the RI approach, methods and results.

1.4 Overview of Current Biota Monitoring Program

The Biota CMP is designed to provide both continual and long-term monitoring of biota. The Biota CMP has detailed objectives, outlined in a technical plan (Stollar et al., 1988) that establishes monitoring guidelines, analytical parameters, and sampling protocol and strategies.

The results of the 1989 Biota Monitoring Program provide further documentation of concentrations of biota contamination as they currently exist; and also as they may change with remedial action activities, relative to concentrations in contemporaneous biota collected from ecologically similar off-post control areas, and relative to past conditions both on- and off-post. These studies provide further information concerning: (1) verification of pathways of contaminant movement in biota; (2) the extent of accumulation or magnification that occurs in these pathways; (3) pathway-related changes through time with increasing distance from identified contaminant sources; and (4) changes during remediation. Further, the monitoring of contaminants in biota provides data needed for development of any measures that may be needed to mitigate any impacts associated with site remediation.

The Biota CMP is composed of two distinct components: the monitoring of contaminants, and surveys associated with black-footed ferrets (Mustela nigripes). Both studies are part of the RI/FS ongoing at RMA, and are being performed in compliance with the National Contingency Plan (NCP), the Endangered Species Act, and the most current (April, 1989) Black-footed Ferret Survey Guidelines.

The monitoring of contaminants in biota involved an intentional sampling program in which tissues from individual species or species groups were collected from several areas delineated to encompass the major foci of known contamination on RMA, as well as from uncontaminated areas. Within each delineated area, relatively sedentary species were collected from specific marked sites or aquatic sampling foci, and more mobile species were usually collected wherever encountered within the specific areas, but close to contamination foci when possible. When dead animals were incidentally encountered, selected fortuitous samples were also collected for potential analysis. All of the tissues from intentional samples were analyzed for the seven target analytes (aldrin, dieldrin, endrin, DDE, DDT, mercury, and arsenic). Some tissues were omitted from specific analyses for certain fortuitous samples.

The survey for ferret presence was not required in 1989 by the U.S. Fish and Wildlife Service (USFWS). Several surveys for black-tailed prairie dogs were completed under another program (Ebasco Services Inc. 1989c) and were, therefore, not duplicated under the Biota CMP.

1.5 Organization of this Biota Annual Report

The sections of this Biota Annual Report that follow present the environmental setting (Section 2.0) and chemical analysis program strategy and methodology (Section 3.0). These sections are based primarily on the Biota CMP Technical Plan (Stollar et al., 1988), with details on methodology taken from the Biota CMP Field Procedures Manual. Section 4.0 presents the results and analysis of data from the 1989 biota chemical analysis program. Section 5.0 provides a discussion of the results from the 1989 biota monitoring program. The literature cited is documented in Section 6.0. A printout of the Installation Restoration Data Management Systems (IRDMS) data (BIOTA.DBF file) is provided as Appendix A and a printout of the field data form information (BIODATA.DBF file) is provided as Appendix B; these two appendices are also provided on diskette. Appendix C provides details of statistical analysis. Appendix D provides additional data collected incidentally during field work.

Sections 1.0, 2.0, and 3.0, and their accompanying tables and figures, are bound as Volume I. Sections 4.0, 5.0, and 6.0, with their accompanying tables and figures, are bound as Volume II. Appendices A, B, C, and D are bound as Volume III.

2.0 ENVIRONMENTAL SETTING

This section provides an overview of the environmental setting of RMA, including abiotic system components and aquatic and terrestrial biotic systems. Characteristics of these systems may influence the distribution and rate of transport of contaminants from one geographic area to another on RMA, and between and within systems.

2.1 General Setting

Being at the western edge of the Great Plains and close to the foothills of the Rocky Mountains, RMA is in a mid-latitude climatic region that is semi-arid. Geologically, it is in the southern portion of the Denver Basin. RMA topography is characterized by gentle, rolling terrain that slopes down in a general direction from the southeast to the northwest. The elevation above mean sea level (msl) ranges from 5,340 ft along the southern boundary to 5,120 ft at RMA's northern border. The South Platte River flows parallel to the northwestern boundary of RMA and is as close as 2 miles (mi) at some points. First and Second Creeks, as well as O'Brian Canal and Burlington Ditch, receive drainage from RMA before flowing, at times intermittently, into the South Platte River. Soils are primarily fine to medium textured and have been transported to RMA by wind and water.

The RMA setting is dominated by grasslands, shrublands, and a considerable number of disturbed and weedy areas. In the southcentral portion of RMA, the Lower Lakes provide extensive aquatic habitat. Within these primary habitats are tree groves, wetlands, ponds, ditches and streams. The terrestrial fauna is characteristic of the prairie, steppe and savannah communities that are found in the Great Plains. The aquatic fauna is characteristic of warm, shallow water lakes, with poorly developed communities present in portions of intermittent streams. Surrounding land uses are primarily urban and rural residential to the west and north, industrial to the south, and ranch and farmland to the east.

2.2 Physical Environment of RMA

The physical environment of RMA provides the foundation for its biotic diversity and abundance. The following subsections present brief descriptions of the climate, geology, soil, and surface water of RMA, with emphasis on the delineated areas of contamination, defined as CMP-Biota Study Areas (CMP-BSAs), selected for the collection of samples to be analyzed chemically. Figure 2.2-1

shows the locations of the eight terrestrial CMP-BSAs and the specific marked sites (Staked Sites) used for collection of sedentary species within each of these BSAs. Staked control sites were established in the northeast and southeast corners of RMA and are shown on Figure 2.2-1. The five aquatic BSAs and sampling foci are shown on Figure 2.2-2. The selection of those locations is discussed in Sections 3.1.2 and 3.2.2.

2.2.1 Climate

The mid-latitude, semi-arid climate of RMA is characterized by low relative humidity, abundant sunshine, relatively light rainfall, moderate to high wind movement, and a large daily range in temperature. The mean maximum temperature ranges from 43 degrees Fahrenheit (°F) in January to 88°F in July. The mean minimum temperature ranges from 16°F in January to 59°F in July. Annual maximum and minimum mean temperatures may vary by 28°F.

Occasionally, Chinook winds, which in the Rocky Mountains are warm and dry, descend the eastern slope of the Front Range, bringing large and sudden temperature rises of as much as 25 to 35°F within a few hours. Chinook winds greatly moderate average winter temperatures in the RMA vicinity.

Precipitation in the RMA area is approximately 15 inches (in) per year. The evapotranspiration rate ranges from 24 to 30 in per year (NOAA, 1957-1976). About half of the precipitation falls between April and July. Snows usually occur from September to May, with the heaviest snowfall in March and possible accumulation as late as June. Thunderstorms occur frequently in the region, particularly during the spring and summer. They may be severe, with heavy showers, severe gusty winds, frequent thunder and lightning, and occasional hail.

Tornadoes occasionally develop during the proper frontal action and convective instability commonly associated with intense thunderstorms in the RMA area. In the summer of 1986 tornadoes damaged several work trailers and buildings in the vicinity of South Plants. Several small tornadoes touched down at RMA in June 1988, including one that did minor damage to facilities being installed near Basin F.

The prevailing winds at RMA are from the south and south-southwest, paralleling the orientation of the foothills west of Denver. Wind speeds average about 9 miles per hour (mph) annually. Occasional winds are also out of the north-northwest, north, and east. The windiest months are

March and April, with gusts as high as 65 mph. These months come immediately after the driest months of the year (November through February) and have the highest potential for dust storms.

Additional details regarding climate and air quality on RMA are presented in the Air Media Report (ESE, 1988b) and the CMP Air Quality Report (Stollar, 1989c).

2.2.2 Geology

The Denver Basin, which contains RMA, is a structural depression that trends in a north-south direction. It is defined by two smaller basins divided by a ridge near Greeley, Colorado. The basin is asymmetric, with gently dipping strata on the east flank and more steeply dipping strata on the west flank. Geologic strata in the southern portion of the basin near RMA dip to the southeast at less than one degree. The Denver Formation is the uppermost geologic unit present at RMA and consists of interbedded sandstone, siltstone, claystone, and lignite. More recent, unconsolidated, eolian and alluvial sediments overlie the erosional surface developed on the Denver Formation. These unconsolidated sediments locally attain a thickness of 130 feet at RMA. The upper water-bearing zone at RMA includes saturated alluvium and portions of the Denver Formation under unconfined conditions. Further details on the geology of the Denver Basin may be found in reports by MKE (1988) and May (1982). Specific information about the geology of different regions of RMA may be found in each of seven Study Area Reports (SARs) (Ebasco Services Inc., 1989a and 1989b; 1989d to 1989h).

Surficial materials are more likely to have received direct contamination from past activities and to have been in direct contact with the biota. The zone of potential contact between substrate and biota has been defined to extend from the surface to a depth of 20 ft (ESE, 1989); however, the most likely contacts with contamination are anticipated within the top five feet.

2.2.3 Soils

The wind- and water-transported geologic materials that form RMA soils are generally fine to medium textured, although remnant outcrops of coarse, cobble-sized alluvium occur on Rattlesnake and Henderson Hills. Although the U.S.D.A. Soil Conservation Service (SCS) soil survey of Adams County includes RMA (USDA-SCS, 1974), Shell and MKE remapped RMA soils during 1988 because of observed discrepancies and lack of detail in the 1974 SCS survey. The results of this

new mapping effort are preliminary, but have been used in the following descriptions because they are expected to change very little before they are finalized.

On RMA, five soil associations, or distinctive groupings of soil types, have been identified (Walsh, 1988). Three associations, the Bresser-Truckton, Ascalon-Satanta, and Weld-Nunn, characterize soils within the five terrestrial CMP-BSAs. One of the two other soil associations, the Bresser-Satanta, occurs in the vicinity of on-post control locations in Sections 7 and 8; the fifth association (Aquic Haplustolls) occurs only along the First Creek drainage in the eastern portion of RMA. The soils in the five terrestrial CMP-BSAs were formed in medium-to coarse-textured alluvial deposits. Surface soil textures range from loamy sands and sandy loams to loams; subsurface textures range from sandy loams and sandy clay loams to loams. Most of these soils are well drained and have slopes ranging from zero to ten percent. The following discussion describes the physical characteristics of soils and sediments in each of the eight terrestrial and five aquatic BSAs.

Soils within the terrestrial CMP-BSAs and staked sites, as well as sediments within the aquatic CMP-BSAs, are of particular interest because of their potential as a pathway of contamination to the biota sampled there. The chemical and physical composition of the soil is important in determining the chemical fate of organic and inorganic chemicals, and their availability to biota. For instance, the concentration of dieldrin found on a particular plant root surface is a direct function of the percent of organic carbon (K_{oc}) in the surrounding soil. This value is important in evaluating the sorption capability of a particular chemical, such as dieldrin, across a given solid/solid boundary (Sukol et al., 1987). Similarly, the particle size distribution of lake sediments is particularly important in evaluating the suspension time of sediments in aquatic systems, and the resultant exposure duration of contaminants in aqueous media to aquatic biota. In both moist and dry soil environments, adsorption of pesticides and metals can be very strong, particularly on surfaces containing high percentages of clays with their specific mineralogical structures. Consequently, losses of contaminants by evaporation or dissolution in aqueous environments decrease under certain soil/sediment textural conditions (Hartley and Graham-Bryce, 1980). In addition, higher calcium carbonate concentrations in soils may affect the mobility of metals in soils and subsequent bioavailability to sedentary biota species. The physical, hydrologic, and chemical characteristics of key soil series associated with CMP-BSAs on RMA are summarized in Tables 2.2-1 and 2.2-2 for terrestrial areas and in Table 2.2-3 for aquatic areas.

In 1989, several new BSAs and staked sites were located on RMA, as supplements to those sites and areas established in 1988. Soil descriptions for the new 1989 BSAs and staked sites follow. Information on the areas established in 1988 can be found in the Biota CMP 1988 Annual Report (Stollar et al., 1990).

2.2.3.1 CMP-BSA 11. Soils in CMP-BSA 11, Toxic Storage Yard (TSY), consist primarily of undifferentiated disturbed and fill materials, with inclusions of eolian-deposited soils and alluvial outwash. There are no RI data on contaminant concentrations in TSY soils. However, prairie dogs sampled in the TSY under the Biota RI contained detectable concentrations of dieldrin and arsenic; this led to the 1989 sampling of this area under the Biota CMP. Due to the lack of soil data, the staked sites in BSA 11 were located primarily in upland areas on the basis of vegetation type, wildlife habitat, and geographic distribution (Figure 2.2-1).

Staked Site BS11-1 is situated on the western end of a relatively level bench above First Creek. The site is bisected by a drainage ditch that carries runoff flow from the north end of the TSY west to First Creek. Soils within this site are a mixture of loams and clays; however, surficial cracking was not evident under last summer's intense heat. Vegetation is fairly abundant at this site, especially within the drainage ditch; subsequently, the erosion hazard is slight. The relatively protected ditch system supports an abundance of vegetation, which provides diverse wildlife habitat.

Staked Sites BS11-2 and BS11-3 occupy upland, xeric sites. Though relatively clayey, Site BS11-2 soils are more extensively disturbed than the other two sites, and contain extensive surface gravels. Vegetation is represented by species more indicative of disturbed areas, including annual forbs and cheatgrasses. The southwestern portion of the site does, however, support native shrubs that have adapted to the gravelly and undifferentiated soil materials. Site BS11-3 has received less surface disturbance, and supports a wide variety of upland native grasses and shrubs, as well as annual introduced species. Although mapped as a disturbed, clayey soil, observations at this site suggest a less disturbed, more sandy loam type. The site is occupied by a large network of small mammal burrows, which is indicative of the loose or friable nature of the surficial horizons. The small mammal burrows at this site, as well as the few observed at Site BS11-1, may serve as pathways for infiltration of precipitation and potential contaminants.

2.2.3.2 CMP-BSA 12. Soils in CMP-BSA 12, the core of the North Plants Area (NPA), are predominantly disturbed clayey materials mixed with unconsolidated fill and debris. The reported

depths of these materials extend from 7 to 21 inches (Walsh, 1988). Natural, undisturbed soils occupy locations in the NPA outside the central manufacturing complex. There is wide variability in physical, chemical and hydrologic characteristics of the disturbed surficial soils. Staked sites in this BSA were placed within foci of chemical contamination and sited in vegetation suitable to provide intentional samples, for appropriate wildlife habitat, and in soil suitable for earthworms.

At both staked sites (BS12-1 and BS12-2), the original surface horizons were either removed and replaced with fill materials of unknown origin or moved around to make way for the myriad of drainage ditches bisecting each of the two sites (Figure 2.2-1). Because of the clayey nature of the surficial soils, and despite the drainage systems at the two sites, the soils are poorly drained and may be saturated for long durations in some locations. The ditch system at Site BS12-1 is deeper than that at Site BS12-2, and the surface soils are less prone to sheet erosion. There is also a paucity of vegetative cover at Site BS12-2, contributing to potential surface erosion. Vegetation at both sites consists primarily of weedy forbs and annual grasses.

2.2.3.3 CMP-BSA 13. CMP-BSA 13 (Administration Area) is dominated by disturbed sandy and loamy materials. The five locations sampled under the Biota CMP in 1989 are all disturbed materials overlain by sodded lawn; given the lack of data on contaminant concentrations in the soil, sampling locations were dispersed within the BSA (Figure 2.2-1). The soils excavated and/or replaced at each of these sampled locations were fine textured with moderate to good permeability. Wind and water erosion are basically nonexistent due to the cultivated lawn.

2.2.3.4 Newly Established Staked Sites for 1989. In 1989, several new staked sites were established in the original five BSAs. In CMP-BSA 3, Sand Creek Lateral and adjacent areas, one new site was established (Site BS3-4). Soils at this site are much like those at the established staked sites to the south. The soils are mapped in the Ascalon series, which tends to have silty to clayey sand textures on the surface. The site occupies part of the toeslope of a sand-mantled alluvial escarpment, and may be subject to moderate wind and water erosion. Part of the site also extends into the Sand Creek Lateral where sediments are deep and organic-matter enriched. Here, as in other CMP-BSA 3 sites, vegetation growth in and adjacent to Sand Creek Lateral is controlled annually to facilitate more efficient drainage.

In CMP-BSA 4, the South Plants area, a new site (BS4-4) was established south of Building 354. The site was located to include a major east-west drainage system. The soils in South Plants are

predominantly disturbed sandy and loamy mixed with unconsolidated fill and debris. Medium- to coarse-textured natural soils also occur as undisturbed inclusions. The ditch system which bisects the site, channels runoff toward Sand Creek Lateral from several contamination sources. Drainage water has been observed in this ditch for much of the year. Sediments in this ditch are deep and organic matter-enriched, and have properties conducive to adsorption of contaminants. The remainder of the site to the south of the ditch consists of hard-packed surficial materials. Infiltration is moderate and vegetative cover consists of weedy forbs and annual grasses.

One new site was established in CMP-BSA 5 (Site BS5-7) adjacent to the extreme eastern edge of Upper Derby Lake. Soils at this site formed in medium- to coarse-textured alluvium overlain by eolian deposits. The site slopes to the north toward the edge of Upper Derby Lake. This poorly drained lowland area is characterized by clayey, organic soils. The surficial soils on the knob defining the upland portion of the site are sandy, permeable and well drained. They are also characterized by high moisture losses from evapotranspiration. This site has a wide variety of vegetative cover and serves as a valuable gathering spot for wildlife.

2.2.4 Surface Water

Surface water on RMA is characterized by several lakes, ponds, depressions, and intermittent ditches and streams (Figure 2.2-2). The manmade lakes and ponds were created for use in industrial cooling and surface runoff control. Upper and Lower Derby Lakes are also supplied with water entering RMA through several ditches from the south. Ladora Lake receives some of its water from the Sand Creek Lateral. Lake Mary, Ladora Lake, Lower Derby Lake, and the Rod and Gun Club Pond comprise CMP-BSAs 6 through 9, respectively. When Upper Derby Lake was filled with water in late spring, it was added as a fifth aquatic BSA (CMP-BSA 10). Aquatic sampling foci (Figure 2.2-2) were established in the lakes near discharge points for potentially contaminated runoff and process water. The basins (A-F), created for storage of waste water, are now dry except for the occasional presence of surface runoff after storm events. Specific detail regarding surface water quality and quantity may be found in the Water RI Report (Ebasco Services Inc., 1989i) and the Surface Water Report (Stollar, 1989b).

2.3 Biotic Environment of RMA

RMA is surrounded by lands with a diversity of uses that influence on-post plant and animal abundance, distribution and diversity. To the north and east of RMA, the dominant land use is dryland agriculture devoted to production of wheat, corn, barley and other crops. To the west and south of RMA, urban and industrial settings are typified by Stapleton Airport, and the Montbello and Commerce City areas. In these industrial and residential areas, the natural course of vegetational growth has been altered, with resultant effects on wildlife abundance. In lands north and northwest of RMA, mixed residential, rural and industrial uses prevail.

In contrast to its surrounding lands with different uses, RMA provides a wide diversity of habitats suitable to support abundant and varied terrestrial and aquatic resources. Land uses on RMA, both prior to and during Army and lessee activities, have exerted considerable influence on present habitat distributions. Many species are more abundant on-post than off RMA. As a result of these factors and the absence of hunting pressure, RMA contains a significant prey base that attracts numerous avian and mammalian predators.

A variety of terrestrial and aquatic ecosystem components have been observed on RMA. Terrestrial systems are typical of those elsewhere on the eastern plains of Colorado, except that unusually extensive habitat alteration on RMA has resulted from disturbances and a variety of former and ongoing management practices. Habitat alterations have led, in some cases, to an increase in diversity and abundance of several plant and animal species, while in other cases, decreased diversity has resulted from persistence of early successional weedy species. Aquatic systems on RMA, which are no longer used as cooling water reservoirs, have recently been periodically managed for their fisheries resources.

2.3.1 Terrestrial Ecosystems

2.3.1.1 Vegetation Resources. RMA is within the Plains Grasslands ecosystem (Küchler, 1964) or Great Plains region that is part of the North Temperate Grassland biome (Shelford, 1963). This biome extends across the central and western portions of the U.S. north toward Alberta, Canada and is larger than any other vegetation region in the United States. Short, warm-season grasses are the predominant vegetation in this region, with interspersed stands of annual and perennial forbs and deciduous shrubs. Taller grasses occupy more moist areas. Riparian woodlands, marshes and

bogs, and wet, open areas tend to be restricted to drainages, swales, and water courses. Throughout the region, successional changes are attributable to the natural and anthropogenic effects of fire and grazing, and have contributed to generally high species diversity.

On RMA, MKE mapped vegetation into five general community types: weedy forbs (13 percent of the RMA area), cheatgrass (Bromus tectorum)/weedy forbs (22 percent), cheatgrass/perennial grass (11 percent), native perennial grassland (20 percent), and crested wheatgrass (Agropyron cristatum) (19 percent) (MKE, 1989b). Several lesser community types, comprising 15 percent collectively, were also identified, and despite their size, are equally important due to the diversity of terrestrial flora and fauna they provide. These lesser types included cottonwood/willow stands, sand sagebrush (Artemesia filifolia) and rubber rabbitbrush (Chrysothamnus nauseosus) shrublands, yucca grasslands, locust thickets, bottomland meadows, cattail marshes, and ornamental trees and shrubs. Table 2.3-1 summarizes the generalized vegetation characteristics of each of the staked sites on RMA. In general, vegetational succession on RMA has been heavily influenced by pre-RMA and RMA-related land uses. Pre-RMA uses included primarily grazing and cultivation. RMA-related uses have included support for RMA activities, open space or buffer zones, borrow activities, and permanent alterations to habitat (e.g., buildings, pavement, and infrastructure). There are also several areas of reclaimed land, evidenced by stands of crested wheatgrass, an introduced grass species designed and often used for revegetation of disturbed right-of-ways and erosion control. Subsequent abandonment of these disturbed areas or failed plantings have left many areas in early successional stages of vegetation development.

MKE identified several unique areas on RMA that contain habitats, vegetative communities or soil types of special interest. These include areas of remnant natural prairie, vulnerable populations of once-abundant native plant species, unique wildlife habitats, or unusual landscape features with limited extent. CMP-BSAs 1, 2, 3 and 4 do not contain unique areas, although three features are present nearby: (1) ancient alluvial terraces containing heavily cemented gravels along the northern edge of Section 36 and southern edge of Section 25, which have the potential to support unique vegetational communities and provide wildlife with a variety of uses not available in the surrounding area; (2) a relatively undisturbed 28-acre parcel of gravelly soils atop Rattlesnake Hill; and (3) remnant areas of natural vegetation dominated by ring-muhly (Muhlenbergia torreyi), winterfat (Ceratoides lanata), and sideoats grama (Bouteloua curtipendula), also on Rattlesnake Hill. BSA 5 contains several of these unique areas, most notably the cottonwood/willow stands, marshes, stream channels and bottomland meadows along the several lakes, ponds and ditches in the BSA.

An area of natural vegetation containing needle-and-thread (Stipa comata), blue grama (B. gracilis), and prairie sandreed (Calamovilfa longifolia) occurs south of Ladora Lake in Section 11 near Staked Sites BS5-5 and BS5-5A. Sand sagebrush shrubland, with a well-developed native perennial understory, occupies about 36 acres of Section 2. Staked Control Sites BCRM-5 and BCRM-6 in Sections 8 and 7, respectively, are located near sand sagebrush shrubland on loamy, alluvial soils (Typic Haplustolls); neither this habitat or soil type are abundant on RMA. Adjacent to Staked Control Site BCRM-6, peach-leaf willow (Salix amygdaloides) and bottomland meadows are evident, interspersed with native perennial grasses.

Vegetation varies markedly among the eight terrestrial CMP-BSAs. The vegetation in BSAs 1 and 2 consists primarily of weedy forb and cheatgrass/weedy forb communities. Several staked sites are vegetated with homogeneous and aggressively competitive stands of cheatgrass (BS2-3/BS2-3A), annual sunflower (BS1-3), or kochia (Kochia iranica) (BS1-5). Minor inclusions of marshes and wet, open ground or other vegetation types enhance existing habitat at Sites BS1-2/BS1-2A, and BS1-3. Plant communities at several of the staked sites (BS1-5, BS2-2A, BS2-3/BS2-3A) are depauperate, having been decimated by prairie dog activity and subsequently invaded by weedy forbs. Other staked sites in BSAs 1 and 2 (BS1-1, BS1-4, BS2-1, BS2-2/BS2-2A, BS2-4, and BS2-5) have been severely disturbed by vehicular traffic, waste effluent drainage, or other RMA activities and contain little more than weedy forbs.

Vegetation within CMP-BSA 3 is characterized by riparian species confined along the banks and bottoms of the Sand Creek Lateral, and a mixture of weedy forbs, cheatgrass and perennial grasses along the adjacent roadways. The Sand Creek Lateral corridor is managed annually to control overgrowth of vegetation and enhance drainage flow. Observed management techniques have included the use of fire and grading along the ditch banks. Site BS3-1 was revegetated with perennial native and introduced grasses and forbs in the fall of 1988 after construction activity in the area was completed. Site BS3-2 was altered slightly in the early spring of 1988 by a controlled burn. Sites BS3-3 and BS3-3A have been unaffected by management activities and support a wide variety of mesic and xeric vegetation. Like other CMP-BSA 3 sites, newly Staked Site BS3-4 is characterized by riparian species along the banks and bottoms of Sand Creek Lateral, and a mixture of weedy forbs, cheatgrass, mixed grasses and xeric subshrubs (remnants of native mixed grass prairie) extending east of the site. This site may be subject to the effects of annual management to control overgrowth of vegetation in Sand Creek Lateral.

BSA 4 is essentially devoid of vegetation, except along roadways, ditches, between buildings, and in peripheral locations near its boundary with BSAs 3 and 5. The three staked sites in BSA 4 (BS4-1, BS4-2, and BS4-3) are dominated by weedy annual forbs, some perennial forbs, and sparse grasses. The majority of cover is bare ground, pavement and debris. Unlike other staked sites in CMP-BSA 4, the new Staked Site BS4-4 contains a variety of vegetation, primarily due to its establishment adjacent to an intermittent ditch system. Annual forbs and grasses occupy the upland portions of the site. Riparian plants, including cattails, sedges, and milkweed constitute a thick, dense subcommunity along the ditch.

Vegetation in CMP-BSA 5 is diverse. Crested wheatgrass and other minor vegetation types characterize Staked Sites BS5-1, and BS5-5/BS5-5A. Weedy forbs and lowland vegetation characterize Staked Site BS5-2, while an early successional mix of cheatgrass/perennial grasses and weedy forbs dominate Site BS5-3A. Staked Sites BS5-3, BS5-4, and BS5-6 are characterized by channel vegetation and riparian woodland mixed with cheatgrass and weedy forbs. The nearby cottonwood/willow stands, along several drainages and near lakes, ponds and marshes, are a stable community that has been present for at least 50 years. Several stands have also been planted since RMA land was purchased by the Army. Staked Site BS5-7 consists of perennial native grasses and xeric community shrubs. This site, adjacent to Upper Derby Lake, is the least disturbed of the staked sites in CMP-BSA 5. Riparian woodlands define the northern edge of this staked site. The nearby cottonwood/willow stands represent a stable community that predates the RMA.

Although vegetation varies markedly among the original five CMP-BSAs, there are several general similarities between vegetation types in CMP-BSAs 11 and 12. In these two BSAs, weedy forb and cheatgrass/weedy forb communities dominate the landscape. Several staked sites are vegetated with homogeneous and aggressively competitive stands of cheatgrass (BS11-1 and BS12-1) and field bindweed (BS12-2). Mixed stands of weedy forbs with minor inclusions of native species occur at Staked Sites BS11-2 and BS11-3. Site BS12-2 has been disturbed by waste effluent drainage and some vehicular traffic.

Of the eight staked control sites available in 1989, two (BCRM-1 and BCRM-5) are mapped as perennial native grass communities. The primary grass in these areas is needle-and-thread mixed with native forbs. Site BCRM-6, though mapped as cheatgrass/weedy forbs, contains sandsage-prairie components and other remnant shortgrass prairie grasses and forbs. Sites BCRM-2, BCRM-3, and BCRM-4 are mapped as cheatgrass/perennial grass habitats, while Site BCRM-5A

is mapped as a cheatgrass/weedy forb habitat. Site BCRM-3A, though mapped as cheatgrass/weedy forb habitat, is adjacent to a rabbitbrush ecotone. Localized small mammal habitat is likely to be influenced by the presence of this native shrub.

2.3.1.2 Wildlife Resources. The prairie, steppe, and savannah communities characteristic of the Great Plains region support a variety of terrestrial fauna. The diversity of wildlife in this region is enhanced by the wide variety of habitats present. Abundant food, cover and other habitat components improve reproductive success and support larger populations. In CMP-BSA 5, total diversity and abundance are especially enhanced by the enriched food and cover base of the riparian woodlands and surface waters. An inventory of RMA wildlife species and details on their distribution are found in the Biota RI (ESE, 1989), which states that within RMA, approximately 471 terrestrial vertebrate species potentially occur; 232 of these species have been observed on RMA (ESE, 1989, Appendix A). Additional information on wildlife is found in the MKE report on wildlife resources of RMA (MKE, 1989a).

Carnivores, at the third trophic level, are represented on RMA by several mammals: badgers (Taxidea taxus), coyotes (Canis latrans), foxes and longtail weasels (Mustela frenata). Coyotes range across all sections of the RMA, excepting the heavily traveled areas of South Plants in CMP-BSA 4. Badgers are also common at RMA. During night surveys of prairie dog towns for the endangered black-footed ferret (M. nigripes) (ESE, 1989), badgers, as well as red fox (Vulpes fulva), gray fox (Urocyon cinereoargenteus), and swift fox (V. velox) were observed, as were raccoons (Procyon lotor), striped skunks (Mephitis mephitis) and longtail weasels. These 1987 night-spotting surveys yielded no black-footed ferret sightings (ESE, 1987).

Top carnivores present on RMA also include seventeen species of raptors that have been observed on RMA by biologists from Ebasco Services, Inc. (EBASCO), ESE, USFWS, or MKE as part of other programs and activities. These raptors vary in abundance seasonally. The ferruginous hawk is the most abundant wintering raptor on RMA (ESE, 1988c). Rough-legged hawks (B. lagopus), Cooper's hawks (Accipiter cooperi), sharp-shinned hawks (A. striatus), red-tailed hawks (B. jamaicensis), bald eagles (Haliaeetus leucocephalus), and golden eagles are also common at RMA during the winter as observed by both EBASCO and ESE personnel. Also present in winter are several owls including long-eared (Asio otus), short-eared (A. flammeus), and resident great horned owls. During the summer, red-tailed hawks, Swainson's hawks (Buteo swainsoni), northern harriers (Circus cyaneus), and American kestrels are the common breeding hawk species on RMA. Great

horned, long-eared, short-eared, and burrowing owls (Athene cunicularia) are common breeding owls. Twenty-one raptor nests were located across RMA in 1987 (MKE, 1989a). CMP-BSA 5, with its abundance of large trees relative to the rest of RMA, contained most of the raptor nests located.

Two species of the wintering raptors are species of Federal interest: the bald eagle (a Federally listed endangered species) and the ferruginous hawk (a species studied for listing by the USFWS). During the past four winters, as many as 38 bald eagles have roosted on RMA. Bald eagles wintering on RMA feed primarily on prairie dogs and rabbits, many of which are stolen from ferruginous hawks. Eagles were commonly observed around the Lower Lakes in BSA 5, but there was little evidence of fish in castings studies by ESE (1988c). Details of the bald eagle study on RMA are found in the 1986-1988 Bald Eagle Studies report (ESE, 1988c).

Raptors, like mammalian carnivores, are at the third trophic level. Hawks and eagles depend primarily on prairie dogs, rabbits, and carrion for food. Owls typically consume smaller rodents, while kestrels subsist on insects and small rodents.

The major prey species for the top carnivores on RMA is the black-tailed prairie dog. Prairie dog colonies occurred within six of the eight terrestrial CMP-BSAs in 1988; they did not occur in CMP-BSA 4 or 13. In the fall of 1988, there was an outbreak of plague in prairie dog colonies in the central and northeast portions of RMA that markedly reduced the numbers of prairie dogs on RMA. In the fall of 1989, the most extensive colonies were north of December Seventh Avenue in Section 35. These colonies were partially within BSA 3. Small remnant towns occurred in BSAs 1, 2, and 5. The populations in BSAs 11 and 12 were gone.

Other prey species include black-tailed jackrabbits (Lepus californicus), cottontails and rodents. Black-tailed jackrabbits are most frequently observed in South Plants (BSA 4) and in areas to the south. Desert cottontails (Sylvilagus audubonii), the predominant species present, are found in all CMP-BSAs. Rodents observed in various study areas during the 1989 CMP program include thirteen-lined ground squirrels (Spermophilus tridecemlineatus), deer mice (Peromyscus maniculatus), grasshopper mice (Onychomys leucogaster), plains harvest mice (Reithrodontomys montanus), prairie voles (Microtus ochrogaster) and meadow voles (M. pennsylvanicus), Ord kangaroo rats (Dipodomys ordi) and hispid pocket mice (Perognathus hispidus). These small- and

medium-sized mammals are, for the most part, primary consumers (herbivores) in the food chain, and are preyed upon by coyotes, badgers, weasels, foxes and raptors on RMA.

Game animals found on RMA include pheasants, mourning doves, mule deer and white-tailed deer (Odocoileus virginianus). Pheasants and mourning doves are common upland game birds that are often seen in riparian, tall grass, and weedy vegetation types throughout RMA. Both mule and white-tailed deer are common on RMA. Total counts for RMA made by the Colorado Division of Wildlife (CDOW) in December 1986 were 133 mule deer and 22 white-tailed deer (MKE, 1989a). Total ground counts in 1986-87 by MKE indicated the presence of 207 mule deer and 56 white-tailed deer. Both species were more abundant on RMA than at off-post comparison areas. BSAs 3 and 5 are frequently used by deer, particularly in the wooded and grassy areas between Upper and Lower Derby Lake and along Sand Creek Lateral near Ladora Lake. Deer are primary consumers (herbivores) in the food web. Coyotes are possible predators for weakened or young deer, but dead deer may be scavenged by any of the raptors or mammalian carnivores.

Several species of reptiles also occur on RMA. Species encountered include the bullsnake (Pituophis melanoleucus), western hognose snake (Heterodon nasicus), common gartersnake (Thamnophis sirtalis), plains gartersnake (T. radix), yellow-bellied racer (Coluber constrictor), and several species of lizards. The plains rattlesnake (Crotalus viridus) has also been reported by various field personnel near the lakes and in more upland areas.

2.3.2 Aquatic Resources

On RMA, the Lower Lakes (Lake Mary, Ladora Lake, Lower Derby Lake, and Upper Derby Lake) and the Rod and Gun Club Pond are the primary bodies of water (Figure 2.2-2). The Havana Ponds and North Bog are smaller ponds on RMA. All of these bodies of water except North Bog are manmade impoundments constructed to support the industrial developments on RMA, serve as recreational areas, and/or contain surface water drainage. North Bog is at the site of a local ground-water upwelling, but has been affected by nearby activities such as grading and ground-water injection. The flow of water among these impoundments is from Upper to Lower Derby Lakes, into Ladora Lake, and then into Lake Mary. Any overflow from Lake Mary can go through a ditch that passes under D Street and a dammed basin in Section 3. Although an overflow ditch can carry water from Lower Derby Lake to the Rod and Gun Club Pond, the pond receives runoff

primarily from the surrounding terrain and what little additional area is intercepted by the ditch. There is no drainage outlet from the Rod and Gun Club Pond.

First Creek, draining from southeast to northwest across the eastern half of the Arsenal, is the only stream flowing through RMA. The stream flow in First Creek receives irregular runoff, and is characterized by fluctuating water levels and intermittent flow. In addition, the Sand Creek Lateral, Uvalda Street Drainage, and the Highland Lateral flow into RMA and join with the aquatic systems mentioned above (Figure 2.2-2). There are also peripheral ditch systems that carry local drainage into or between these systems. Management of the Lower Lakes for runoff control has recently resulted in Upper Derby Lake being kept empty and available to receive unanticipated quantities of runoff. In the spring of 1988, a series of storm events resulted in the protracted diversion of runoff into Upper Derby Lake; the lake contained water for the remainder of 1988 and at least until September 1989.

RMA lakes tend to have viable yet restricted aquatic communities due to changes in water quality and quantity through the years, and to periodic fishery management programs. The management of fisheries has been reported as early as the 1940s, when patients from Fitzsimmons Army Hospital occasionally fished the lakes (Finley, 1959). After construction of Lake Mary in 1960, the USFWS became actively involved in managing the aquatic resources on RMA (Rosenlund, 1981). After the draining and dredging of contaminated sediments from Upper and Lower Derby Lakes and Ladora Lake in 1964 and 1965, the lakes were restocked by the USFWS (Mullan, 1971). Several management programs were subsequently initiated in the different lakes from 1961 to 1982. In many cases, the programs varied from lake to lake. Table 2.3-2 presents documented fish stocking programs on RMA, which are discussed in detail in MKE (1987). Aquatic systems in lakes and ponds at RMA have been most recently characterized in studies conducted primarily by MKE and the USFWS from 1986 through 1988 (MKE, 1987; ESE, 1989). Phytoplankton and macro- and micro-zooplankton communities occupy Lower Derby Lake, Ladora Lake, and Lake Mary. Documented diversities tended to be lower in Lower Derby Lake than the other lakes, although densities were higher.

Several species of fish were observed in the lakes (MKE, 1987; ESE, 1989). Based on these studies, dominant species in Lower Derby Lake include largemouth bass, bluegill, carp (Cyprinus carpio), and bullhead. Less abundant species include northern pike, minnows (family Cyprinidae) and green sunfish (L. cyanellus). In Ladora Lake, bluegill and largemouth bass constitute the predominant

fish species, while yellow perch (Perca flavescens), northern pike, carp, bullhead and green sunfish are also observed. Bluegill are the most abundant fish species in Lake Mary, but carp, channel catfish (Ictalurus punctatus), bluegill, black crappie (Pomoxis nigromaculatus) and largemouth bass are also observed.

Several species of aquatic plants occur in the lakes, including leafy pondweed (Potamogeton foliosus), American pondweed (P. nodosus), coontail (Ceratophyllum demersum), cress (Nasturtium officinale), water plantain (Alisma spp.), arrowhead (Sagittaria spp.), numerous sedges (Carex spp.) and rushes (Juncus spp.), and cattail (Typha spp.). The density and diversity of aquatic species present varies not only between lakes, but between different locations within each body of water (ESE, 1989). The species of pondweed collected for the 1988 and 1989 CMP Biota Monitoring program has been determined to be P. pectinatus (sego) rather than P. foliosus (leafy) reportedly collected during previous studies on RMA (see Section 5.0). Water milfoil (Myriophyllum spicatum) was dominant in Lake Mary and Ladora Lake in 1989. This species had been reported in previous studies but never as a dominant species

During 1989 CMP aquatic collection each of the target species (largemouth bass, channel catfish, bullhead and bluegill) were observed on RMA, as were several nontarget species (northern pike, carp, black crappie, green sunfish, and yellow perch) Based on previous studies (Rosenlund et al., 1986; ESE, 1989), the black bullhead was the species anticipated for 1988 sampling. However, based on observation of definitive taxonomic characteristics, the 1988 bullhead observed by CMP fishery biologists were brown bullhead (I. nebulosus) (Stollar et. al, 1990). In 1989 both species were collected. Lake Mary contained largemouth bass, channel catfish, bluegills, American and sego pondweed, and coontail, as well as plankton. Ladora Lake contained northern pike, largemouth bass, bluegill, and all three plant species, as well as plankton. Lower Derby Lake contained the same species as Ladora Lake, except brown bullhead were also present. The Rod and Gun Club Pond contained no fish or aquatic plants and was virtually dry in 1989. Large adult largemouth bass were not abundant in Lake Mary or Lower Derby Lake. Adult bluegill were much less abundant than the next youngest age class in all lakes where bluegill occurred. Large numbers of carp (up to 13 per net) were present in Lower Derby Lake. Additional information can be found in Section 5.2 of this report as well as in studies by Rosenlund et al. (1986) and Rocky Mountain Fisheries Consultants, Inc. (1978). These provide generalized population density and diversity information in addition to that provided by MKE for the Biota RI.

The broad, shallow nature of Upper Derby Lake, the fact that it generally contains water only during the spring, and the presence of rooted vegetation across most of the substrate, make it a suitable breeding area for certain amphibians; but it does not have a well-developed aquatic community. In 1988 when Upper Derby Lake was flooded, schools of hundreds of small (20 to 50 millimeters) fish of unknown species were observed near the Upper Derby Lake outlet to Lower Derby Lake. None of these fish were captured. No other fish and no aquatic plants were observed in this lake. No more flooding has occurred and, except for waterfowl, no aquatic sampling was conducted in BSA 10 in 1989.

Waterfowl are a prominent feature of aquatic communities on RMA, particularly in BSA 5 and the southern portion of BSA 3. Overall, Ladora Lake is the most heavily used permanent water body in terms of total numbers of waterfowl present per count. However, numbers per hectare are higher at some of the smaller water bodies such as Havana Pond and Lake Mary (ESE, 1989). Predominant species observed during the 1989 CMP field season are the Canada goose (Branta canadensis), mallard, northern pintail (Anas acuta), blue-winged teal, green-winged teal (A. crecca), and redhead Other prevalent water birds include American coots, western grebes (Aechmophorus occidentalis), and pied-billed grebes (Podilymbus podiceps). Upper Derby Lake was dry at the time of the Biota RI studies, but during summer 1989 it contained water and was used extensively by waterfowl. This was the only lake where mallard broods were found in both 1988 and 1989.

Wading birds observed in BSA 5 during the 1988 and 1989 field seasons and by ESE during earlier investigations (ESE, 1989) include the great blue heron (Ardea herodias) and black-crowned night heron (Nycticorax nycticorax). Great blue herons do not nest on-post, but feed regularly in the shallows of the Lower Lakes, Havana Pond, and marshy areas along First Creek. Black-crowned night herons are less frequently observed, but may have nested on RMA. Gulls and shorebirds (order Charadriiformes) seen at the Lower Lakes are typical for the region.

The northern chorus frog (Pseudacris triseriata) occurs in large numbers in most cattail stands and intermittent wet areas (such as Upper Derby Lake) on RMA. The northern leopard frog (Rana pipens) and the bullfrog (R. catesbeiana) were also observed regularly in Lake Mary and Ladora Lake during the Biota RI field programs (ESE, 1989). Woodhouse's toads (Bufo woodhousei), Great Plains toads (B. cognatus), and plains spadefoot toads (Scaphiopus bombifrons) also occur and were observed near the Derby Lakes and in the Basin A area during both the CMP and RI programs (ESE, 1989).

3.0 CHEMICAL ANALYSIS PROGRAM STRATEGY AND METHODOLOGY

3.1 Strategy

3.1.1 Selection of Contaminants for Monitoring

At least 666 chemicals have been attributed to activities of the Army and lessees at RMA (Ebasco Services Inc., 1986). The compounds considered for monitoring in the Biota Element of the CMP were limited to the 22 chemicals that had been previously detected in RMA biota (see CMP Biota Monitoring Technical Plan, Table 3.1-1; Stollar et al., 1988). Based on the procedure described below, seven contaminants (aldrin, arsenic, DDE, DDT, dieldrin, endrin and mercury) were selected for monitoring in the Biota CMP.

To select specific chemicals for biota monitoring from the list of 22 contaminants previously detected in biota, the 16 flagging criteria developed by the U.S. Environmental Protection Agency (USEPA) for pesticide review (FR50:38118, 9/20/85) were considered. Five of these 16 criteria were determined to be more applicable to the selection of contaminants for monitoring in biota and are listed below:

- The chemical has been reported in the literature to be carcinogenic.
- The chemical has been reported in the literature to be teratogenic.
- The solubility of the chemical in water is greater than 30 micrograms per liter ($\mu g/l$).
- The chemical has a soil-water partition coefficient (K_d) that is less than 5. Chemicals with a low K_d are readily leached from the soil.
- The chemical has an octanol/water partition coefficient (K_{ow}) that is greater than 1,000. Chemicals with a high K_{ow} are highly soluble in lipids and likely to be found in fish and wildlife. K_{ow} is, therefore, an indicator of possible bioaccumulation.

As a final criterion, each chemical was evaluated as to whether it had been previously detected in the RMA soil, water, or air, as well as in the biota. These criteria were used as a measure of toxicity and to facilitate selection of chemicals that are most likely to negatively impact biota. The

criteria will not be used as a measure of injury, since the focus of concern regarding injury is on biota populations rather than individuals.

The 22 chemicals listed as potential contaminants for biota monitoring were ranked on the basis of the number of these criteria met (Table 3.1-1 in Biota CMP Technical Plan; Stollar et al., 1988). The carcinogenic, teratogenic and K_{ow} criteria were given double weight because they apply specifically to biota. A chemical with a rank of five or greater was considered for potential monitoring in biota. This rank value ensured that all chemicals present in biota and the RMA environment that are either carcinogens or teratogens and bioaccumulate, or are highly soluble and readily leached, would be identified for potential inclusion in the biota monitoring program.

Ten of the 22 chemicals had a rank greater than five and were considered for potential monitoring in biota: aldrin, arsenic, cadmium, chlordane, DBCP, DDE, DDT, dieldrin, endrin, and mercury. The other 12 chemicals were eliminated primarily because they are not reported to be carcinogenic or teratogenic and are not expected to bioaccumulate. From the 10 chemicals with a rank greater than five, cadmium, chlordane and DBCP were eliminated as target analytes because they were either present in a limited areal extent, occurred naturally, or had no record of use or disposal on RMA.

The final list of contaminants that were monitored in the Biota CMP (i.e., target analytes) is:

- Aldrin
- Arsenic
- DDE
- DDT
- Dieldrin
- Endrin
- Mercury

This independent process of selecting contaminants for monitoring in the Biota CMP resulted in the same target analytes as those for which samples were to be analyzed during the Biota RI (ESE, 1987), except that DDE and DDT were added as definite components of the Biota CMP. Different selection criteria were used for the Biota CMP to evaluate the results of the Biota RI selection process. Although the criteria used to select the target analytes were different for the Biota RI

(ESE, 1989), the results were the same. The attainment of the same results from different approaches reinforces these results.

Although the target analytes comprise both compounds (aldrin, dieldrin, DDT, DDE, and endrin) and elements (arsenic and mercury) the term chemical is used in this report to refer to any one or more of the seven target analytes.

3.1.2 Spatial Distribution of Monitoring Effort

The RI/FS at RMA was designed to define the nature and extent of contamination in the air, biota, buildings, water, soils and sewers on RMA. Phase I and Phase II site-specific investigations were completed for each of nearly 200 potential soil, sewer and building contamination sites. The results of these investigations were presented in Contamination Assessment Reports (CARs) and in specific media reports (ESE, 1988a; ESE, 1988b). These data were then summarized by EBASCO et al. (1989a to 1989b, 1989d to 1989h) in the Southern, Western, North Plants, Eastern, South Plants, Central and North-Central Study Area Reports (SARs). This information was largely available as a foundation for planning the 1988 Biota CMP; the Biota RI (ESE, 1989) was not yet available. The 1989 Biota CMP built upon the framework established in 1988 with changes based on the knowledge gained during 1988, USFWS comments on the Biota Monitoring Technical Plan and the Biota RI documents, and the availability of new information.

The major areas and sources of abiotic contamination identified in the CARs were considered as locations for the 1988 collection of biota specimens under the Biota CMP. The spatial distribution of Biota CMP sampling was based on a more extensive abiotic data base than was the Biota RI and had as its intent the sampling of contamination where it was most likely to be, rather than the Biota RI goal of determining the nature and extent of contamination in RMA biota. The major sampling areas considered are listed below and described in the Biota CMP Technical Plan:

- South Plants Manufacturing Complex
- Basin A
- Basins B, C, D, and E
- Basin F
- Lower Lakes

- Other Sites -- North Bog, Sewage Treatment Plant and ponds, North Plants Complex, Sand Creek Lateral, locations of buried lake sediments, and the Rod and Gun Club Pond

Consideration of each of these locations resulted in the selection of the five terrestrial CMP-BSAs and five aquatic CMP-BSAs on RMA in 1988. Three terrestrial CMP-BSAs were added in 1989; one of these was in the Toxic Storage Yard (CMP-BSA 11), and a second was in North Plants (CMP-BSA 12) (Figure 2.2-1). The intent of the monitoring program was to collect specimens that would be representative of the most contaminated areas on RMA. This results in monitoring a worst case scenario where, if contamination were available to the biota and assimilated by them, it would be detected. Thus, CMP-BSA 12 was established on the basis of Phases I and II soil data from the RI that indicated the presence of the biota target analytes (Ebasco Services Inc., 1989e). CMP-BSA 11 was established because the Biota RI showed prairie dog contamination there. The third additional 1989 CMP-BSA was near the Administration Building (CMP-BSA 13) and was established to collect more information relevant to the small bird mortality periodically observed there. The BSAs are briefly identified below. The 1988 BSAs are fully described in the Biota CMP Technical Plan (Stollar et al., 1988). The 1989 BSAs are described in the Biota Monitoring Field Procedures Manual. Collection of nearly all intentional samples representative of contamination on RMA occurred within these BSAs. Pheasants were collected from the two northern tiers of RMA sections in areas outside of the BSA boundaries. Select fortuitous samples were salvaged from many areas on RMA, both within and outside of the CMP-BSAs.

Terrestrial BSAs on RMA include the following:

- BSA 1, encompassing Basin A
- BSA 2, encompassing Basins B, C, D, E, and F and adjacent areas
- BSA 3, encompassing the Sand Creek Lateral corridor
- BSA 4, encompassing South Plants
- BSA 5, encompassing the uplands around the Lower Lakes
- BSA 11, Toxic Storage Yard
- BSA 12, North Plants
- BSA 13, Administration Building

Aquatic BSAs on RMA include the following:

- BSA 6, Lake Mary
- BSA 7, Lake Ladora
- BSA 8, Lower Derby Lake
- BSA 9, Rod and Gun Club Pond
- BSA 10, Upper Derby Lake

During the 1989 field season, Upper Derby Lake still had water from 1988 and was a tenth area of collection for some species.

In addition to the BSAs used for the collection of biota most likely to be contaminated, control areas were established to provide specimens with natural background concentrations for comparison. For the more sedentary species to be collected from staked sites in the BSAs, on-post control areas were selected on the basis of their edaphic characteristics, the absence of historical evidence of contamination, and the results of the abiotic RI studies. Northeast and Southeast Control Areas (Figure 2.2-1) for terrestrial species were established on RMA, with the control sites distributed as shown. Two additional control areas were staked in 1989. For more mobile terrestrial species, 1988 and 1989 terrestrial off-post control areas (Figure 3.1-1) were selected in keeping with prior off-post sampling programs, as dictated by access, and availability of adequate populations to sample, and in avoidance of known or likely contamination. The aquatic off-post control site, McKay Reservoir, was used during the Biota RI. Prairie dog control samples were collected at the Trilby Lateral and pheasant control samples were collected at Duck Creek.

The boundaries of terrestrial and aquatic CMP-BSAs were determined on the basis of contamination foci in the soils and sediments. This process is described in the following subsections. Further detail on the spatial distribution of the monitoring effort within BSAs is provided in Section 3.2.2.2. In that section the selection of specific sampling locations is discussed.

3.1.2.1 Terrestrial BSAs. The specific boundaries of each of the terrestrial BSAs were defined on the basis of contamination foci identified within them as shown on Figure 3.1-2. Only areas that exhibited higher concentrations of the selected target analytes, based on data from individual soil borings and presented in site-specific CARs, were included. As explained in Section 3.2.2.2, the contamination foci were also the basis for locating specific staked sites for the collection of

more sedentary terrestrial species. For a given BSA, the more mobile species were usually collected wherever encountered within the BSA boundary, but close to the contamination foci when possible. This approach was based on the assumption that the most contaminated biota are most likely to be found in or near the most contaminated abiotic locations.

Because habitat and vegetation resources were inadequate in certain contamination foci on Figure 3.1-2, they were not selected for sampling. The contamination foci selected for sampling in BSA 1 (Figure 2.2-1) were the lime settling basins southwest of Basin A and the Basin A perimeter (Figures 1.1-2 and 3.1-2). In BSA 2, selected sampling locations focused upon Basin B and the nearby Sand Creek Lateral, accessible portions of Basin F, a ditch leading to the southeast corner of Basin C, Basin D, and the northern portions of Basin C.

In BSA 3, selected sampling locations were the Sand Creek Lateral north-northwest of Lake Ladora, and the Sand Creek Lateral south of December Seventh Avenue. In BSA 4, the contamination foci selected for study included the Arsenic Storage Silos, the Sanitary Landfill at the west side of South Plants, and the Lewisite/Pesticide Manufacturing Area, followed by the Mustard/Pesticide Manufacturing Area, the Salt Storage Pad, and the South Tank Farm. In BSA 5, selected foci were the Section 11 and 12 Buried Lake Sediments, disturbed areas adjacent to the Section 1 trash dump, Derby Lake near the entry point for the process water ditch from South Plants, the process water ditch on the north shore of Lower Derby Lake, and the Overflow Basin in Section 3.

The contamination foci selected for sampling in BSAs 11, 12, and 13 used the same criteria established for the five terrestrial BSAs established in 1988. Table 3.1-1 lists the ranges of contaminant concentrations within or above respective indicator concentrations that were detected in these areas during the RI program. Contaminant concentrations in soils investigated during the RI program, and subsequently within staked sites selected for study under the 1988 Biota CMP and in the sediments of the aquatic study areas were presented in the 1988 Biota CMP Annual Report (Stollar et al., 1990). These same locations were used for sampling in 1989. Table 3.1-2 provides similar data for CMP-BSA 12. As there were no RI data available for staked sites located in BSAs 11 and 13, there are no tables that provide analytical soil data for these specific areas. Table 3.1-1, however, provides analytical information for soil bores analyzed within 300 ft of each of the three BSA 11 staked sites. There were also no additional RI data available for the new staked sites in either BSA 3, BSA 4, or BSA 5.

In BSA 11, selected sampling locations were distributed geographically within the TSY, primarily within the vast expanse of the storage shed areas. Concentrations of arsenic in soils were all reported within indicator levels in the 0 to 2 ft and 2 to 5 ft intervals all in soil borings within 300 ft of each of the three staked sites (Tables 3.1-1). No other target analyte of concern to the CMP program was detected during the RI.

In BSA 12, none of the five organochlorine pesticide (OCP) target analytes were detected in either of the two staked sites (Table 3.1-1). However, arsenic and mercury were both detected in the ditches that bisect the two sites at concentrations well above their respective indicator levels. Arsenic was detected at Site BS12-1 at concentrations of up to 4,800 microgram per gram ($\mu g/g$) (2 to 3 ft interval). Concentrations of arsenic in surficial soils at Site BS12-2 were as high as 190 $\mu g/g$. Mercury was detected in surficial sediments at both sites at concentrations ranging from 0.11 to 27 $\mu g/g$ (Site BS12-2). BSA 13 sampling locations were systematically distributed throughout the site.

Table 3.1-1 lists the ranges of contaminant concentrations within or above respective indicator concentrations that were detected during the RI program. These ranges are representative of soil conditions within the contamination foci identified for the CMP Biota Monitoring Program (Figure 3.1-2). The ranges generally reflect multiple detections from one to several borings, and are reported separately for the 0 to 2 ft, 2 to 5 ft, and 5 to 20 ft depth intervals. It is understood that the maximum depth of biota activity varies by site as geology, soil profile, water table depth, and species present vary. However, 20 ft was accepted by the then Biota Assessment Committee (succeeded by the Biota Assessment Working Group and then the Natural Resources Conservation Committee) as a reasonable approximation of that maximum depth, and the maximum depth to which contamination will be considered for biota.

3.1.2.2 Aquatic BSAs. Within the five aquatic BSAs, contamination foci were also identified (Figure 3.1-2), although the boundary of each BSA was defined by the shoreline of that specific lake or pond. Because of the aqueous medium to which both contaminants and biota are exposed, firmly bounded staked sites were not established within the aquatic BSAs; rather, more general sampling foci were used. The initial aquatic sampling foci (Figure 2.2-2) were located near ditch entry points, and the remaining foci were distributed to provide representative coverage of the lakes. When aquatic BSAs were established, Upper Derby Lake was dry. Later in the spring, a protracted diversion of stormwater runoff onto RMA was allowed to accumulate in Upper Derby

Lake and it became available as an aquatic BSA. However, it was used in 1988 and 1989 only to collect mallards.

The results of the RI investigations found that organochlorine pesticide (OCP) detections were widespread throughout the sediments in RMA lakes, although most detections occurred in Upper and Lower Derby Lakes and in Lake Ladora. These data are summarized in the Biota CMP 1988 Annual Report (Stollar et al., 1990).

3.1.3 Species, Life Stages, and Seasons for Monitoring

The selection of species, life stages and seasons for biota monitoring was guided by the available information on contaminants in biota and the natural history of the species being considered. The specific life stages and seasons for sampling each species were chosen to maximize the detection of contaminants and the exposure of the collected individual to the RMA environment. The goals were to sample representative trophic levels, to select species that were interrelated in an important food web, and to maximize the detection of contaminants during monitoring.

The term species is commonly used in the following sections to define a target group of different species as well as individual species. Some species have been grouped into taxa above the species level when the trophic level and food web utilization of the component species is approximately identical. For example, grasshoppers that are known to be used in the food web have been grouped into the higher taxon (family) of Acrididae. The terms sedentary or mobile are commonly used in the following sections to describe the potential for species migration from either study areas or RMA. A species (e.g., deer mice) may be mobile, but considered in this report to be sedentary if its home range is likely to be found entirely within a particular staked site. Alternatively, some species or groups of different species (e.g., plankton) may exhibit relatively low inherent mobility, but are considered mobile due to environmental influences (e.g., water movement and wind action). For the purposes of this report, 12 species are classed as sedentary (lactuca, cheatgrass, kochia, sunflower, earthworm, grasshopper, ground beetle, thirteen-lined ground squirrel, deer mouse, coontail, sego pondweed, and American pondweed), and 15 species are classed as mobile (black-tailed prairie dog, desert cottontail, western meadowlark, mourning dove, burrowing owl, ring-necked pheasant, mallard, American coot, killdeer, northern pike, largemouth bass, channel catfish, bullhead, bluegill, and plankton). These two somewhat arbitrary categories are sampled differently as discussed in Section 3.2.2.2.

To select the species for sampling, criteria were developed and applied as detailed in Subsection 3.1.3.1 of the Biota CMP Technical Plan (Stollar et al., 1988). The process was similar to the gilding approach commonly followed in the Habitat Evaluation Procedure (HEP) studies used for impact assessment projects. During the selection process, particular emphasis was given to selecting species that are part of food webs and chemical pathways leading directly to humans, higher level carnivores, or to threatened or endangered species. The criteria used for the selection of species during the Biota RI were reviewed and, when appropriate, incorporated into the selection criteria used in the CMP Biota Monitoring Program.

The intent of the Biota CMP was to independently select species, life stages and seasons for monitoring to reevaluate, validate and complement the Biota RI methodology.

The specific criteria used to select the species for the CMP Biota Monitoring Program were:

- Taxonomic group
- Trophic level
- Game species status
- Importance as a prey item for endangered species
- Threatened or endangered status
- Distribution on RMA
- Home range relative to RMA
- Ability of population to support collection
- Prior sampling under the Biota RI
- Existence of other historical contaminant data

Further detail can be found in the Biota CMP Technical Plan, Section 3.1.3 (Stollar et al., 1988). The application of these selection criteria to the species of biota present on RMA resulted in the selection of 22 primary species or other taxa (Table 3.1-3). Two alternate species were selected for sampling during field implementation of the program as most similar available substitutes when the species they replaced was absent. The way in which the selection criteria applied to the intentional species is shown in Table 3.1-4. They applied similarly to prickly lettuce (Lactuca sp.) for the kochia it occasionally replaced. Further detail on the rationale for selecting the primary species is provided in Section 3.1.3.2 of the Biota CMP Technical Plan (Stollar et. al., 1988).

All of the terrestrial animal species selected for 1988 monitoring were the same as those sampled during the Biota RI program except deer mouse, which was added under the Biota CMP. The terrestrial plant species are also the same except for the addition of cheatgrass and substitution of kochia for field bindweed. Of the aquatic species selected, all were also collected during the RI program, except channel catfish, which was present in Lake Mary and the aquatic control lake (McKay Reservoir), while bullhead were absent in these two locations.

Five terrestrial species were added for the 1989 Biota CMP: western meadowlark, burrowing owl, mourning dove, killdeer, and ground beetle. Deer and American kestrels were not sampled in 1989 in accordance with the every-other-year sampling strategy for these species. Thirteen-lined ground squirrels were not needed as an alternative species to deer mice in 1989. Both brown and black bullhead were sampled in 1989. Further detail on bullhead taxonomic determinations is in Appendix D.

3.1.4 Tissues to be Sampled

A variety and combination of tissues have historically been analyzed in the investigation of biota contamination on RMA. Increasing knowledge of where particular chemicals tend to concentrate in biota tissues has enabled greater accuracy in the detection of contaminants by focusing sampling efforts on specific tissues. Another primary consideration in selecting the tissues to be sampled was the food web position of the organism being sampled and the portion of the organism typically consumed by the next higher trophic level. An additional consideration was the size and type of organism being sampled.

Based upon these three tissue selection criteria, eight specific tissues and/or tissue combinations were considered for sampling and analysis: whole body composite, whole body or whole egg, dressed carcass, muscle, liver, kidney, brain and above-substrate parts. Table 3.1-3 lists for each species the tissues and life stages selected to provide samples for monitoring. In some cases, additional tissues (e.g., brain, kidney, kidney fat, stomach contents, spleen, heart and gizzard) were collected and held as potential samples to maximize the available data from specimens of large species. At the laboratory, each sample was homogenized and 8 ounces (about 226 grams [g]) were retained for analysis. After analysis residual quantities were returned to the freezer and for the duration of the contract will be available for any needed additional analyses.

Whole body samples were analyzed for species that are eaten whole by the next higher trophic level organism to provide the best indication of the total amount of a contaminant passing to that higher trophic level. Whole body (egg) samples were taken for fish and kestrel eggs. When individuals were too small to compose a sample alone, whole body composite samples were taken, as for deer mice, beetles, grasshoppers, earthworms, and plankton.

Dressed-carcass samples were defined to include all body parts typically eaten by humans or top carnivores. Thus, for game species, feathers, tarsi, and gastrointestinal tract were removed from birds (pheasants, mallards, and coots), and fur, skin, feet, head and gastrointestinal tract were removed from mammals (cottontails). For nongame birds (kestrels, killdeer, meadowlarks, and burrowing owls), preparation was the same as game species preparation game species, except the head was left on and the beak was removed; mourning doves were prepared like nongame birds because of their small size. For nongame mammals (prairie dogs), preparation was the same as game species preparation. Adult pheasant and mallard livers were analyzed because of the common human consumption of this organ. Thus, dressed carcass samples of adult pheasants and of mallards did not include liver tissue.

Separate tissues, muscle, liver, and brain were also collected as samples from fortuitous specimens, since there was no assured duplication of individuals, and no controls were planned. From select individuals, additional tissues such as kidney, kidney fat, and gizzard, were frozen for potential later analysis. Liver and kidney each have a high capacity to absorb and bind chemicals, and thus concentrate more toxins than are found in other organs. Brain tissue frequently contains proportionately higher concentrations of lipid-soluble and un-ionized contaminants than other tissues. Further discussion of the rationale for selecting muscle, liver and brain tissue as samples is in the Biota CMP Technical Plan (Stollar et al., 1988). Because of the relative partitioning of the target analytes among muscle, liver and brain, it was decided subsequent to the Biota CMP Technical Plan (Stollar et al., 1988) during discussions among the Army, Midwest Research Institute (MRI), and EBASCO to analyze all three tissues for organochlorine pesticides, brain and liver for arsenic, and liver and muscle for mercury.

Finally, above-substrate parts of both terrestrial and aquatic plants were collected since it is this portion of the plant most likely to be consumed by higher trophic organisms.

The goal in each case was to provide 50 to 100 g of tissue for a sample. However, for some species, grasshoppers or earthworms, for example, this was difficult at some staked sites. Since only 11 g were required for the chemical analyses, samples lighter than 50 g were sometimes acceptable. Generally, at least 25 g was collected for each sample.

3.1.5 Replication of Samples

The number of replicate samples collected and analyzed for each species and life stage was based on three criteria: (1) the degree of precision desired in sample estimates; (2) the biological impact of sampling on the population being studied; and (3) the cost of sampling. The overall aim of sample replication was to achieve reasonable precision in sample-based estimates of concentrations of contaminants in biota populations without having a substantial impact on these populations or being unnecessarily costly.

At the time sample size was determined, no analytical results from the Biota RI were available to estimate variability of RMA samples. Thus, the Student's t statistic was used in concert with the other two criteria to estimate the minimum sample size needed to provide adequate precision, recognizing that this statistic is based on normal distribution of data. Within each BSA, it was determined that sample sizes of at least three and preferably five would be collected. Sample sizes (i.e., numbers of location replicates) for each species are presented in Table 3.1-3. Further discussion on the determination of sample size can be found in the Biota CMP Technical Plan (Stollar et al., 1988).

3.2 Field Methodology

The field methodologies used during the 1988 field program are described in detail in the working copy of the Biota CMP Field Procedures Manual (Ebasco Services Inc., 1989j) and summarized in this section.

3.2.1 Field Protocol

Prior to entering the field, documents pertinent to the Biota CMP were reviewed by all field personnel, and appropriate signoffs on these documents and health and safety requirements were obtained. The documents read by personnel before entering the field were the Biota CMP

Technical Plan, CMP Health and Safety Plan, CMP Quality Assurance/Quality Control (QA/QC) Manual, and a working copy of the Biota CMP Field Procedures Manual.

While working at RMA, the specific requirements outlined in the Biota CMP Field Procedures Manual were followed regarding coordination with the Army Security Staff, the Stollar CMP Site Coordinator, the Biota Field Coordinator, and the Health and Safety Field Coordinator. Further, the personal protective equipment (PPE) required for certain tasks or in certain geographic areas was used as required in the Biota CMP Field Procedures Manual.

3.2.2 Program Implementation

As a guide for consistent and thoughtful field implementation of the Biota CMP, the Biota CMP Field Procedures Manual was written to provide details regarding equipment, sampling location selection, individual specimen selection, general sampling procedures, and species specific sampling procedures. During 1988, a working draft of the Biota CMP Field Procedures Manual was used and revised by field and support group personnel. It was further refined during the 1989 field season. Information on field procedures is summarized in the following subsections to the extent it has bearing on understanding and interpretation of, or confidence in, the results that are presented in Section 4.0.

3.2.2.1 Equipment. A variety of standard field sampling techniques, each specific to the organism being collected, were used in the Biota CMP (Stollar et al., 1989a). Each of these methods of collection had its own specialized and specified equipment. Prior to first use, all new metal equipment was rinsed with hexane, washed with trisodium phosphate (TSP) solution, rinsed and air-dried. Thereafter, this and other permanent equipment, including glass containers, were washed with TSP solution, rinsed and air-dried between specimens during subsequent sampling events. Aluminum foil used to wrap samples was wiped or rinsed with hexane before use.

Checklists of available equipment facilitated the planning of each collecting foray and were available to verify that the necessary equipment was on hand for a given day. A van equipped as a field laboratory was used as a field vehicle, and to the extent practical, was also used to process samples so that specimens collected both on and off RMA could be handled in the same manner. Samples were also processed in a laboratory in Building 313 or in 741, as appropriate to the species and situation.

3.2.2.2 Selection of Sampling Locations. As noted in Sections 2.1 and 3.1.2, eight terrestrial BSAs and five aquatic BSAs were defined by data on contamination of the abiotic environment. Within each of the terrestrial BSAs, staked sites for the sampling of more sedentary species were associated with these contamination foci. There is a similar association between aquatic sampling foci and the contamination foci. This correlation can be seen by comparing Figures 2.2-1 and 3.1-2.

The first staked sites within a BSA were established within or adjacent to the most contaminated foci in the area; the last sites were placed as necessary to provide balance to the coverage of the BSA. Within these foci, the specific location of each staked site was based on two criteria: the presence of sufficient and appropriate habitat for small mammals such as deer mice, and the presence of at least one of the plant species to be sampled. If these criteria were absent or inadequate throughout a given focus of contamination, then the focus next lower in priority was examined. Thus, the paucity of vegetation in many of the South Plants locations resulted in the use of the South Tank Farm, Arsenic Storage Silos, and the Sanitary Landfill for staked sites.

Of the species selected for the intentional sampling program, deer mice, grasshoppers, earthworms, sunflower, kochia and cheatgrass were designated for collection from staked sites. Based on the plan to collect up to 26 individuals of any one of these sedentary species, 26 permanent staked sites were originally established and dispersed among the study and control areas: five in BSA 1, five in BSA 2, three in BSA 3, three in BSA 4, five in BSA 5, three in the Northeast Control Area and two in the Southeast Control Area (Figure 2.2-1).

Once sampling began in 1988 at these staked sites, not all intentional species could be found there. Thus, several alternative sites were established as close as possible to the original site. These alternative sites are designated with an "A" if they were indeed close to the original location, or by a new number if they had been moved substantially (Figure 2.2-1). Even though collection of some species had already been completed when a site had to be moved because another species was totally absent, at least two species were collected from every site, when possible. In 1989, the original and alternative staked sites established in 1988 were used. In addition, several new staked sites and potential alternative staked sites (Figure 2.2-1) were identified prior to the 1989 field season. These new sites were delineated with rebar stakes only if they were used for sampling.

Each of the staked sites was 0.13 to 0.18 hectares (ha) in area. Given a 5 meter (m) buffer on each side, the effective collecting area ranged from 0.24 to 0.25 ha. Most sites were rectangular, but a few were configured differently to fit the features of the site (e.g., ditches), the distribution of contamination, and vegetation/habitat. For each of the staked sites, a map was drawn in the field notes at the time it was staked, and later these maps were computerized on a MacIntosh and annotated as a part of the data packet for each sample collected. Figures 3.2-1 and 3.2-2 provide maps of differently configured staked sites as examples.

For more mobile species within a given BSA, the first effort was to collect in an appropriate habitat and either inside of the first priority contamination focus or within an approximate home range radius of it. A reasonable length of time was devoted to each collection effort before proceeding to a lower priority area. Collecting efforts extended beyond these foci as species availability necessitated. Maps for each terrestrial CMP-BSA were available so that collection location for every mobile species sample could be plotted on a map; these maps comprised part of the sample data packet. Figures 3.2-3 through 3.2-10 provide the most recent versions of these maps.

Within each aquatic CMP-BSA, the number of foci was based on the maximum number of samples for any one species to be taken in that BSA. As in terrestrial BSAs, the first foci were located to sample areas of known contamination, and other foci were distributed to balance the distribution of sampling within the BSA. Each of the aquatic plant species was collected as close to the foci as possible. Each of the fish species was also netted as close to the foci as possible, given differences in water depth and fish distribution. The plankton tows were also performed as close to the foci as water depth and boat operation allowed.

Although the aquatic plants were associated with the areas of focus to the extent that their distribution in the lakes allowed, the aquatic animal species collected were all mobile, and the plankton was free-floating. Furthermore, all of the species were surrounded by an aqueous environment that allowed dispersion of fairly water-soluble chemicals. Thus, while collection of each of the aquatic samples was centered on the foci identified for Lake Mary, Lake Ladora, Lower Derby Lake, and the Rod and Gun Club Pond, it was not confined by them. After the 1989 sampling season had begun, Upper Derby Lake was retained as a collection location and was the only location where mallard juveniles were found. The most recent versions of the maps used as part of the sample data packet are shown as Figures 3.2-11 through 3.2-15.

3.2.2.3 Selection of Individuals for Specimens. Criteria for the selection of samples for specimens was based on location and age. Samples of the species being sought were generally collected within staked sites, or near terrestrial or aquatic foci, as appropriate to the sampling plan for their species.

The age class of each of the organisms collected is listed in Table 3.1-3 and detailed in Section 3.3.4 of the Biota CMP Field Procedures Manual. Age class was selected to maximize exposure on RMA, as well as minimize the likelihood that an individual specimen acquired any contaminants away from the collection site. Specimens were, for the most part, collected within the appropriate age class. Some individual prairie dogs, deer mice, and fall pheasants may have been young-of-the-year, but all were full-sized and indistinguishable from adults when they were field-identified just prior to collection.

3.2.2.4 Sampling Procedures. Documentation of all field activities followed very specific guidelines. The day's activities were recorded in a field notebook including team members' names, starting and ending time, activity engaged in, area worked in, sites worked in or near, species sought and general observations throughout the day. Locations where any of the target species were observed were recorded for future use in finding specimens. For each individual sample collected, a sample tag, chain-of-custody and field data form were completed.

As mentioned above, two types of biota sampling were conducted as part of the CMP Biota Monitoring Program: intentional sampling and fortuitous sampling. The intentional sampling was done in each of the eight terrestrial BSAs at staked sites for the more sedentary species and at focused, but not defined, sites for more mobile species. Intentional sampling was also done in the five defined aquatic BSAs, but at focused though not defined sites, since all of the aquatic animal species being sampled were mobile. Each of these samples was given a "B" sample number, recorded in the sample logbook, frozen, and shipped to the laboratory for analysis. Sample tags, chains-of-custody, and field data forms were filled out according to an established protocol. This protocol is explained in the Biota CMP Field Procedures Manual. The 1989 versions of these three forms are included here as Figures 3.2-16 through 3.2-18.

The Biota CMP Technical Plan prescribed the collection of 344 samples of terrestrial species and 179 samples of aquatic species. Note that for some species (e.g., ring-necked pheasant and mallard) more than one sample was to be taken from a single specimen. In addition to these biota samples,

five soil and five water samples were collected to bring the total planned terrestrial samples to 354. Because of varying availability and distribution of some species, which was marked in this hot, dry summer, the prescribed number was not collected in every case, and the distribution of samples among BSAs and staked sites was not always exactly as prescribed. Overall, 327 terrestrial samples were collected under the intentional program, including the abiotic samples. Of the 179 aquatic samples prescribed, 149 were collected.

The Biota CMP Technical Plan (Stollar et al., 1988) prescribed the analysis of each sample for all seven target analytes. Occasionally, during the process of chemical analysis, a sample tracking, analytical or QA/QC problem arose. These problems may have affected all analyses of a sample, or only one analyte. In 1988, such occurrences resulted in the need to reanalyze 11 intentional samples representing three terrestrial species, two intentional samples representing two aquatic species, and 42 fortuitous samples representing 14 species. As a result, all discussion of the 1988 fortuitous sample data was to be held for presentation in this Biota CMP 1989 Annual Report. Where sufficient homogenate was available, these samples were reanalyzed. Results of this reanalysis are reported in Section 4.3.

To facilitate the recording of data in the field and the tabulation and presentation of data for this report, acronyms were used for species and collection location. For species, the acronym was based on the first two letters of the genus and species scientific names, unless the "species" was really a higher taxon, in which case the first four letters of the taxon name were used. Acronyms for collection location were based on the BSA and staked site (e.g., BS1-1 indicated biota sample, BSA 1, Staked Site 1) where that was appropriate; the collection year is used in the site identification number in the database to identify the data collection year, but it is not used when referring only to the site. Acronyms used for collection locations outside of staked sites were more variable, but were generally tied to a section number, or a boring number, and retained the BSA number when appropriate. Control location acronyms were numbered for staked control sites, and used a name abbreviation for off-post collection areas. Greater standardization has been added to the locational acronym for 1989. The Glossary located immediately following the List of Figures in each volume provides a legend for the acronyms used in the presentation of results in Section 4.0 and elsewhere in the document.

The fortuitous sampling was of dead animals encountered by chance. Fortuitous (as well as replacement or incomplete) samples were consecutively assigned an "F" number and logged in the

Incomplete Sample Log Book. Sample tags, chains-of-custody, and field data forms were completed in a fashion similar to that for intentional samples.

The particular method of collection for each species is briefly listed in Table 3.1-3. Some individuals were collected with firearms, while others were trapped, clipped, dug, or netted, as appropriate. The Biota CMP Field Procedures Manual provides detailed procedures for each species. To maximize effectiveness and efficiency, alternative methods were occasionally improvised in the field when the planned method was not yielding adequate results. These alternative methods have been fully documented in the Biota CMP Field Procedures Manual.

3.2.2.5 General Handling Procedures. Once a specimen was collected, it was prepared as a sample, frozen, and shipped to the laboratory. When reasonably possible, each sample weighed 50 to 100 g so that after analysis of sample aliquots for all analytes, there would be a residual sample to be kept in the freezer for contingency purposes. Details of tissue selection and sample preparation are provided for each species in the Biota CMP Field Procedures Manual. Samples were packaged in TSP-washed amber glass jars or wrapped in hexane-rinsed foil. Specific packaging procedures are discussed in the Biota CMP Field Procedures Manual.

3.3 Health and Safety

The Health and Safety Plan (HASP) for the CMP (Stollar et al., 1988) outlined the information necessary to conduct the biota monitoring program in a safe and healthful manner by preventing exposures and employee injuries. The information provided in this section serves only as a summary of the HASP information specific to the biota monitoring program.

Biota sampling on RMA was conducted at various land and water sites that had different degrees of contamination. In addition, biota sampling was conducted at off-post control areas such as wildlife refuges, state parks, game farms, upland fields, rivers and ponds.

In developing the guidelines for levels of PPE appropriate to each area and species, all planned activities were discussed with the CMP Health and Safety Group. In most areas of RMA, the presence of health and safety personnel or equipment was unnecessary, and the use of modified Level D PPE was adequate, due to the generally nonintrusive nature of the Biota CMP. When earthworms were collected from the soil, health and safety monitoring equipment (organic vapor

analyzers [OVAs]) were used. PPE requirements generally meant the standard wearing of cotton coveralls and rubber safety boots, and the absence of respiratory protection during collecting activities. To protect against parasites and/or bites while collecting, field samplers wore leather or cotton gloves when handling warm-blooded animals. In BSAs 1 (Basin A), 2 (Basin F), and 4 (South Plants), inner nitrile gloves were added (only when encountering moisture in BSAs 2 and 4), and a respirator was available. A respirator was used if noxious odors were detected or if wind blown dust was excessive. Further, Tyvek and outer booties were added to BSA 1 requirements, while activity within the Basin F fence in BSA 2 required Saranex, a polyvinyl chloride (PVC) rainsuit, butyl gloves covered by leather gloves, and a self-contained breathing apparatus (SCBA).

Any firearms that were used on RMA were properly registered with RMA Security, and their use was coordinated with Security. To minimize the risk from use of firearms, the time of day of collection and the public use of areas where collection was actively occurring were adjusted when necessary. For example, fishermen's use of the Lower Lakes was curtailed when firearms were used to collect birds there.

3.4 Laboratory Methodology

The objective of the laboratory analysis program was to provide the Army with reliable and statistically supportable data for organochlorine pesticide, mercury and arsenic concentrations in biota samples from RMA. Table 4.0-1 of the CMP Biota Monitoring Technical Plan (Stollar et al., 1988) listed the target analytes along with the intended certification procedure, the reference analytical method and the type of analytical method. These target analytes and listed procedures and methods were supplied by the U.S. Army Program Manager for Rocky Mountain Arsenal (PMRMA) to Midwest Research Institute (MRI) and ESE together with the desired concentration ranges to be consistently achieved with stated reliability as the upper and lower certification limits.

When supplied with these procedures and methods, MRI and ESE began the process of certification on standard samples, and achieved PMRMA approval of each method before that method was used to analyze any samples collected under the Biota CMP. The certification process demonstrated to PMRMA that a laboratory has the ability to perform a method to fit specific established QA/QC criteria. A precertification of calibration standards was followed by a certification of performance samples. Data packages from each process were reviewed by the PMRMA and checked against established guidelines to determine if the laboratory had demonstrated the expected method

proficiency. When accepted, the method was given a unique Method Number to be used when reporting data.

The methods provided to MRI and ESE by the PMRMA were modified during certification for this program because of a number of factors, including differences in hardware, columns and other equipment. The process of certification and the methodological details ultimately certified by PMRMA for MRI and ESE are documented in an extensive body of correspondence. The methods are summarized briefly in the following subsections to the level of detail needed to support the data. Further detail on each can be found in the analytical methods documentation (MRI, 1988; 1989a; 1989b; 1989c).

3.4.1 Analysis for Organochlorine Pesticides in Biota Tissue by Gas Chromatography/Electron Capture Detection (GC/ECD)

Analysis of organochlorine pesticides in biota tissue by gas chromatography/electron capture detection (GC/ECD) is U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) Certified Method H-6 for fat (animal) tissue and USATHAMA Certified Method K-6 for nonfat (plant) tissue. In both of these methods, an aliquot of homogenated sample is soxhlet extracted with methylene chloride for fat and with hexane/diethyl ether for nonfat tissues. Both types of extracts are Gel Permeation Chromatograph (GPC) and Florisil cleaned. The fat extract is then exchanged to hexane. Both extracts are analyzed with a 2 microliter (μl) injection into a GC with a DB-17 fused-silica megabore column and detected by an ECD. As shown in Table 3.4-1, lower certified reporting limits (CRL) range from 0.0416 μg/g to 0.753 μg/g for nonfat analysis and 0.0740 μg/g to 0.118 μg/g for fat analysis, depending on the analyte.

3.4.2 Analysis for Mercury in Biota Samples by Cold Vapor Atomic Absorption Spectroscopy

Analysis for mercury in biota samples by cold vapor atomic absorption spectroscopy is USATHAMA Certified Method J6A for fat (animal) and J6P for nonfat (plant) tissue. In both versions of this method, an aliquot of homogenated sample is digested with concentrated nitric and sulfuric acids, heat, and 30 percent hydrogen peroxide. The digestate is filtered and analyzed on a Perkin-Elmer Cold Vapor Atomic Absorption Spectrometer that is calibrated daily. As shown in Table 3.4-1, the lower CRLs are 0.0463 μg/g for fat and 0.574 μg/g for nonfat tissue analysis.

3.4.3 Analysis for Arsenic in Biota Samples by Graphite Furnace Atomic Absorption Spectroscopy

Analysis for arsenic in biota samples by graphite furnace atomic absorption spectroscopy is USATHAMA Certified Method G6 for both fat (animal) and nonfat (plant) tissue. In this method, an aliquot of homogenated sample is digested with concentrated nitric acid, heated, cooled, and 30 percent hydrogen peroxide is added to complete the process. The digestate is centrifuged and analyzed by a Perkin-Elmer Graphite Furnace Atomic Absorption Spectrometer that was previously calibrated. Lower CRLs are 0.438 μg/g for fat and 0.250 μg/g for nonfat tissue analysis (Table 3.4-1).

3.5 Quality Assurance Procedures

Specific RMA QA/QC requirements and responsibilities for biota sampling are contained in the CMP QA/QC Plan (Stollar et al., 1988), and are summarized briefly here. As designed, the QA/QC Plan ensured that valid and properly formatted data were reported at the appropriate precision, accuracy, and sensitivity for each method certified by PMRMA for biota. Further, standardized procedures were developed to ensure and control the quality of field methods used to collect biota tissue samples.

In the field, QA/QC procedures were monitored by the CMP Biota Element Field Coordinator to ensure proper sample collection (species identification, sample collection methods and equipment decontamination), sample preparation, sample handling (appropriate containers for specific tissues and analyses, appropriate field documentation and packaging techniques), and data recording (field documentation and chain-of-custody practices). Corrective actions were initiated, as needed, by the QA/QC Field Supervisor, who was in frequent communication with the CMP Biota Element Field Coordinator.

Upon receipt of the samples by the laboratory, all samples were handled within the guidelines of PMRMA/USATHAMA procedures for sample receipt, sample storage, documentation, and sample analysis. In the laboratory, daily QC of the analytical systems was used to ensure accurate and reproducible results. Careful calibration and the introduction of control samples (control spikes and blanks) were prerequisites for obtaining accurate and reliable results. Instrumental and sample lot

controls are described in the CMP QA/QC Plan (Stollar et al., 1988) and in the analytical methods documentation (MRI, 1988; 1989a; 1989b; 1989c).

For QA/QC purposes, certain samples were split from a randomly determined ten percent of the species and tissues collected. The laboratory treated these splits as independent samples and analyzed for all seven analytes. As a QA check on the analytical data from a single organism or composite, results from analysis of the splits were compared with those from analysis of the primary samples by calculating a relative percent difference (RPD). This approach was selected to document the precision of the data, prevent decimation of particular species through increased levels of collection, and still provide an adequate amount of tissue for planned chemical analyses and QA. Samples under about 25 g were not candidates to provide splits. Any homogenate remaining following analysis of primary and split aliquots was frozen at MRI or ESE and will remain available during the term of the contract for any additional analyses that might be required.

MRI and ESE maintained a chemical data file for each lot of samples analyzed. Each file includes the following documents: (1) copies of sample receipt logsheets; (2) relevant analysts' notebook pages; (3) extraction logsheets; (4) instrument calibration logsheets; and (5) raw data sheets including calibration curve data, calculation worksheets, final data, and the location of chromatograms and chain-of-custody records.

Internal laboratory QC reviews were conducted. In these reviews, the Laboratory QC Coordinator monitored analytical controls and calibration or control sample QC criteria to detect situations that were out-of-control for the precision and accuracy of the method. Any out-of-control situations were rectified in accordance with PMRMA guidelines. Specific discussions of analytical controls are contained in the QA/QC Plan (Stollar et al., 1988).

During active periods of chemical analyses, the laboratory QA staff submitted a weekly QA Program Status Report to the Project QA Coordinator. This submittal included hard copies of the lot accuracy and precision control charts. All points indicating out-of-control situations were evaluated and explained, and the necessary corrective actions to prevent recurrence were described. Results of this review were then submitted to PMRMA/USATHAMA for approval.

3.6 Data Management

This section summarizes the procedures specific to the management of data generated pursuant to the Biota Element's objectives; a more detailed presentation is provided in the Biota CMP Technical Plan (Stollar et al., 1988).

Biota CMP data are of two types: (1) field information on the location and environment of the organism collected, as well as the procurement of the tissue comprising the sample; and (2) laboratory data from chemical analyses of the samples.

The type of information generated for the Biota CMP, and the dedicated nature of many of the fields and abbreviations available in the IRDMS did not permit the exclusive use of the IRDMS for management and analysis of the biota data. Consequently, a Biota Data Management System (BDMS) was established to integrate the analytical results contained in the IRDMS with field information. The BDMS facilitated data analyses and summary reporting, and provided the means to more accurately identify and describe samples. Printouts of the IRDMS and BDMS are provided as Appendix A and Appendix B, respectively; diskettes containing this information are also provided.

The BDMS was developed in dBASE IV to provide flexibility, portability, and exportability of files to other software packages. Field data were entered into the BDMS from the field data forms and chains-of-custody.

Analytical data were entered into the PMRMA IRDMS analytical data system. Laboratory personnel were responsible for the proper coding format and entry of chemical analysis data, initial checking of these data and their transfer to the CMP Data Management group in Denver. All data entry was in accordance with the procedures described in the current versions of the Installation Restoration Data Management User's Guide and the Quality Assurance Plan (USATHAMA, 1987a; 1987b). An extensive body of correspondence documents minor changes to the use of the IRDMS, as agreed upon.

Once analytical data were uploaded from MRI or ESE transfer files, they were available for cooperative interface with the BDMS data files. Before analytical data can be made public, they must have achieved final status in the IRDMS. Map record data were developed by scaling off

sampling site locations on an RMA map annotated with northing and easting coordinates. These data were provided to D.P. Associates, who implement the IRDMS. However, biota map files were not formally used in the IRDMS because the coordinates for control samples collected off-post are not recognized by the IRDMS.

Once the data verification process was complete, the analysis of biota data was done via the BDMS; PC-based statistics and graphics software were integrated into the overall analysis of the biota data.

3.7 Data Description, Analysis, and Evaluation

Data from the BDMS files containing field and analytical information were extracted and combined in a number of ways to enable their description, analysis, and evaluation. The analytical data may fall into three quality categories. Laboratory analytical methodologies have both lower and upper limits for certifiable data. The data may fall below certifiable reporting limits (BCRL), occur within the limits, or exceed the upper certifiable reporting limits (UCRL). The variability of the lower certifiable reporting limit between plant and animal tissues for the same analyte and among analytes and between labs (Table 3.4-1) somewhat influences the reporting of frequency of detected concentrations.

The first step in describing the data was to define and create basic group databases that contained both the field and analytical information. Basic groups were defined by such parameters as species, study area, sex, and tissue. The basic groups were defined for terrestrial species in Table 3.7-1 and for aquatic groups in Table 3.7-2 of the Biota CMP 1988 Annual Report (Stollar et al., 1990). The contaminated samples in each group were used to report the minimum and maximum concentrations and all the samples were used to compute basic descriptive statistics such as the USFWS geometric mean, geometric standard deviation, and geometric variance for the group.

Larger data sets were then created by combining basic groups into defined combination groups. Rules for combining basic groups were based on logical combinations such as samples from all areas on RMA for a single species or all species belonging to a trophic group from a single area or from all areas on RMA. These groupings and the trophic level designations used to group species were shown on Tables 3.7-1 and 3.7-2 of the Biota CMP 1988 Annual Report (Stollar et al, 1988). Species added to the Biota CMP for 1989 were assigned to trophic levels as follows: mourning dove to terrestrial herbivores (THER), beetles and western meadowlarks to terrestrial omnivores (TOMN),

burrowing owls to terrestrial carnivores (TCAR), blue-winged teal to aquatic water column omnivores (AWCO), and killdeer to aquatic primary carnivores (APCA). The aforementioned descriptive statistics were also calculated for these combination data sets. Finally, for each analyte, all samples within a given BSA were grouped. Appendix C provides the methods for calculating the various statistics used in this report.

Table 2.2-1 Hydrologic and Other Physical Characteristics for Terrestrial CMP-Biota Study Area Soils on RMA

Soil Series 1/	Texture 2/	Typical Depth of Profile (ft)	% Clay 3/	Bulk Density (g/cm^3)	Hydraulic Conductivity (in/hr) 3/	Available Water Holding Capacity (in/in of soil) 3/	Erosion Hazard 3/
Ascalon (1,2,3,C)	SM, SC, CL, SM/SC	67	14-28	0.91-1.6	0.14-7.0	0.12-0.17	Slight-Severe
Bresser (1,2,3,4,5,C)	SM, SM/SC, SC	60	6-18	1.5-1.8	0.14-7.0	0.090-0.14	Moderate-Severe
Nunn (C)	CL, CL/ML, CH, SC, SM/SC, SM	69	36-44	1.3-1.5	0.0010-1.4	0.21-0.24	Slight-Moderate
Satanta (5)	ML, CL, CL/ML, SM, SC	60	7-30	1.5-1.6	0.14-14	0.090-0.20	Slight-Moderate
Truckton (5, C)	SM, SM/SC, SM/SP	60	10-16	1.4-1.6	1.4-14	0.090-0.12	Moderate
Weld (2,5,C)	ML, CL/ML, CL, SM, SM/SC	70	27-50	1.2-1.4	0.0010-7.0	0.18-0.23	Moderate-Severe
Aquic Haplustolls (1, 5, C)	ML, CL, SC	62	16-30	NA	0.14-7.0	0.14-0.22	Moderate-Severe
Disturbed Land (1,2,3,4,5, 11,12,13)	SM, SM/SC, SP	4/	4/	1.4-2.1	4/	4/	4/
Petrocalcic (1,2) Paleustolls	SM, SM/SC, GP	33	6-18	NA	<0.0010-7.0	0.090-0.15	Slight-Moderate

Source: MKE 1988
NA = information not available
1/ Numbers in parentheses denote CMP-BSAs 1, 2, 3, 4, 5, 11, 12, or 13; "C" denotes Control Area.
2/ Textural key: CH = inorganic clay (high plasticity); CL = inorganic clay (low to medium plasticity); GP = poorly graded gravel; MH = inorganic silt; ML = inorganic silt & very fine sand; SC = clayey sand; SM = silty sand; SP = poorly graded sand; texture varies dependent on position in profile.
3/ Typical pedon characteristics vary with depth.
4/ properties too variable to be estimated.

Table 2.2-2 Chemical Characteristics for Terrestrial CMP-Biota Study Area Soils on RMA

Soil Series	Soil pH [1]	% Organic Carbon [1]	Electrical Conductance (mmhos/cm) [1]	Cation Exchange Capacity (meq/100 g) [1]	[illegible]	Sodium Absorption Ratio [1]
Ascalon	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Bresser	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nunn	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Satanta	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Truckton	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Weld	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Aquic Haplustolls	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Disturbed Land	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Petrocalcic Paleustolls	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Sources: USDA-SCS [illegible], [illegible], MKE [illegible]
mmhos/cm = millimhos per [illegible]
meq/100 g = milliequivalents per [illegible] grams
[1] typical pedon characteristics [illegible]

CMP Biota Table [illegible]
6/20/90

Table 2.2-3 Physical/Chemical Characteristics for Aquatic CMP-Biota Study Area Sediments

Parameter	Lake Mary (CMP-BSA 6)	Lakota Lake (CMP-BSA 7)	Lower Derby Lake (CMP-BSA 8)	Rod & Gun Club Pond (CMP-BSA 9)	Upper Derby Lake (CMP-BSA 10)
Geologic Material	Organic silty sands; gravelly sands	Clays; sands; silts	Organic silts; sandy clays; gravelly sands	Silty sands, clayey sands	Silty sands, clayey sands; silt
% Moisture	12-23	15-25	13-77	7.7-29	4.8-26
Particle Size Analyses					
% Passing Sieve No.					
4 (Gravel)	100	100	100	100	100
10 (Sand)	98-100	96-100	98-100	99-100	99-100
40 (Sand)	26-94	37-94	91-100	86-95	72-100
200 (Silts/clays)	3-65	6-64	12-97	16-35	15-97
Total Organic Carbon (%)	ND-0.53	ND-1.0	0.050-2.6	0.090-1.1	0.050-1.4
Soil Reaction (pH)	6.6-7.9	6.7-8.5	6.9-8.2	5.2-7.6	5.9-8.8
Electrical Conductivity (µmhos/cm)	104-1340	123-1110	54-840	117-925	22-832
Redox Potential (mV)	206-403	67-238	1.4-332	421-504	273-354

Source: EBASCO 1989a
mV = Millivolts
ND = Not detected
µmhos/cm = Micromhos per centimeter

Table 2.3-1
Generalized Vegetation Characteristics of Terrestrial Staked Sites and Control Sites on RMA

CMP-BSA 1	Habitat Code	Habitat Description
BS1-1	AF-01	Annual Forb
BS1-2	AF-01	Annual Forb
BS1-2A	AF-01	Annual Forb
BS1-3	AF-01	Annual Forb
BS1-4	AF-01	Annual Forb
BS1-5	AF-01	Annual Forb
CMP-BSA 2		
BS2-1	PNG/LS-05	Perennial Native Grasses, Light Soil
BS2-2	AF-01	Annual Forb
BS2-2A	AF-01	Annual Forb
BS2-3	C/WF-02	Cheatgrass/Weedy Forb
BS2-3A	AF-01	Annual Forb
BS2-4	C/WF-02	Cheatgrass/Weedy Forb
BS2-5	C/WF-02	Cheatgrass/Weedy Forb
CMP-BSA 3		
BS3-1	C/WF-02	Cheatgrass/Weedy Forb
BS3-2	C/WF-02	Cheatgrass/Weedy Forb
BS3-3	C/WF-02	Cheatgrass/Weedy Forb
BS3-3A	C/WF-02	Cheatgrass/Weedy Forb
BS3-4	MM/SS-14	Subshrubs/Succulents
CMP-BSA 4		
BS4-1	AF-01	Annual Forb
BS4-2	C/WF-02	Cheatgrass/Weedy Forb
BS4-3	AF-01	Annual Forb
BS4-4	AF-01	Annual Forb
CMP-BSA 5		
BS5-1	CW-06	Crested Wheatgrass
BS5-2	C/WF-02	Cheatgrass/Weedy Forb
BS5-3	PEW-08	Persistent Emergent Wetland
BS5-3A	C/WF-02	Cheatgrass/Weedy Forb
BS5-4	RF-10	Riparian Forest
BS5-5	PNG/LS-05	Perennial Native Grasses-Light Soil
BS5-5A	PNG/LS-05	Perennial Native Grasses-Light Soil
BS5-6	C/WF-02	Cheatgrass/Weedy Forb
BS5-7	PNG/LS-05	Perennial Native Grasses-Light Soil
CMP-BSA 11		
BS11-1	AF-01	Annual Forb
BS11-2	C/WF-02	Cheatgrass/Weedy Forb
BS11-3	C/WF-02	Cheatgrass/Weedy Forb
CMP-BSA 12		
BS12-1	C/WF-02	Cheatgrass/Weedy Forb
BS12-2	AF-01	Annual Forb

Table 2.3-1
Generalized Vegetation Characteristics of Terrestrial Staked Sites and Control Sites on RMA

CMP-BSA 13	Habitat Code	Habitat Description
BS13-1 through BS13-5	MM/CS-18	Cultivated
On-Site Control Areas		
BCRM-1	PNG/LS-05	Perennial Native Grasses-Light Soil
BCRM-2	C/PG-03	Cheatgrass/Perennial Grasses
BCRM-3	C/PG-03	Cheatgrass/Perennial Grasses
BCRM-3A	C/WF-02	Cheatgrass/Weedy Forb
BCRM-4	C/PG-03	Cheatgrass/Perennial Grasses
BCRM-5	PNG/LS-05	Perennial Native Grasses-Light Soil
BCRM-5A	C/WF-02	Cheatgrass/Weedy Forb
BCRM-6	C/WF-02	Cheatgrass/Weedy Forb

Source: MKE, Undated draft vegetation map.

Table 2.3-2 **Fish Stocking History for Rocky Mountain Arsenal (1961-1982); Number (Size, cm) of each Species**[1/]

Water Body	Year	Rainbow Trout	Northern Pike	Channel Catfish	Bass	Sunfish	Bluegill	Black Crappie
Mary	1961	500	—	300	—	900 (5)	—	—
	1964	2,000	—	—	—	—	—	—
	1965	4,000	—	—	—	—	—	—
	1967	7,000	—	—	—	—	—	—
	1968	8,176 (17)	—	—	—	—	—	—
	1969	8,000 (20)	—	—	—	—	—	—
	1970	7,000 (17)	—	1,500 (17)	—	—	—	—
	1971	8,547 (20)	—	—	—	—	—	—
	1972	8,000 (20)	—	—	—	—	—	—
	1973	7,400 (20)	—	1,500 (20)	—	—	—	—
	1974	5,900 (20)	—	—	—	—	—	—
	1975	3,500 (15)	—	1,500 (5)	—	—	—	—
	1976	9,000 (22)	—	2,000 (5)	—	—	—	—
	1977	476 (20)	—	—	—	—	—	—
	1978	896	—	—	—	—	—	—
	1979	250	—	—	—	—	—	—
	1982	—	—	—	—	—	—	—
Lower Derby	1976	—	3,000 (5)	—	—	—	—	—
	1978	—	200 (12)	—	—	—	—	—
	1979	—	4,250 (2)	—	—	—	—	—
Ladora	1967	—	—	25,000 (2)	—	—	Unknown[2/]	—
	1968	—	500,000 (2)	5,000 (6)	—	—	—	—
	1969	—	—	—	16,000 (5)	—	4,000 (5)	—
	1970	—	39 (7)	—	—	—	—	—
	1976	—	3,000 (7)	—	—	—	—	—
	1978	—	300 (12)	—	—	—	—	—
	1979	—	4,250 (2)	—	—	—	—	—
Upper Derby	1979	—	1,000 (2)	—	—	—	—	—
Rod & Gun Club	1976	—	1,600 (5)	—	—	—	—	—
	1979	—	500 (2)	—	—	—	—	—
Toxic Storage Yard	1976	—	600 (5)	—	—	—	—	—
North Bog	1976	—	600 (5)	—	—	—	—	—

Source: MKE 1987.

1/ Some conflicting data was reported in the documents. Numbers reported here were from the most recent source.

2/ Undocumented number of bluegill transferred from Lake Mary.

Table 3.1-1 **Ranges of Contaminant Concentrations Within or Above Respective Indicator Levels Detected in Soils During the RI Program** 1/

BIOTA STUDY AREA	CMP-BSA 1			CMP-BSA 2		
DEPTH INTERVAL (ft)	0-2	2-5	5-20	0-2	2-5	5-20
ANALYTE CONCENTRATION (µg/g)						
Aldrin	0.0020 - 40	0.046 - 80	0.015 - 36	0.0020 - 5.0	0.0030 - 9.3	0.003 - 30
Dieldrin	0.0040 - 23	0.0010 - 96	0.0080 - 70	0.020 - 10	2.3 - 6.5	0.0070 - 7.5
Endrin	0.033 - 0.083	BCRL	0.0020	0.13 - 1.7	2.8 - 9.0	1.1 - 5.2
DDE	0.0020 - 10	1.4 - 1.9	BCRL	0.007 - 1.0	.012	BCRL
DDT	0.0040 - 7.0	0.0060	BCRL	0.003 - 0.030	.006	BCRL
Arsenic	3.3 - 100	4.9 - 74	6.4 - 94	5.3 - 170	5.3 - 32	6.4 - 25
Mercury	0.050 - 2.1	0.059 - 100	0.062 - 22	0.060 - 2.2	0.060 - 1.3	0.060 - 0.21

BIOTA STUDY AREA	CMP-BSA 3			CMP-BSA 4		
DEPTH INTERVAL (ft)	0-2	2-5	5-20	0-2	2-5	5-20
ANALYTE CONCENTRATION (µg/g)						
Aldrin	0.53 - 400	0.0090 - 100	0.019 - 0.026	0.0048 - 3000	0.30 - 3000 2/	0.037 - 30
Dieldrin	0.0050 - 100	0.0020 - 80	0.0099 - 0.10	0.0074 - 400	0.011 - 300	0.029 - 9.0
Endrin	BCRL	BCRL	BCRL	0.065	BCRL	BCRL
DDE	0.045 - 0.29	0.014 - 0.021	BCRL	0.0063 - 10	BCRL	0.073
DDT	0.015 - 6.0	0.0038	BCRL	0.0036 - 20	BCRL	0.0036 - 0.13 2/
Arsenic	4.2 - 6.3	BCRL	BCRL	3.0 - 13	2.8 - 3.1 2/	3.1
Mercury	0.20 - 0.86	0.072	BCRL	0.079 - 1.1	0.067	0.089 - 0.17

Source: EBASCO 1989a-1989g

BCRL = Below Certified Reporting Limits

1/ Ranges shown reflect values within or above indicator levels only, expressed as micrograms per gram (µg/g).

2/ Constitutes detection of this analyte in only one of the three sampling locations in this study area.

Table 3.1-1 Ranges of Contaminant Concentrations Within or Above Respective Indicator Levels Detected in Soils During the RI Program [1/]

BIOTA STUDY AREA		CMP-BSA 5	
DEPTH INTERVAL (ft)	0-2	2-5	5-20
ANALYTE CONCENTRATION (µg/g)			
Aldrin	0.0043 - 100	0.0024 - 54	0.0042 - 35
Dieldrin	0.0051 - 300	0.0046 - 52	0.0042 - 53
Endrin	0.013 - 40	0.031 - 0.73	BCRL
DDE	0.0038 - 5.5	0.0039 - 0.35	0.0051 - 0.052
DDT	0.0033 - 90	0.0030 - 0.31	0.024 - 0.73
Arsenic	3.6 - 14	3.0 - 5.5	BCRL
Mercury	0.087 - 7.7	0.055 - 18	0.055 - 2.3

Source: EBASCO 1989a-1989g
BCRL = Below Certified Reporting Limits
1/ Ranges shown reflect values within or above indicator levels only, expressed as micrograms per gram (µg/g).
2/ Constitutes detection of this analyte in only one of the three sampling locations in this study area.

Table 3.1-1 Ranges of Contaminant Concentrations Within or Above Respective Indicator Levels Detected in Soils During the RI Program 1/

BIOTA STUDY AREA	CMP-BSA 11 2/			CMP-BSA 12		
DEPTH INTERVAL (ft)	0-2	2-5	5-20	0-2	2-5	5-20
ANALYTE CONCENTRATION (µg/g) 1/						
Aldrin	BCRL	BCRL	BCRL	BCRL	BCRL	BCRL
Dieldrin	BCRL	BCRL	BCRL	BCRL	BCRL	BCRL
Endrin	BCRL	BCRL	BCRL	BCRL	BCRL	BCRL
DDE	BCRL	BCRL	BCRL	BCRL	BCRL	BCRL
DDT	BCRL	BCRL	BCRL	BCRL	BCRL	BCRL
Arsenic	2.8-4.6	4.2	BCRL	2.9-4800	3.0-7.5	BCRL
Mercury	BCRL	BCRL	BCRL	0.11-27	BCRL	BCRL

Source: EBASCO 1989a-1989g
BCRL = Below Certified Reporting Limits
1/ Analytical results provided for borings nearest to each of three locations in BSA-11.
2/ Constitutes detection of this analyte in only one of the three sampling locations in this study area.

Table 3.1-2 Analytical Results for Soils at CMP-BSA 12 Staked Sites

CMP BIOTA SITE NO.	BS12-1			
RI SITE NAME	NP Region 4			
BORE NO.	0037			
DEPTH INTERVAL (ft)	0-2	2-5	5-20	
SUBINTERVAL SAMPLED (ft)	0-1	4-5	9-10	14-15
ANALYTE CONCENTRATION (µg/g)				
Aldrin	BCRL	BCRL	BCRL	BCRL
Dieldrin	BCRL	BCRL	BCRL	BCRL
Endrin	BCRL	BCRL	BCRL	BCRL
DDT	BCRL	BCRL	BCRL	BCRL
DDE	BCRL	BCRL	BCRL	BCRL
Arsenic	8.2	3.2	BCRL	BCRL
Mercury	2.9	BCRL	BCRL	BCRL

CMP BIOTA SITE NO.	BS12-1			
RI SITE NAME	NP Region 4			
BORE NO.	0041			
DEPTH INTERVAL (ft)	0-2	2-5	5-20	
SUBINTERVAL SAMPLED (ft)	0-1	4-5	9-10	14-15
ANALYTE CONCENTRATION (µg/g)				
Aldrin	BCRL	BCRL	BCRL	BCRL
Dieldrin	BCRL	BCRL	BCRL	BCRL
Endrin	BCRL	BCRL	BCRL	BCRL
DDT	BCRL	BCRL	BCRL	BCRL
DDE	BCRL	BCRL	BCRL	BCRL
Arsenic	9.2	BCRL	BCRL	BCRL
Mercury	0.11	BCRL	BCRL	BCRL

Source: EBASCO, 1988. Final Phase II Data Addendum, North Plants Complex, Version 3.2

Table 3.1-2 Analytical Results for Soils at CMP-BSA 12 Staked Sites

CMP BIOTA SITE NO.	BS12-1					
RI SITE NAME	NP Region 4					
BORE NO.	0042					
DEPTH INTERVAL (ft)	0-2	2-5		5-20		
SUBINTERVAL SAMPLED (ft)	0-1	4-5	9-10		14-15	18-19
ANALYTE CONCENTRATION (µg/g)						
Aldrin	BCRL	BCRL	BCRL		BCRL	BCRL
Dieldrin	BCRL	BCRL	BCRL		BCRL	BCRL
Endrin	BCRL	BCRL	BCRL		BCRL	BCRL
DDT	BCRL	BCRL	BCRL		BCRL	BCRL
DDE	BCRL	BCRL	BCRL		BCRL	BCRL
Arsenic	4,800	BCRL	BCRL		BCRL	BCRL
Mercury	0.15	BCRL	BCRL		BCRL	BCRL

CMP BIOTA SITE NO.	BS12-1				
RI SITE NAME	NP Region 4				
BORE NO.	0091/91B(redrill)				
DEPTH INTERVAL (ft)	0-2	2-5		5-20	
SUBINTERVAL SAMPLED (ft)	0-1	2-3	9-10	14-15	16-17
ANALYTE CONCENTRATION (µg/g)					
Aldrin	BCRL	BCRL	BCRL	BCRL	BCRL
Dieldrin	BCRL	BCRL	BCRL	BCRL	BCRL
Endrin	BCRL	BCRL	BCRL	BCRL	BCRL
DDT	BCRL	BCRL	BCRL	BCRL	BCRL
DDE	BCRL	BCRL	BCRL	BCRL	BCRL
Arsenic	2.9	7.5	BCRL	BCRL	BCRL
Mercury	0.41	BCRL	BCRL	BCRL	BCRL

Source: EBASCO, 1988. Final Phase II Data Addendum, North Plants Complex, Version 3.2

Table 3.1-2 Analytical Results for Soils at CMP-BSA 12 Staked Sites

CMP BIOTA SITE NO.	BS12-2			
RI SITE NAME	NP Region 2			
BORE NO.	0027			
DEPTH INTERVAL (ft)	0-2	2-5	5-20	
SUBINTERVAL SAMPLED (ft)	0-1	4-5	9-10	14-15
ANALYTE CONCENTRATION (µg/g)				
Aldrin	BCRL	BCRL	BCRL	BCRL
Dieldrin	BCRL	BCRL	BCRL	BCRL
Endrin	BCRL	BCRL	BCRL	BCRL
DDT	BCRL	BCRL	BCRL	BCRL
DDE	BCRL	BCRL	BCRL	BCRL
Arsenic	190	3.0	BCRL	BCRL
Mercury	27	BCRL	BCRL	BCRL

CMP BIOTA SITE NO.	BS12-2					
RI SITE NAME	NP Region 2					
BORE NO.	0075					
DEPTH INTERVAL (ft)	0-2	2-5			5-20	
SUBINTERVAL SAMPLED (ft)	0-1	2-3	4-5	9-10	14-15	18-19
ANALYTE CONCENTRATION (µg/g)						
Aldrin	BCRL	BCRL	BCRL	BCRL	BCRL	BCRL
Dieldrin	BCRL	BCRL	BCRL	BCRL	BCRL	BCRL
Endrin	BCRL	BCRL	BCRL	BCRL	BCRL	BCRL
DDT	BCRL	BCRL	BCRL	BCRL	BCRL	BCRL
DDE	BCRL	BCRL	BCRL	BCRL	BCRL	BCRL
Arsenic	3.8	3.4	BCRL	BCRL	BCRL	BCRL
Mercury	BCRL	BCRL	BCRL	BCRL	BCRL	BCRL

Source: EBASCO, 1988. Final Phase II Data Addendum, North Plants Complex, Version 3.2

Table 3.1-3 Summary of 1989 Contaminant Monitoring Field Program

Species (Terrestrial)	Life Stage	Collection			No. of Location Replicates RMA a/									
		Season	Method	Tissue	1	2	3	4	5	11	12	13	Control	Total
Black-tailed Prairie Dog	Adults	Late Spring	Shotgun/ .22 rifle	Carcass	10	10	10	0	0	3	2	0	10	45
Desert Cottontail	Sick Adults Only	Spring/ Summer	Hand	Carcass	0	0	0	0	0	0	0	5	0	5
Deer Mouse	Adults	Spring	Live-trap	Whole body	4	4	4	4	5	3	2	0	5	31
Thirteen-lined Ground Squirrel	Adults	Spring	Live-trap	Whole body	3	3	0	0	0	0	0	0	3	9
Western Meadowlark	Adults	Summer	Shotgun	Carcass			5[c]						0	5
Mourning Dove	Adults	Early Summer	Shotgun	Carcass	2	2	2	2	2	0	0	0	0	10
	Juveniles	Mid Summer	Shotgun	Carcass	2	2	2	2	2	0	0	0	0	10
	Adults	Late Summer	Shotgun	Carcass	2	2	2	2	2	0	0	0	5[d/]	15
Burrowing Owl	Large Juveniles	Summer	Shotgun/ Hand noose	Carcass			5[c]						0	5
Ring-necked Pheasant	Juveniles	Summer	Shotgun	Carcass	3	3	2	2	3	0	0	0	0	13
	Adults	Fall	Live-trap	Carcass	3	3	2	2	3	0	0	0	5	18
				Liver	3	3	2	2	3	0	0	0	5	18
Ground beetle	All	Summer	Pitfall Trap	Whole Body Composite			6[c]						3	9
Grasshopper	Nymphs	Summer	Sweep Net	Whole	5	5	4	4	5	3	2	0	5	33
Earthworm	All	Spring	Excavation	Whole Body Composite	2	3	3	3	3	0	0	5	4	23

Table 3.1-3 Summary of 1989 Contaminant Monitoring Field Program

Species (Terrestrial)	Life Stage	Collection			No. of Location Replicates RMA a/									
		Season	Method	Tissue	1	2	3	4	5	11	12	13	Control	Total
Sunflower	Seed Stage	Summer	Hand	Portions of Above Substrate Parts	5	5	4	4	5	3	2	0	5	33
Kochia	Flowering Stage	Summer	Hand	Above-Substrate Parts	5	5	4	0	5	0	0	0	5	24
Cheatgrass	Rapid Growth Stage	Late Spring	Hand	Above-Substrate-Parts	5	5	4	4	5	0	0	0	5	28
Lactuca	Flowering Stage	Summer	Hand	Above-Substrate Parts	3	0	0	4	0	0	0	0	3	10
Water					0	0	0	0	0	0	0	5 b/	0	5
Soil					0	0	0	0	0	0	0	5 b/	0	5
Subtotal														354

Table 3.1-3 Summary of 1989 Contaminant Monitoring Field Program

Species (Aquatic)	Life Stage	Collection Season	Collection Method	Tissue	No. of Location Replicates RMA b/ 6	7	8	9	10	Control	Total
Mallard	Juveniles	Summer	Shotgun	Carcass			6/c			5	11
				Liver			6/c			5	11
American Coot	Juveniles	Summer	Shotgun	Carcass			6/c			5	11
Killdeer	Adults	Summer	Shotgun	Carcass			5c/			0	5
Northern Pike	Adults	Late Summer	Gillnet Trapnet	Whole Body	0	0	0	0	0	5	5
Largemouth Bass	Adults	Late Summer	Gillnet Trapnet	Whole Body	5	5	5	0	0	5	20
Channel Catfish	Adults	Late Summer	Gillnet Trapnet	Whole Body	5	0	0	0	0	5	10
Bullhead	Adults	Late Summer	Gillnet Trapnet	Whole Body	0	0	5	0	0	5	10
Bluegill	Adults	Late Summer	Gillnet Trapnet	Whole Body	5	5	5	0	5	5	25
American Pondweed	Mature	Late Summer	Hand	Above-Substrate Parts	4	4	4	0	0	5	17
Sego Pondweed	Mature	Late Summer	Hand	Above-Substrate Parts	3	3	3	4	0	5	18
Coontail	Mature	Late Summer	Hand	Above-Substrate Parts	3	3	0	0	0	5	11
Plankton	All	Late Summer	Plankton Net	Whole Body Composite	5	5	5	0	5	5	25
Subtotal											179

Table 3.1-3 Summary of 1989 Contaminant Monitoring Field Program

Species (Aquatic)	Life Stage	Collection: Season	Collection: Method	Tissue	No. of Location Replicates RMA b/: 6	7	8	9	10	Control	Total
Fortuitous Samples	All			Muscle			15/c			0	15
				Liver			15/c			0	15
				Brain			6/c			0	6
				Whole Body/ Carcass			22/c			0	22
				Miscellaneous			8/c			0	8
Subtotal											66
Total											589*

*Plus 10 percent QA/QC subsamples

a/ Primary terrestrial biota study areas: 1 = Basin A and adjacent area; 2 = Basins B, C, D, E, and F and adjacent area; 3 = Sand Creek Lateral and ditches connecting South Plants Complex; 4 = South Plants complex; 5 = Area around Upper and Lower Derby Lakes, Lake Ladora, Lake Mary, Lake Mary Overflow Basin, and Rod and Gun Club Pond; 11 = Toxic Storage Yard; 12 = North Plants; 13 = Administration Building.

b/ Aquatic biota study areas: 6 = Lake Mary; 7 = Lake Ladora; 8 = Lower Derby Lake; 9 = Rod and Gun Club Pond; 10 = Upper Derby Lake.

c/ Replicates will be nonspecific and distributed over areas as they are available.

d/ 5 adults off-post coordinated with CDOW including Duck Creek Wildlife Area and Tamerack Ranch Wildlife Area (both near Crook, Colorado).

Table 3.1-4 Selection Criteria for RMA Biota Monitoring Species

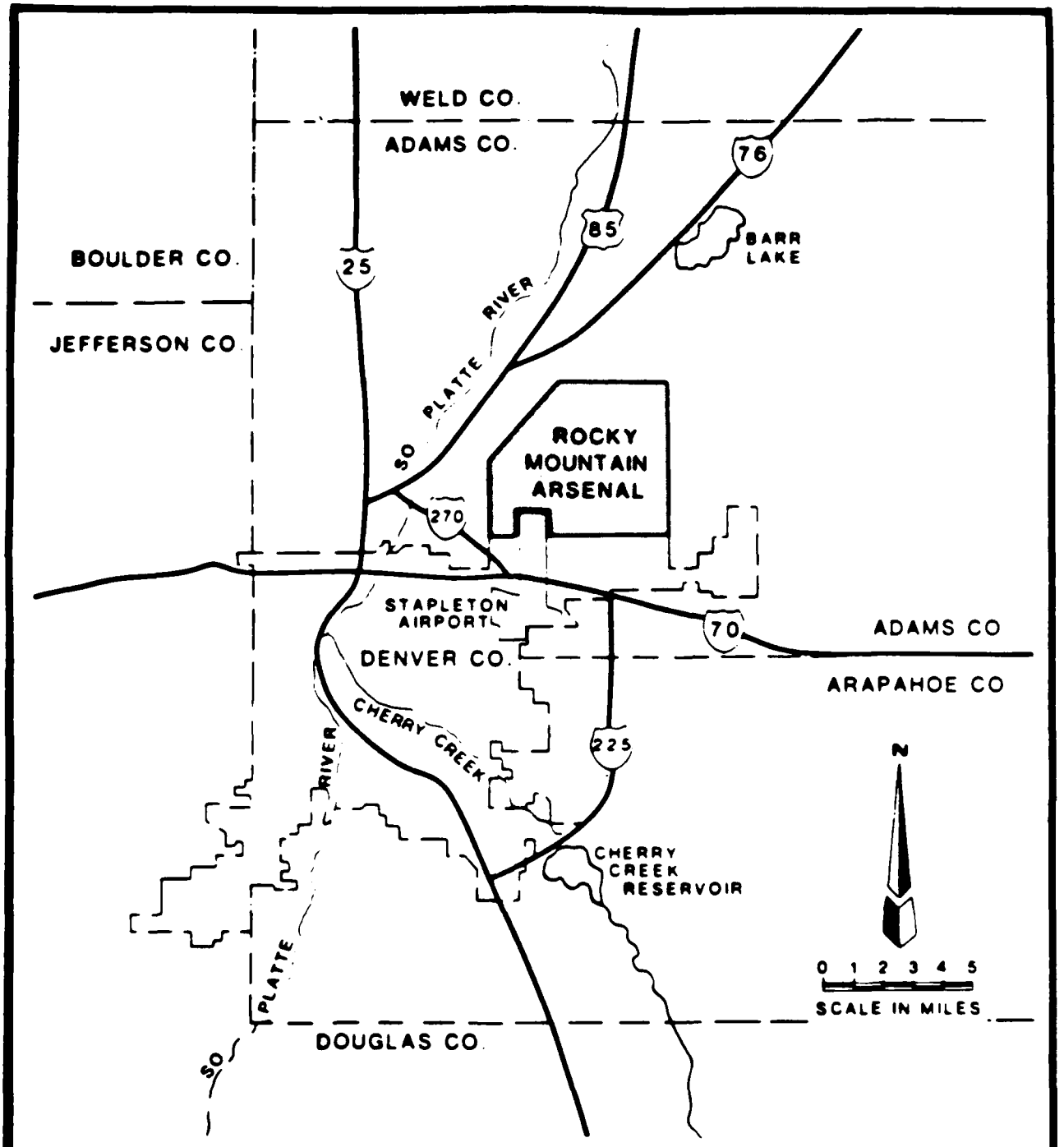
	Taxonomic Group	Trophic Level	Game Species	Prey Item for Endangered Species	Not Threatened or Endangered	Widespread Distribution on RMA	Home Range Limited to RMA	Popul Sufficiently Large	Sampled in 1986 Biota Assessment	Other Historical Contaminant Data
Black-tailed Prairie Dog/Adult	mammal	herbivore		X	X		X	X	X	X
Deer Mouse/Adult	mammal	omnivore			X	X	X	X	X	X
Burowing Owl/ Juvenile	bird	carnivore			X		X	X		
Western Meadowlark/ Adult	Bird	omnivore			X	X	X	X		X
Mourning Dove/ Juvenile/Adult	bird	herbivore	X		X	X		X	X	X
Ring-necked Pheasant/Juvenile	bird	insectivore	X		X	X	X	X	X	X
Ring-necked Pheasant/Adult	bird	omnivore	X		X	X		X	X	X
Killdeer/Adult	bird	primary carnivore			X			X		
Ground Beetle	invertebrate	omnivore			X	X	X	X		X
Grasshopper	invertebrate	herbivore	X		X	X		X	X	X
Earthworm	invertebrate	detritivore			X		X		X	X
Terrestrial Plants	plant	primary producer			X	X	X	X	X	X
Mallard/Juvenile	bird	omnivore	X		X	X	X	X	X	X

Table 3.1-4 Selection Criteria for RMA Biota Monitoring Species

	Taxonomic Group	Trophic Level	Game Species	Prey Item for Endangered Species	Not Threatened or Endangered	Widespread Distribution on RMA	Home Range Limited to RMA	Popul. Sufficiently Large	Sampled in 1986 Biota Assessment	Other Historical Contaminant Data
American Coot/ Juvenile	bird	herbivore			X		X	X	X	X
Largemouth Bass	fish	top carnivore	X		X	X	X	X	X	X
Channel Catfish/ Black Bullhead/ Brown Bullhead	fish	bottom feeding omnivore	X		X	X	X	X	X	X
Bluegill	fish	primary carnivore	X		X	X	X	X	X	X
Aquatic Macrophytes	plant	primary producer			X	X	X	X	X	X
Plankton	plant	primary producer			X	X	X	X	X	X

Table 3.4-1 **Certified Reporting Limits (CRLs) for Target Analytes in Biota Tissue**

	Midwest Research Institute		Environmental Science & Engineering	
Method/Analyte	Lower CRL in ug/g	Upper CRL in ug/g	Lower CRL in ug/g	Upper CRL in ug/g
H-6 Fat Tissue			M6 Fat Tissue	
Aldrin	0.103	0.790	0.013	0.3
Dieldrin	0.0840	0.802	0.018	0.3
DDE	0.100	0.812	0.063	1.88
DDT	0.118	0.804	0.132	3.75
Endrin	0.0740	0.810	0.036	0.6
K-6 Nonfat Tissue				
Aldrin	0.0663	0.790	not certified	not certified
Dieldrin	0.0592	0.802		
DDE	0.0416	0.812		
DDT	0.0753	0.804		
Endrin	0.0465	0.810		
J6A Fat Tissue			C6 Fat Tissue	
Mercury	0.0463	1.00	0.05	0.4
J6P Nonfat Tissue			C6 Nonfat Tissue	
Mercury	0.0574	1.00	0.05	0.4
G6-Fat Tissue			B6 Fat Tissue	
Arsenic	0.438	5.00	0.25	5.0
G6-Nonfat Tissue			B6 Nonfat Tissue	
Arsenic	0.250	5.00	0.25	5.0



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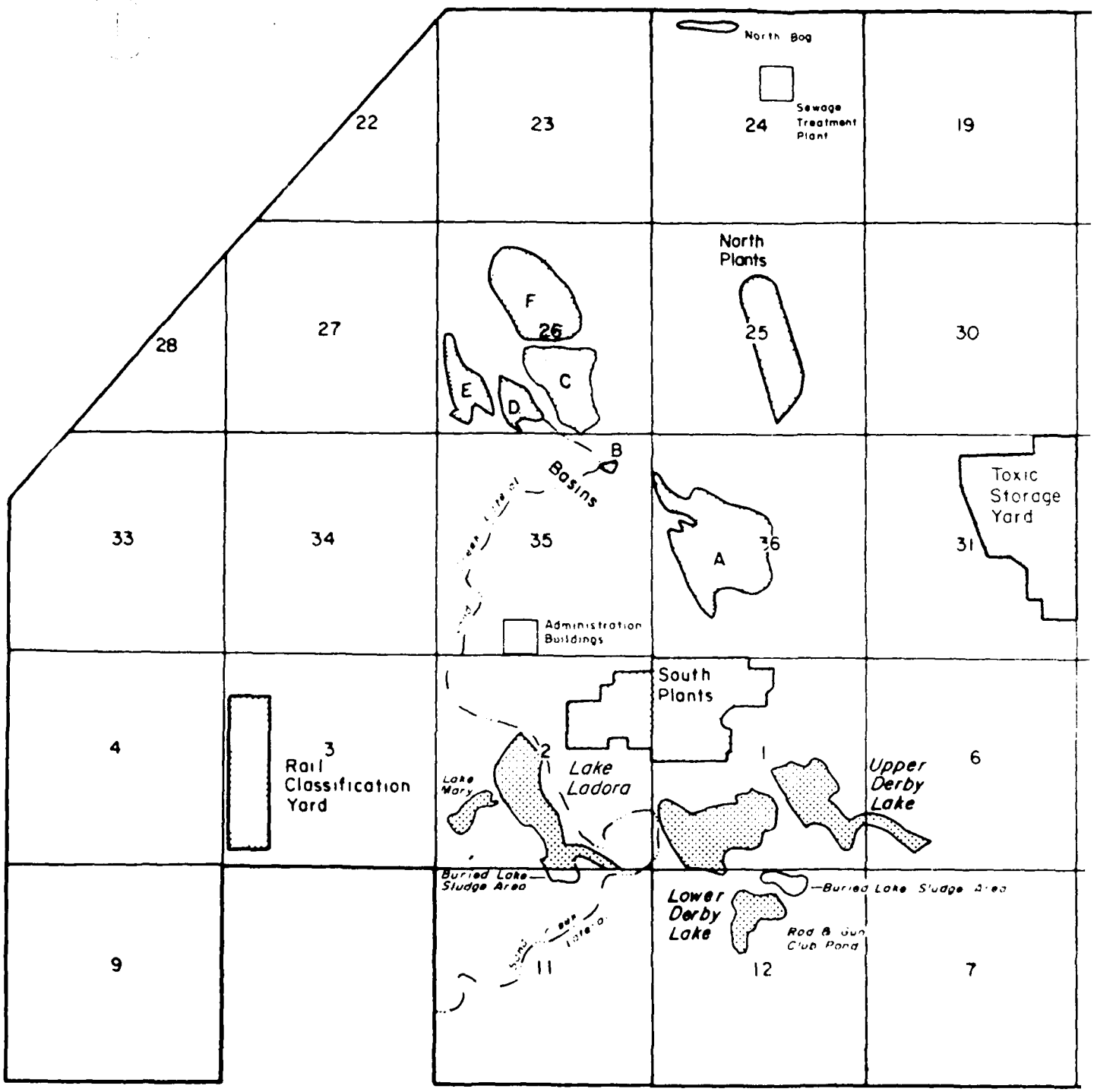
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:
R.L. Stollar & Associates, Inc.
Ebasco Environmental

FIGURE 1.1-1

General Location of Rocky Mountain Arsenal

Revised: 3/23/90
Biota CMP
Source: RMA, 1983. ESE, 1987

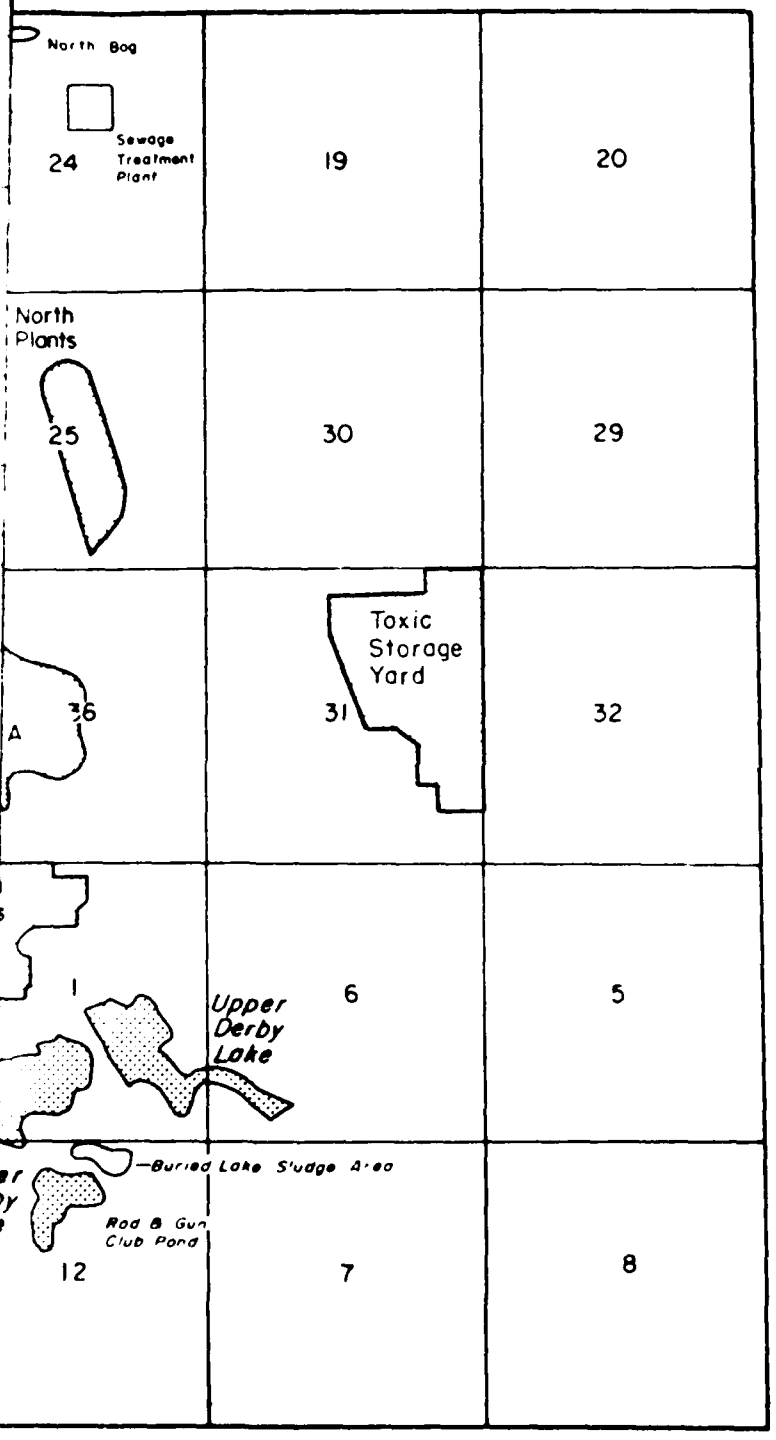


Prepared for :

U.S. Army Program Manage
Rocky Mountain Arsenal
Commerce City, Colorad

Prepared by:

R.L. Stollar & Associate
Ebasco Environmental



Explanation

Major Potential Contamination Sites

N

0 2640 5280

Approx. Scale in Ft

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Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:

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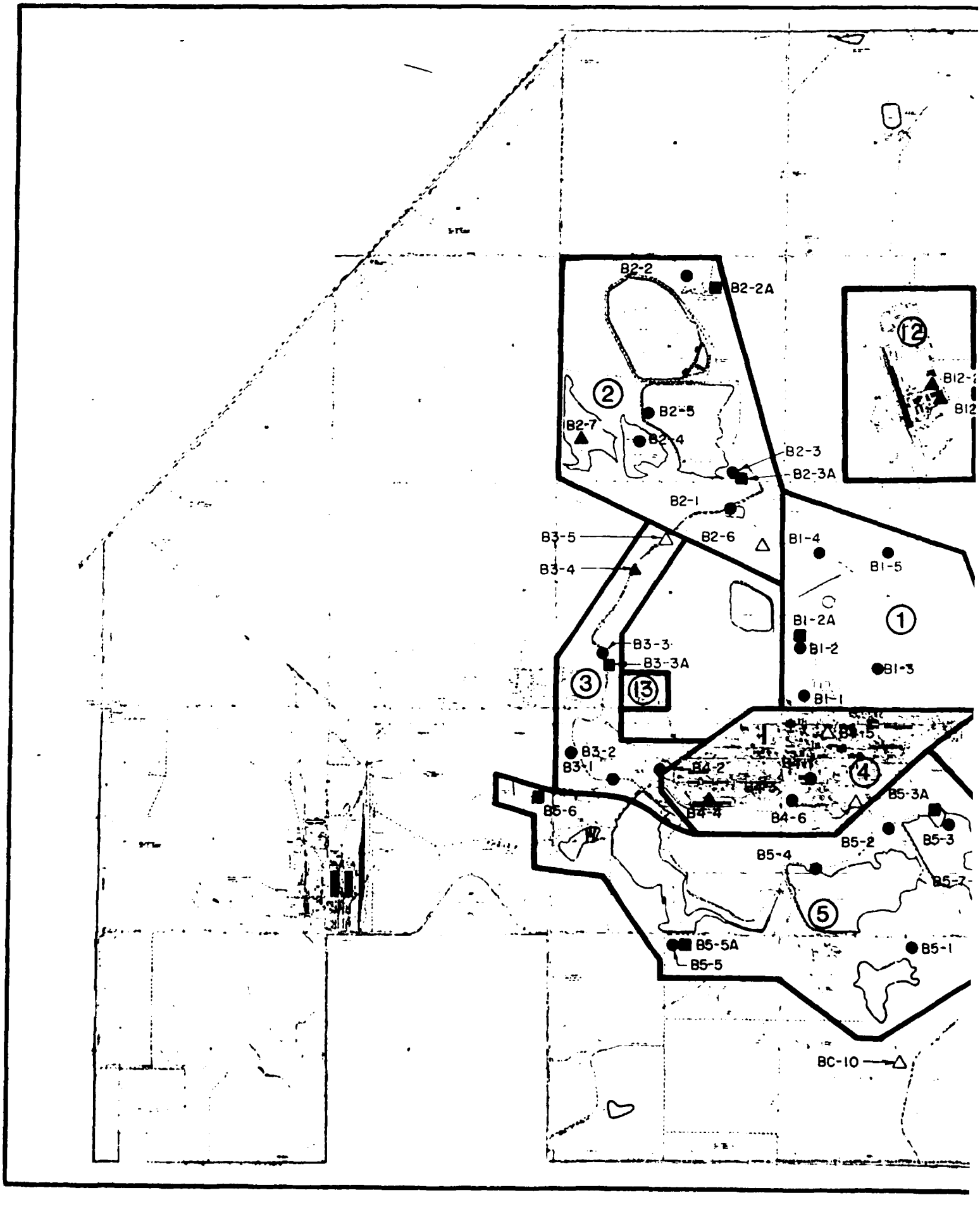
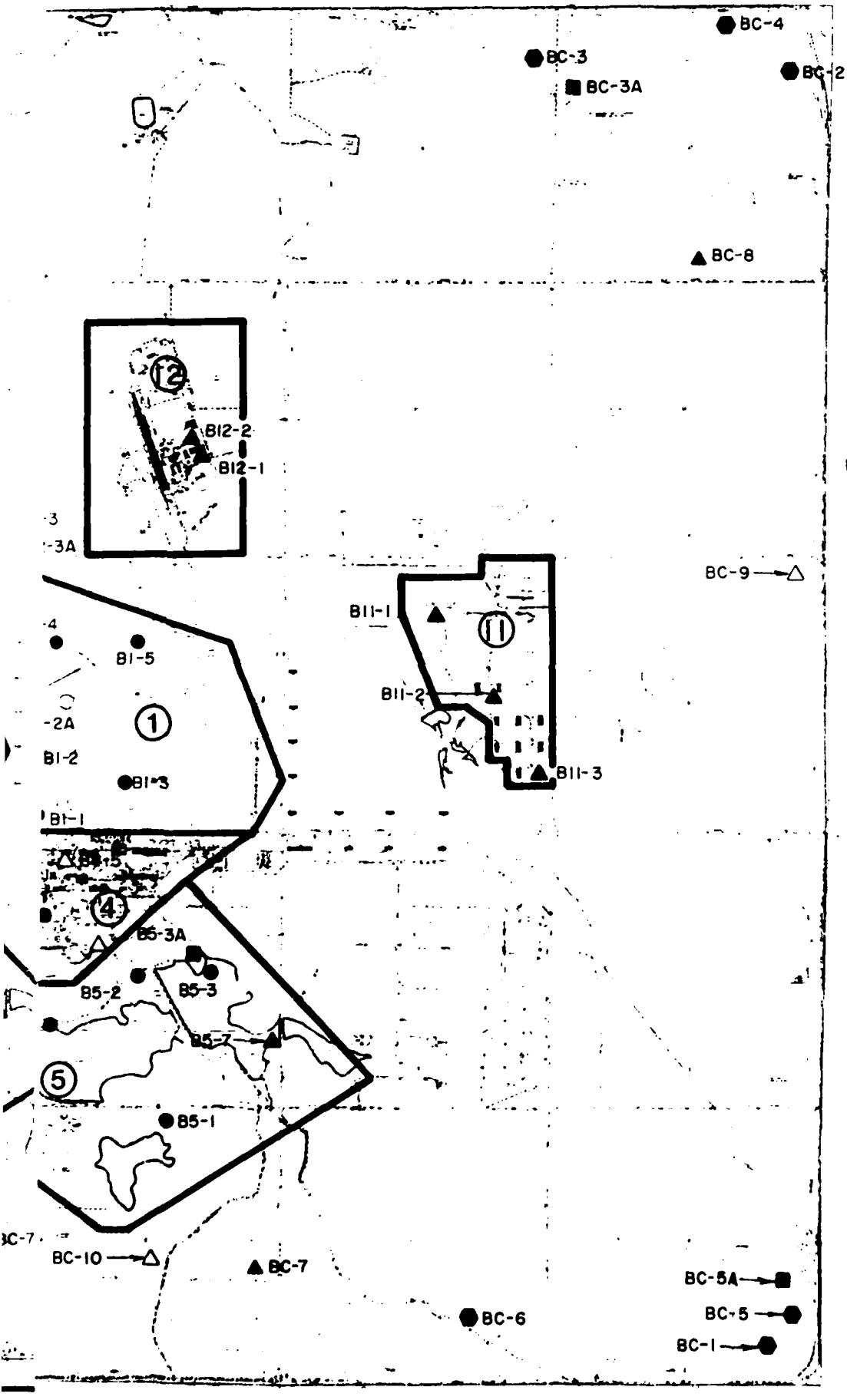
FIGURE 1.1-2

Primary Areas of Potential Contamination on Rocky Mountain Arsenal

Biota CMP
Revised: 6/20/90

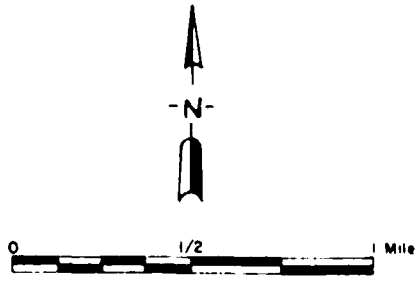

B2-2
B2-2A
B2-5
B2-7
B2-4
B2-3
B2-3A
B2-1
B2-6
B3-5
B3-4
B1-4
B1-5
B1-2A
B1-2
B1-3
B1-1
B3-3
B3-3A
B3-2
B3-1
B4-2
B4-4
B4-6
B5-6
B5-3A
B5-2
B5-3
B5-4
B5-5A
B5-5
B5-1
BC-10
1
2
3
4
5
12
13



EXPLANATION

- 1988 Biota Staked Sites
- 1988 Staked Control Sites
- 1988 Alternative Staked Sites
- 1989 New Staked Sites
- 1989 Potential Alternative Staked Sites
- (12) Biota Study Area (BSA) Designation

Note: Staked Site Numbers on this figure differ slightly in format from those used elsewhere in this report. The format correpondence is: BC-1= BCRM-1
B1-1 = BS1-1



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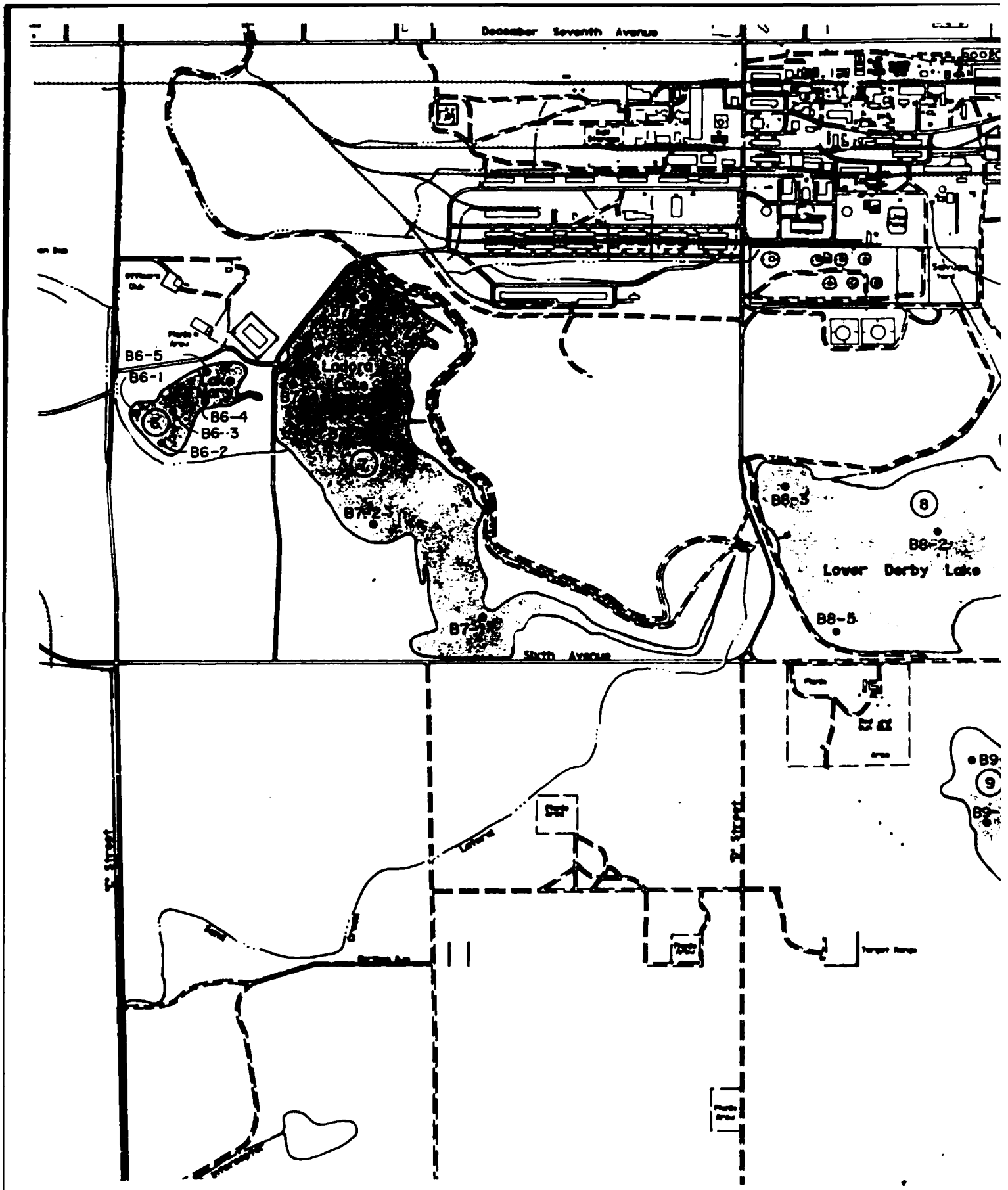
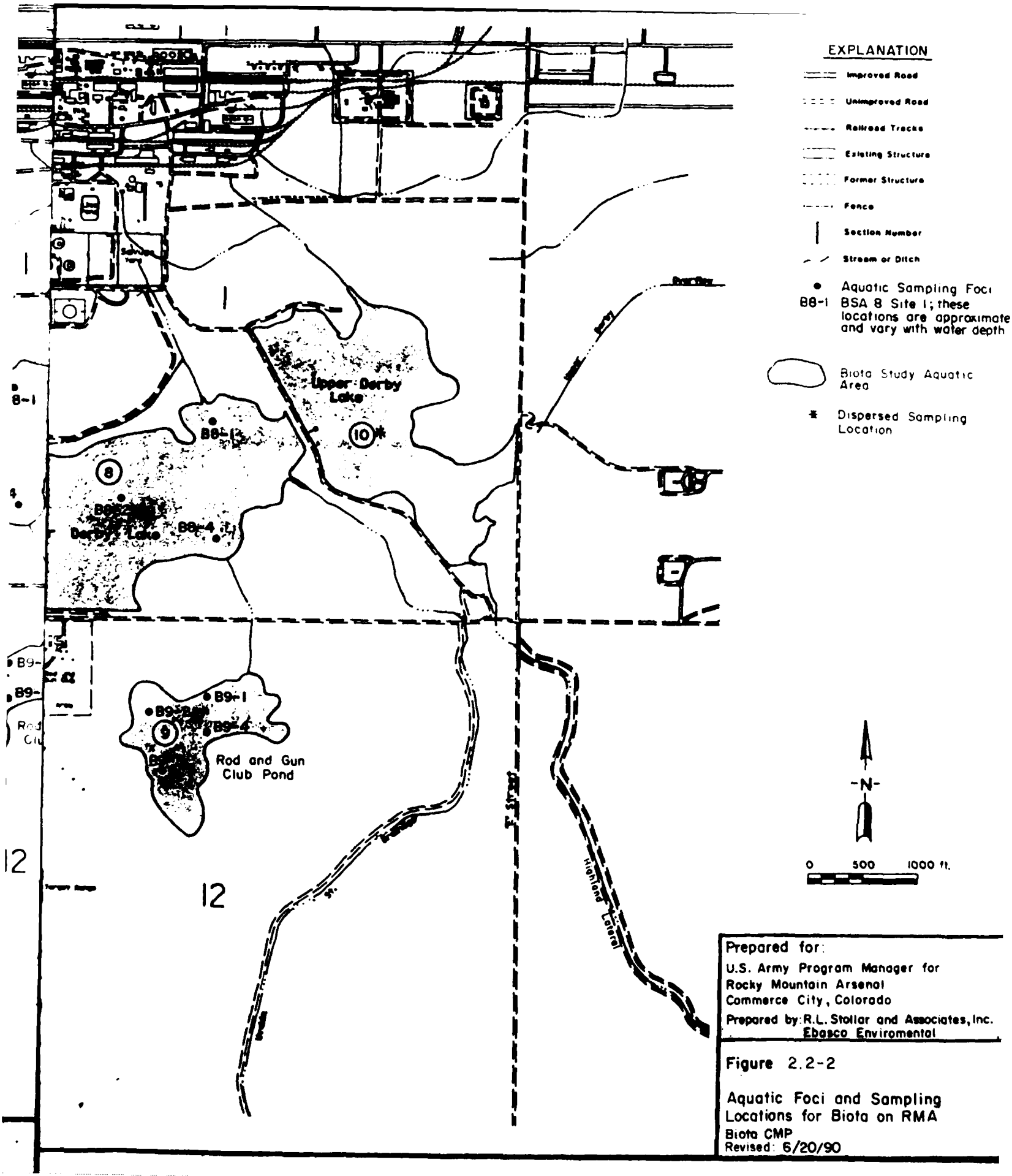
Ebasco Environmental

Figure 2.2-1

Fixed On-Site Sampling Locations
CMP Biota Program

Biota CMP
Revised: 3/23/90


December Seventh Avenue
B6-5
B6-1
B6-4
B6-3
B6-2
Lagona Lake
B7-2
B7-1
B8-3
B8-2
Lower Derby Lake
B8-5
Sixth Avenue
T Street
T Street



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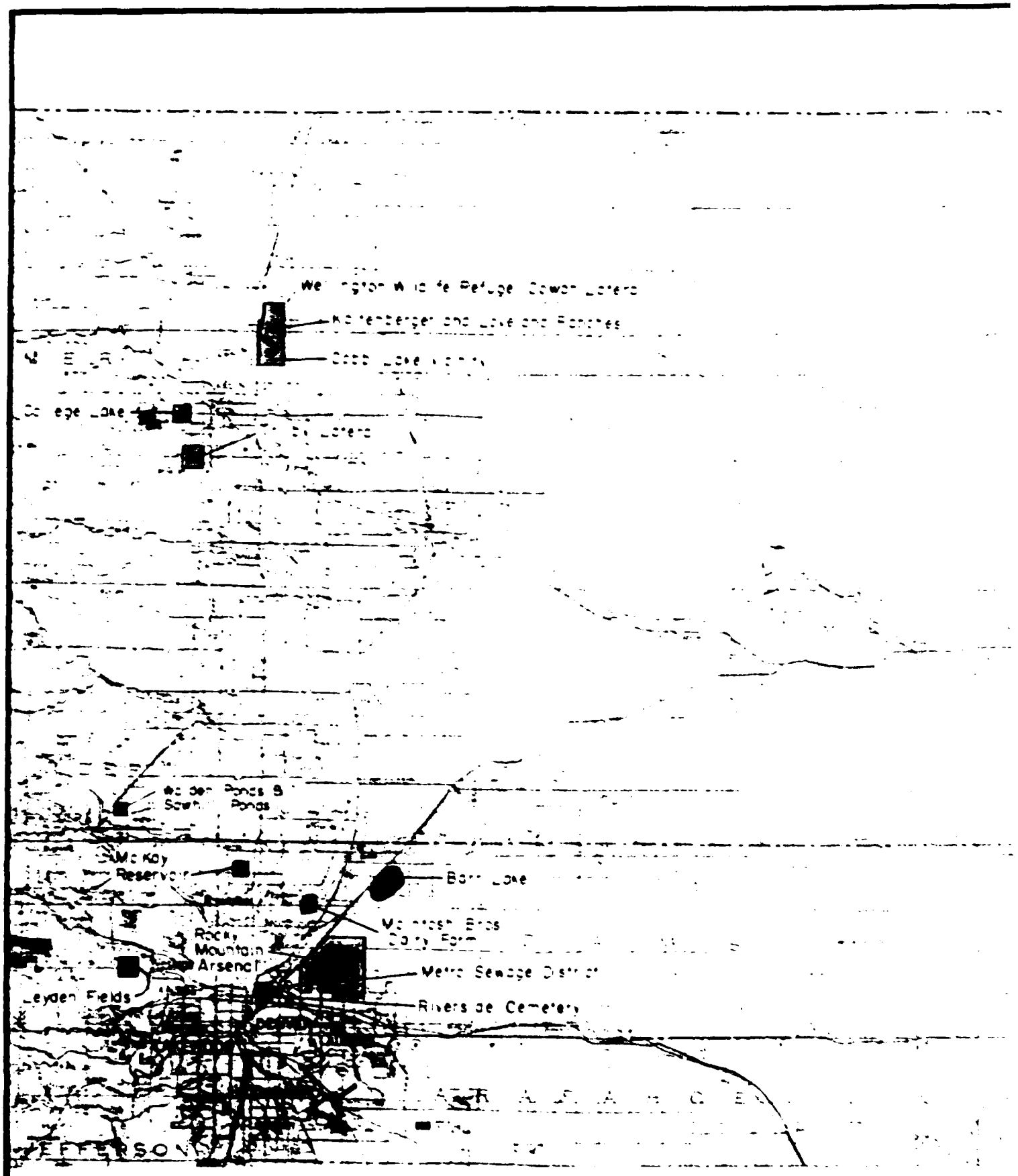
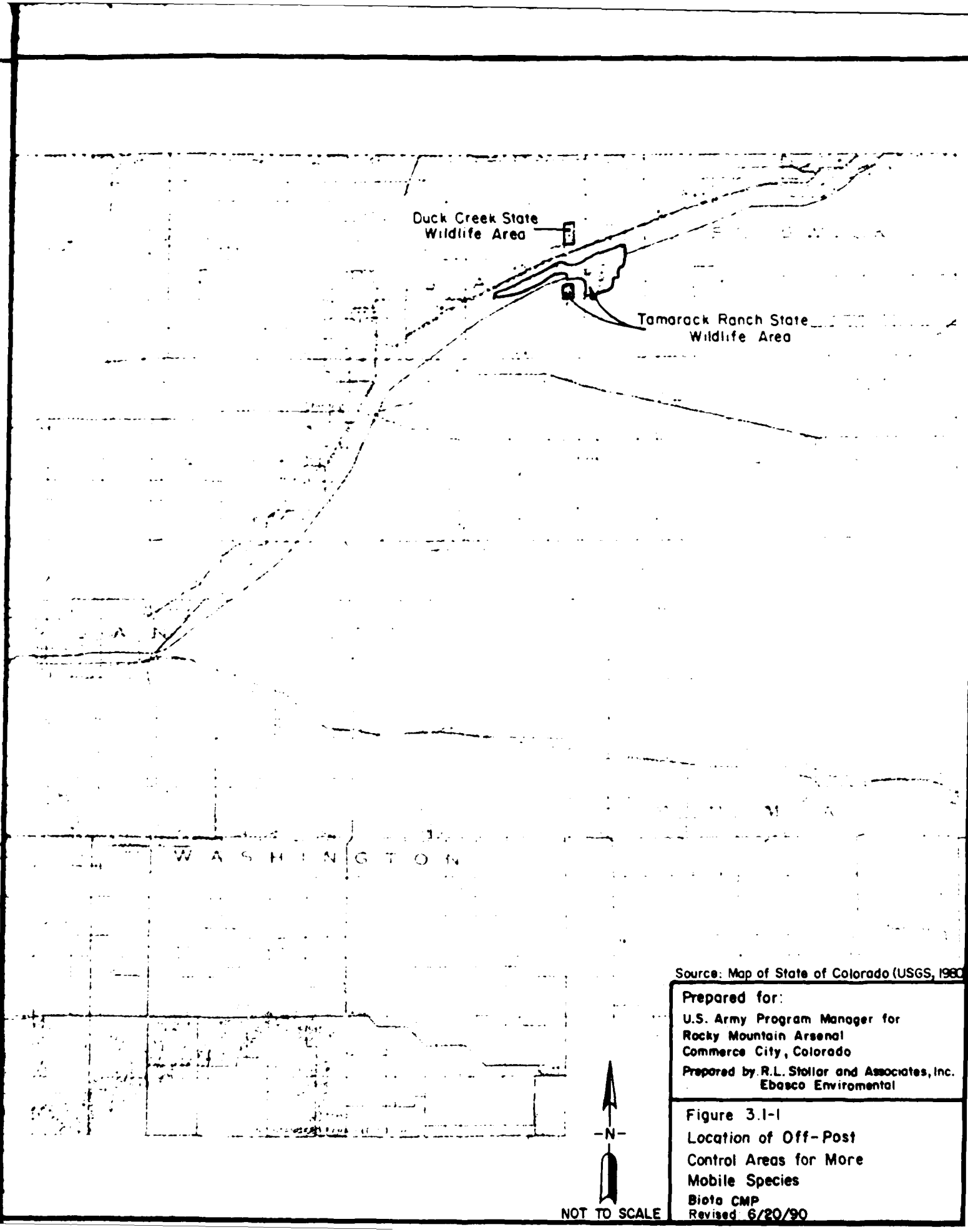
Ebasco Environmental

Figure 2.2-2

Aquatic Foci and Sampling Locations for Biota on RMA
Biota CMP
Revised: 6/20/90


Rocky Mountain Arsenal
Leyden Fields
Metro Sewage District
Riverside Cemetery
Barr Lake
McKay Reservoir
JEFFERSON



Source: Map of State of Colorado (USGS, 1980

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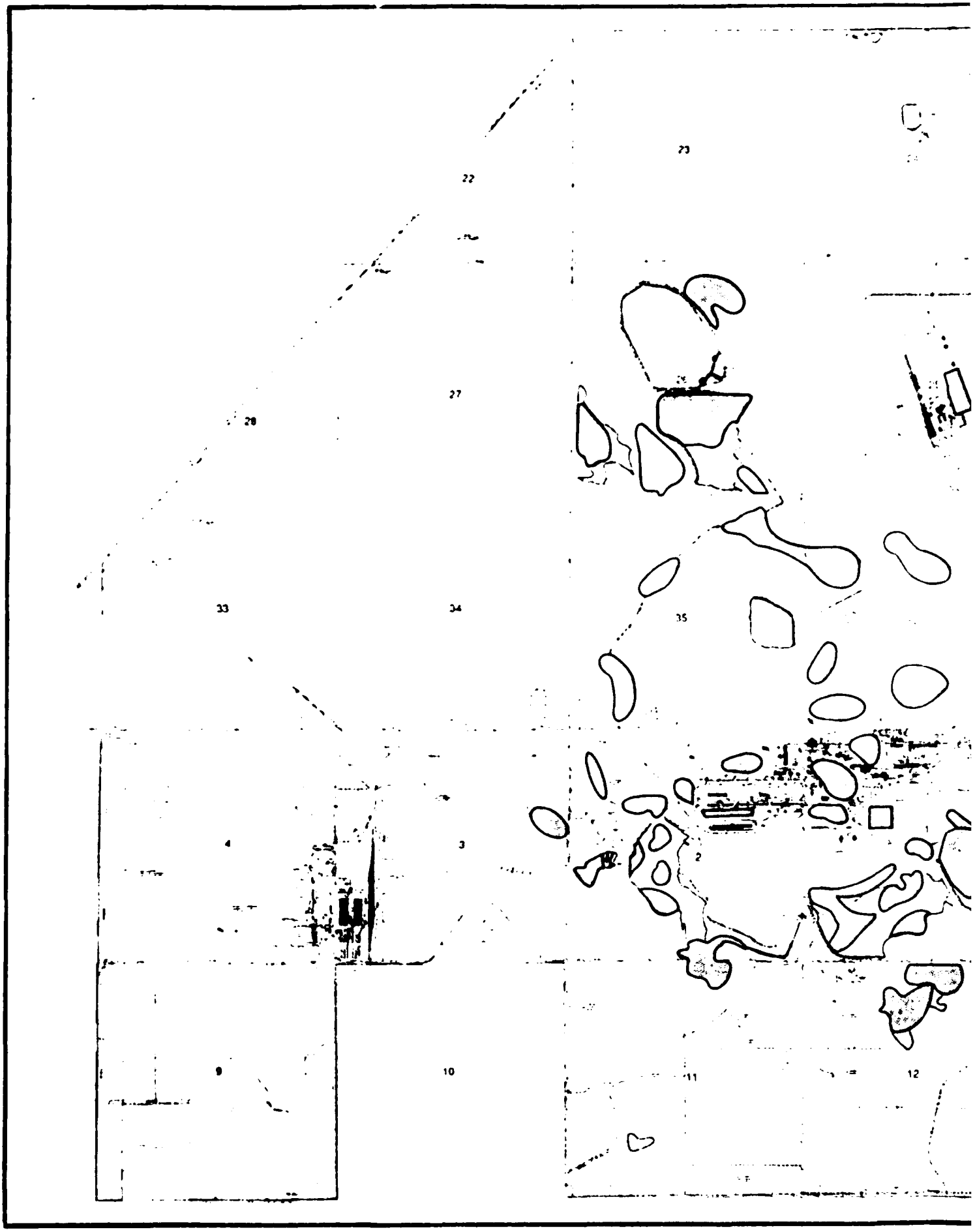
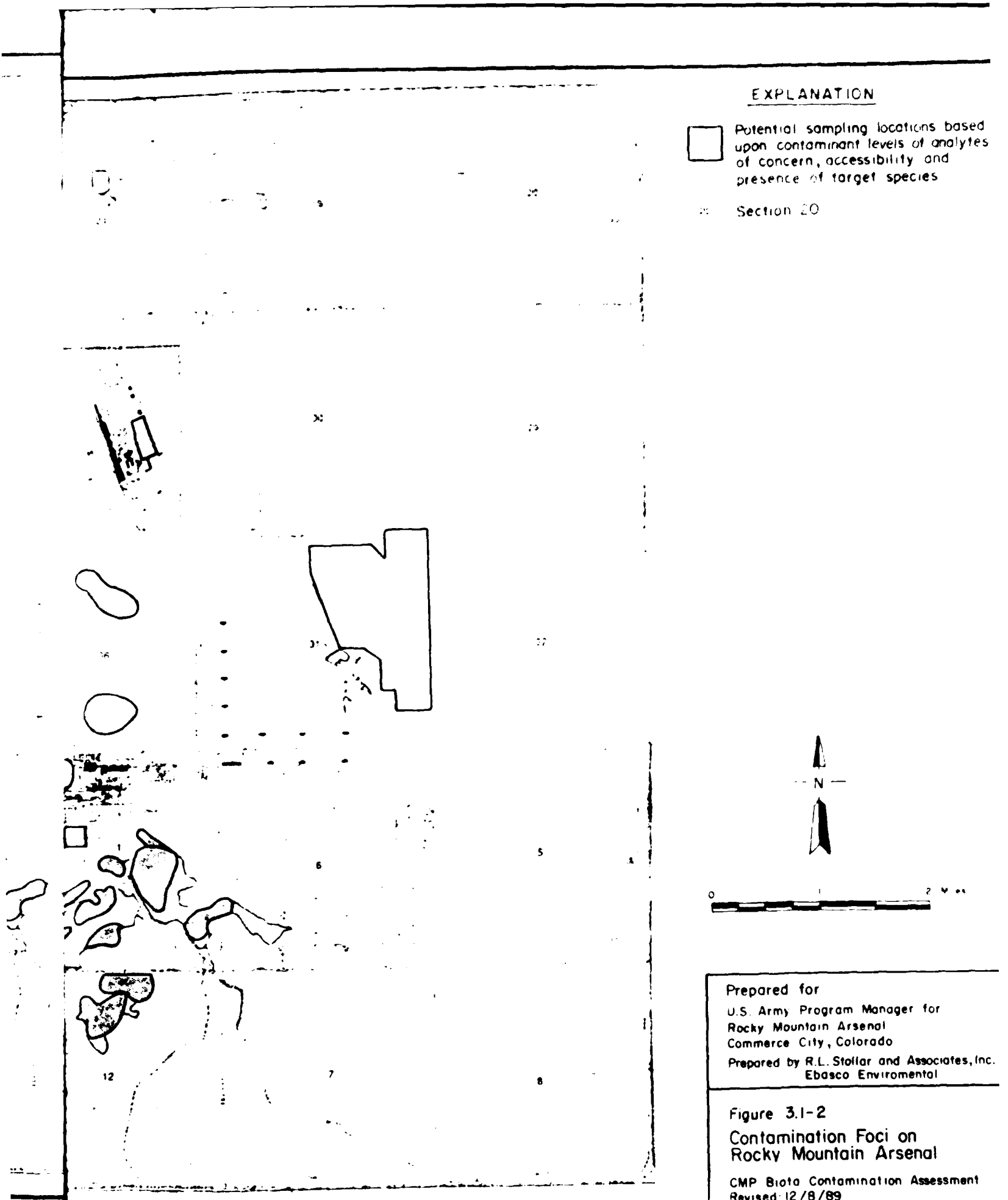
U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by R.L. Stollar and Associates, Inc.
Ebasco Enviromental

Figure 3.1-1
Location of Off-Post
Control Areas for More
Mobile Species
Biota CMP
Revised 6/20/90


22
23
27
28
33
34
35
4
3
2
9
10
11
12



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Commerce City, Colorado
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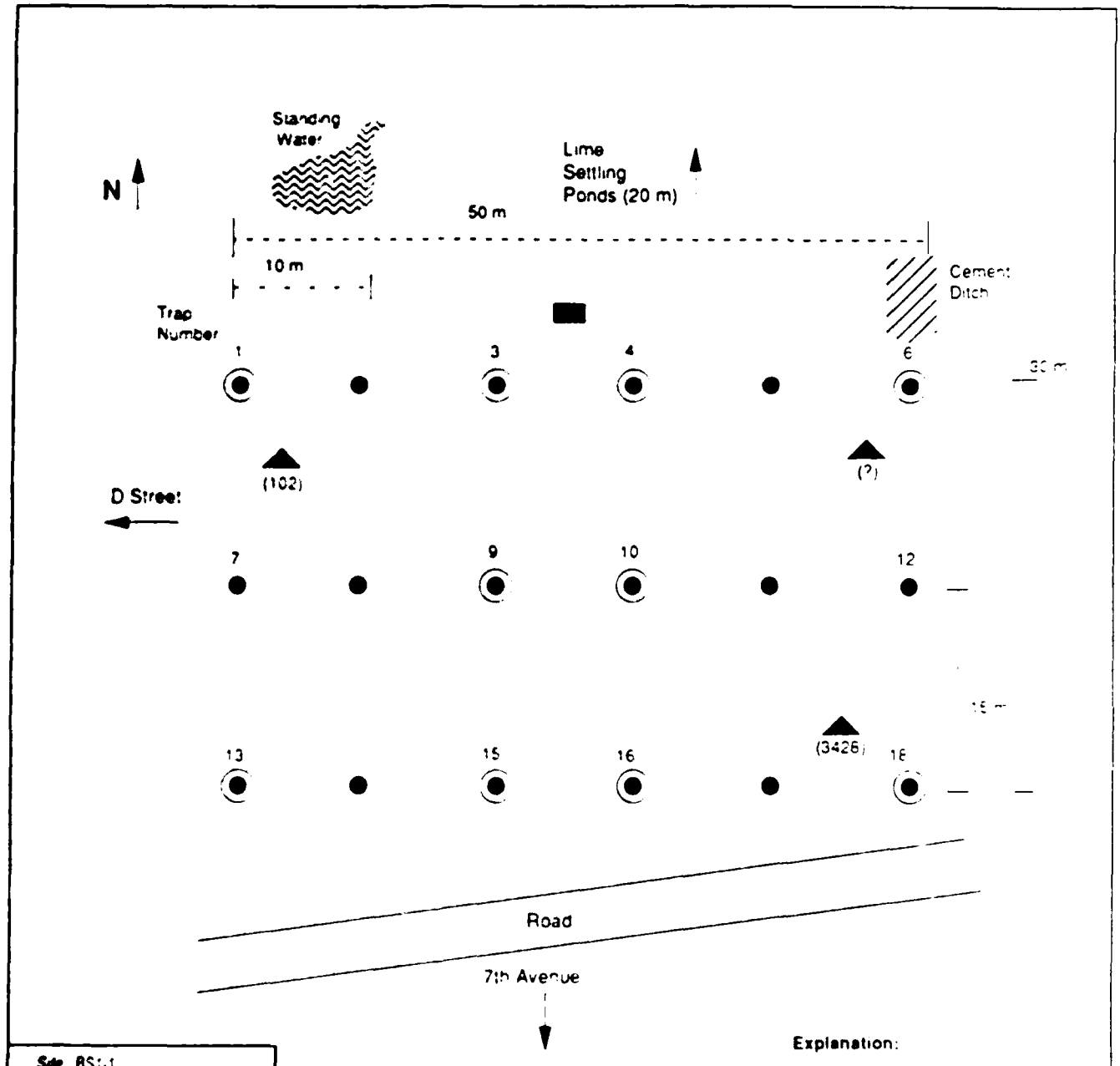
Figure 3.1-2
Contamination Foci on
Rocky Mountain Arsenal

CMP Biota Contamination Assessment
Revised: 12/8/89



Site: BS1-1
Plot Size: 30 x 50 m
Staked Area: 0.15 ha
Effective Area: 0.24 ha
Plot Orientation: N-S
Borings in Plot: Borings 3428 (redrill), 102(14), and unknown

Location: Section 36 (Lime Settling Ponds)
Number of Traps: 18
Trap Spacing: N/S-15 m
E/W-10 m
Date Established: 5-9-88

Northing: 180,700
Easting: 2,184,500

Trapping Priority: 1-7-17-18-5-6, 2-8, 11-12, 3-9-4-10-16, 13-14-15

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Commerce City, Colorado

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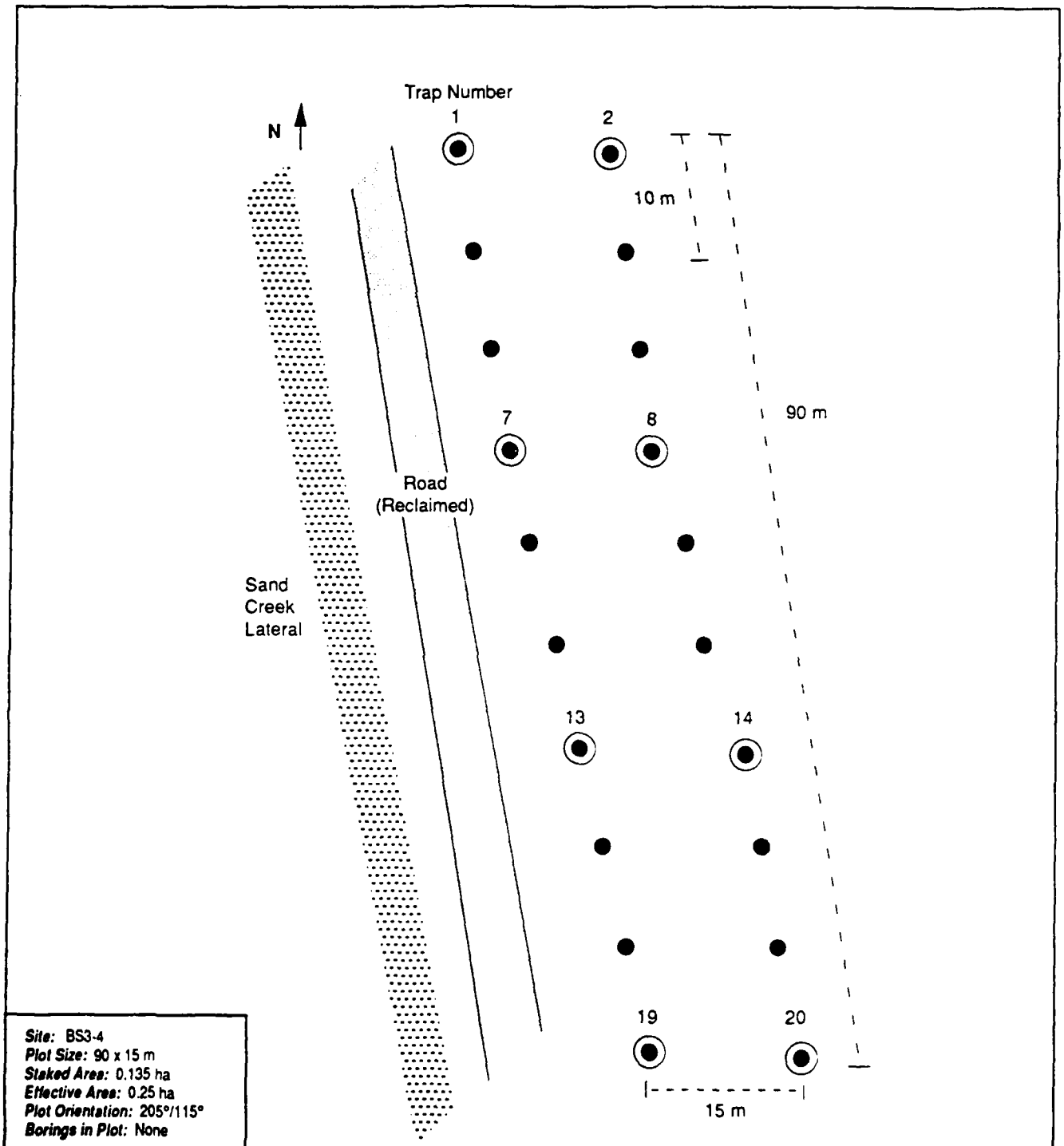
Ebasco Environmental

Figure 3.2-1

Biota Sampling Location, Staked Site BS1-1

Biota CMP
Revised: 3/23/90



Site: BS3-4
Plot Size: 90 x 15 m
Staked Area: 0.135 ha
Effective Area: 0.25 ha
Plot Orientation: 205°/115°
Borings in Plot: None

Location: Section 35 (Sand Creek Lateral)
Number of Traps: 20
Trap Spacing: N/S - 10 m
E/W - 15 m
Date Established: 5-2-89

Northing: 183,200
Easting: 2,180,000

Trapping Priority: 9-10-11-12, 7-8-13-14, 5-6-15-16, 3-4-17-18, 1-2-19-20

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Commerce City, Colorado

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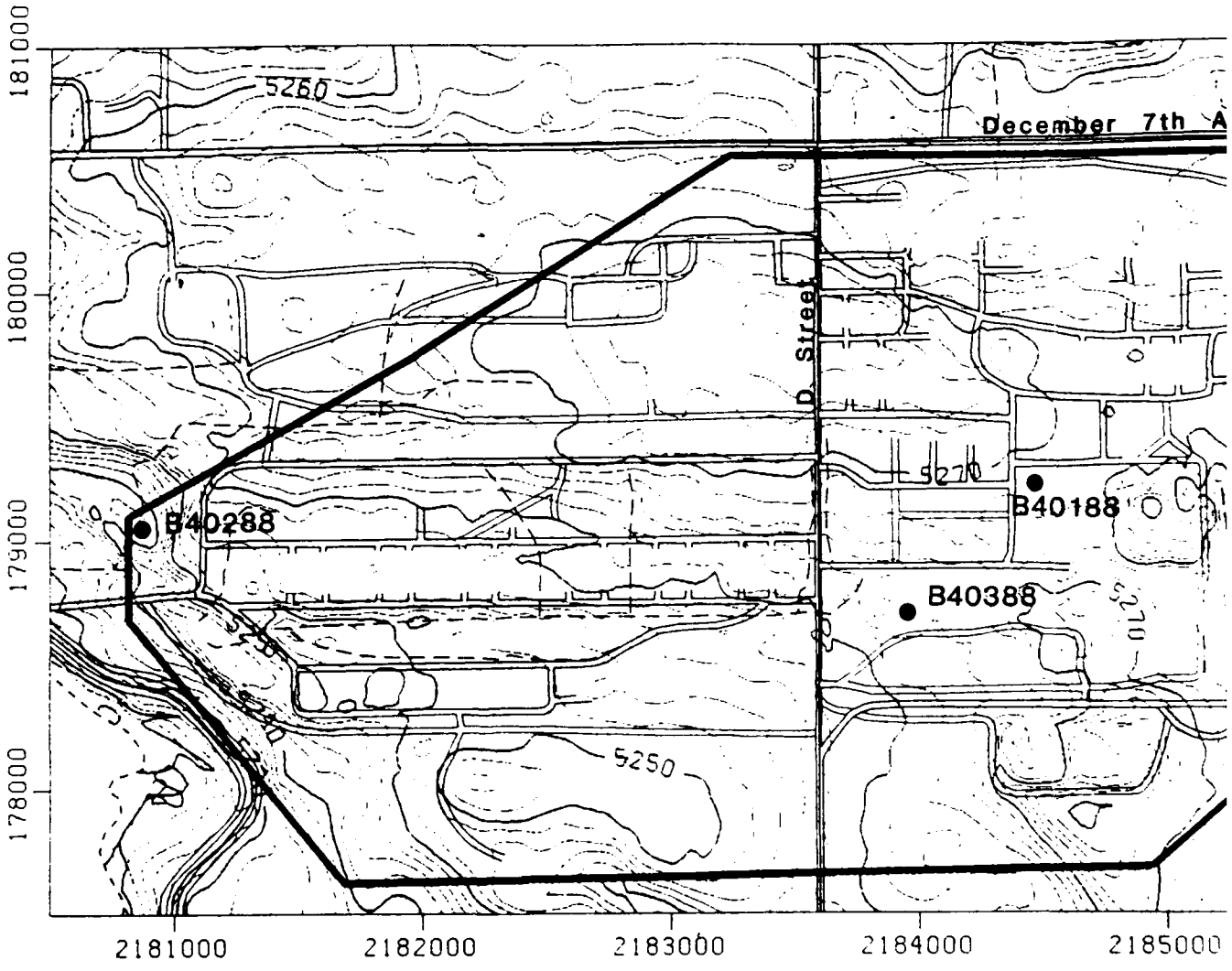
Ebasco Environmental

Figure 3.2-2

Biota Sampling Location, Staked Site BS3-4

Biota CMP
Revised: 3/23/90

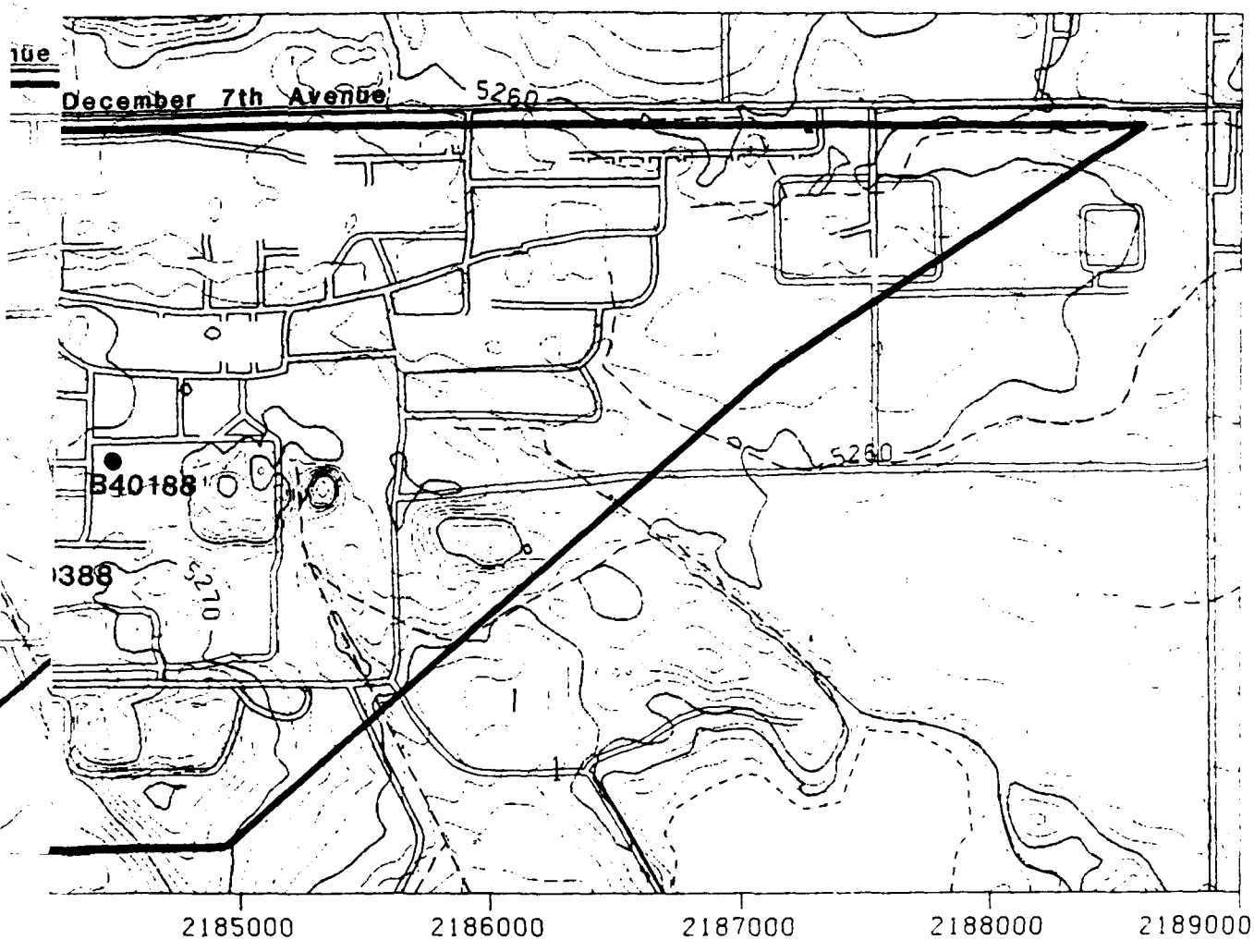


EXPLANATION

- Biota Staked Sites Established in 1988
- Drainage Ditch
- Biota Study Area Boundary
- Improved Road
- Section 1
- 179000 State Planar Coordinates

0

2' C



N

0 660 1320

FEET

2' Contour Interval

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Commerce City, Colorado

Prepared by:

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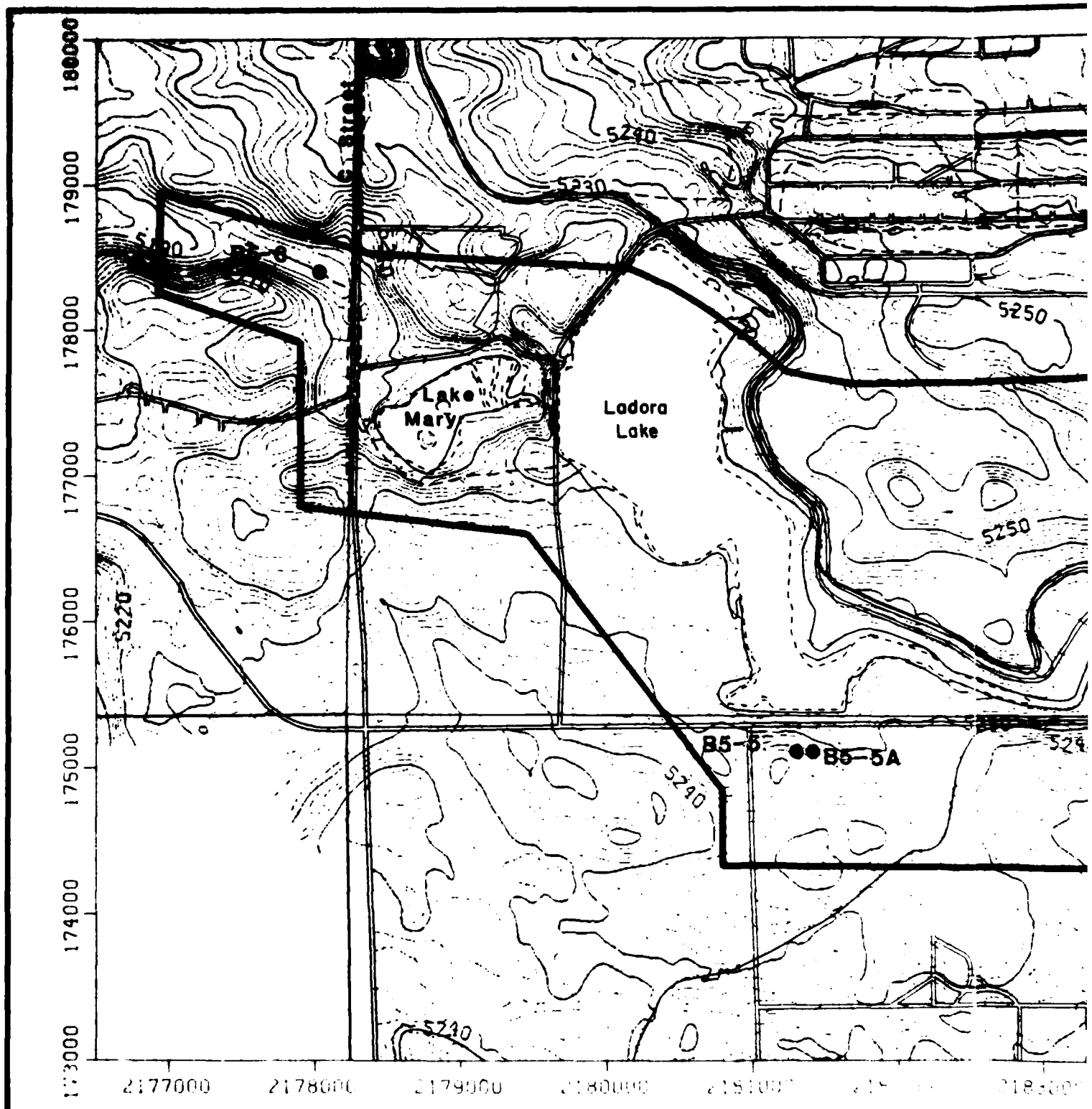
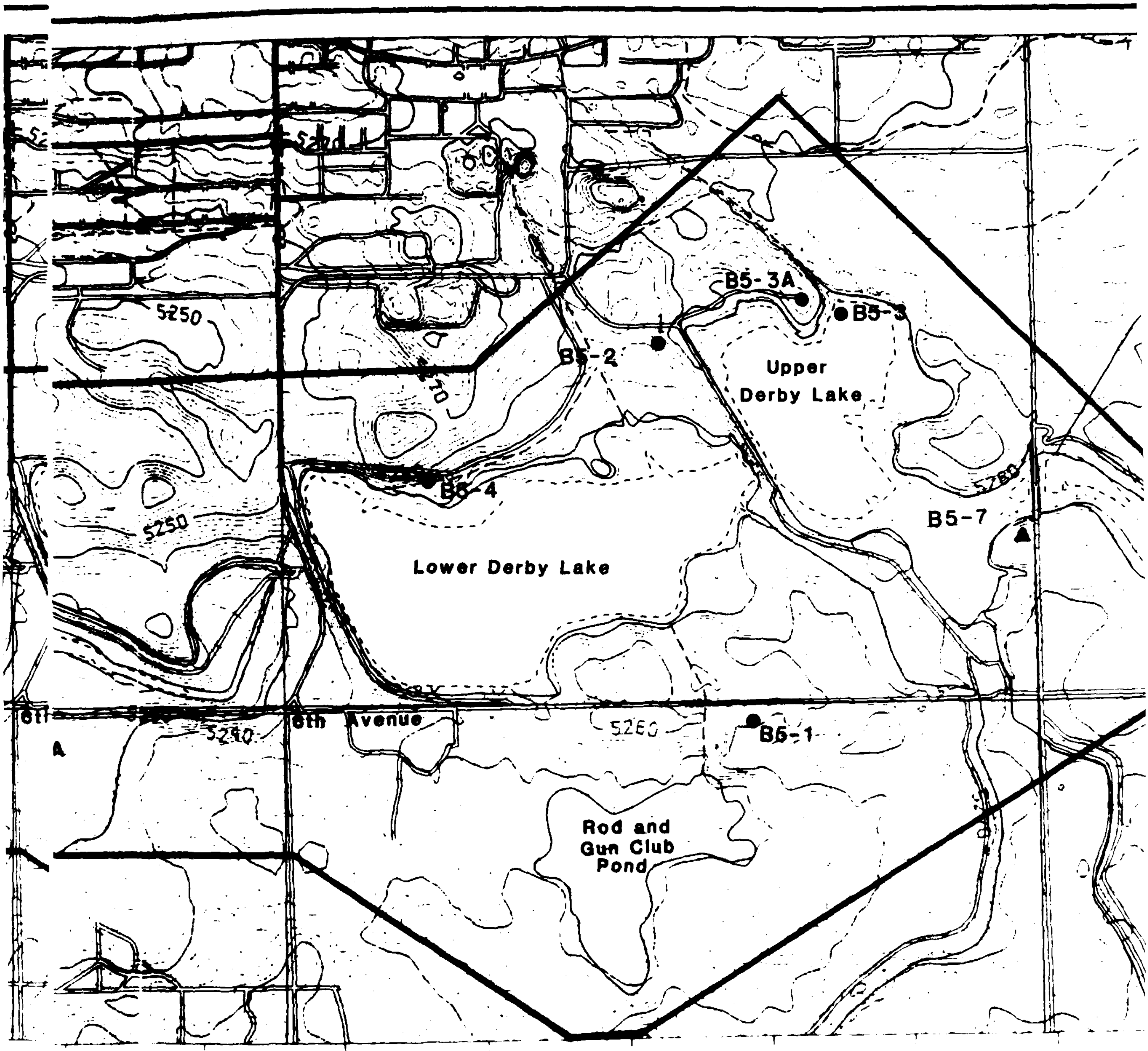
Ebasco Environmental

Figure 3.2-6

CMP-BSA 4, RMA

CMP Biota Contamination Assessment
Revised: 12/8/89
CMP BI FY88


180000
179000
178000
177000
176000
175000
174000
173000
2177000
2178000
2179000
2180000
5240
5230
5250
5220
Lake Mary
Ladora Lake
B5-5
B5-5A
EXPLANATION
Biota Staked Sites Established in 1988
Biota Staked Sites Established in 1989
Drainage Ditch
Improved Road
Biota Study Area Boundary
1 Section 1
176000 State Planar Coordinates
Note: Staked Site Numbers on this figure differ slightly in format from those used elsewhere in this report. The formal correspondence is



0 800 1600
FEET
2' Contour Interval

N

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Commerce City, Colorado

Prepared by:
R.L. Stollar & Associates, Inc.
Ebasco Environmental

Figu

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Biota
Revi

s Numbers on this figure
ly in format from those
are in this report. The
spondence is B1-1 B51-1

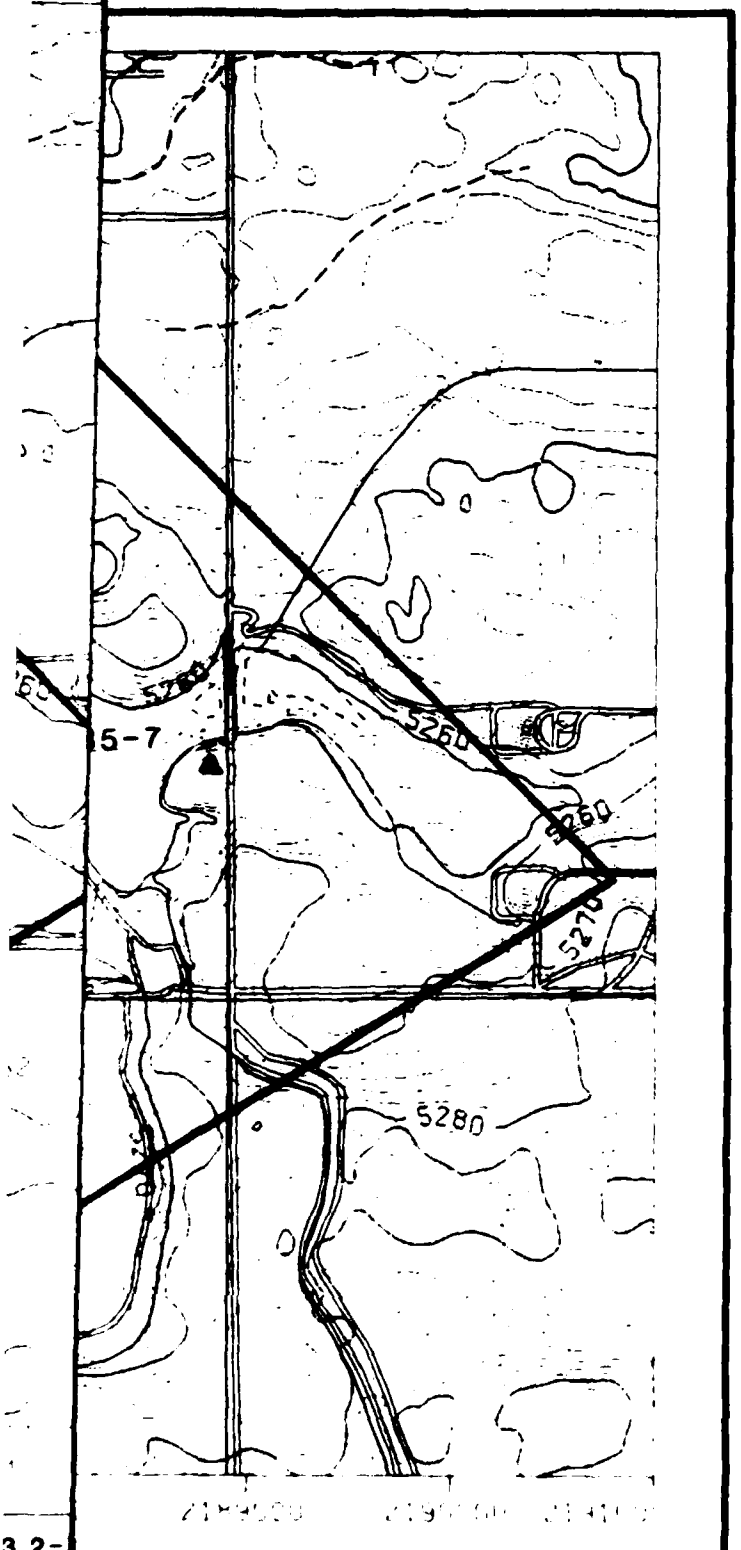


Figure 3.2-7

CMP-BSA 5, RMA

Biota CMP
Revised: 3/23/90

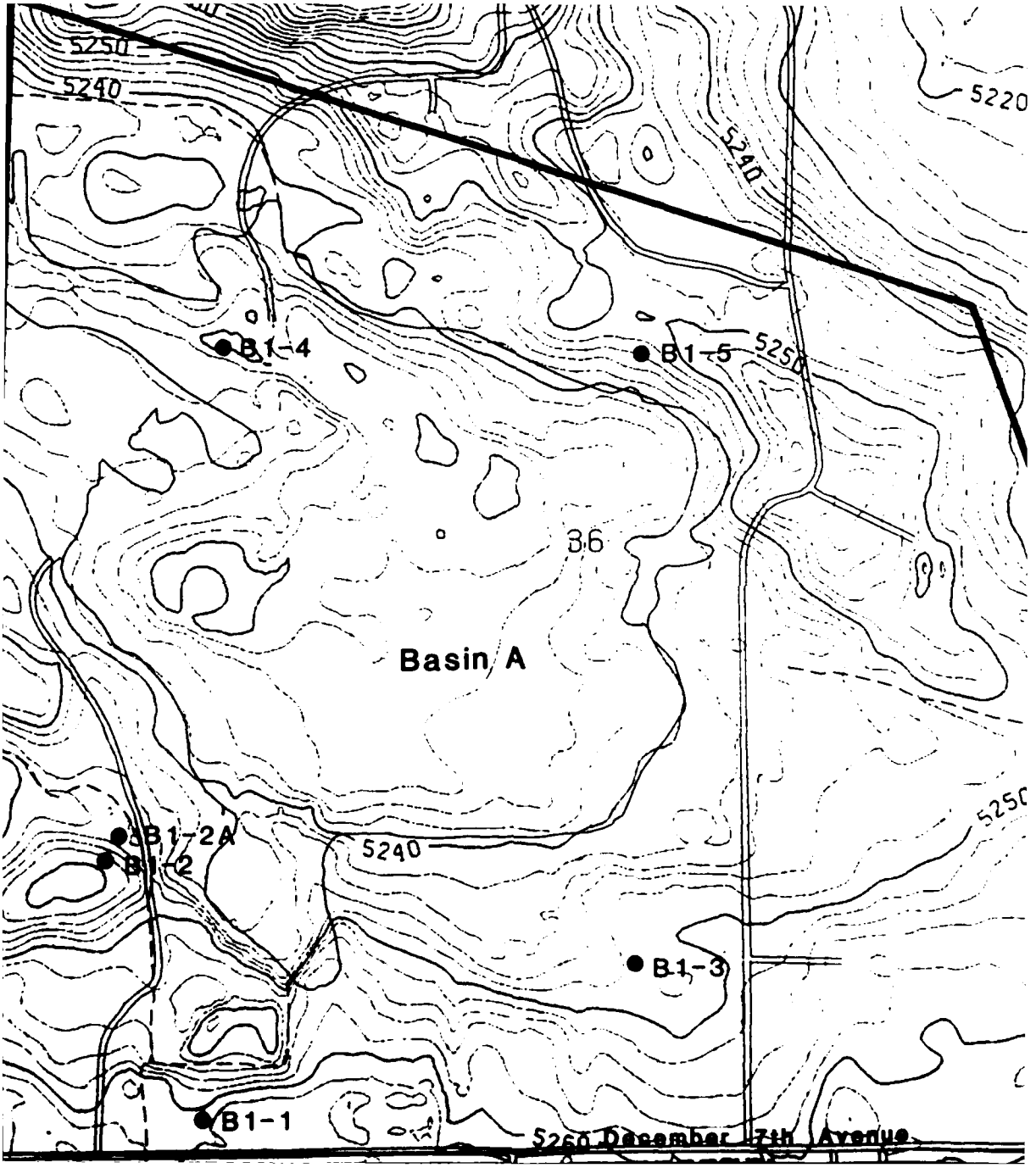
am Manager
tain Arsenal
, Colorado

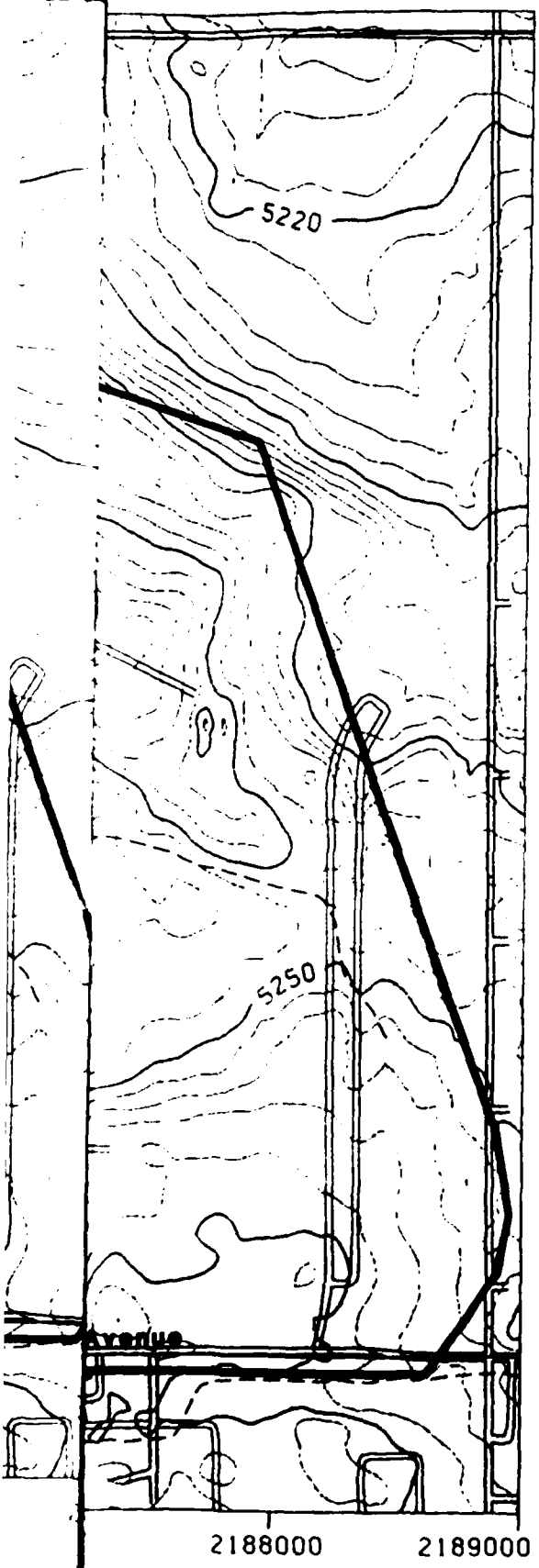
Associates, Inc.
mental

3.2-

SA 5

3/23/


5250
5240
5220
5240
B1-4
B1-5
5250
36
Basin A
B1-2A
B1-2
5240
5250
B1-3
B1-1
5260 December 7th Avenue



EXPLANATION

- Biota Staked Sites Established in 1988
- Drainage Ditch
- Biota Study Area Boundary
- Improved Road
- 36 Section 36
- 182000 State Planar Coordinates

Note: Staked Site Numbers on this figure differ slightly in format from those used elsewhere in this report. The format correspondence is: BI-1=BSI-1

N

0 660 1320

FEET

2' Contour Interval

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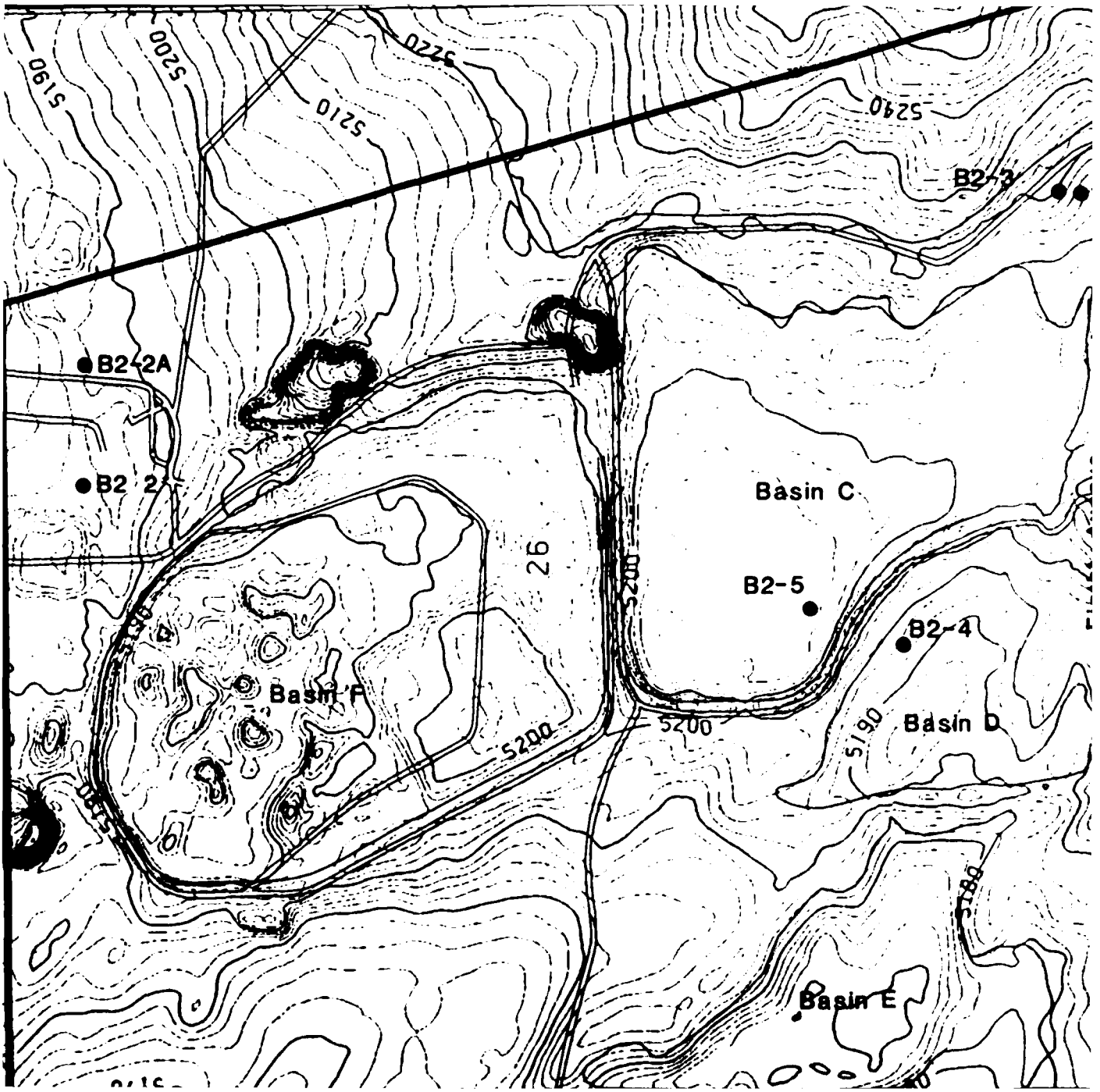
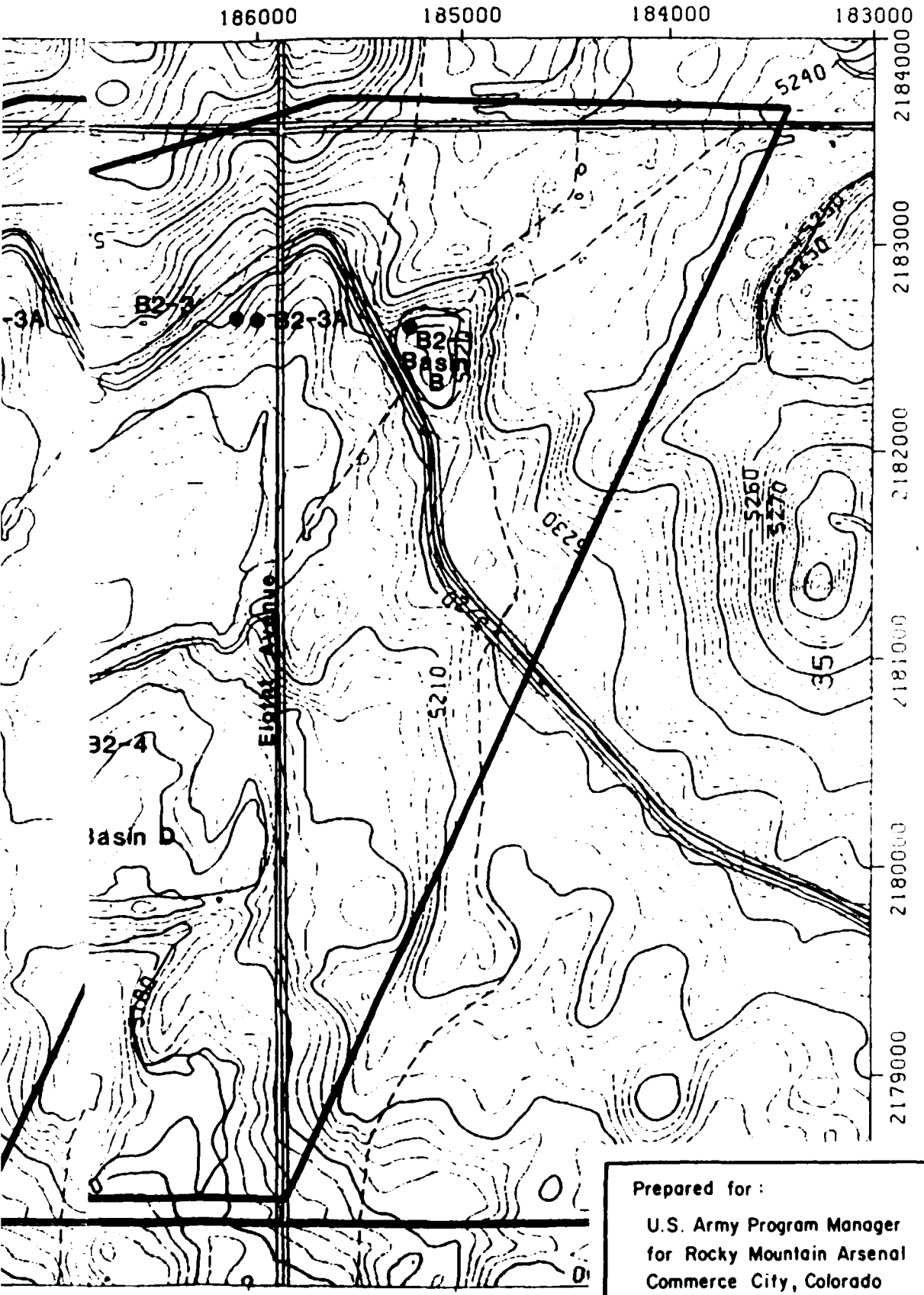
Figure 3.2-3

CMP-BSA 1, RMA

Biota CMP
Revised: 3/23/90


5190
5200
5210
5220
5240
B2-3
B2-2A
B2-2
Basin C
B2-5
B2-4
Basin F
Basin D
Basin E
5200
5190
26



EXPLANATION

- Biota Staked Site Established in 19
- Drainage Ditch
- Biota Study Area Boundary
- Improved Road
- 26 Section 26
- 2180000 State Planar Coordinates

N

0 660 132

FEET

2' Contour Interval

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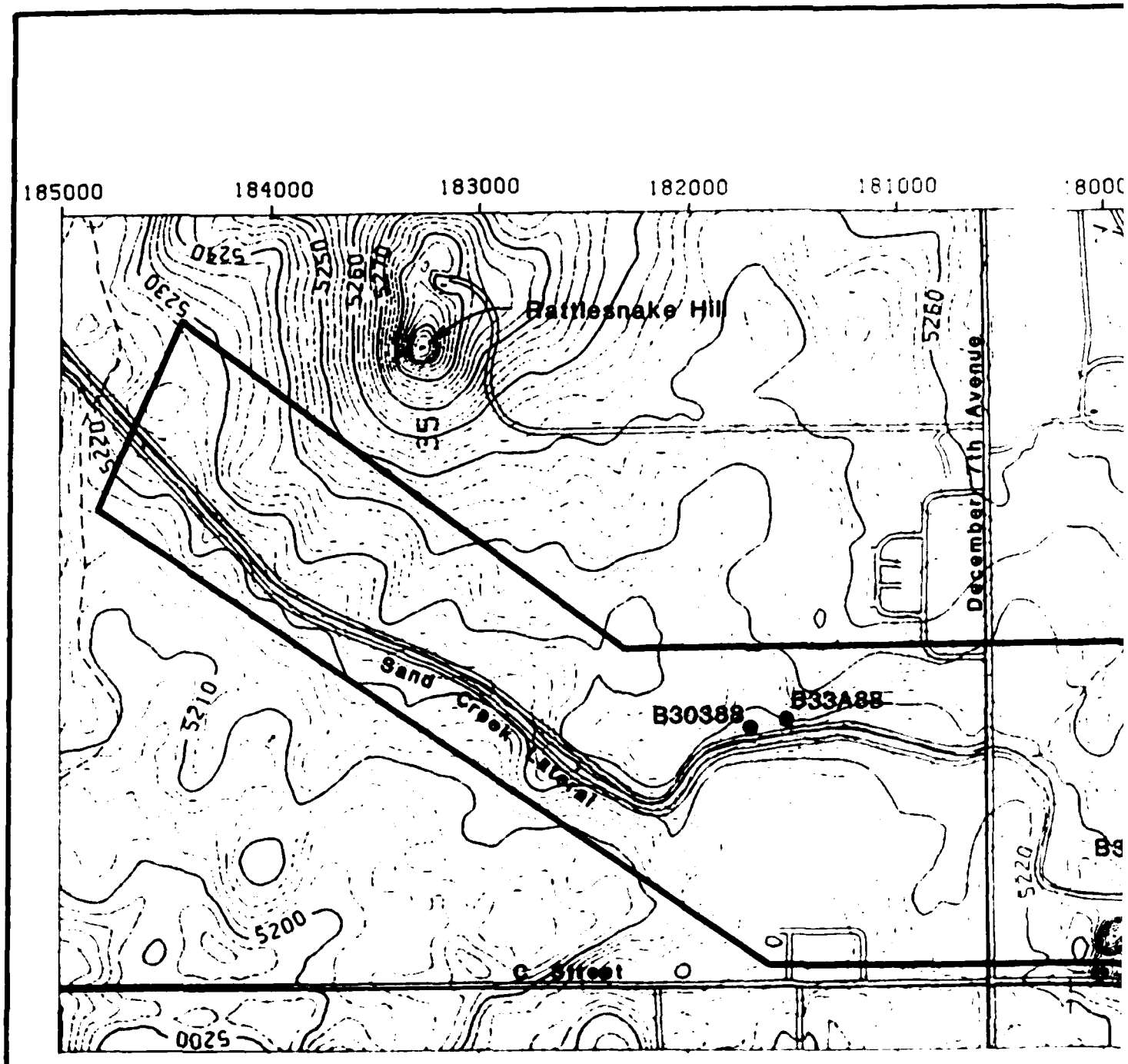
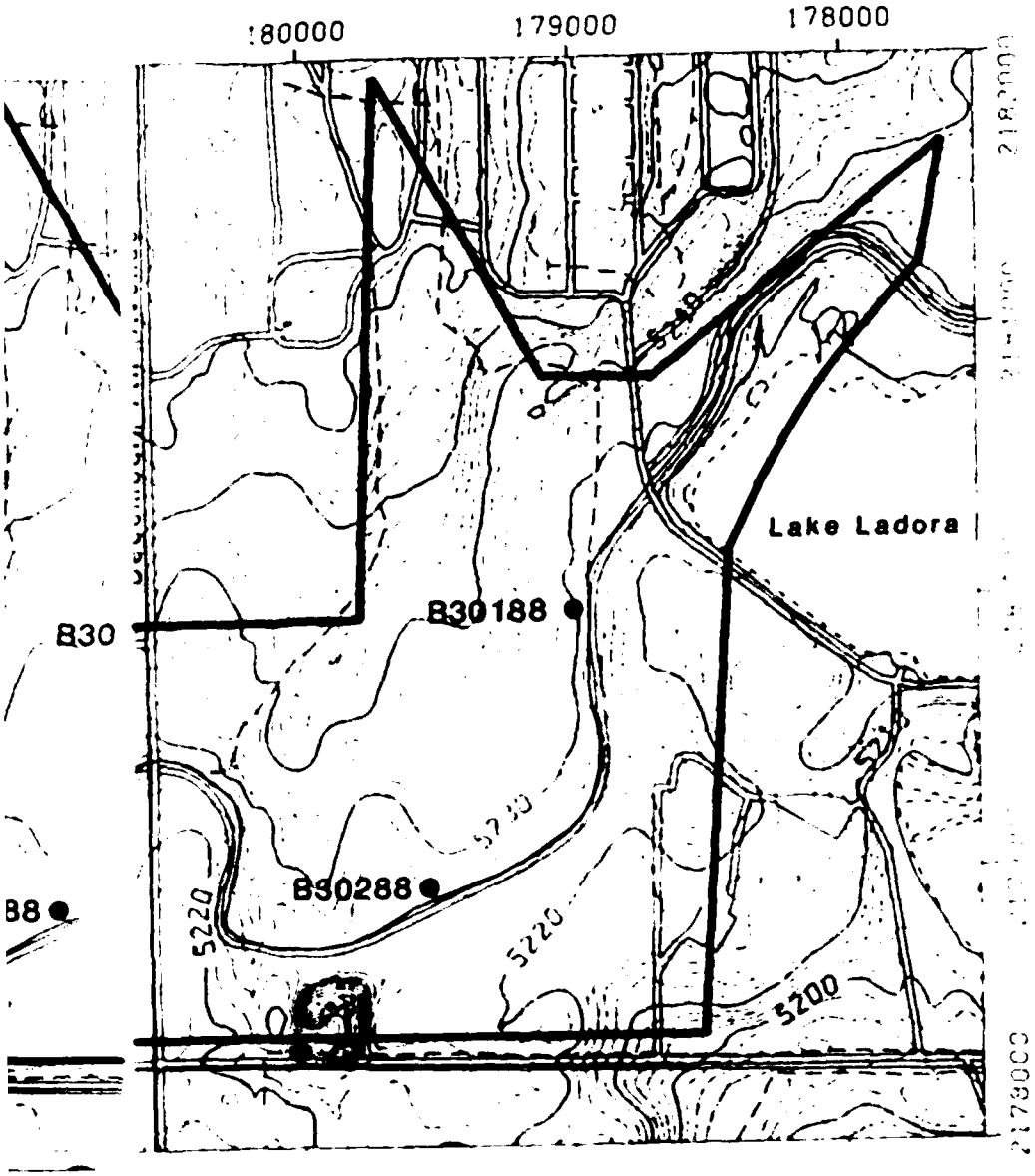
Figure 3.2-4

CMP-BSA 2, RMA

CMP Biota Contamination Assessment

Revised: 12/8/89
CMP BI FY88


185000
184000
183000
182000
181000
5240
5230
5220
5210
5200
5250
5260
35
Rattlesnake Hill
December 7th Avenue
Sand Creek Lateral
B30389
B33A88
5220



EXPLANATION

- Biota Staked Sites Established in 1988
- Drainage Ditch
- Biota Study Area Boundary
- Improved Road
- 35 Section 35
- 2180000 State Planar Coordinates

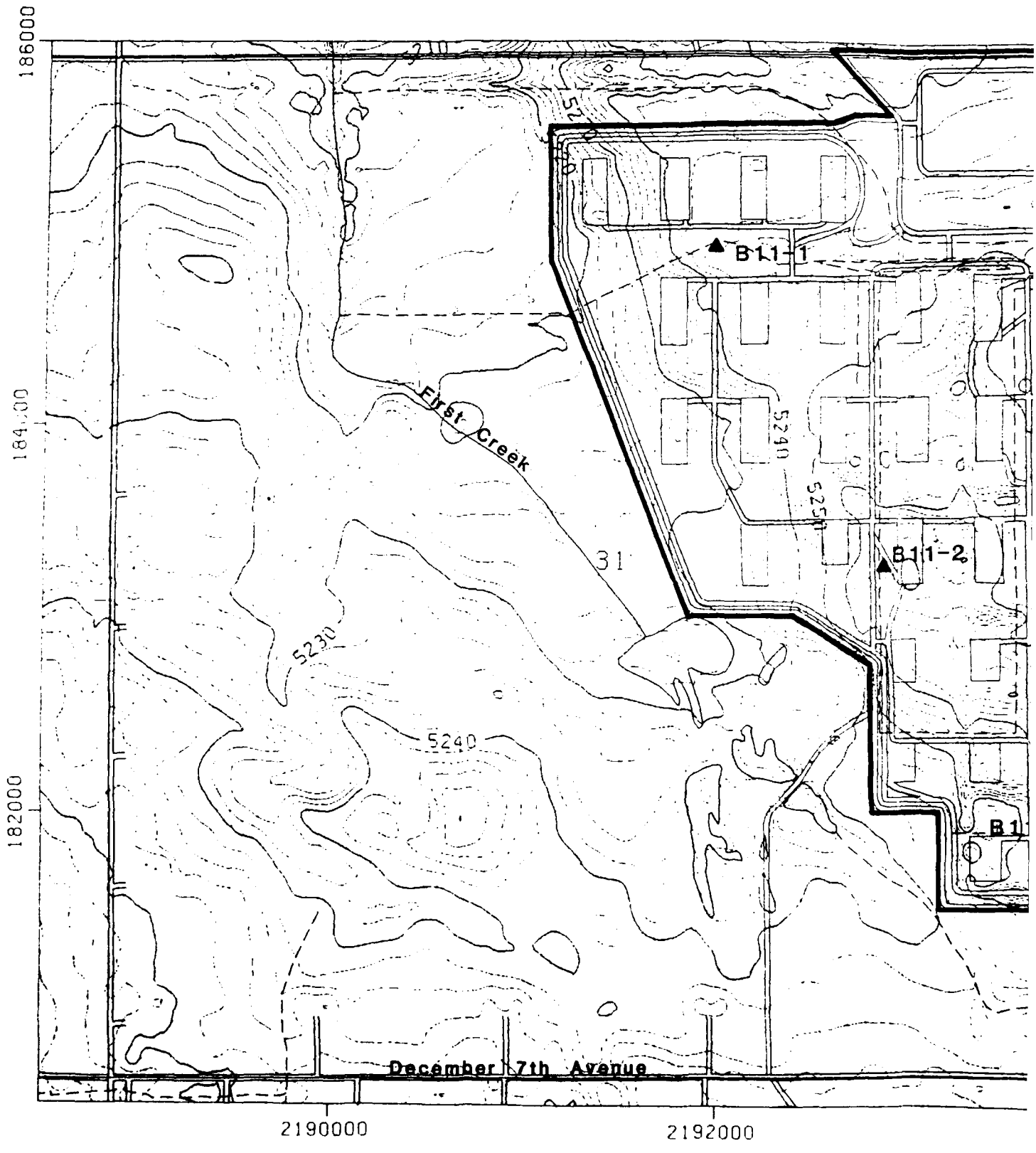
N

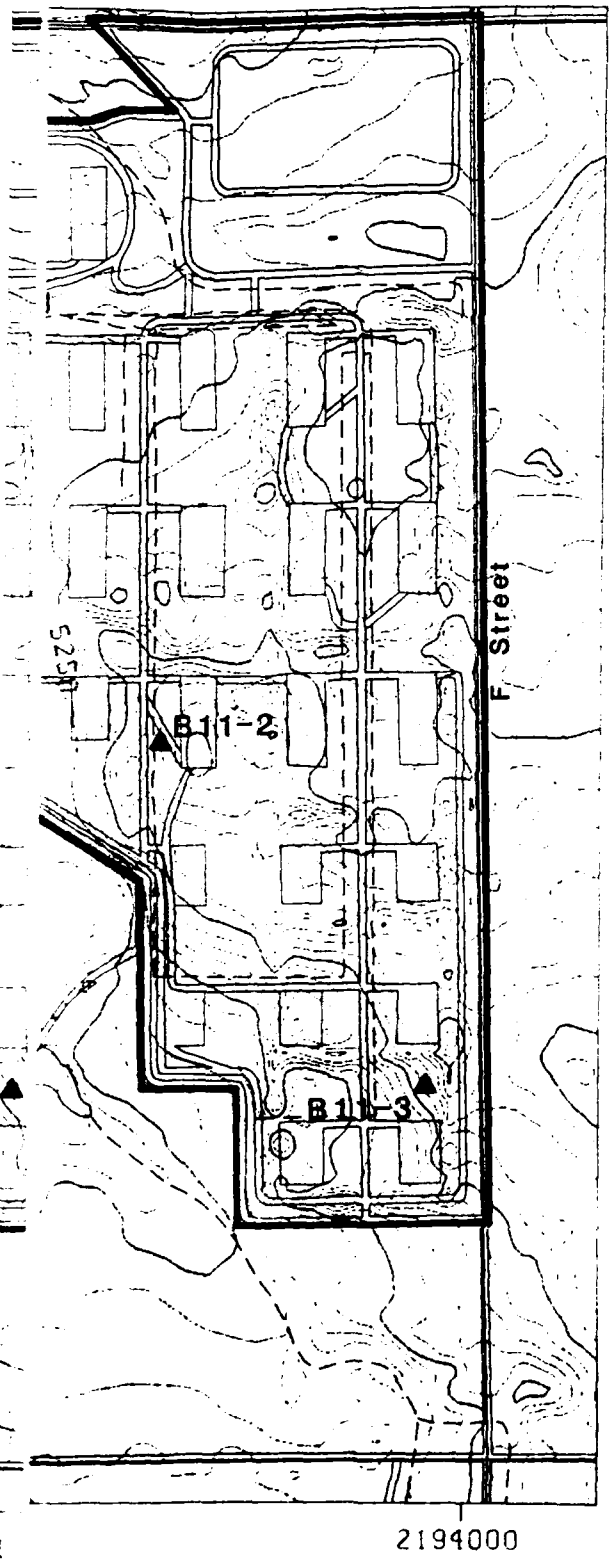
0 660 1320

FEET

2' Contour Interval

Prepared for: U.S. Army Program Manager for Rocky Mountain Arsenal Commerce City, Colorado Prepared by: R. L. Stollar & Associates, Inc. Ebasco Environmental	Figure 3.2-5 **CMP-BSA 3, RMA** CMP Biota Contamination Assessment Revised: 12/8/89 CMP BI FY88


186000
184000
182000
2190000
2192000
B11-1
B11-2
B1
First Creek
December 7th Avenue
5210
5240
5250
5230
5240
31



N

0 660 1320

FEET

2' Contour Interval

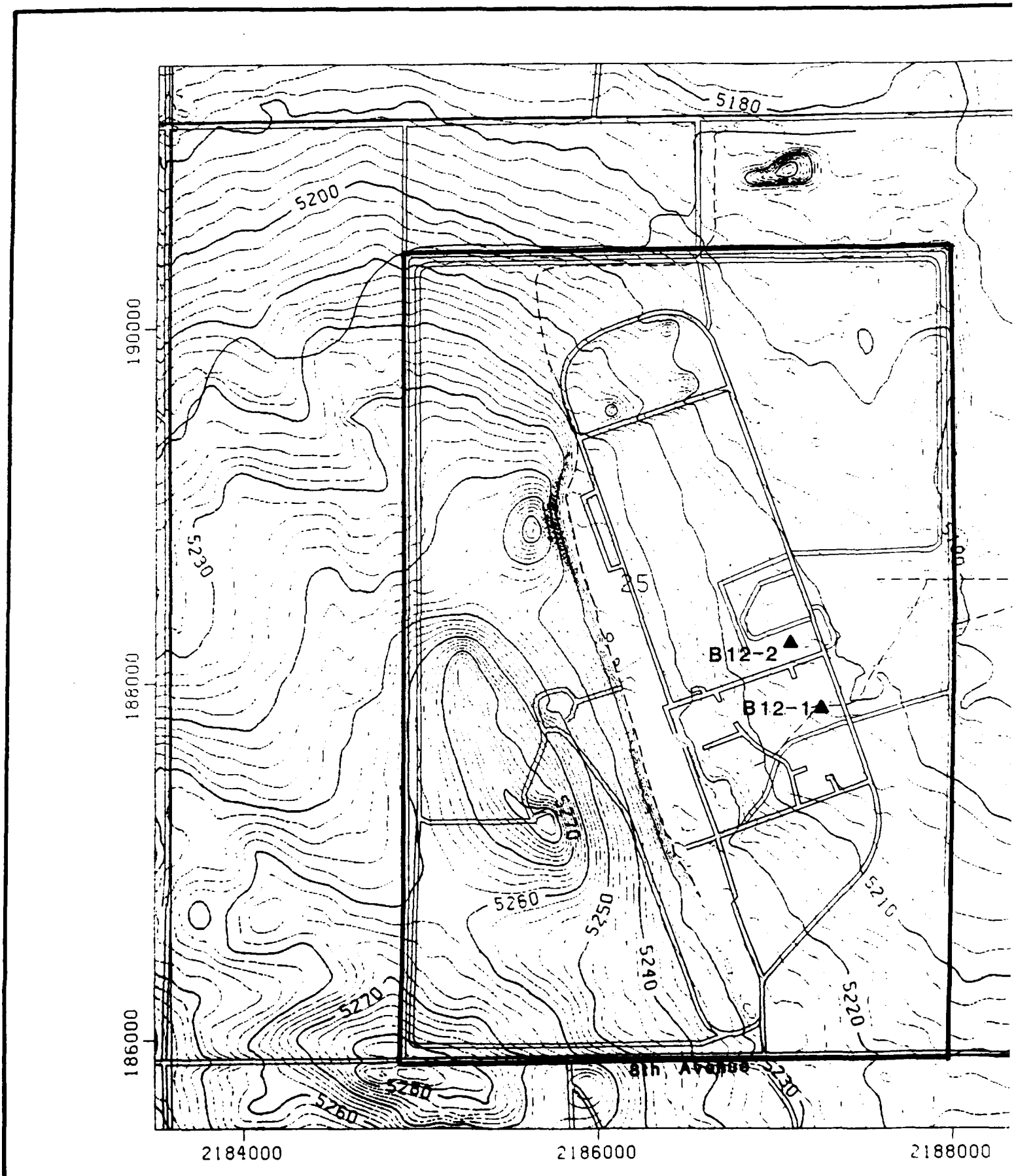
EXPLANATION

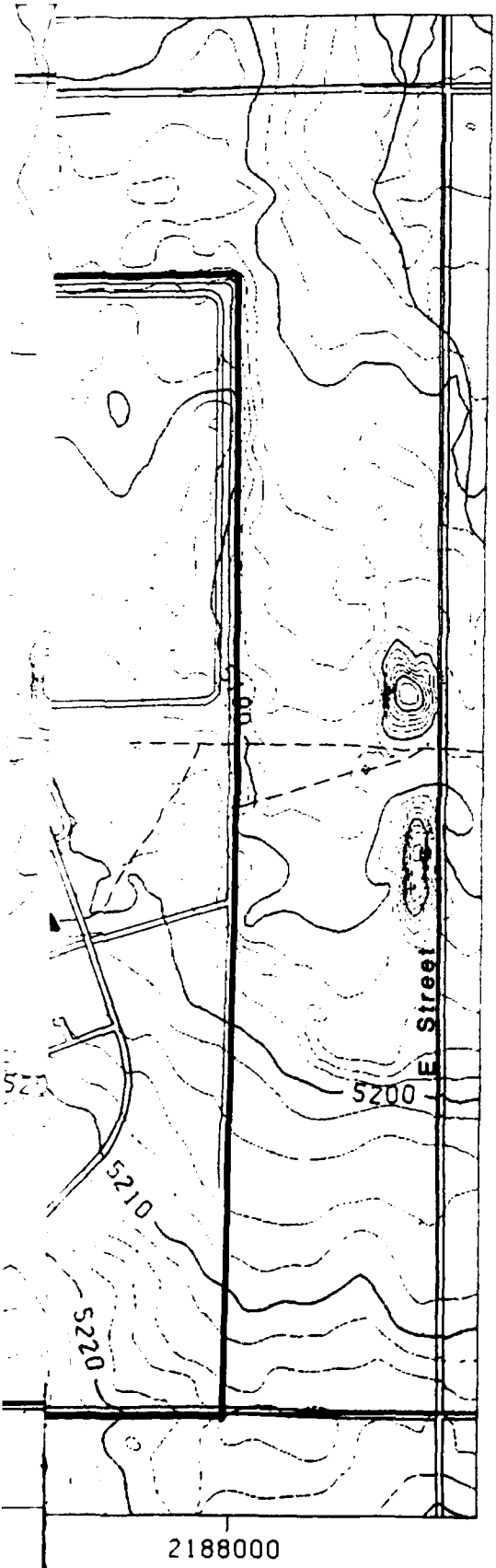
▲ Biota Staked Sites Established in 1989

——— Drainage Ditch

Note: Staked Site Numbers on this figure differ slightly in format from those used elsewhere in this report. The format correspondence is: BI-1 = BSI-1

Prepared for: U.S. Army Program Manager for Rocky Mountain Arsenal Commerce City, Colorado Prepared by: R. L. Stollar & Associates, Inc. Ebasco Environmental	Figure 3.2-8 CMP-BSA 11, RMA Biota CMP Revised: 3/23/90


5180
5200
190000
5230
186000
B12-2
B12-1
5270
5260
5250
5240
5210
5220
186000
5280
5260
8th Avenue
5230
2184000
2186000
2188000



N

0 660 1320

FEET

2' Contour Interval

EXPLANATION

▲ Biota Staked Sites Established in 1989

——— Drainage Ditch

Note: Staked Site Numbers on this figure differ slightly in format from those used elsewhere in this report. The format correspondence is: BI-1 = BSI-1

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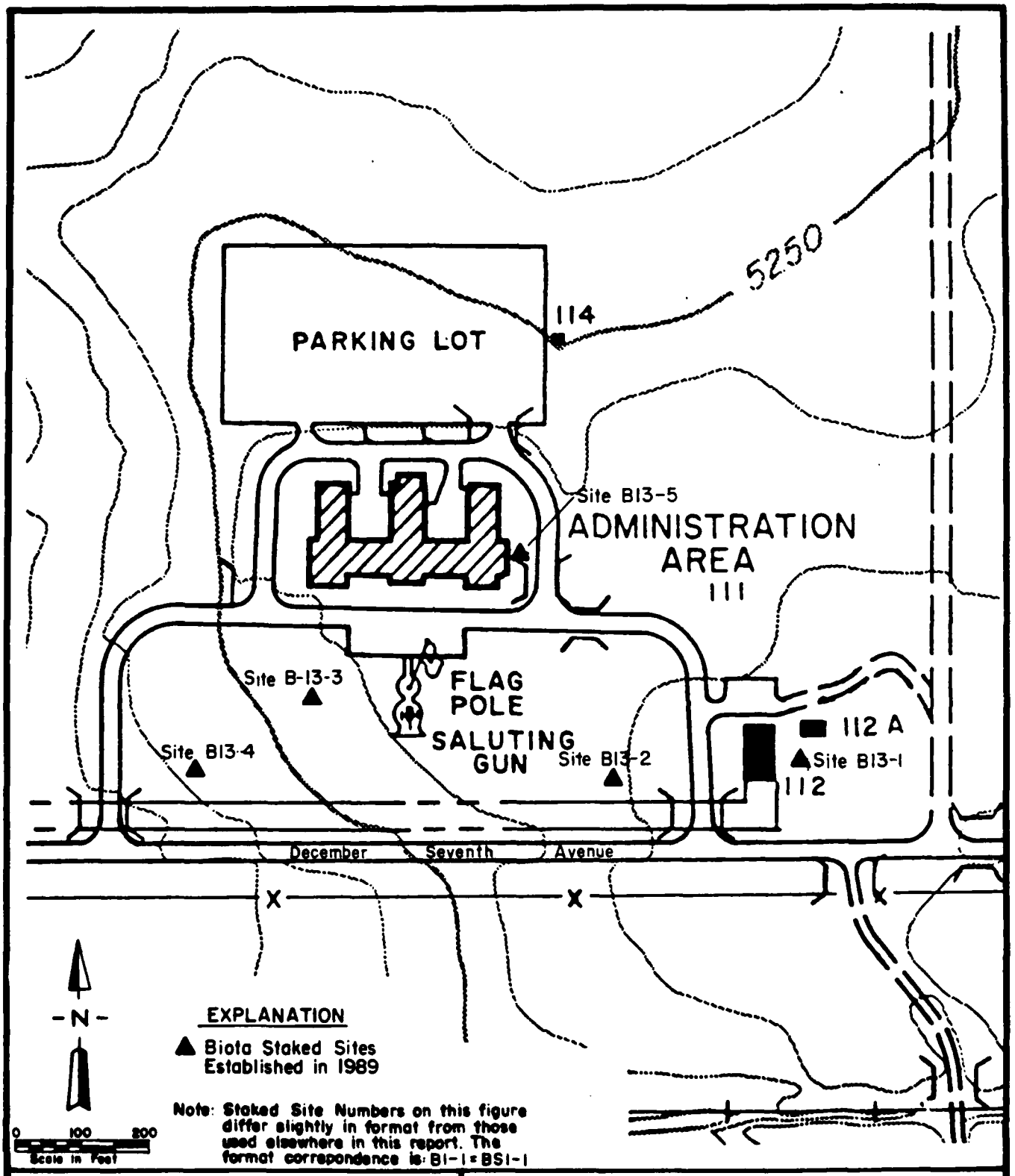
Figure 3.2-9

CMP-BSA 12, RMA

Biota CMP
Revised: 3/23/90



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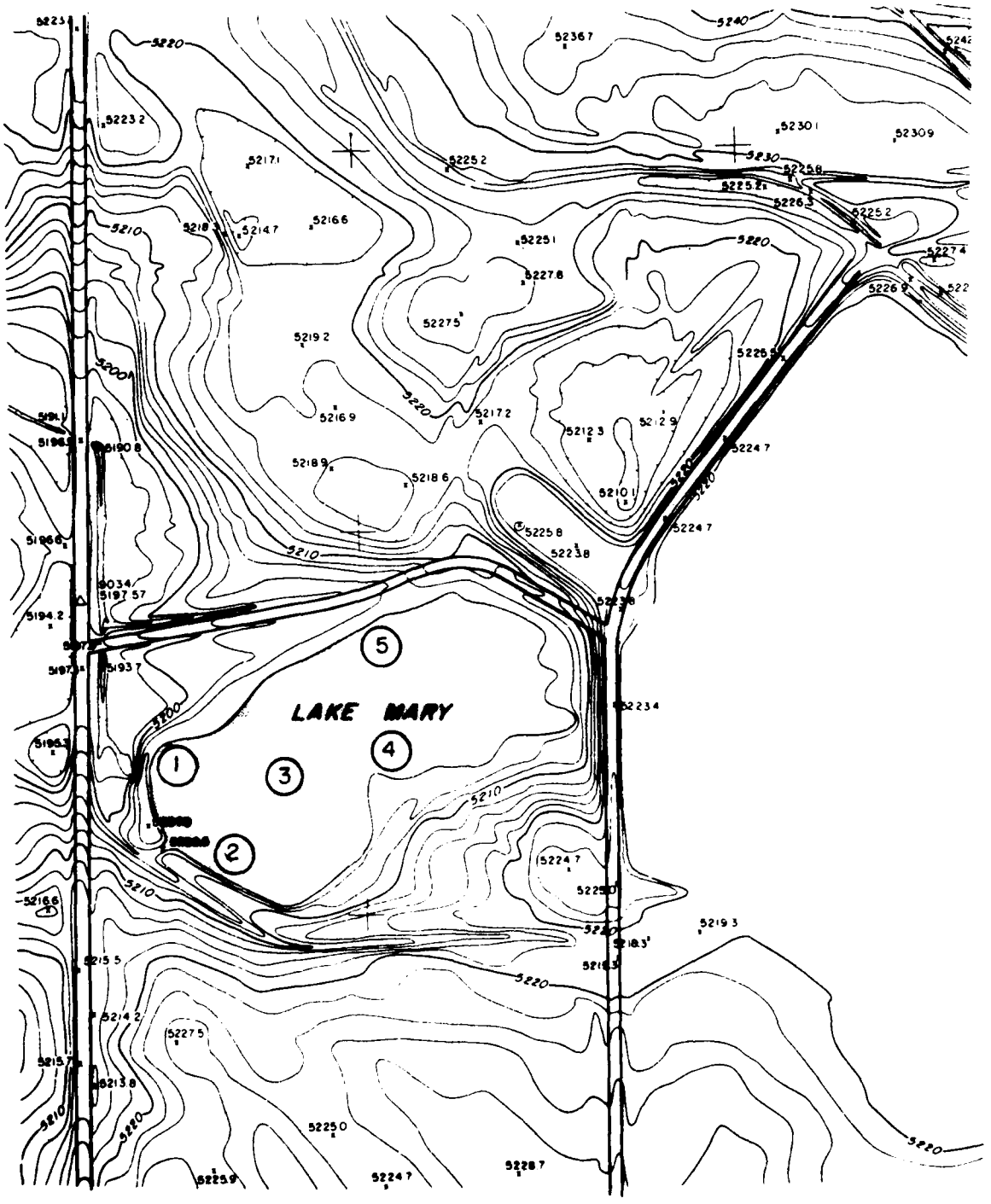
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by:
R.L. Stollar & Associates, Inc.
Ebasco Environmental

Figure 3.2-10

CMP-BSA 13, RMA Administration Area

Biota CMP
Revised: 3/23/90



EXPLANATION

(1) Aquatic Sampling Foci

Roads

2' Contour Interval

Prepared for:

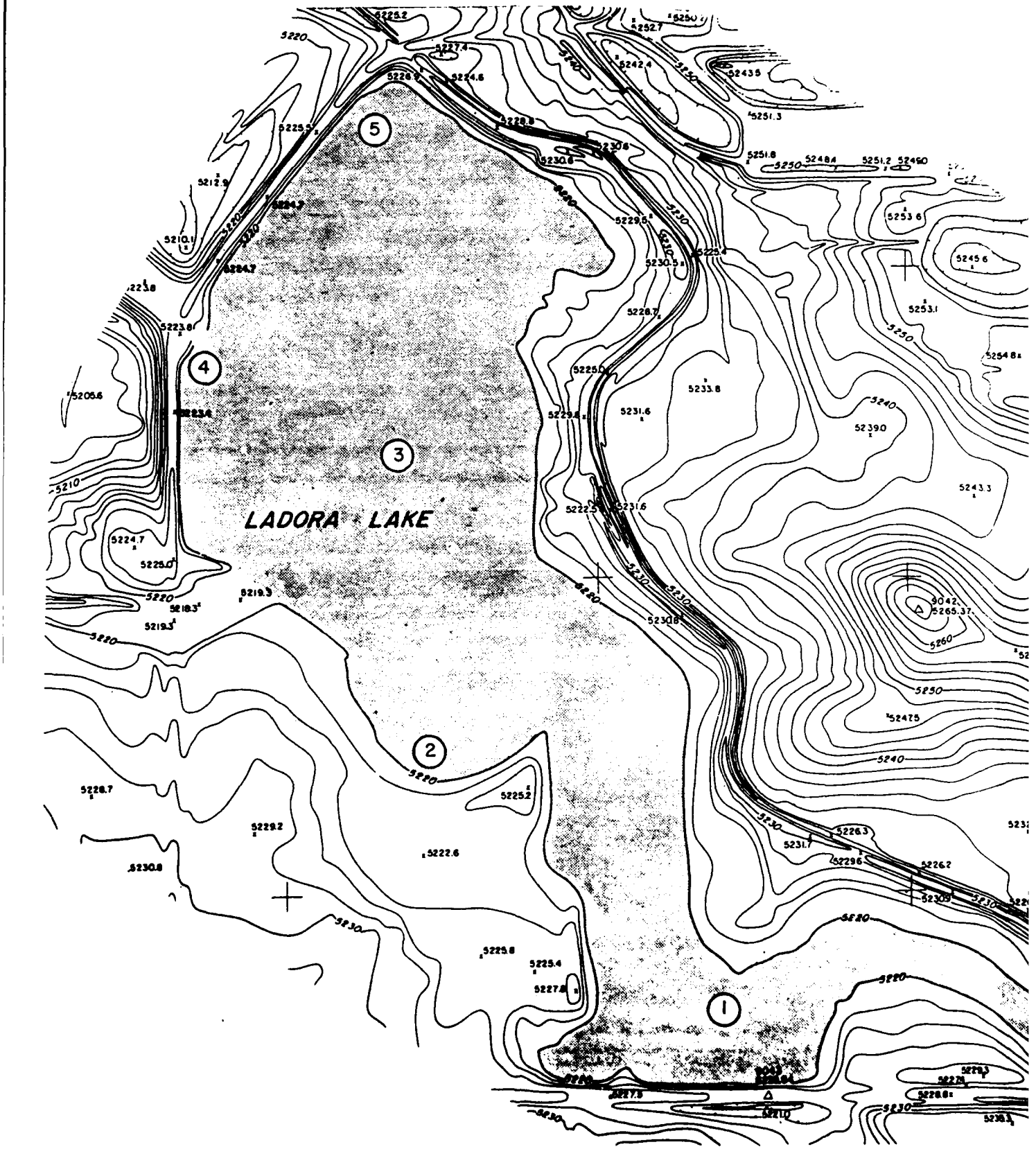
U. S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

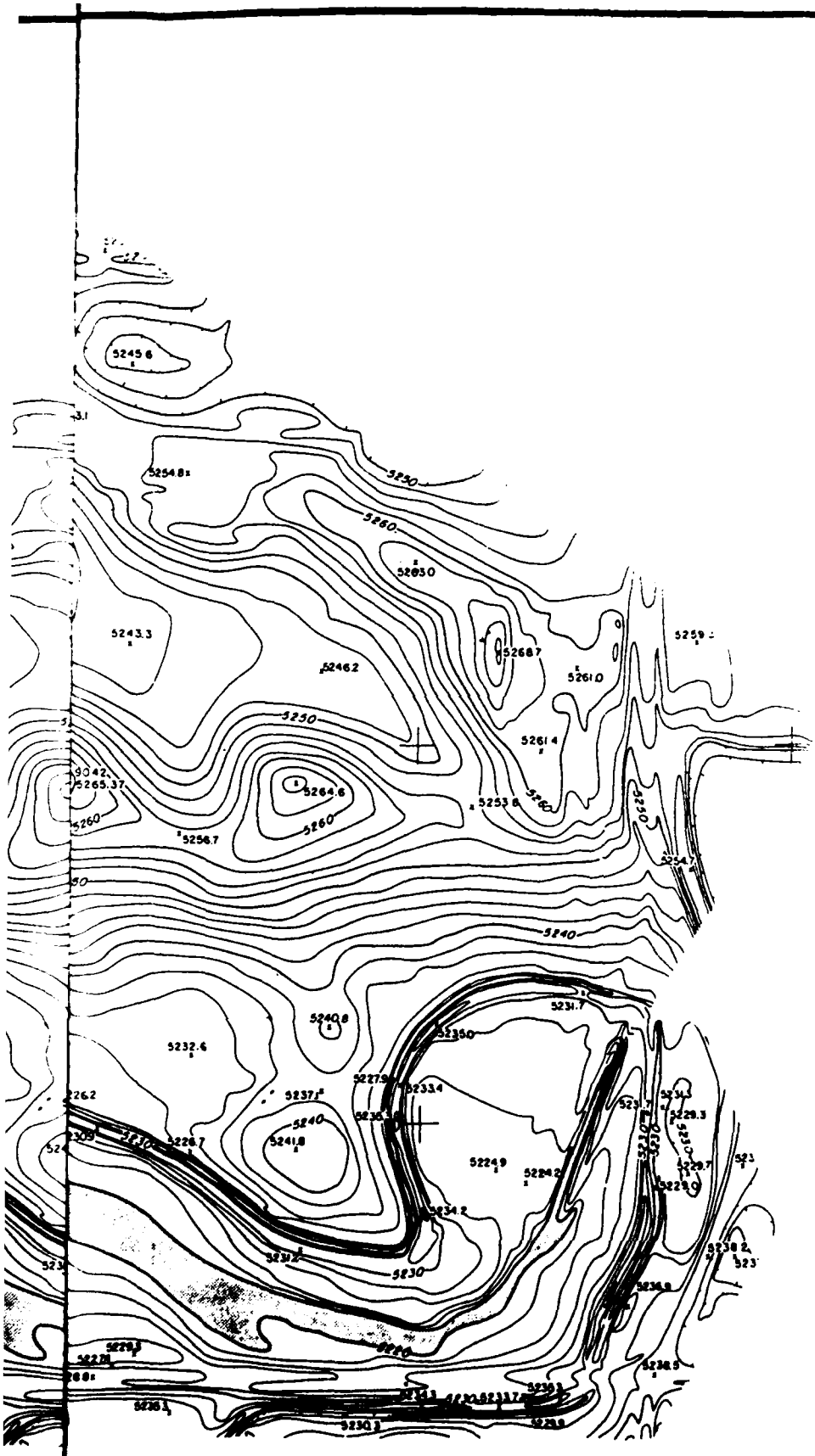
Prepared by R.L. Stollar and Associates Inc
Ebasco Environmental

Figure 3.2-11

Aquatic Sampling Foci
CMP-BSA 6, Lake Mary, RMA

Biota CMP
Revised: 12/8/89


LADORA LAKE
1
2
3
4
5



EXPLANATION

(1) Aquatic Sampling Foci

2' Contour Interval

N

0 400

SCALE IN FEET

Prepared for:

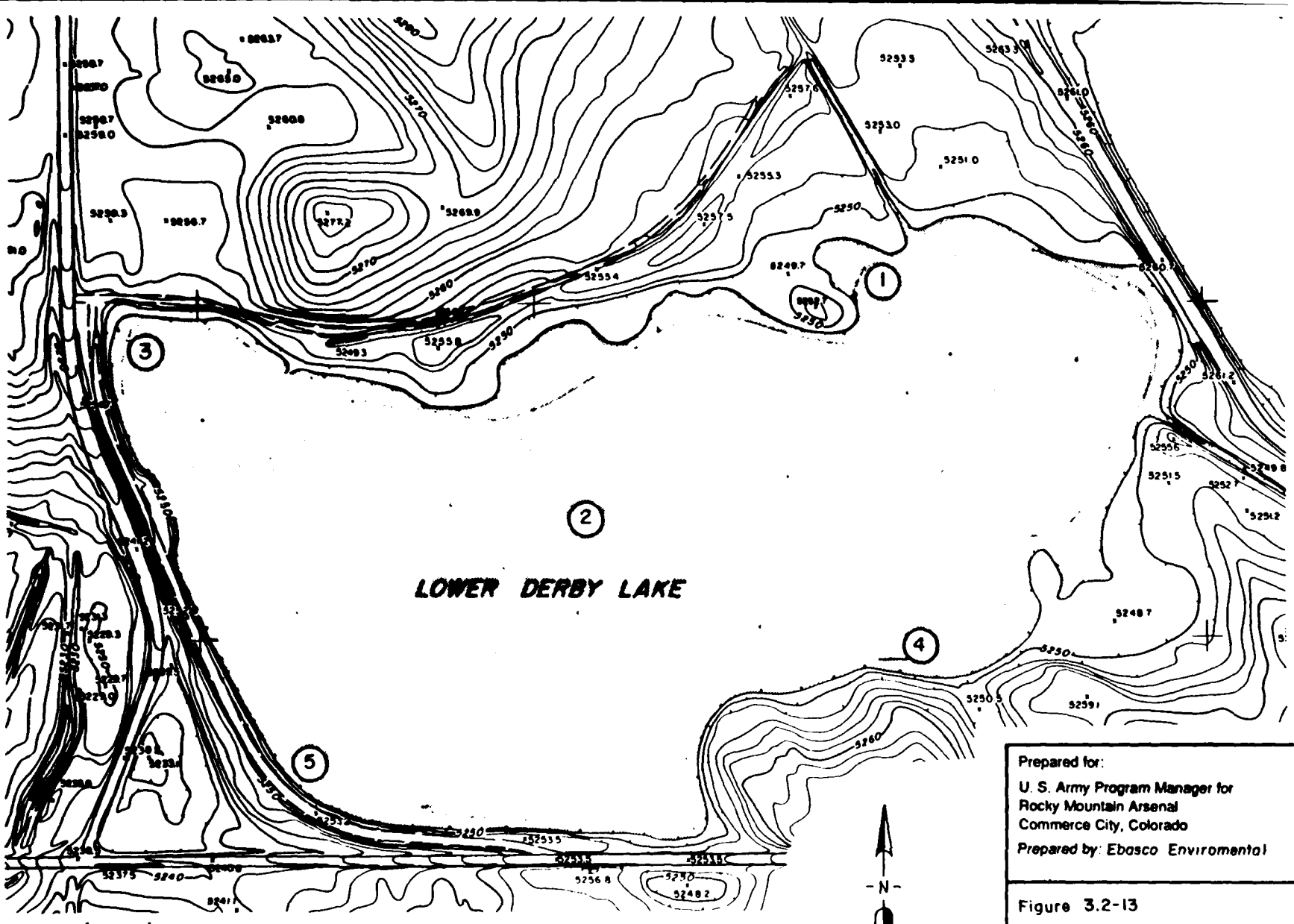
U. S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by: R.L. Stollar and Associates, Inc.
Ebasco Environmental

Figure 3.2-12

Aquatic Sampling Foci
CMP-BSA 7,
Ladora Lake, RMA

Biota CMP
Revised: 12/8/89



Legend

(1) Aquatic Sampling Station

2' Contour Interval

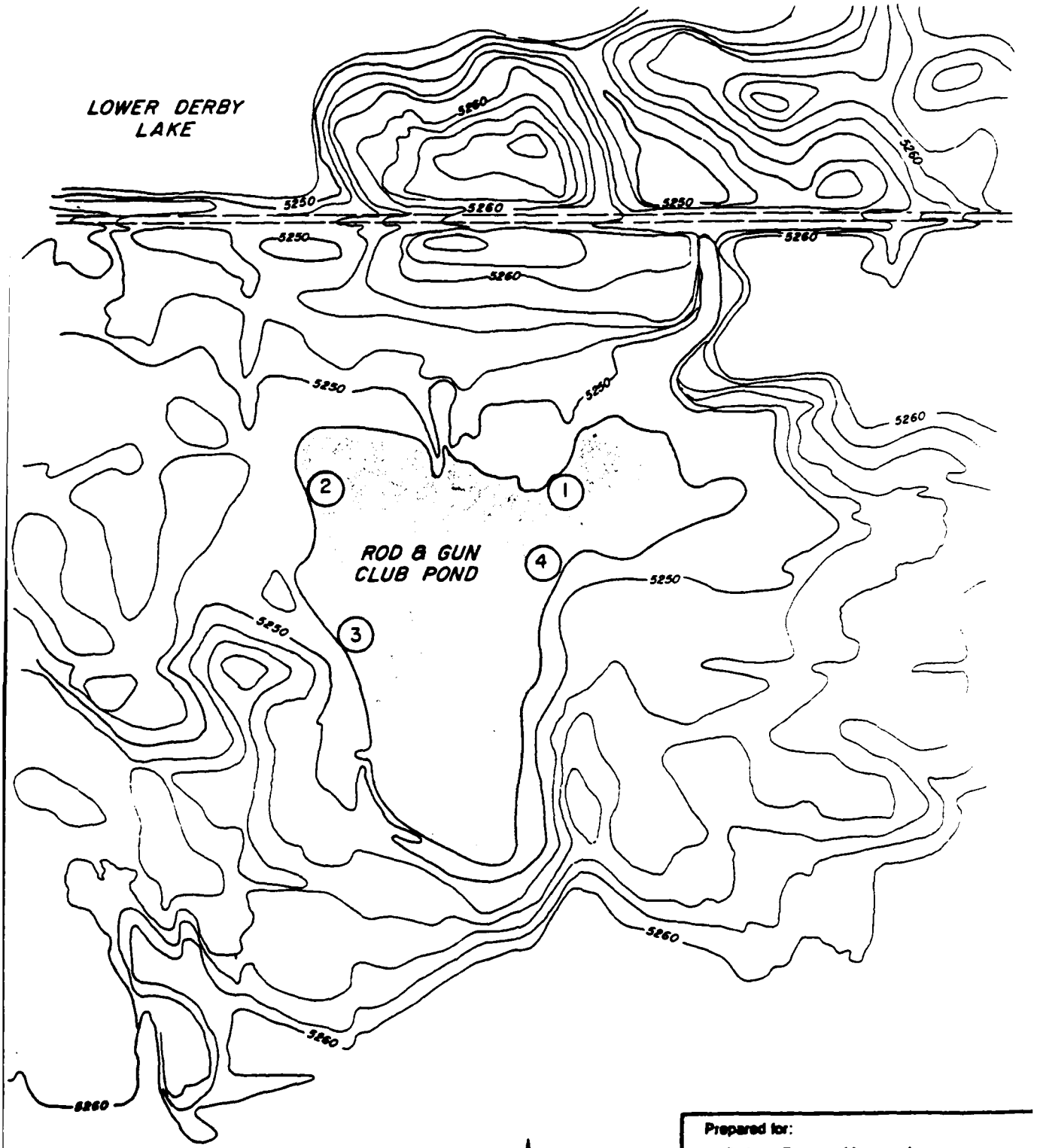
Prepared for:

U. S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by: Ebasco Environmental

Figure 3.2-13

Aquatic Sampling Foci
CMP-BSA 8, Lower Derby Lake, RMA
Biota CMP
Revised: 6/20/90



Prepared for:

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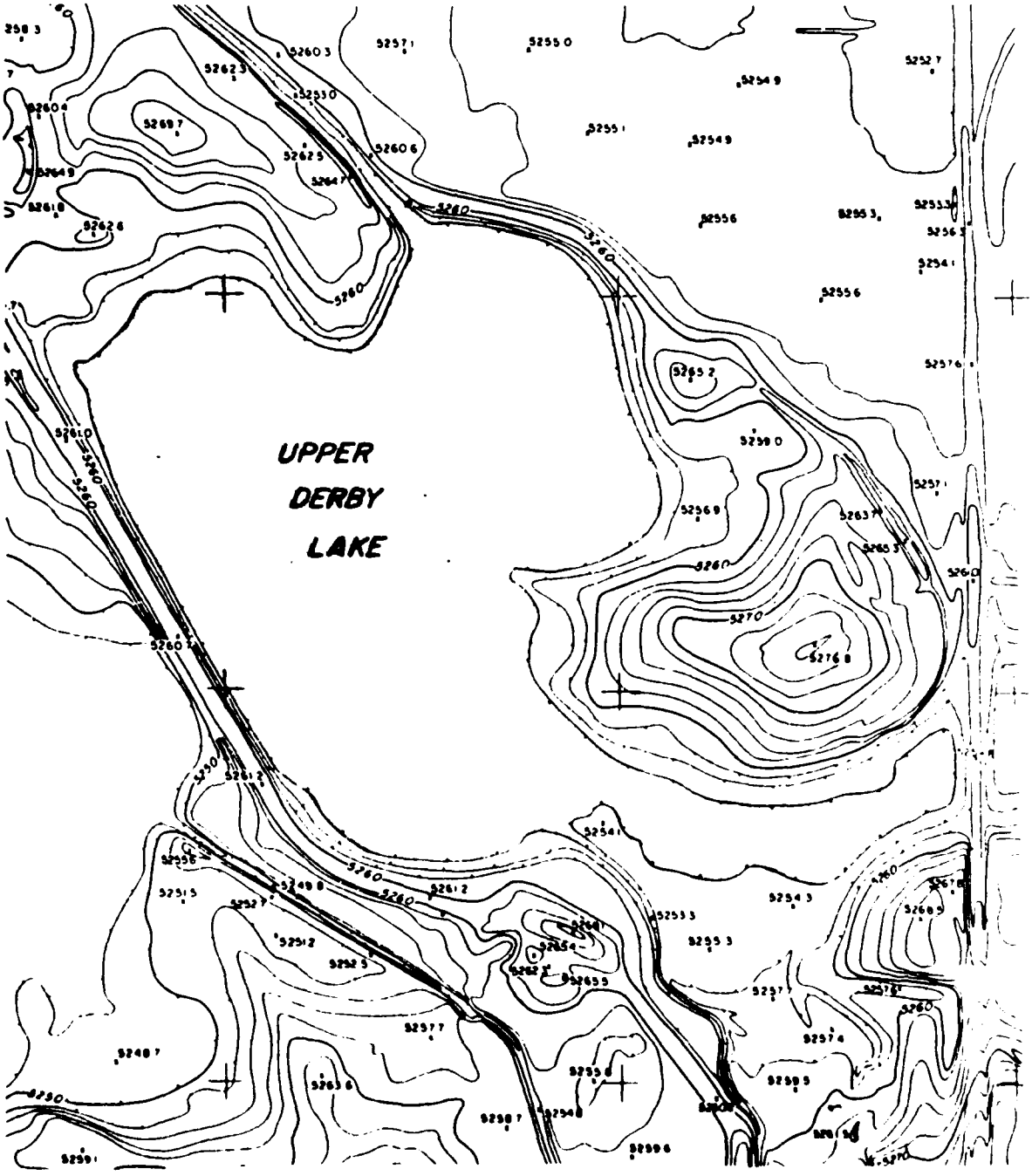
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by: R.L. Stollar and Associates, Inc.
Ebasco Environmental

Figure 3.2-14
Aquatic Sampling Foci CMP-BSA 9, Rod & Gun Club Pond, RMA

Biota CMP
Revised: 12/8/89



EXPLANATION

2' Contour Interval

N

0 400

SCALE IN FEET

Prepared for:

U S Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by R.L. Stollar and Associates, Inc
Ebasco Environmental

Figure 3.2-16

Aquatic Sampling Foci CMP-BSA 10, Upper Derby Lake, RMA

Biota CMP
Revised 12/8/89

Sample Tag / Identification Number:	Site Identification:	Site Type: BIOL	Sample Technique: G
	Analyses Requested: Mercury Cold Vapor A A Arsenic A A OCP, GC / ECD	R. L. STOLLAR & ASSOC. INC. 143 UNION BLVD. LAKEWOOD	Project Name: COMPREHENSIVE MONITORING PROGRAM BIOTA ELEMENT
Sample Date:			
Collection time:			
Species:	Samplers (Signatures)		
Tissue:			
Remarks:			

Prepared for:

U. S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by: R.L. Stollar and Associates, Inc.
Ebasco Environmental

Figure 3.2-16
CMP Biota Sampling Sample Tag Form, 1988 - 1989

Biota CMP

Revised: 3/23/90

CHAIN OF CUSTODY RECORD

R.L. STOLLAR & ASSOCIATES INC
ENVIRONMENTAL PROGRAM AT ROCKY MOUNTAIN ARSENAL

Project Name:
COMPREHENSIVE MONITORING PROGRAM
BIOTA ELEMENT

Samplers: _____

(Signature)

Sample Date: _____
(Mo/Date/Yr)

SAMPLE TAG NUMBER	SITE IDENTIFICATION	SITE TYPE	COLLECTION TIME (Military Standard)	SAMPLE TECHNIQUE	SPECIES	TISSUE	ANALYSIS REQUESTED: OCPs	ARSENIC	MERCURY
B	B 8 9	B I O L		G			X	X	X
							X	X	X
							X	X	X
							X	X	X
							X	X	X

Relinquished by: (Signature)	Date / Time	Received by: (Signature)	Relinquished by: (Signature)	Date / Time	Received by: (Signature)
Relinquished by: (Signature)	Date / Time	Received by: (Signature)	Relinquished by: (Signature)	Date / Time	Received by: (Signature)
Relinquished by: (Signature)	Date / Time	Received for laboratory by: (Signature)	Date / Time	Remarks	
Relinquished by: (Signature)	Date / Time	Received for laboratory by: (Signature)	Date / Time		

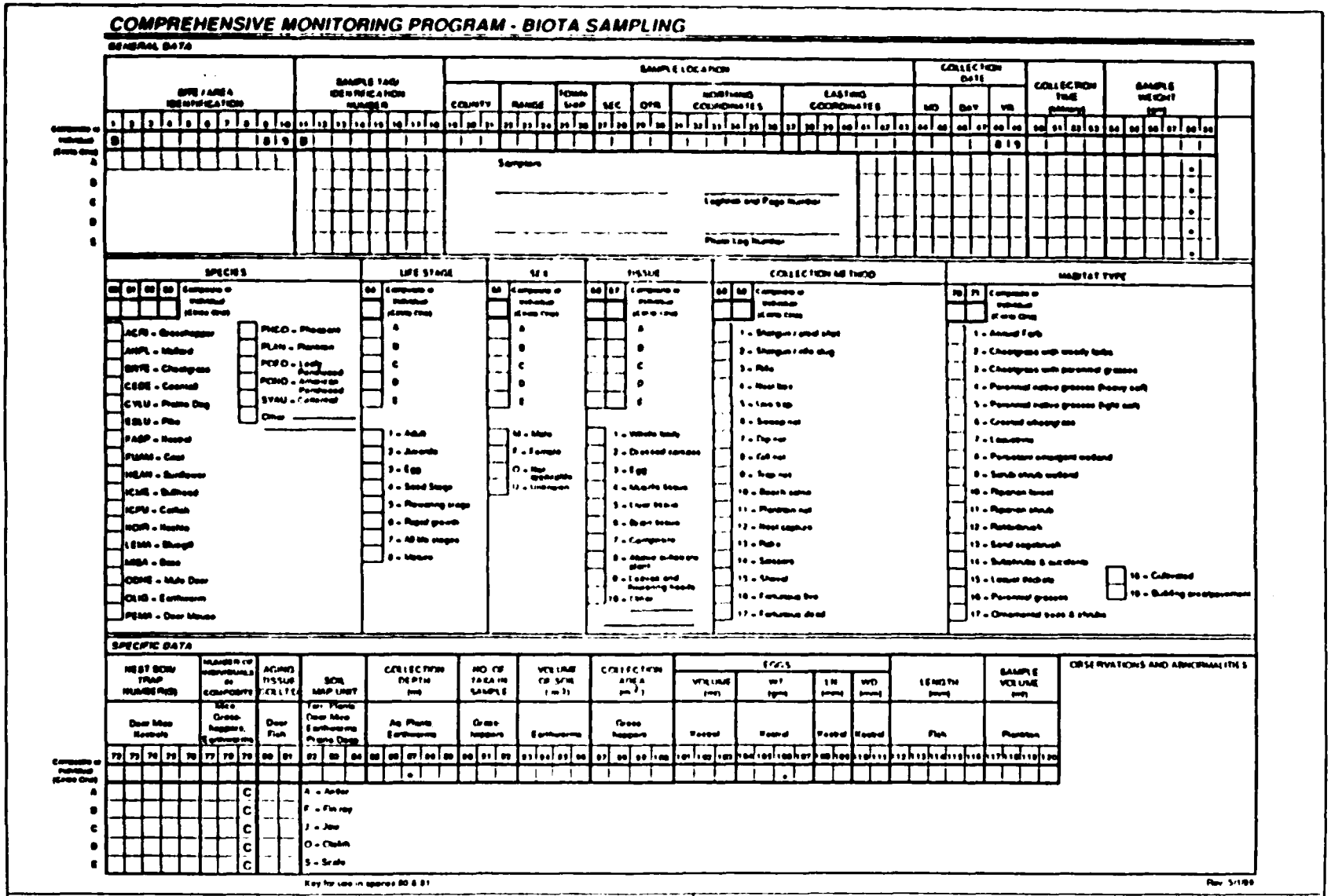
Prepared for:
U. S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by: R.L. Stollar and Associates, Inc
Ebasco Environmental

Figure 3.2-17
CMP Biota Sampling Chain of Custody Record Form, 1988 - 1989

Biota CMP

Revised: 3/23/90



Prepared for:
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Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by: R.L. Stollar and Associates, Inc.
Ebasco Environmental

Figure 3.2-18
CMP Biota Sampling Field Data Form, 1988 - 1989

Biota CMP

Revised: 3/23/90