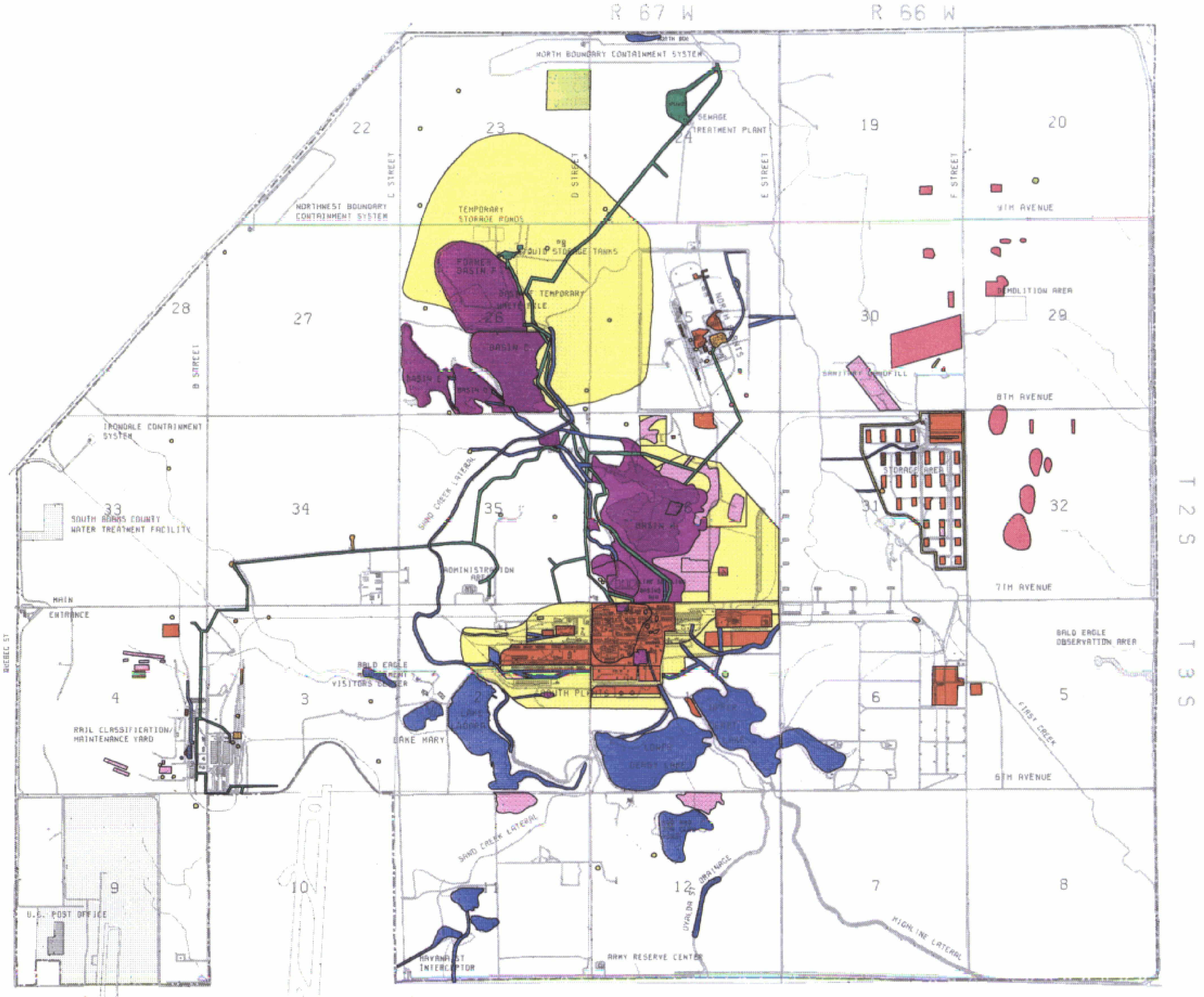
Appendix A3

Nature and Extent of Contamination
Figures and Plates

Remedial Investigation Summary Report



LEGEND

— Major Drainage
— Minor Drainage
— Railroad Tracks
○ Basin
○ Former Basin
○ Lakes and Ponds
▭ RMA Property/Leased
— Road
3 Section Number
▨ Structure
▨ Former Structure
—·— Arsenal Boundary

Site Types

🟪 Basins and Lagoons
🟦 Ditches,Lakes, and Ponds
🟥 Ordnance Testing and Disposal Areas
🟪 Solid Waste Burial Sites
🟧 Buildings, Equipment, and Storage Sites
🟧 Spill Sites
🟩 Sewer Sites

Surficial Soil and Other Predominantly Near-Surface Contamination
  🟨 Predominantly Near-Surface
  ☐ 0 - 2 inch
🟩 Isolated Contamination

Note 1: Sites of contamination are grouped by similar physical characteristics and/or historical use

Note 2: Due to scale of this map, details of the chemical, sanitary sewers, and the process water systems are not shown

— N —

0 3000 Feet
Scale: 1" = 3000'

Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A3.1-1

Location of Soil Contaminant Site Types
at Rocky Mountain Arsenal

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

LEGEND

Minor Drainage
Section Number
Structure
Former Structure
Arsenal Boundary

Site Types

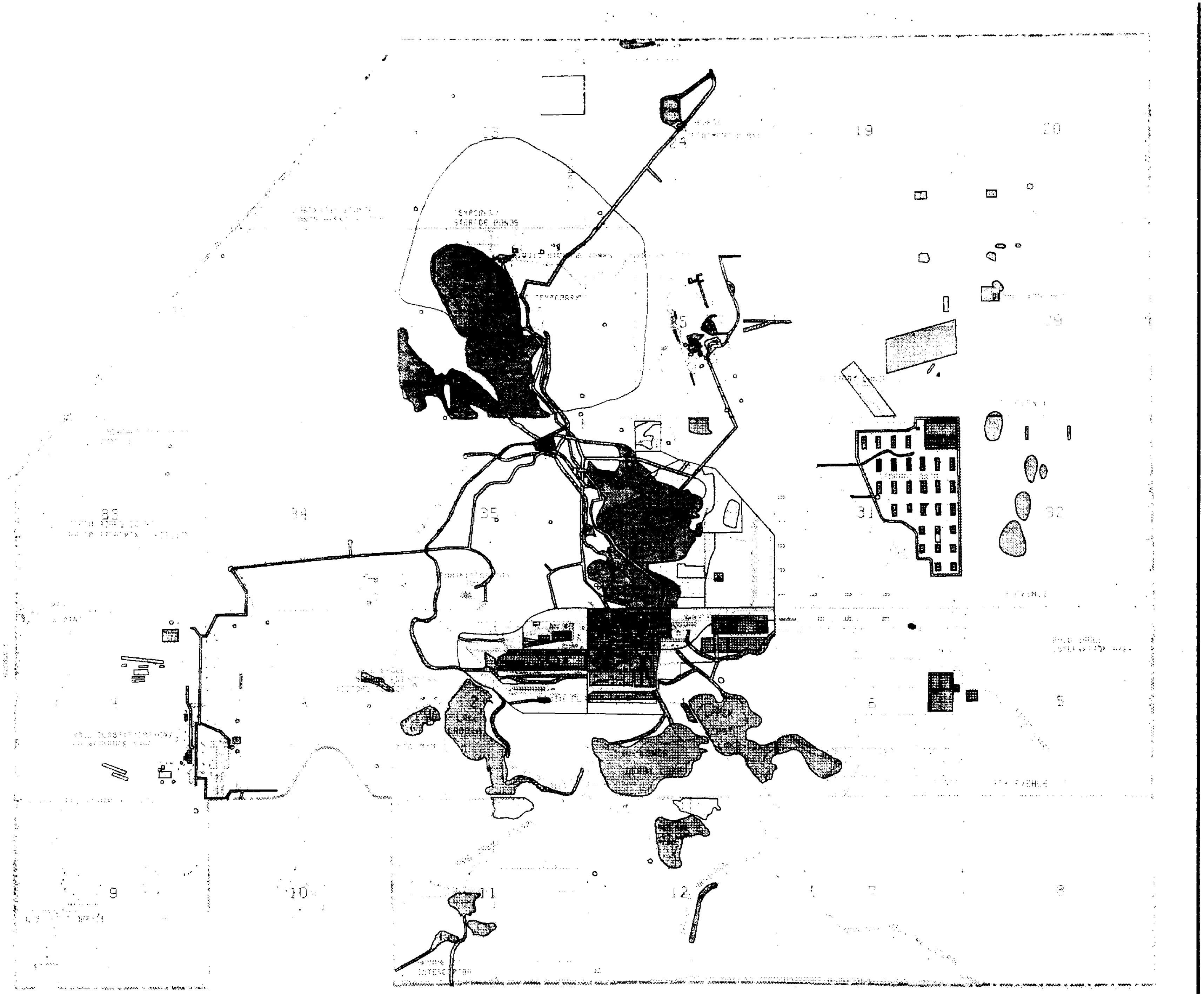
- ▨ Basins and Lagoons
- ▨ Ditches,Lakes,and Ponds
- ▨ Ordnance Testing and Disposal Areas
- ☐ Solid Waste Burial Sites
- ▨ Buildings, Equipment, and Storage Sites
- ☐ Spill Sites
- ☐ Sewer Sites
- Surficial Soil and Other Predominantly Near-Surface Contamination
  - ☐ Predominantly Near-Surface
  - ☐ 0 – 2 inch
- ☐ Isolated Contamination

Note: Sites of contamination are grouped by similar physical characteristics and/or historical use

N

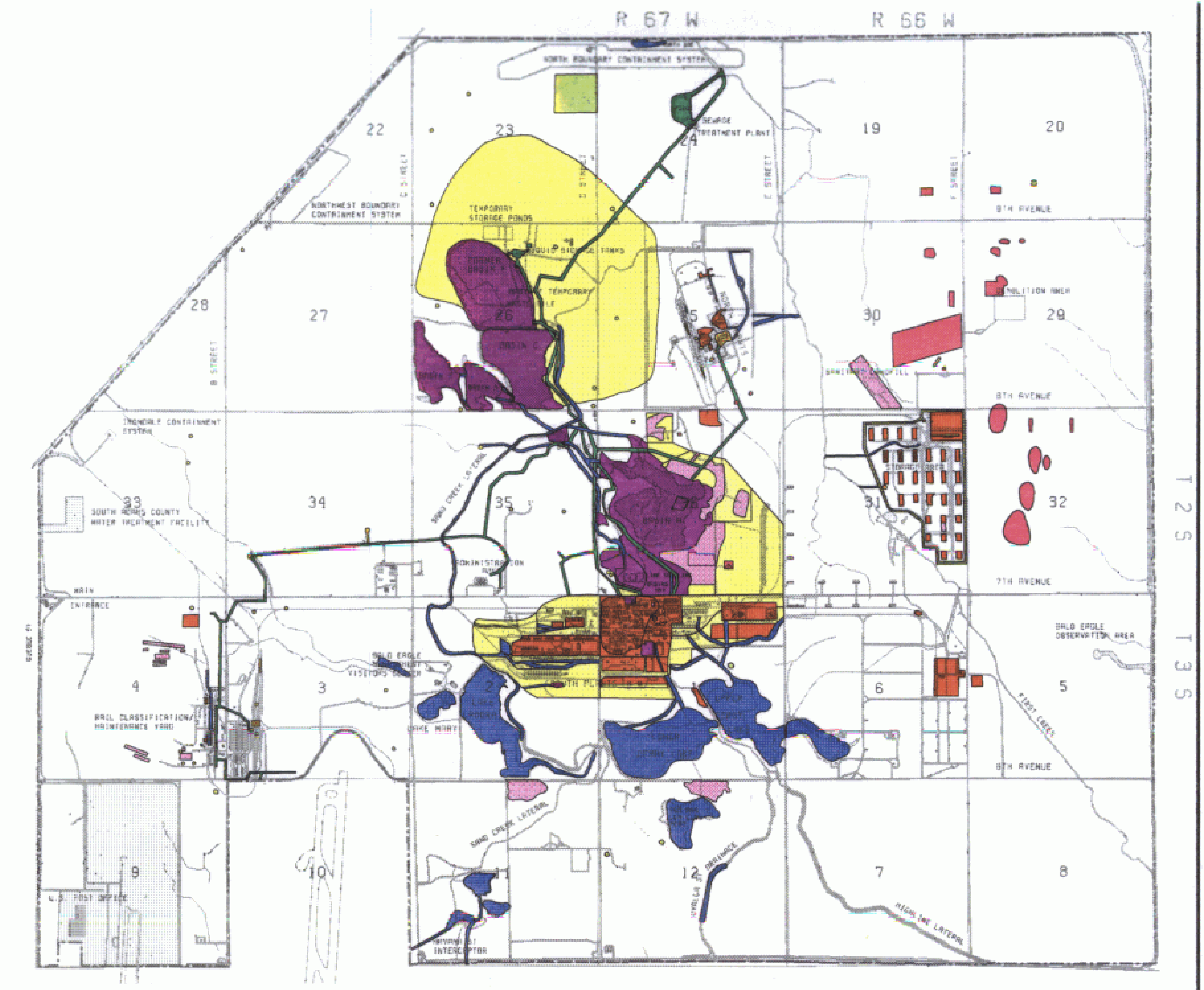
0 3600 Feet

Scale: 1" = 3600'



Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal
Prepared August 1991

FIGURE RISR A3.1-2
Relationship Between RI Soil Boring
Locations and Soil Contaminant
Site Types
Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



LEGEND

Major Drainage
Minor Drainage
Railroad Tracks
Basin
Former Basin
Lakes and Ponds
RMA Property/Leased
Road
3 Section Number
Structure
Former Structure
Arsenal Boundary

Site Types

🟪 Basins and Lagoons
🟦 Ditches,Lakes,and Ponds
🟥 Ordnance Testing and Disposal Areas
🟪 Solid Waste Burial Sites
🟧 Buildings, Equipment, and Storage Sites
🟧 Spill Sites
🟩 Sewer Sites

Surficial Soil and Other Predominantly Near-Surface Contamination

🟨 Predominantly Near-Surface
☐ 0 – 2 inch

🟩 Isolated Contamination

Note: Sites of contamination are grouped by similar physical characteristics and/or historical use.

N

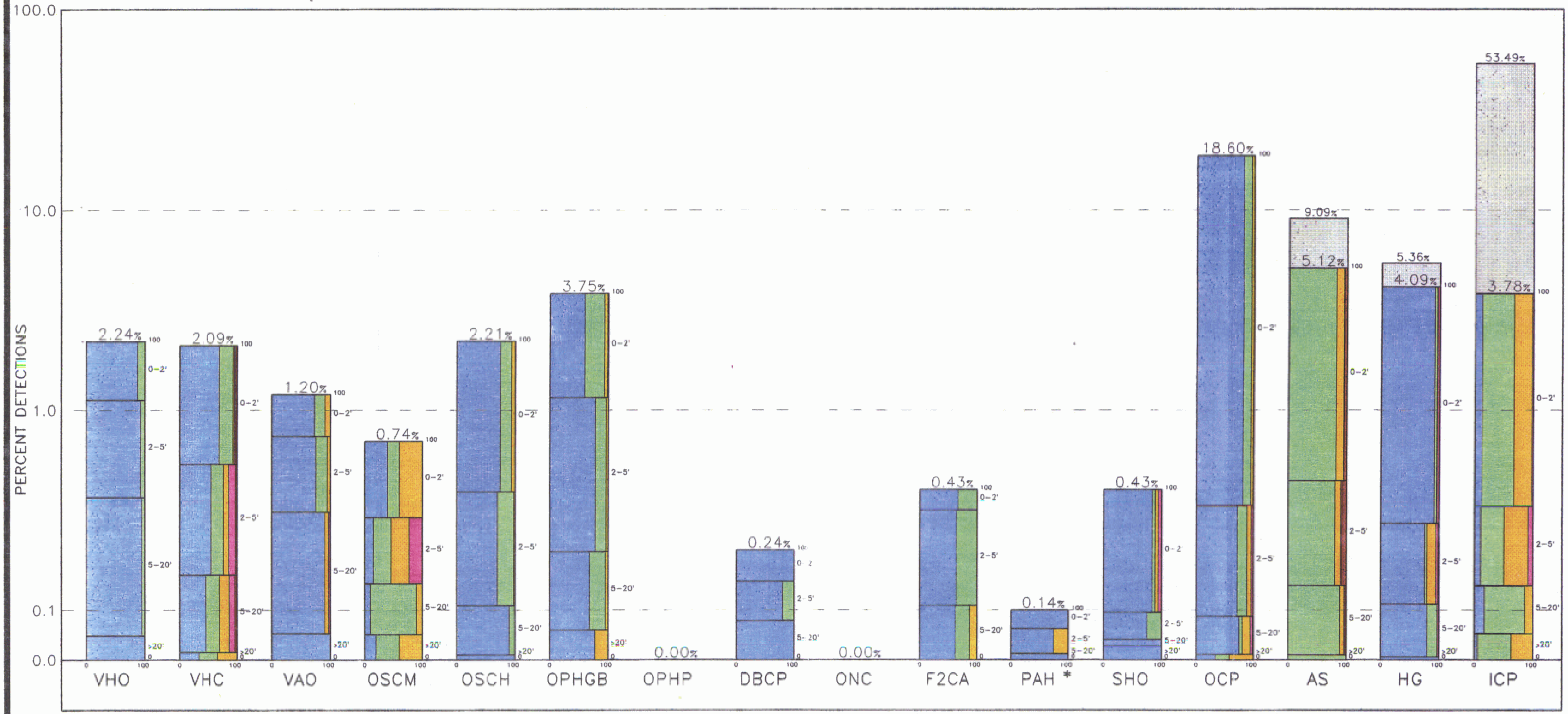
0 3600 Feet

Scale: 1" = 3600'

Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal
Prepared August 1991

FIGURE RISR A3.1–2
Relationship Between RI Soil Boring Locations and Soil Contaminant Site Types
Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

Basins and Lagoons



	VHO	VHC	VAO	OSCM	OSCH	OPHGB	OPHP	DBCP	ONC	F2CA	PAH *	SHO	OCP	AS	HG	ICP
DETECTIONS	131	122	70	43	129	219	0	14	0	25	8	25	1086	531	313	3124
ANALYSES	5774	2209	2759	2618	4248	2124	3939	1099	85	124	8	1122	8625	1253	1099	5227

* Group comprised entirely of TICs

CONCENTRATION RANGES

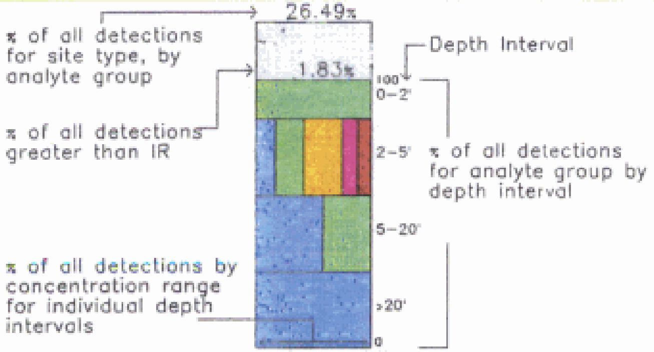
🟥	>10,000 ug/g
🟪	>1,000 to 10,000 ug/g
🟧	>100 to 1000 ug/g
🟩	>10 to 100 ug/g
🟦	CRL to 10 ug/g

INDICATOR RANGES for METALS

Arsenic(As)	CRL–10 ug/g
Mercury(Hg)	CRL–0.10 ug/g
Cadmium(Cd)	CRL–2.0 ug/g
Chromium(Cr)	CRL–40 ug/g
Copper(Cu)	CRL–35 ug/g
Lead(Pb)	CRL–40 ug/g
Zinc(Zn)	CRL–80 ug/g

Total Detections for all Analytes 5840

Total Analyses for all Analytes 42313



Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

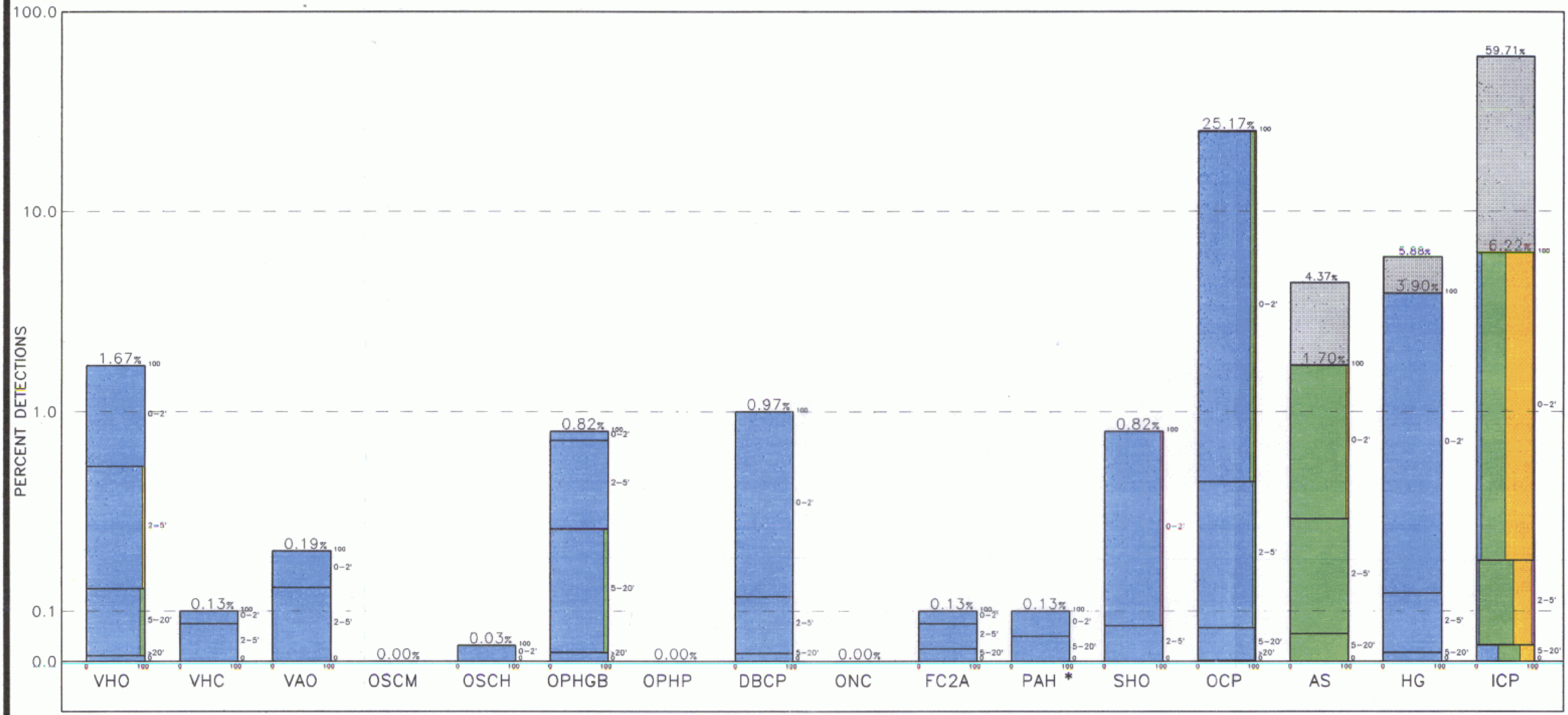
Prepared August 1991

FIGURE RISR A3.1–3

Analyte Group Detection Frequencies
for Basins and Lagoons

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

Ditches, Lakes, and Ponds



	VHO	VHC	VAO	OSCM	OSCH	OPHGB	OPHP	DBCP	ONC	FC2A	PAH *	SHO	OCP	AS	HG	ICP
DETECTIONS	53	4	6	0	1	26	0	31	0	4	4	26	801	139	187	1900
ANALYSES	3642	1511	1610	1355	2206	974	3049	1236	35	32	4	918	7241	601	833	3315

* Group comprised entirely of TICs

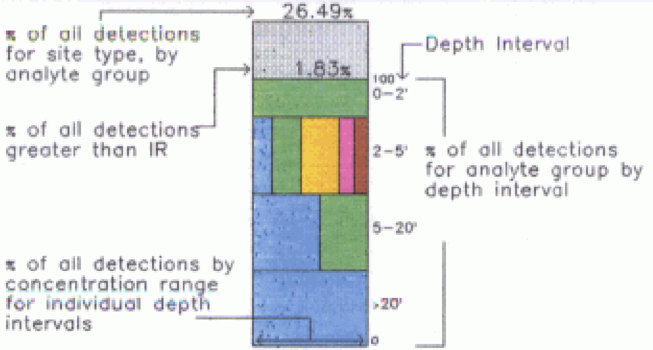
CONCENTRATION RANGES

🟥	>10,000 ug/g
🟪	>1,000 to 10,000 ug/g
🟨	>100 to 1000 ug/g
🟩	>10 to 100 ug/g
🟦	CRL to 10 ug/g

INDICATOR RANGES for METALS

Arsenic(As)	CRL–10 ug/g
Mercury(Hg)	CRL–0.10 ug/g
Cadmium(Cd)	CRL–2.0 ug/g
Chromium(Cr)	CRL–40 ug/g
Copper(Cu)	CRL–35 ug/g
Lead(Pb)	CRL–40 ug/g
Zinc(Zn)	CRL–80 ug/g

Total Detections for all Analytes	3182
Total Analyses for all Analytes	28562



Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

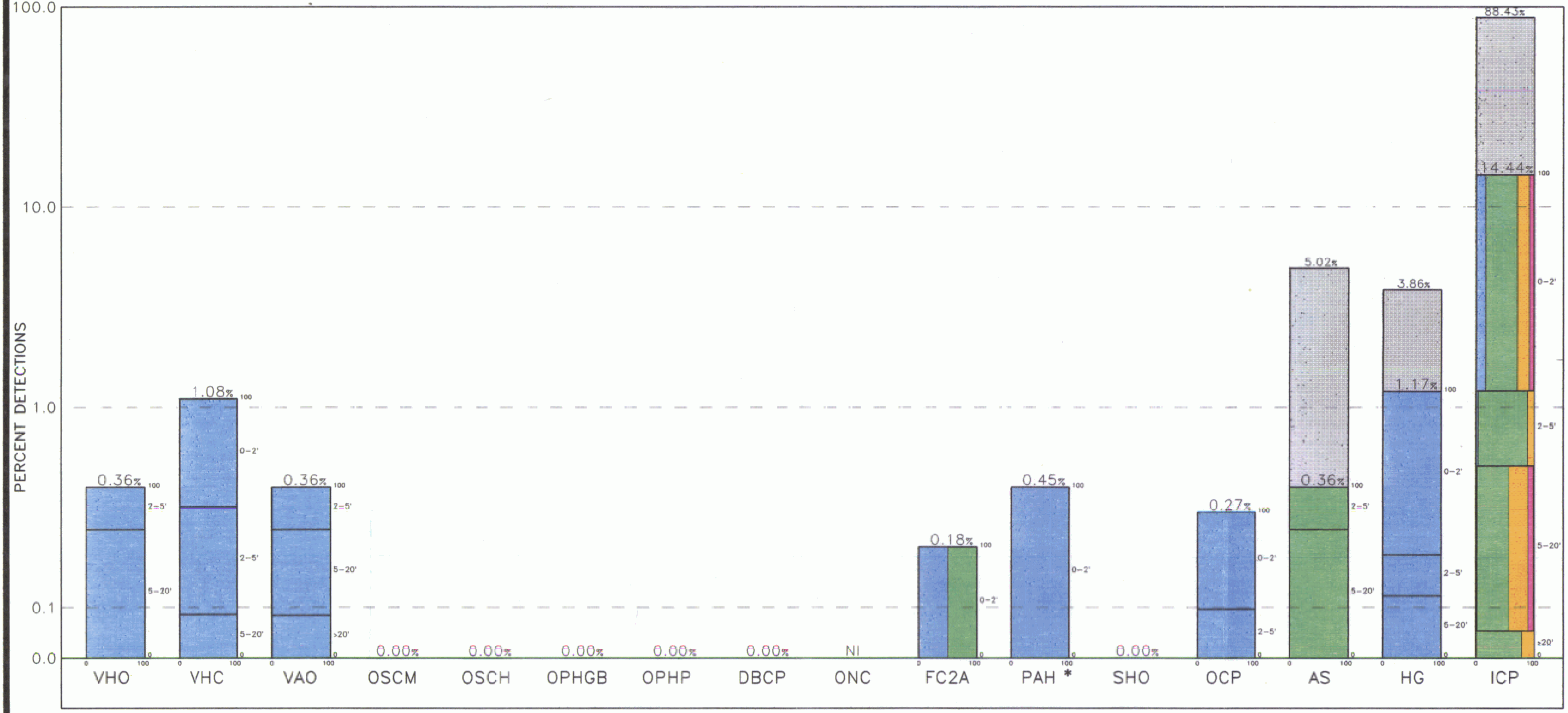
Prepared August 1991

FIGURE RISR A3.1–4

Analyte Group Detection Frequencies
for Ditches, Lakes, and Ponds

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

Ordnance Testing and Disposal Areas



	VHO	VHC	VAO	OSCM	OSCH	OPHGB	OPHP	DBCP	ONC	FC2A	PAH *	SHO	OCP	AS	HG	ICP
DETECTIONS	4	12	4	0	0	0	0	0	0	2	5	0	3	56	43	986
ANALYSES	767	462	370	725	1040	672	1735	275	0	27	5	296	2186	303	310	1566

* Group comprised entirely of TICs

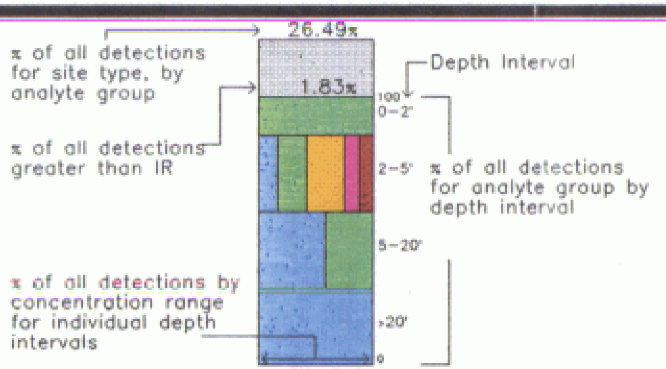
CONCENTRATION RANGES

- 🟥 >10,000 ug/g
- 🟪 >1,000 to 10,000 ug/g
- 🟧 >100 to 1000 ug/g
- 🟩 >10 to 100 ug/g
- 🟦 CRL to 10 ug/g

INDICATOR RANGES for METALS

Arsenic(As)	CRL-10 ug/g
Mercury(Hg)	CRL-0.10 ug/g
Cadmium(Cd)	CRL-2.0 ug/g
Chromium(Cr)	CRL-40 ug/g
Copper(Cu)	CRL-35 ug/g
Lead(Pb)	CRL-40 ug/g
Zinc(Zn)	CRL-80 ug/g

Total Detections for all Analytes	1115
Total Analyses for all Analytes	10739



Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

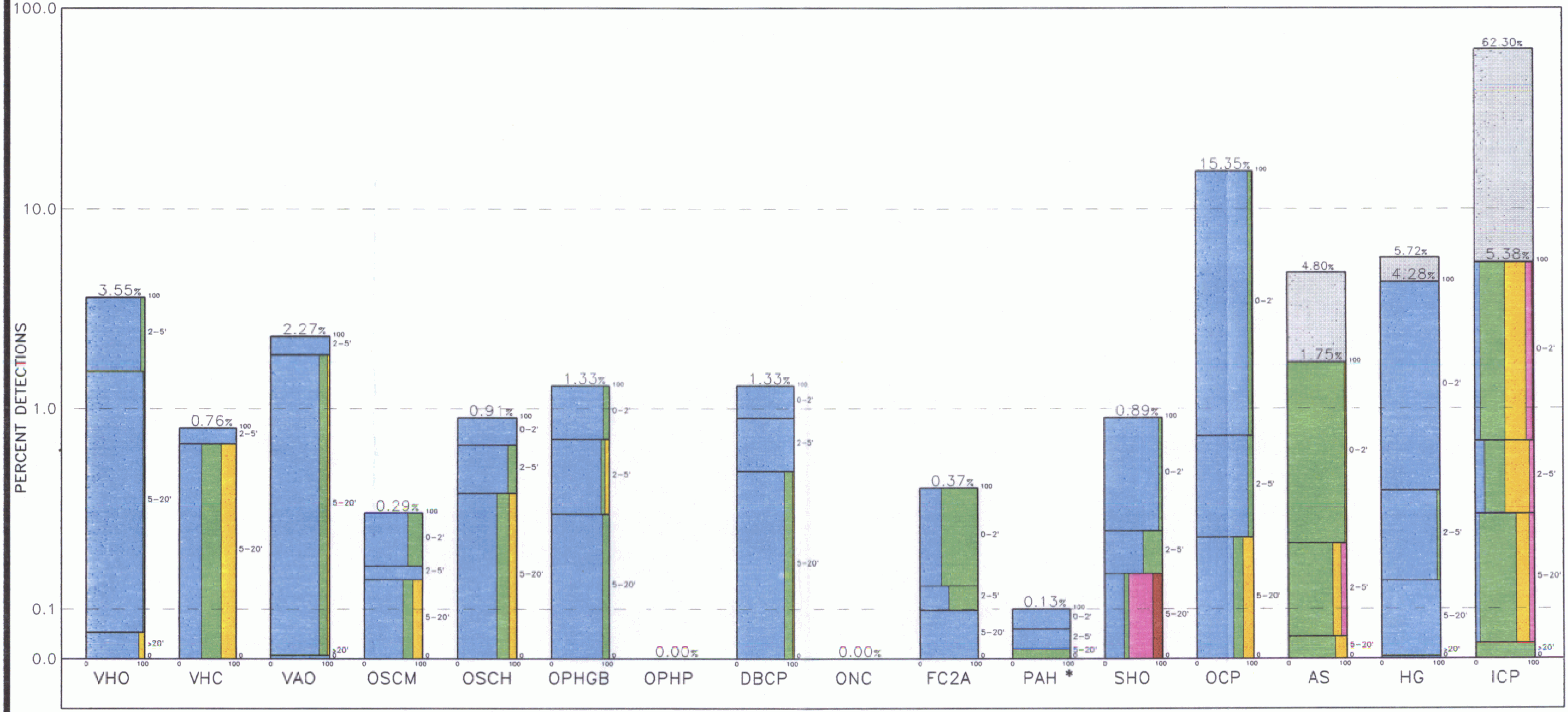
Prepared August 1991

FIGURE RISR A3.1-5

Analyte Group Detection Frequencies
for Ordnance Testing
and Disposal Areas

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

Solid Waste Burial Sites



	VHO	VHC	VAO	OSCM	OSCH	OPHGB	OPHP	DBCP	ONC	FC2A	PAH *	SHO	OCP	AS	HG	ICP
DETECTIONS	136	29	87	11	35	51	0	51	0	14	5	34	588	184	219	2386
ANALYSES	5718	2110	2185	2023	3323	1580	3946	1344	3	58	5	872	6722	823	980	4146

* Group comprised entirely of TICs

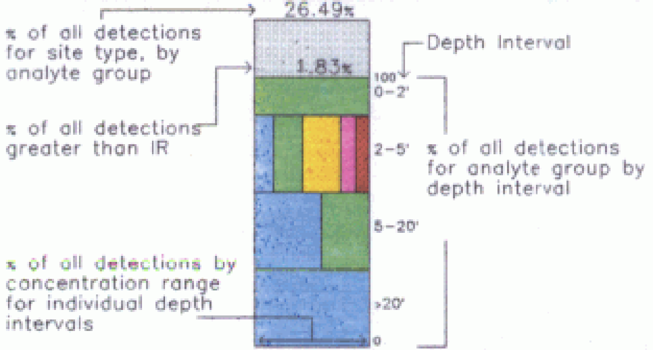
CONCENTRATION RANGES

🟥	>10,000 ug/g
🟪	>1,000 to 10,000 ug/g
🟨	>100 to 1000 ug/g
🟩	>10 to 100 ug/g
🟦	CRL to 10 ug/g

INDICATOR RANGES for METALS

Arsenic(As)	CRL-10 ug/g
Mercury(Hg)	CRL-0.10 ug/g
Cadmium(Cd)	CRL-2.0 ug/g
Chromium(Cr)	CRL-40 ug/g
Copper(Cu)	CRL-35 ug/g
Lead(Pb)	CRL-40 ug/g
Zinc(Zn)	CRL-80 ug/g

Total Detections for all Analytes	3830
Total Analyses for all Analytes	35838



Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

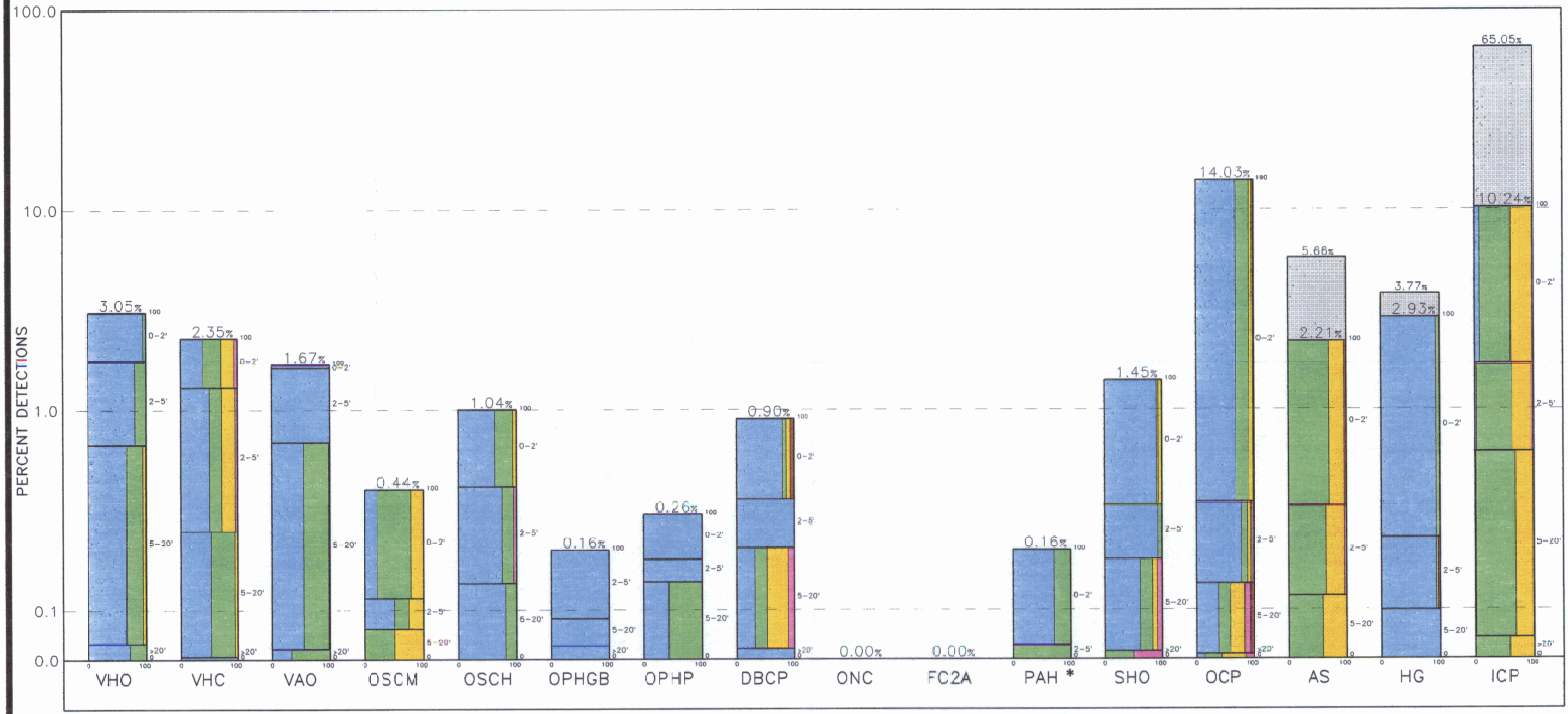
Prepared August 1991

FIGURE RISR A3.1-6

Analyte Group Detection Frequencies
for Solid Waste Burial Sites

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

Buildings, Equipment, and Storage Sites



	VHO	VHC	VAO	OSCM	OSCH	OPHGB	OPHP	DBCP	ONC	FC2A	PAH *	SHO	OCP	AS	HG	ICP
DETECTIONS	152	117	83	22	52	8	13	45	0	0	8	72	699	282	188	3241
ANALYSES	7213	2902	2848	3119	4336	1696	5754	2044	466	11	8	1270	9073	1032	1100	5241

* Group comprised entirely of TICs

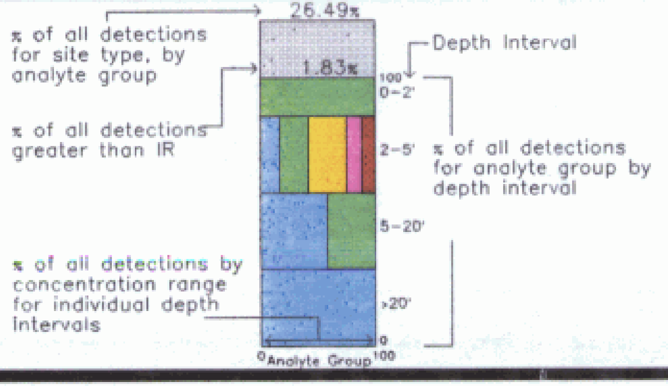
CONCENTRATION RANGES

🟫	>10,000 ug/g
🟪	>1,000 to 10,000 ug/g
🟨	>100 to 1000 ug/g
🟩	>10 to 100 ug/g
🟦	CRL to 10 ug/g

INDICATOR RANGES for METALS

Arsenic(As)	CRL−10 ug/g
Mercury(Hg)	CRL−0.10 ug/g
Cadmium(Cd)	CRL−2.0 ug/g
Chromium(Cr)	CRL−40 ug/g
Copper(Cu)	CRL−35 ug/g
Lead(Pb)	CRL−40 ug/g
Zinc(Zn)	CRL−80 ug/g

Total Detections for all Analytes	4982
Total Analyses for all Analytes	48113



Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

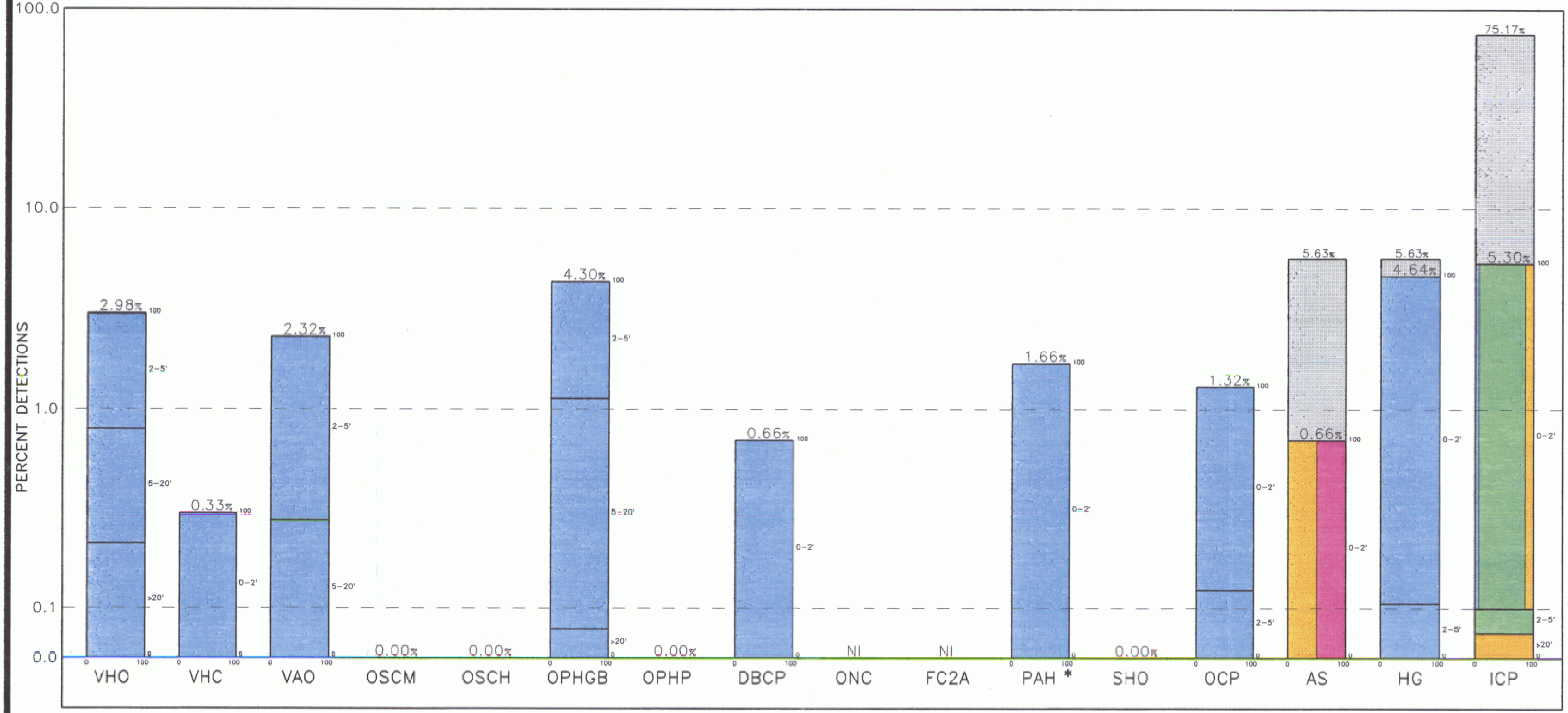
Prepared August 1991

FIGURE RISR A3.1−7

Analyte Group Detection Frequencies
for Buildings, Equipment,
and Storage Sites

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

Spill Sites



	VHO	VHC	VAO	OSCM	OSCH	OPHGB	OPHP	DBCP	ONC	FC2A	PAH *	SHO	OCP	AS	HG	ICP
DETECTIONS	9	1	7	0	0	13	0	2	0	0	5	0	4	17	17	227
ANALYSES	689	271	375	322	362	304	510	190	0	0	5	104	728	80	91	375

* Group comprised entirely of tentatively identified compounds (TIC); NI – Analyte group not investigated during the Remedial Investigation (RI)

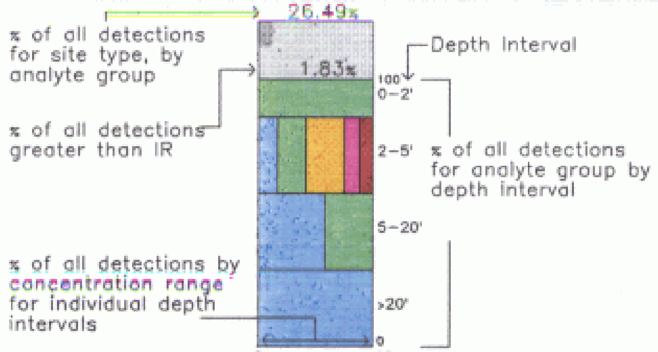
CONCENTRATION RANGES

🟥	>10,000 ug/g
🟪	>1,000 to 10,000 ug/g
🟧	>100 to 1000 ug/g
🟩	>10 to 100 ug/g
🟦	CRL to 10 ug/g

INDICATOR RANGES for METALS

Arsenic(As)	CRL-10 ug/g
Mercury(Hg)	CRL-0.10 ug/g
Cadmium(Cd)	CRL-2.0 ug/g
Chromium(Cr)	CRL-40 ug/g
Copper(Cu)	CRL-35 ug/g
Lead(Pb)	CRL-40 ug/g
Zinc(Zn)	CRL-80 ug/g

Total Detections for all Analytes	302
Total Analyses for all Analytes	4406



Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

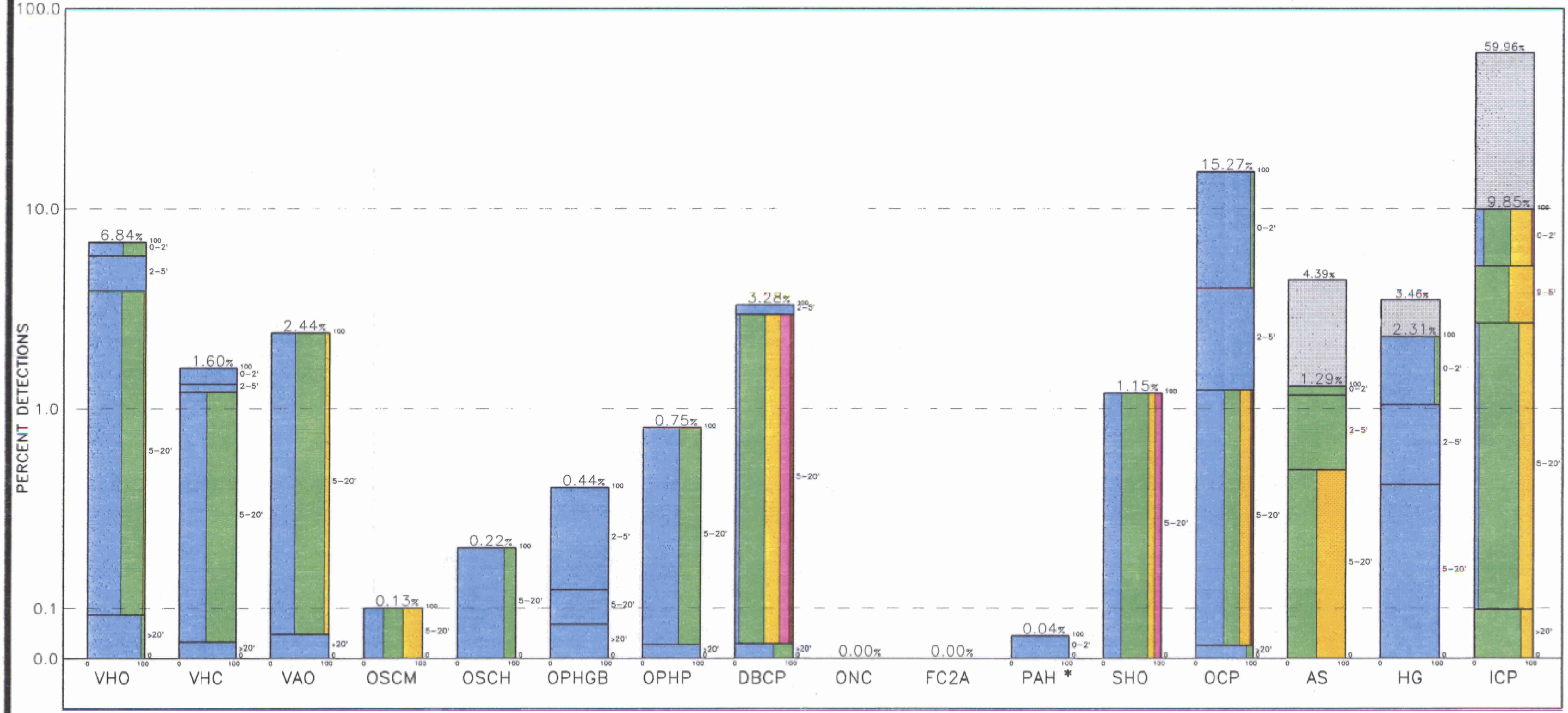
Prepared August 1991

FIGURE RISR A3.1-8

Analyte Group Detection Frequencies
for Spill Sites

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

Sewer Sites



DETECTIONS	154	36	55	3	5	10	17	74	0	0	1	26	344	99	78	1351
ANALYSES	3199	1217	1449	1299	1598	720	2171	765	5	9	1	509	3615	377	429	2264

* Group comprised entirely of TICs

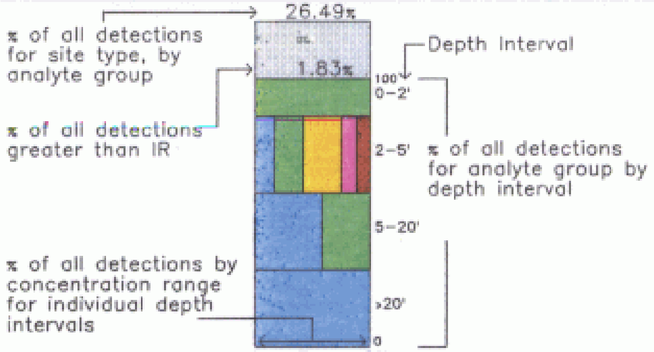
CONCENTRATION RANGES

- 🟫 >10,000 ug/g
- 🟪 >1,000 to 10,000 ug/g
- 🟨 >100 to 1000 ug/g
- 🟩 >10 to 100 ug/g
- 🟦 CRL to 10 ug/g

INDICATOR RANGES for METALS

Arsenic(As)	CRL−10 ug/g
Mercury(Hg)	CRL−0.10 ug/g
Cadmium(Cd)	CRL−2.0 ug/g
Chromium(Cr)	CRL−40 ug/g
Copper(Cu)	CRL−35 ug/g
Lead(Pb)	CRL−40 ug/g
Zinc(Zn)	CRL−80 ug/g

Total Detections for all Analytes	2253
Total Analyses for all Analytes	19627



Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

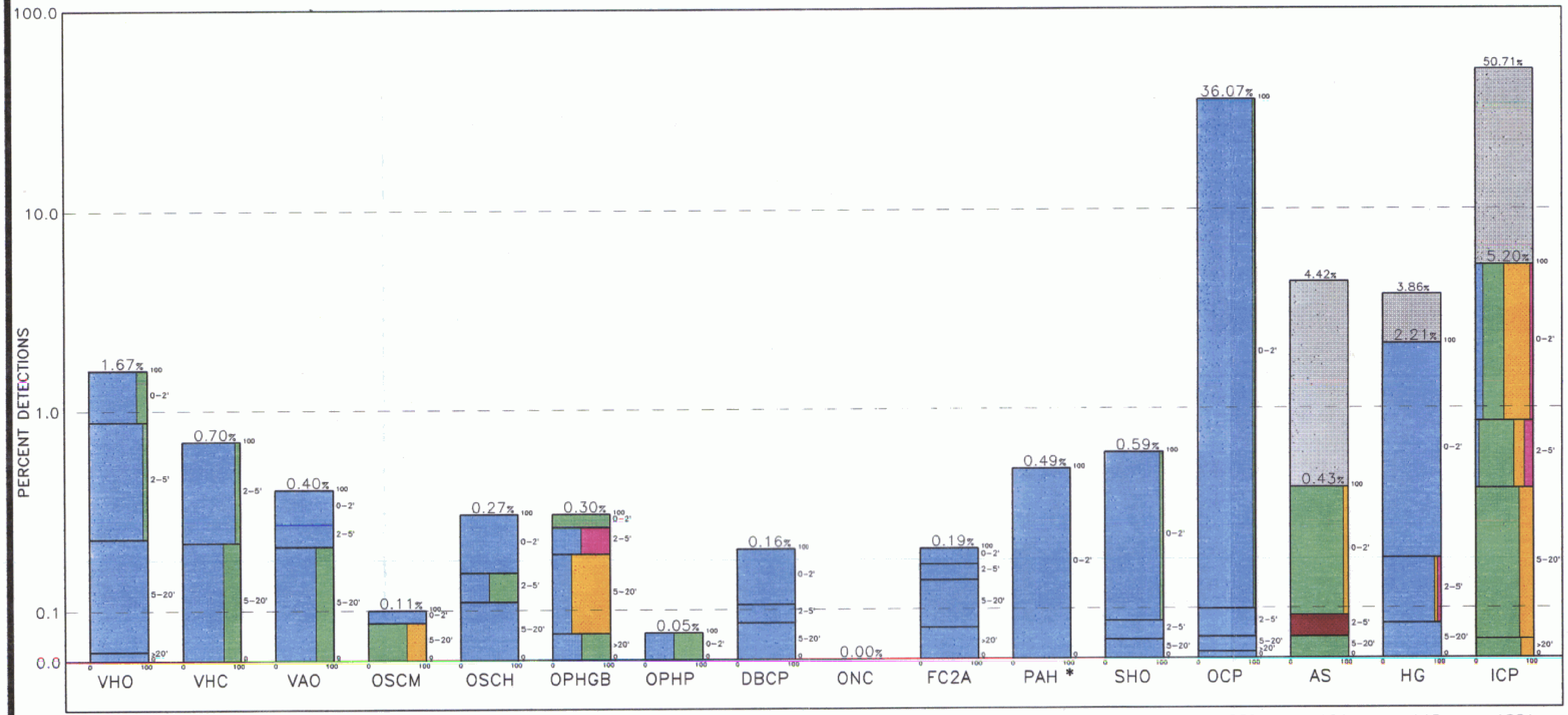
Prepared August 1991

FIGURE RISR A3.1−9

Analyte Group Detection Frequencies
for Sewer Sites

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

Surficial Soil and Other Predominantly Near-Surface Contamination



	VHO	VHC	VAO	OSCM	OSCH	OPHGB	OPHP	DBCP	ONC	FC2A	PAH *	SHO	OCP	AS	HG	ICP
DETECTIONS	62	26	15	4	10	11	2	6	0	7	18	22	1338	164	143	1881
ANALYSES	3959	1970	1885	1890	3122	1375	3860	1261	123	25	18	1151	8620	679	735	3252

* Group comprised entirely of TIC's

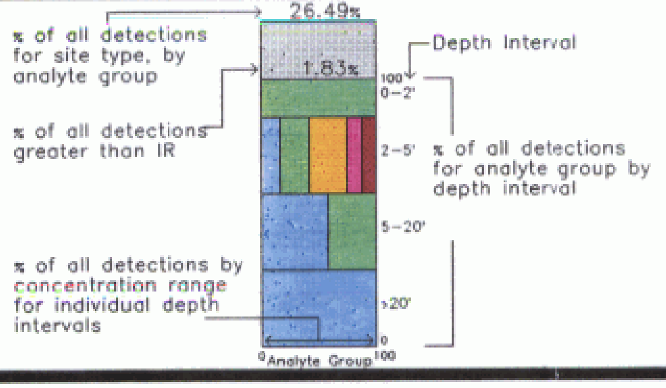
CONCENTRATION RANGES

- 🟥 >10,000 ug/g
- 🟪 >1,000 to 10,000 ug/g
- 🟧 >100 to 1000 ug/g
- 🟩 >10 to 100 ug/g
- 🟦 CRL to 10 ug/g

INDICATOR RANGES for METALS

Arsenic(As)	CRL-10 ug/g
Mercury(Hg)	CRL-0.10 ug/g
Cadmium(Cd)	CRL-2.0 ug/g
Chromium(Cr)	CRL-40 ug/g
Copper(Cu)	CRL-35 ug/g
Lead(Pb)	CRL-40 ug/g
Zinc(Zn)	CRL-80 ug/g

Total Detections for all Analytes	3709
Total Analyses for all Analytes	33925



Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

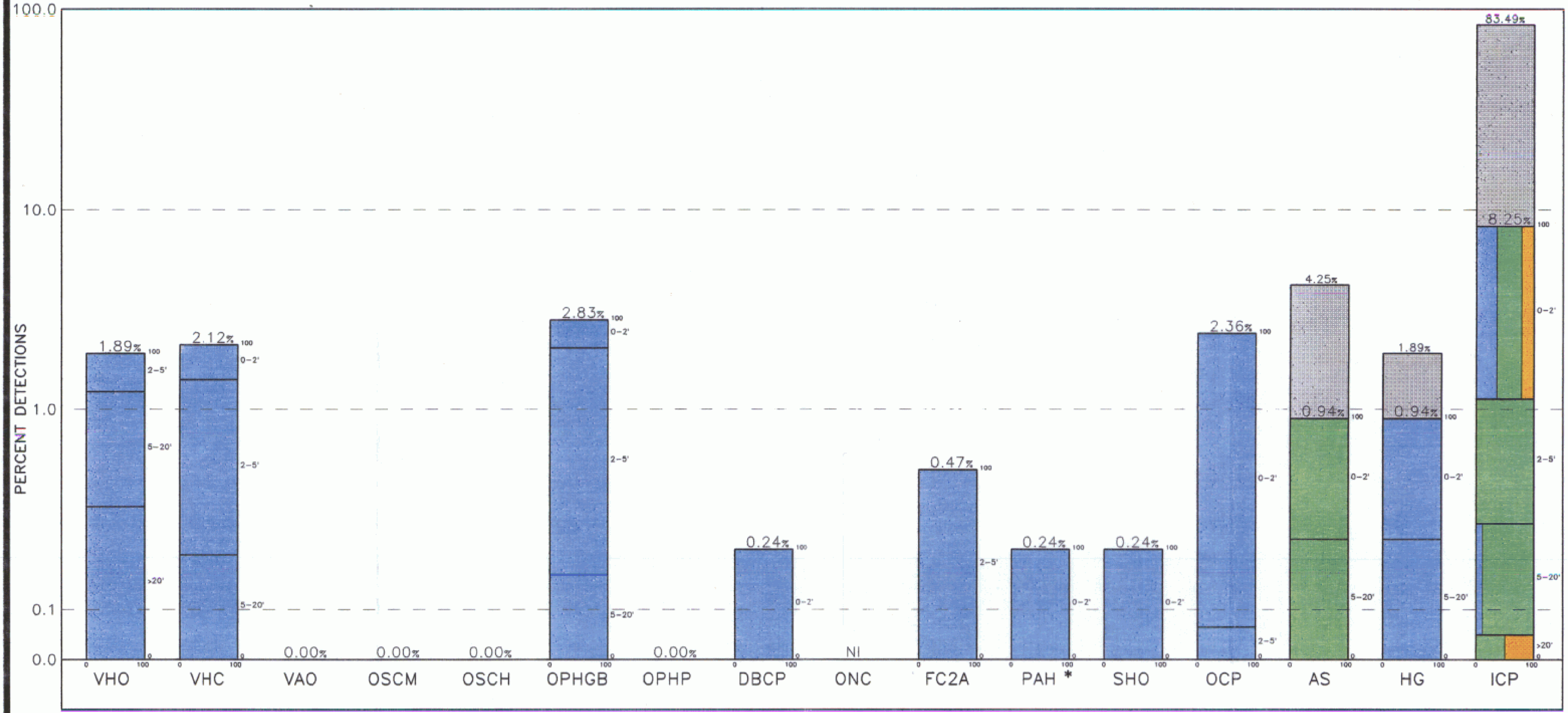
Prepared August 1991

FIGURE RISR A3.1-10

Analyte Group Detection Frequencies
for Surficial Soil and Other
Predominantly Near-Surface Contamination

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

Isolated Contamination



	VHO	VHC	VAO	OSCM	OSCH	OPHGB	OPHP	DBCP	ONC	FC2A	PAH *	SHO	OCP	AS	HG	ICP
DETECTIONS	8	9	0	0	0	12	0	1	0	2	1	1	10	18	8	354
ANALYSES	718	276	245	254	394	213	575	191	0	4	1	99	801	122	115	615

* Group comprised entirely of tentatively identified compounds (TIC); NI – Analyte group not investigated during the Remedial Investigation (RI)

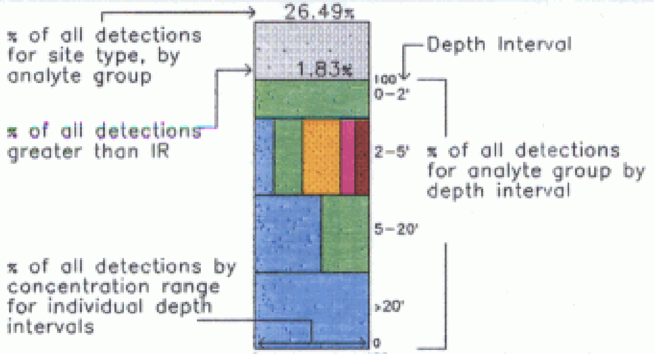
CONCENTRATION RANGES

🟥	>10,000 ug/g
🟪	>1,000 to 10,000 ug/g
🟧	>100 to 1000 ug/g
🟩	>10 to 100 ug/g
🟦	CRL to 10 ug/g

INDICATOR RANGES for METALS

Arsenic(As)	CRL–10 ug/g
Mercury(Hg)	CRL–0.10 ug/g
Cadmium(Cd)	CRL–2.0 ug/g
Chromium(Cr)	CRL–40 ug/g
Copper(Cu)	CRL–35 ug/g
Lead(Pb)	CRL–40 ug/g
Zinc(Zn)	CRL–80 ug/g

Total Detections for all Analytes	424
Total Analyses for all Analytes	4623



Prepared for:

U.S. Army Program Manager

for Rocky Mountain Arsenal

Prepared August 1991

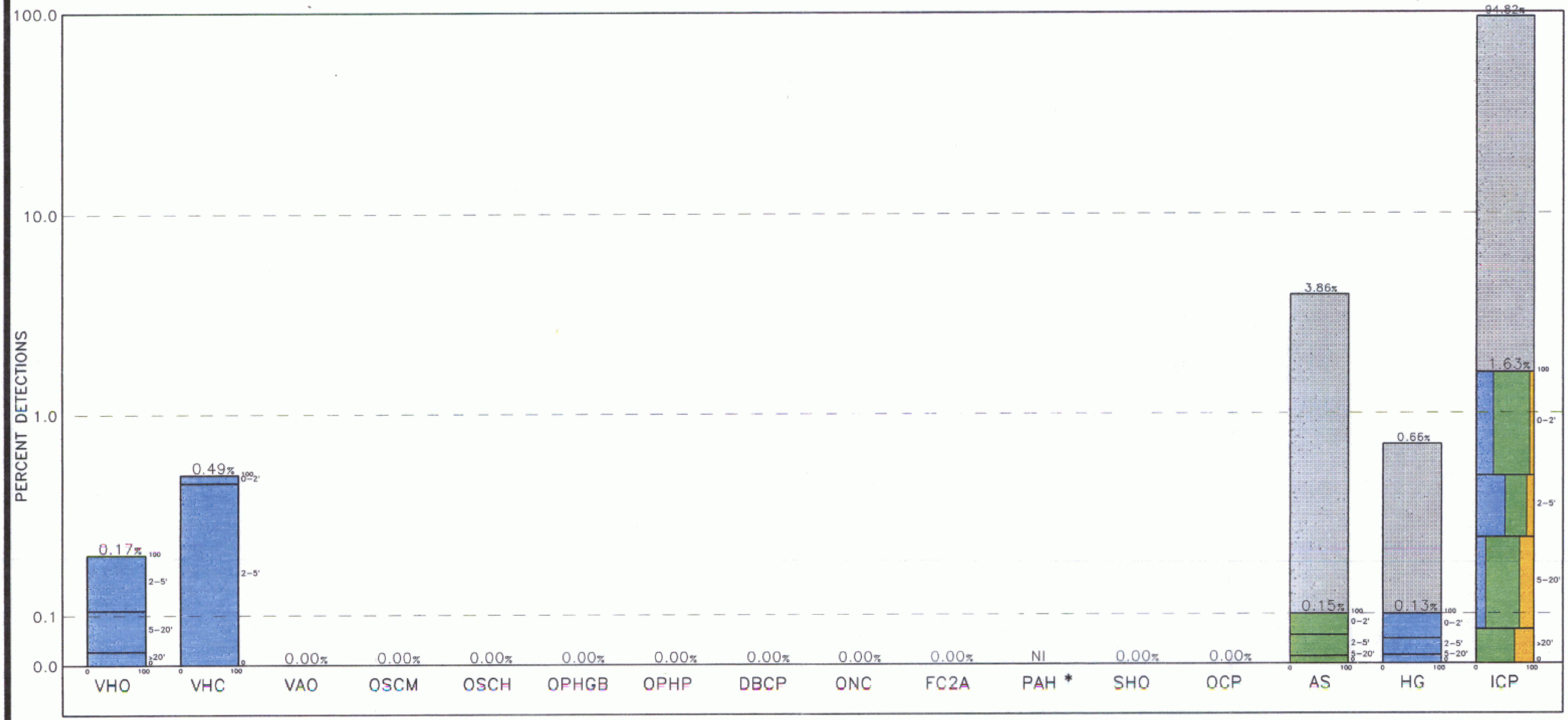
FIGURE RISR A3.1–11

Analyte Group Detection Frequencies

for Isolated Contamination in Soils

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

Balance of Areas Investigated



	VHO	VHC	VAO	OSCM	OSCH	OPHGB	OPHP	DBCP	ONC	FC2A	PAH *	SHO	OCP	AS	HG	ICP
DETECTIONS	8	23	0	0	0	0	0	0	0	0	0	0	0	180	31	4427
ANALYSES	3371	2350	1570	3259	4885	2622	7612	2139	33	19	0	1143	10366	1561	1547	7704

* Group comprised entirely of tentatively identified compounds (TIC); NI – Analyte group not investigated during the Remedial Investigation (RI)

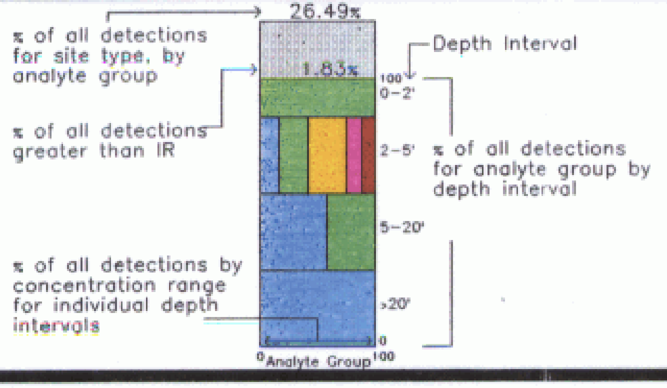
CONCENTRATION RANGES

- 🟫 >10,000 ug/g
- 🟪 >1,000 to 10,000 ug/g
- 🟨 >100 to 1000 ug/g
- 🟩 >10 to 100 ug/g
- 🟦 CRL to 10 ug/g

INDICATOR RANGES for METALS

Arsenic(As)	CRL–10 ug/g
Mercury(Hg)	CRL–0.10 ug/g
Cadmium(Cd)	CRL–2.0 ug/g
Chromium(Cr)	CRL–40 ug/g
Copper(Cu)	CRL–35 ug/g
Lead(Pb)	CRL–40 ug/g
Zinc(Zn)	CRL–80 ug/g

Total Detections for all Analytes	4669
Total Analyses for all Analytes	50181



Prepared for:

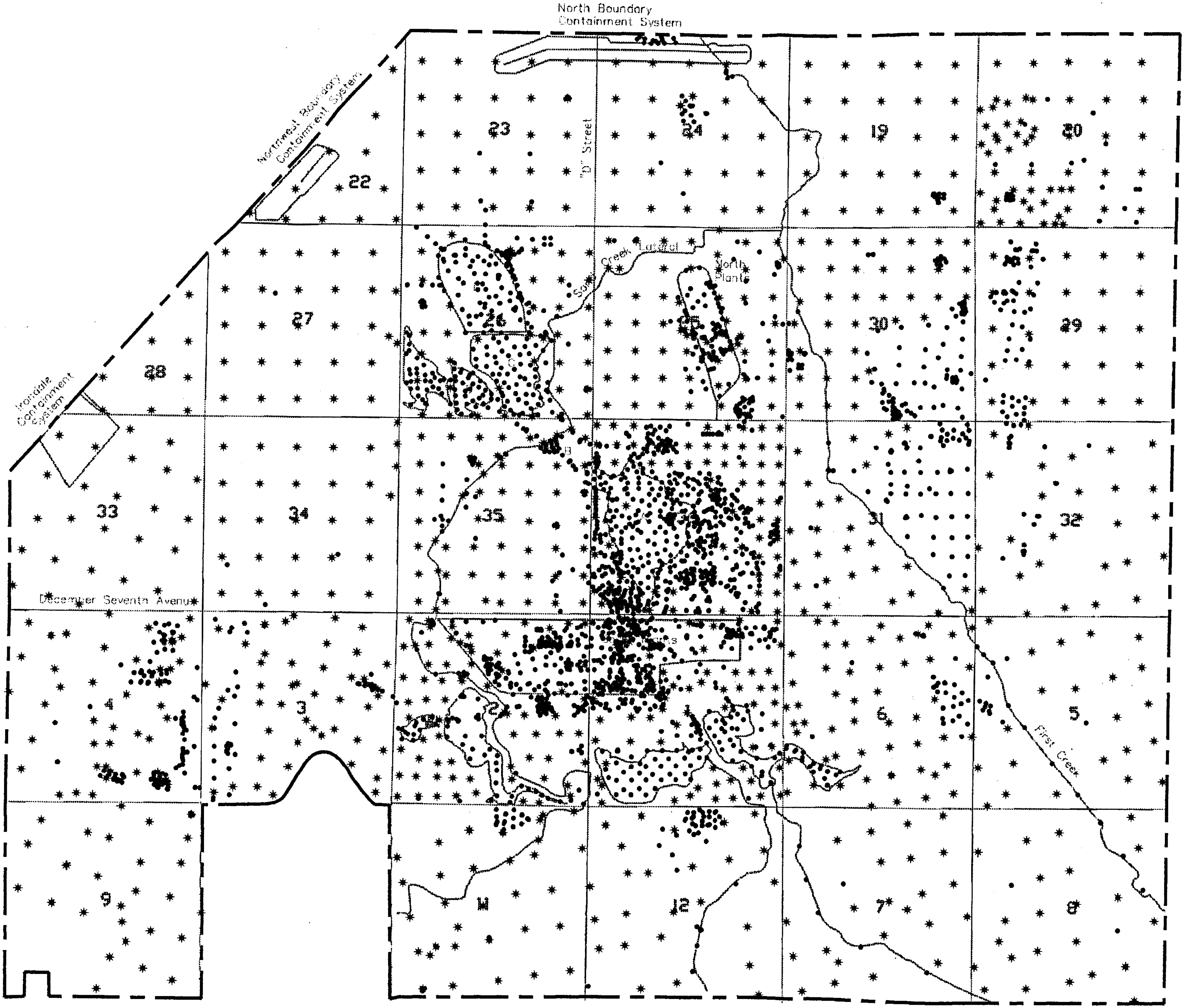
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A3.1–12

Analyte Group Detection Frequencies
for Balance of Areas Investigated

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend:

Rocky Mountain Arsenal Boundary

Section Lines

Streams

Lakes

Basins

● Boring Location

* Composite Soil Sample Location

Note: At composited sample locations, the 0 to 1 ft and 4 to 5 ft soil samples were composited.

N

0 3000 Feet

Scale: 1" = 3000'

Prepared for:

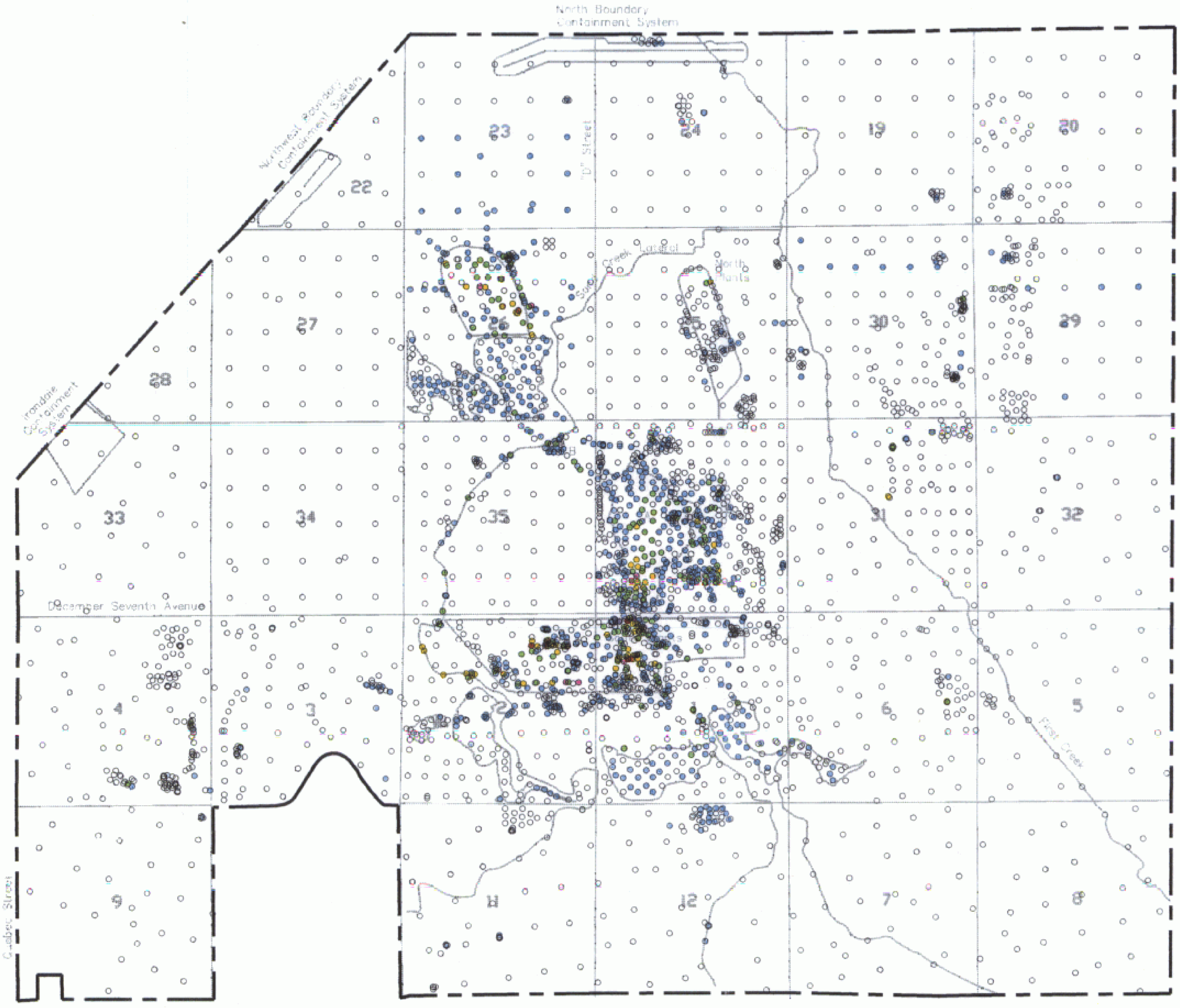
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared: August 1991

FIGURE RISR A3.1-13

Remedial Investigation
Soil Boring Location Map
for Phase I and Phase II

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend:

- ▬ ▬ Rocky Mountain Arsenal Boundary
- ── Section Lines
- 〰 Streams
- ⬭ Lakes
- Ⓐ Basins

Concentration Ranges

- 🟫 > 10,000 ug/g
- 🟪 > 1000 to 10,000 ug/g
- 🟧 > 100 to 1000 ug/g
- 🟩 > 10 to 100 ug/g
- 🟦 CRL to 10 ug/g
- ○ BCRL

N

0 3000 Feet

Scale: 1" = 3000'

Prepared for:

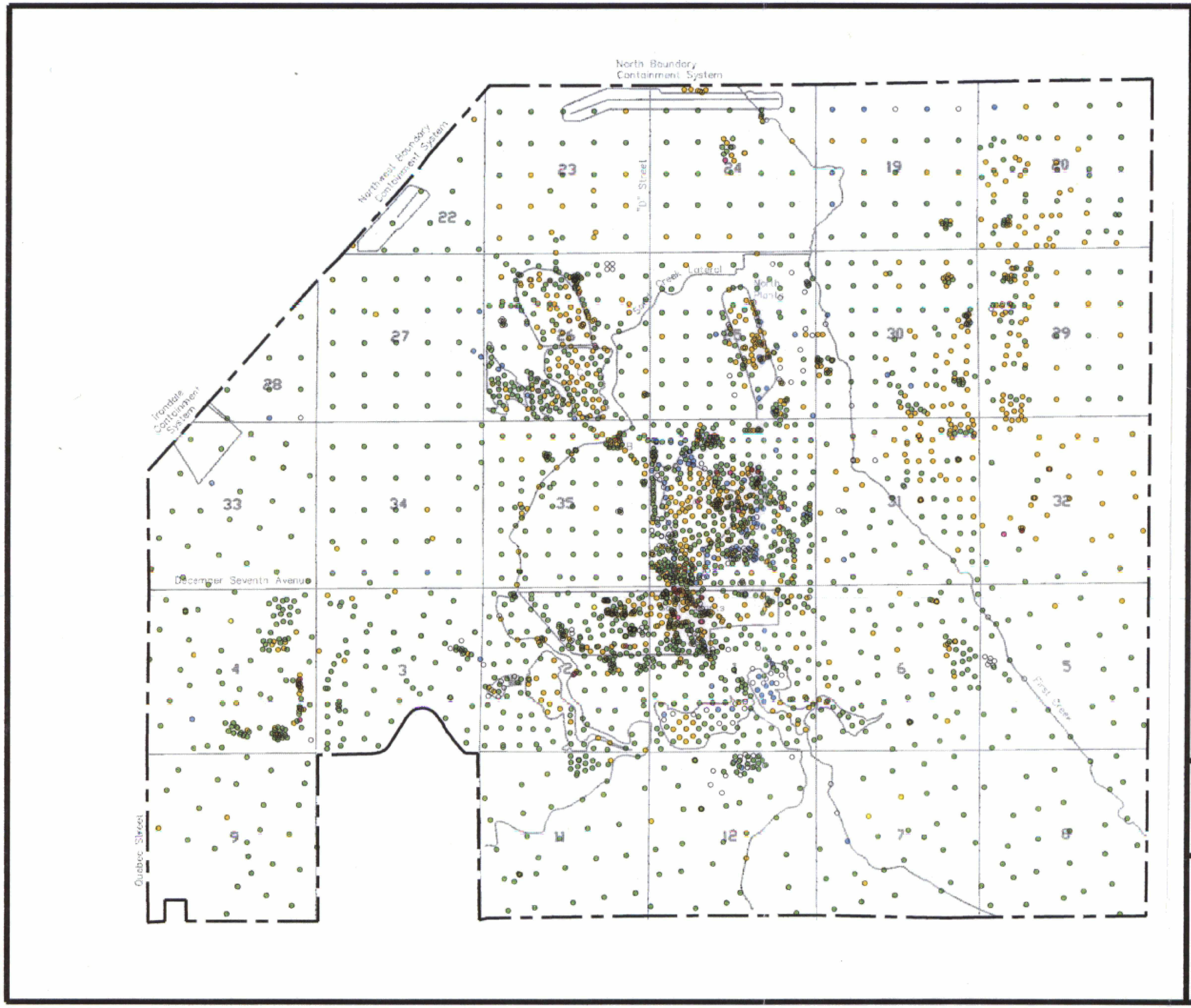
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared: August 1991

FIGURE RISR A3.1-14

Distribution of
Total Organic Analytes in Soils
in the 0 to 2 ft Depth Interval

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend:

- ▬ ▬ Rocky Mountain Arsenal Boundary
- ─ Section Lines
- ∼ Streams
- ⬭ Lakes
- Ⓐ Basins

Concentration Ranges

- 🟫 > 10,000 ug/g
- 🟪 > 1000 to 10,000 ug/g
- 🟨 > 100 to 1000 ug/g
- 🟩 > 10 to 100 ug/g
- 🟦 CRL to 10 ug/g
- ○ BCRL

N

0 3000 Feet

Scale: 1" = 3000'

Prepared for:

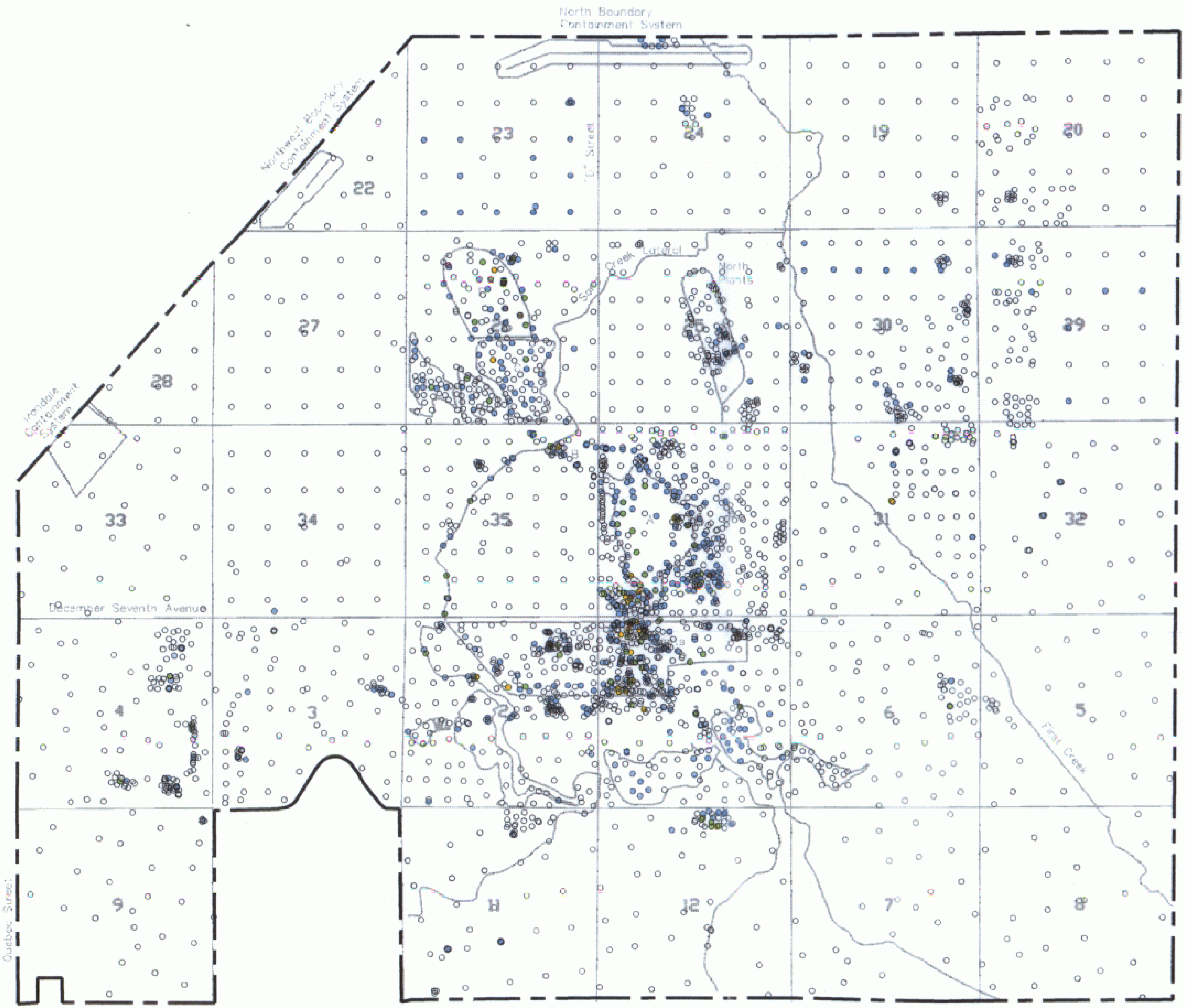
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared: August 1991

FIGURE RISR A3.1–15

Distribution of
Total Inorganic Analytes in Soils
in the 0 to 2 ft Depth Interval

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend:

Rocky Mountain Arsenal Boundary
Section Lines
Streams
Lakes
Basins

Concentration Ranges

🟫 > 10,000 ug/g
🟪 > 1000 to 10,000 ug/g
🟨 > 100 to 1000 ug/g
🟩 > 10 to 100 ug/g
🟦 CRL to 10 ug/g
○ BCRL

N

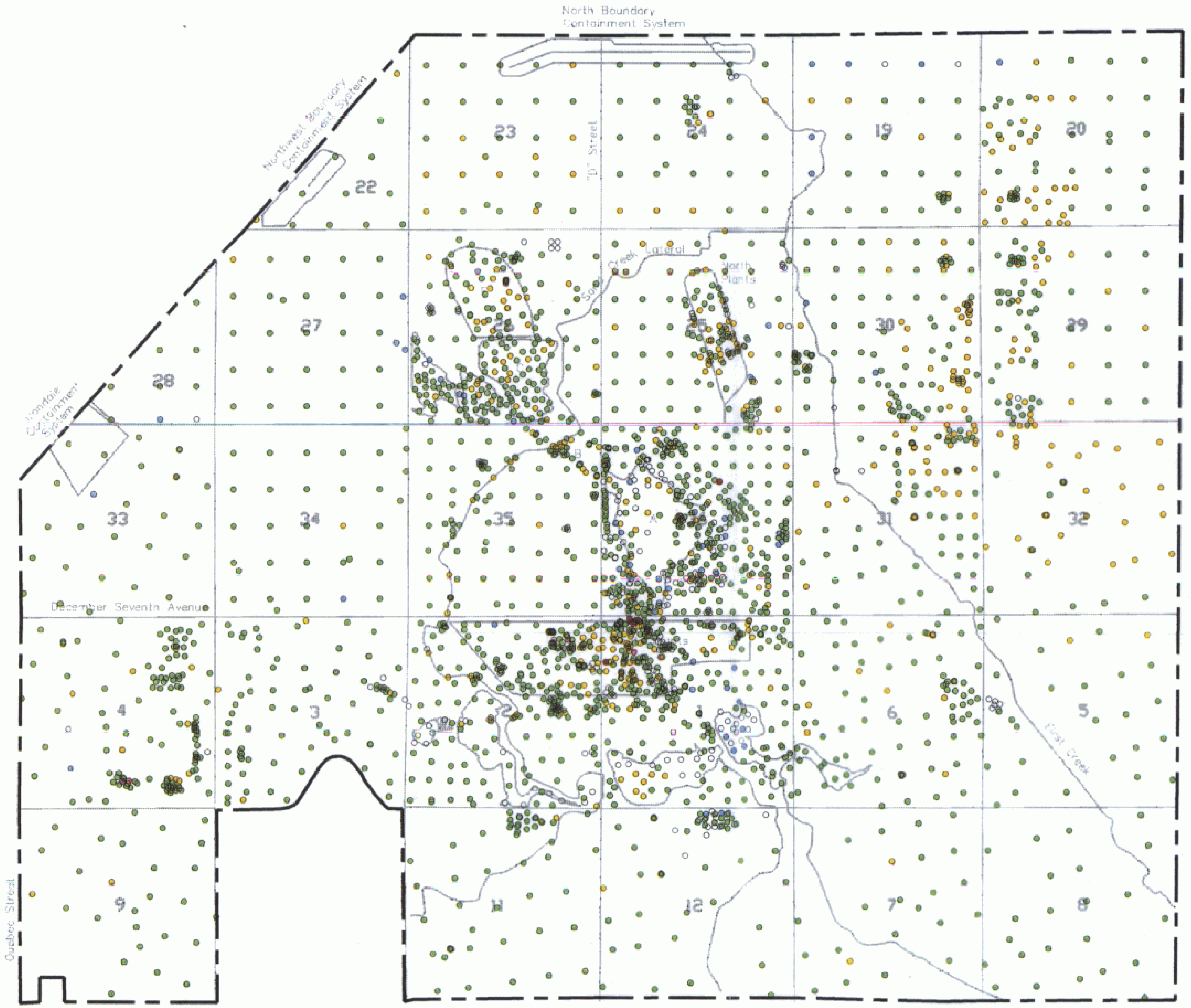
0 3000 Feet
Scale: 1" = 3000'

Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared: August 1991

FIGURE RISR A3.1-16
Distribution of
Total Organic Analytes in Soils
in the 2 to 5 ft Depth Interval

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend:

Rocky Mountain Arsenal Boundary
Section Lines
Streams
Lakes
Basins

Concentration Ranges

🟥 > 10,000 ug/g
🟪 > 1000 to 10,000 ug/g
🟨 > 100 to 1000 ug/g
🟩 > 10 to 100 ug/g
🟦 CRL to 10 ug/g
○ BCRL

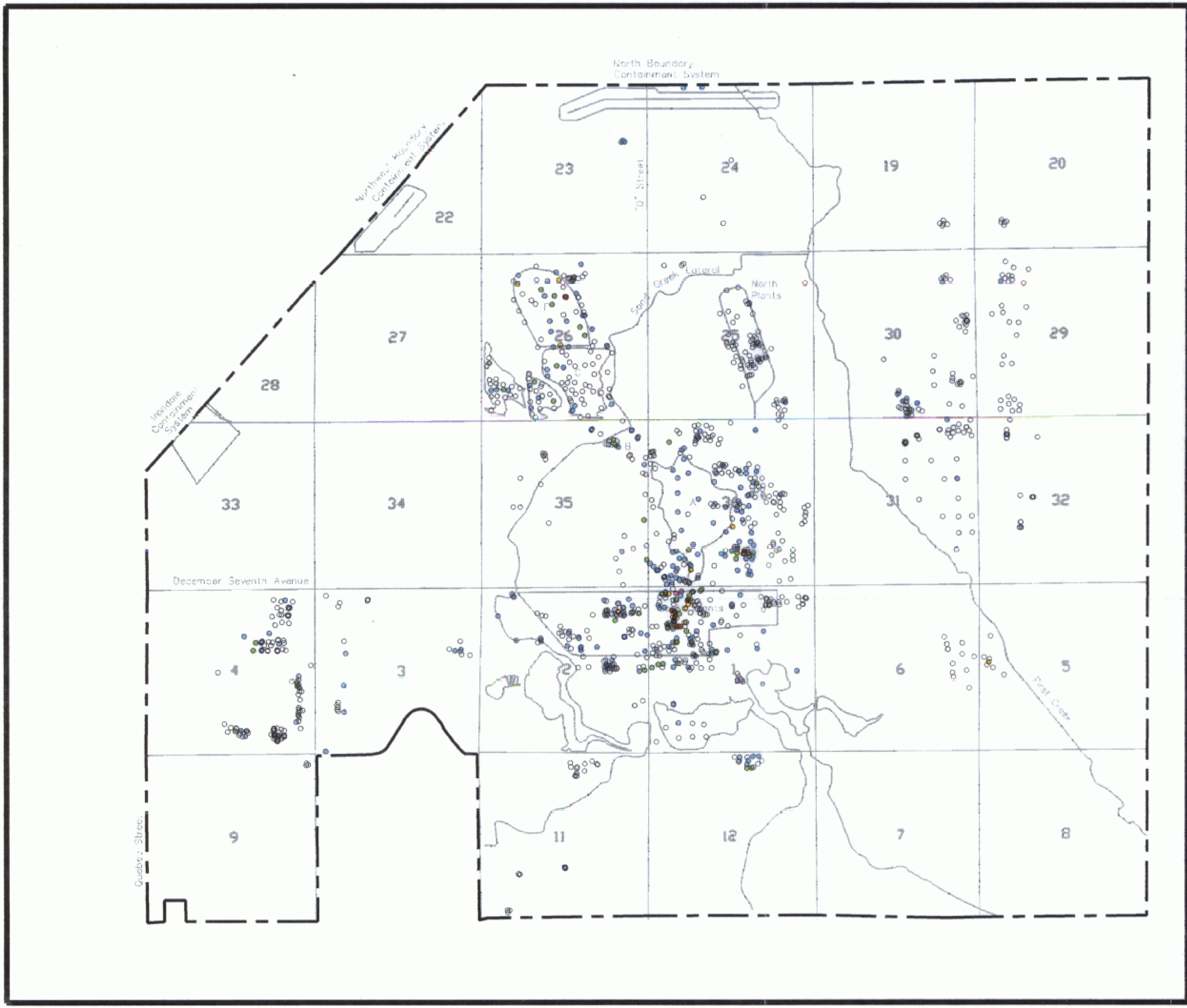
N

0 3000 Feet
Scale: 1" = 3000'

Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal
Prepared: August 1991

FIGURE RISR A3.1-17
Distribution of
Total Inorganic Analytes in Soils
in the 2 to 5 ft Depth Interval

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend:

- Rocky Mountain Arsenal Boundary
- Section Lines
- Streams
- Lakes
- Basins

Concentration Ranges

- 🟫 > 10,000 ug/g
- 🟪 > 1000 to 10,000 ug/g
- 🟨 > 100 to 1000 ug/g
- 🟩 > 10 to 100 ug/g
- 🟦 CRL to 10 ug/g
- ○ BCRL

N

0 3000 Feet

Scale: 1" = 3000'

Prepared for:

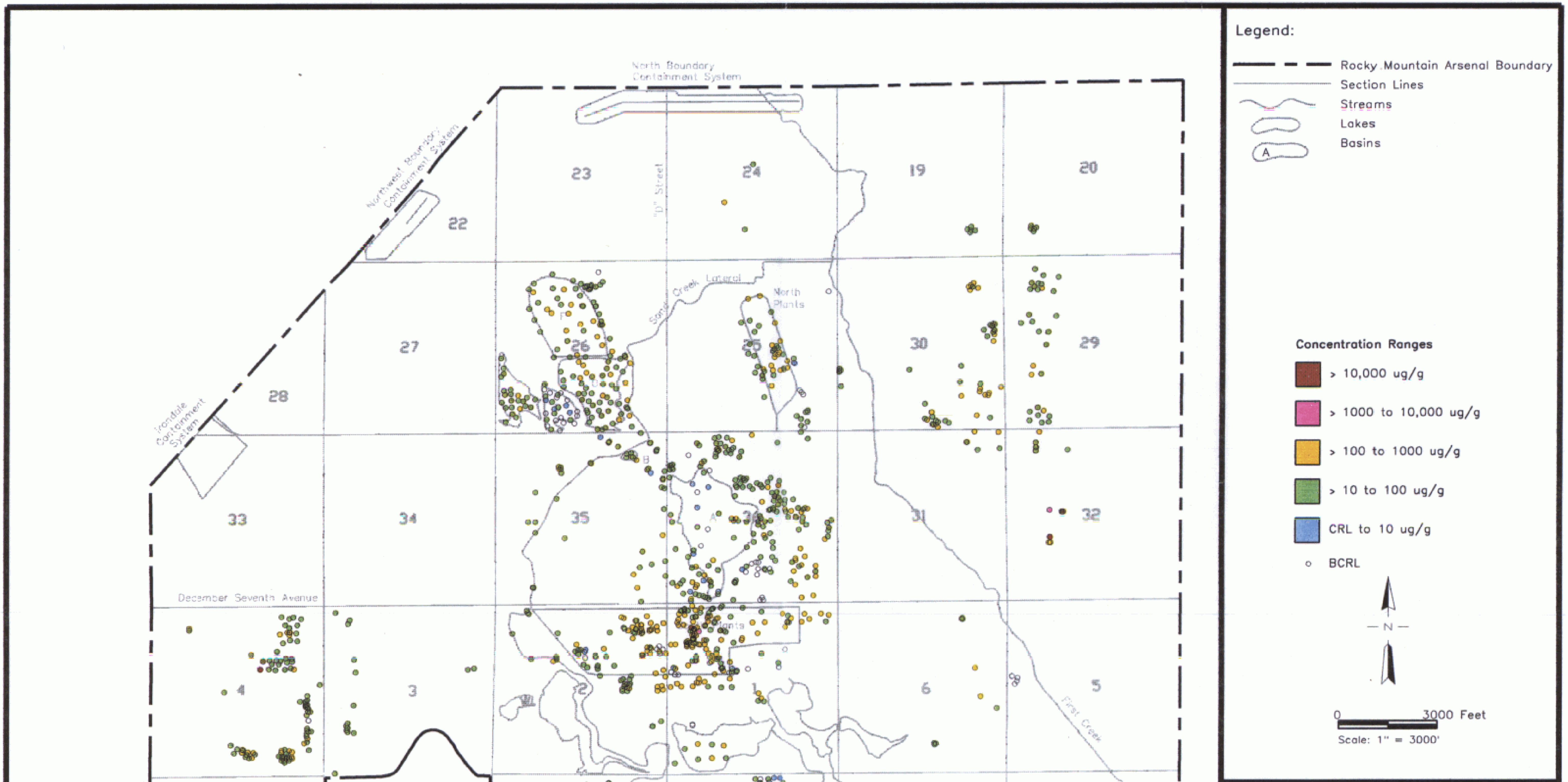
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared: August 1991

FIGURE RISR A3.1–18

Distribution of
Total Organic Analytes in Soils
in the 5 to 20 ft Depth Interval

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Prepared for:

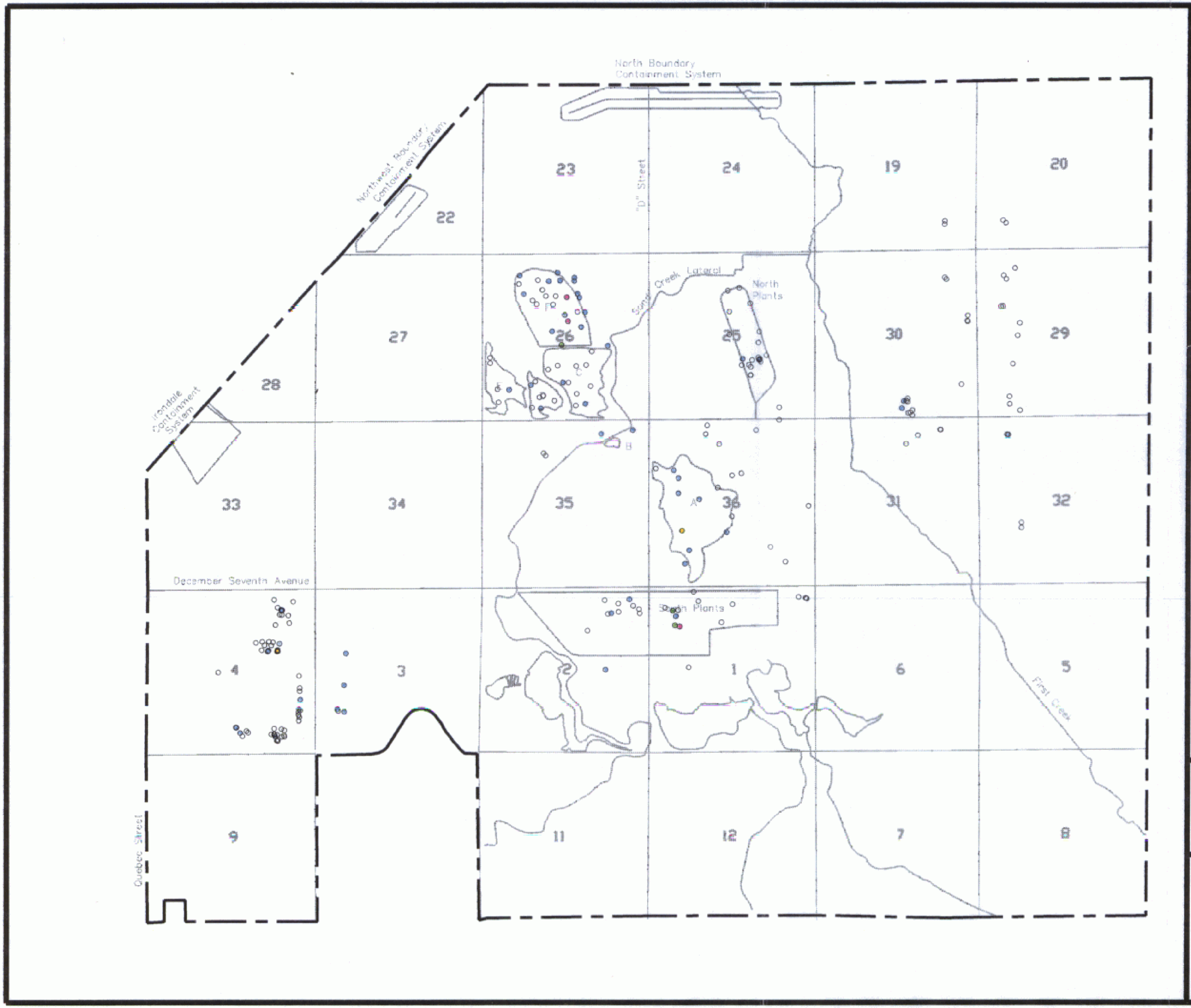
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared: August 1991

FIGURE RISR A3.1–19

Distribution of
Total Inorganic Analytes in Soils
in the 5 to 20 ft Depth Interval

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Prepared for:

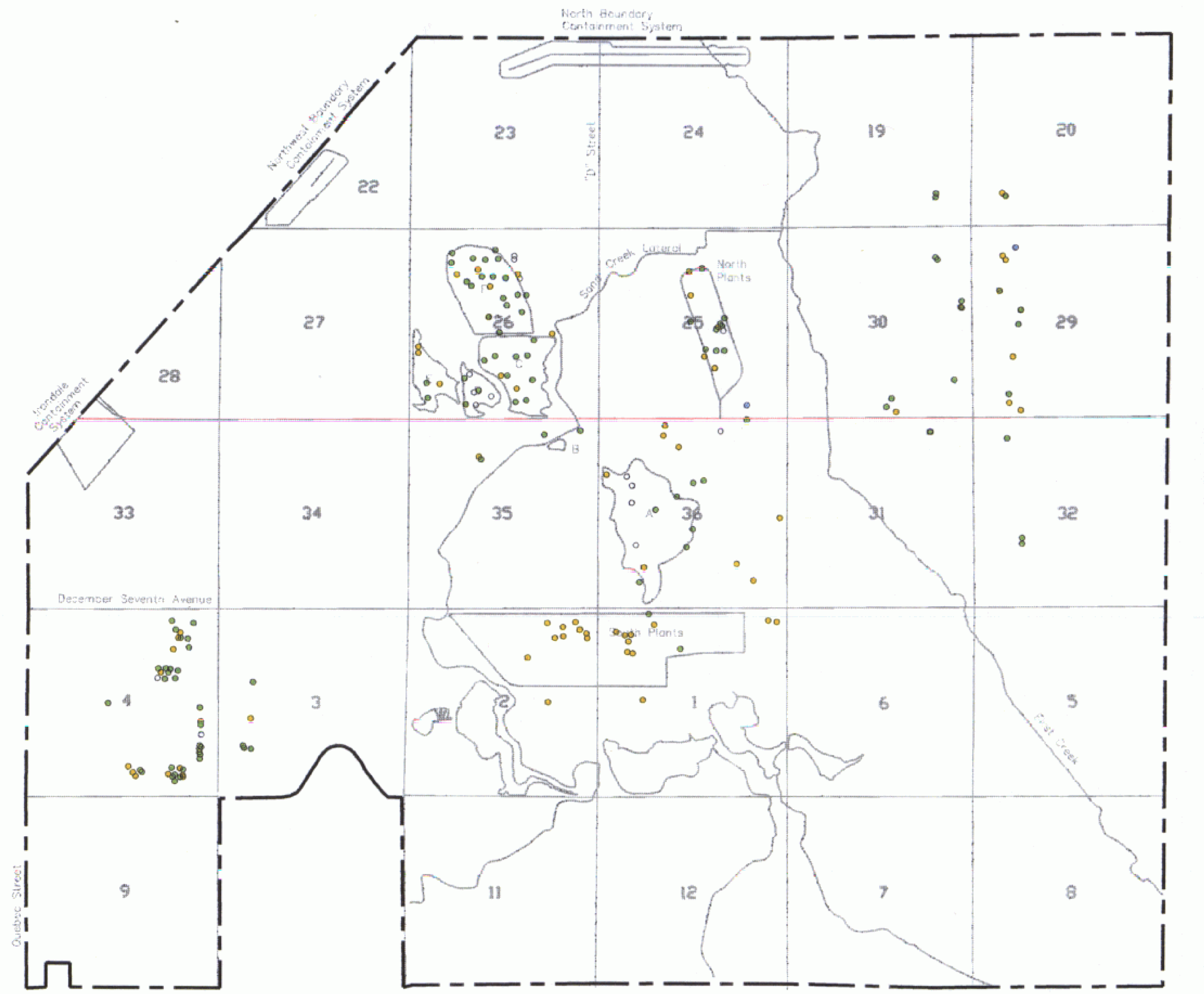
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared: August 1991

FIGURE RISR A3.1-20

Distribution of
Total Organic Analytes in Soils
Greater than 20 ft

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend:

Concentration Ranges

🟫	> 10,000 ug/g
🟪	> 1000 to 10,000 ug/g
🟨	> 100 to 1000 ug/g
🟩	> 10 to 100 ug/g
🟦	CRL to 10 ug/g
o	BCRL

Scale: 1" = 3000'

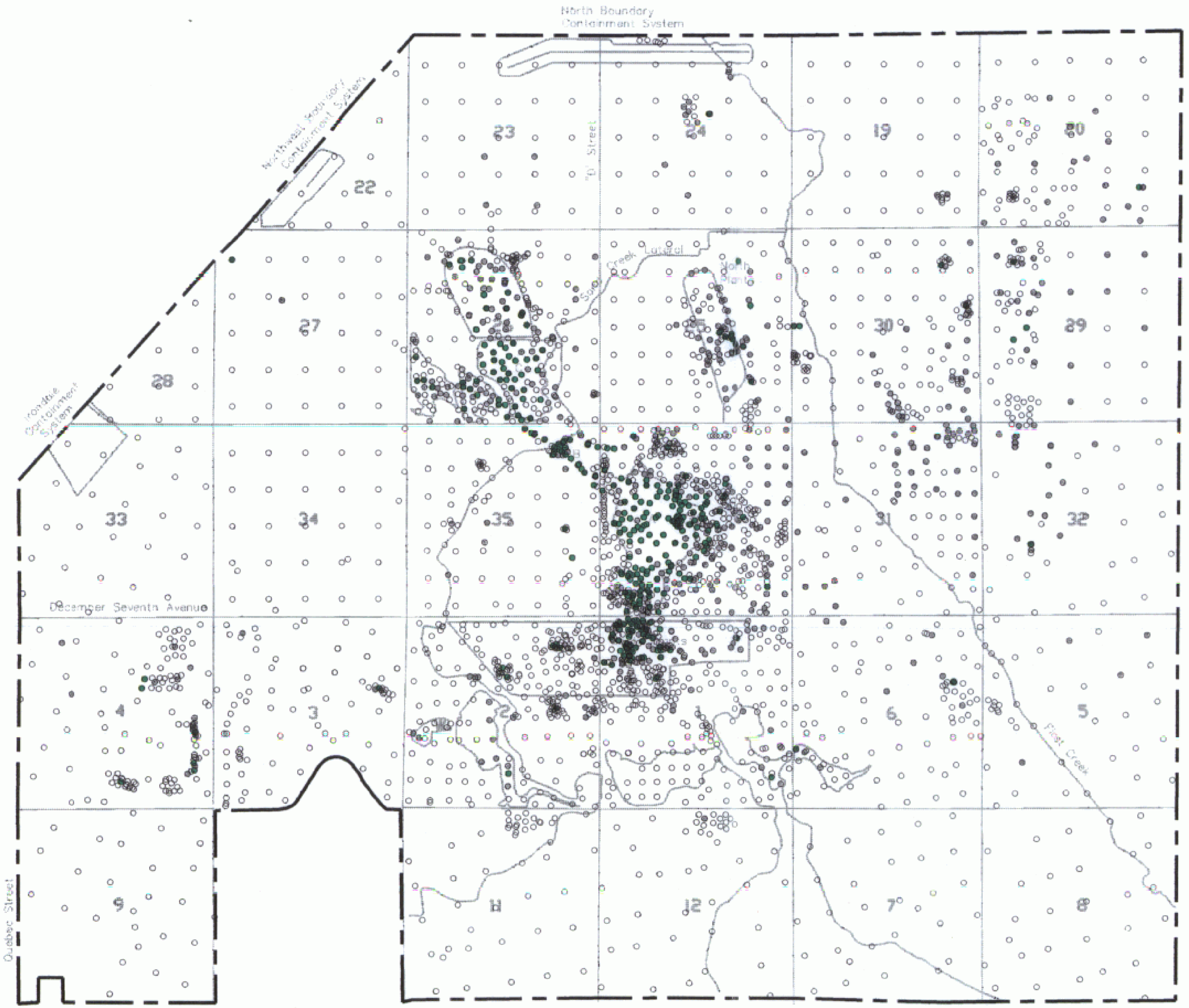
Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared: August 1991

FIGURE RISR A3.1–21

Distribution of
Total Inorganic Analytes in Soils
Greater than 20 ft

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend:

Rocky Mountain Arsenal Boundary

Section Lines

Streams

Lakes

Basins

Indicator Range (ug/g)

Arsenic CRL – 10

🟩 > Indicator Range

▨ Within Indicator Range

○ BCRL

N

0 3000 Feet

Scale: 1" = 3000'

Prepared for:

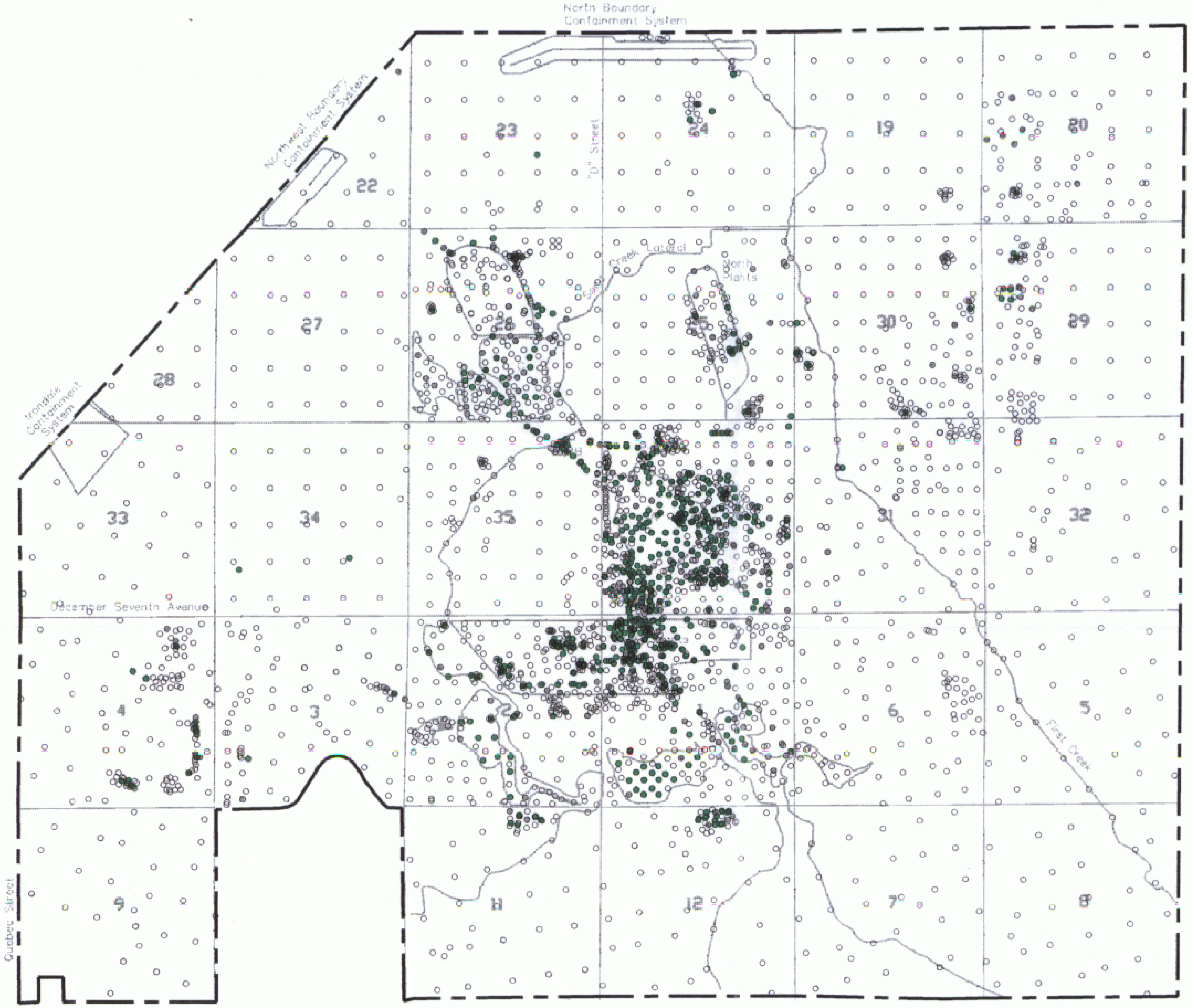
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared: August 1991

FIGURE RISR A3.1–22

Distribution of Arsenic
Greater than the Indicator Range
in Soils

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend:

Rocky Mountain Arsenal Boundary
Section Lines
Streams
Lakes
Basins

Indicator Range (ug/g)

Mercury CRL – 0.10

🟩 > Indicator Range

▨ Within Indicator Range

○ BCRL

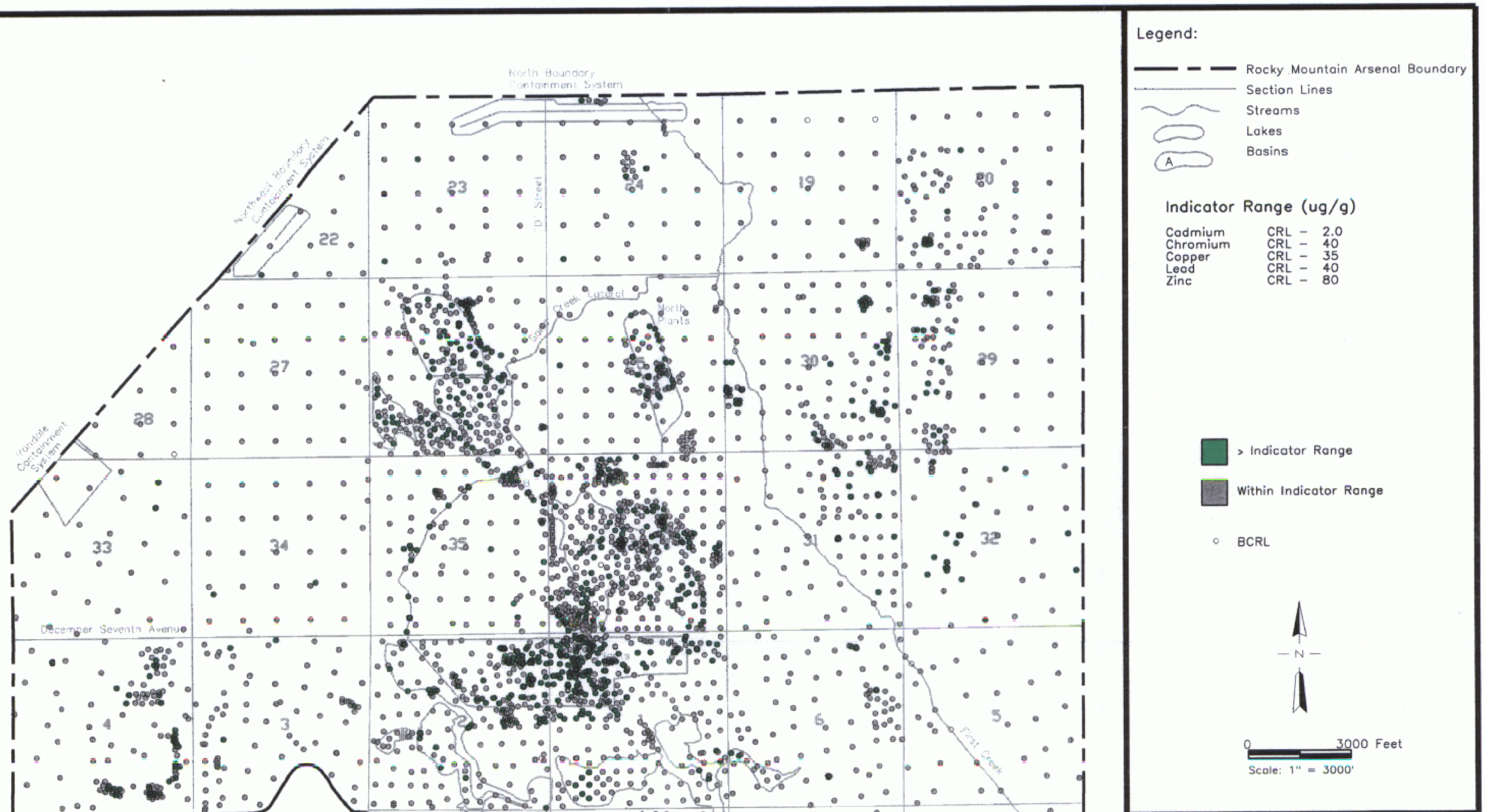
N

0 3000 Feet
Scale: 1" = 3000'

Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal
Prepared: August 1991

FIGURE RISR A3.1–23
Distribution of Mercury
Greater than the Indicator Range
in Soils

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

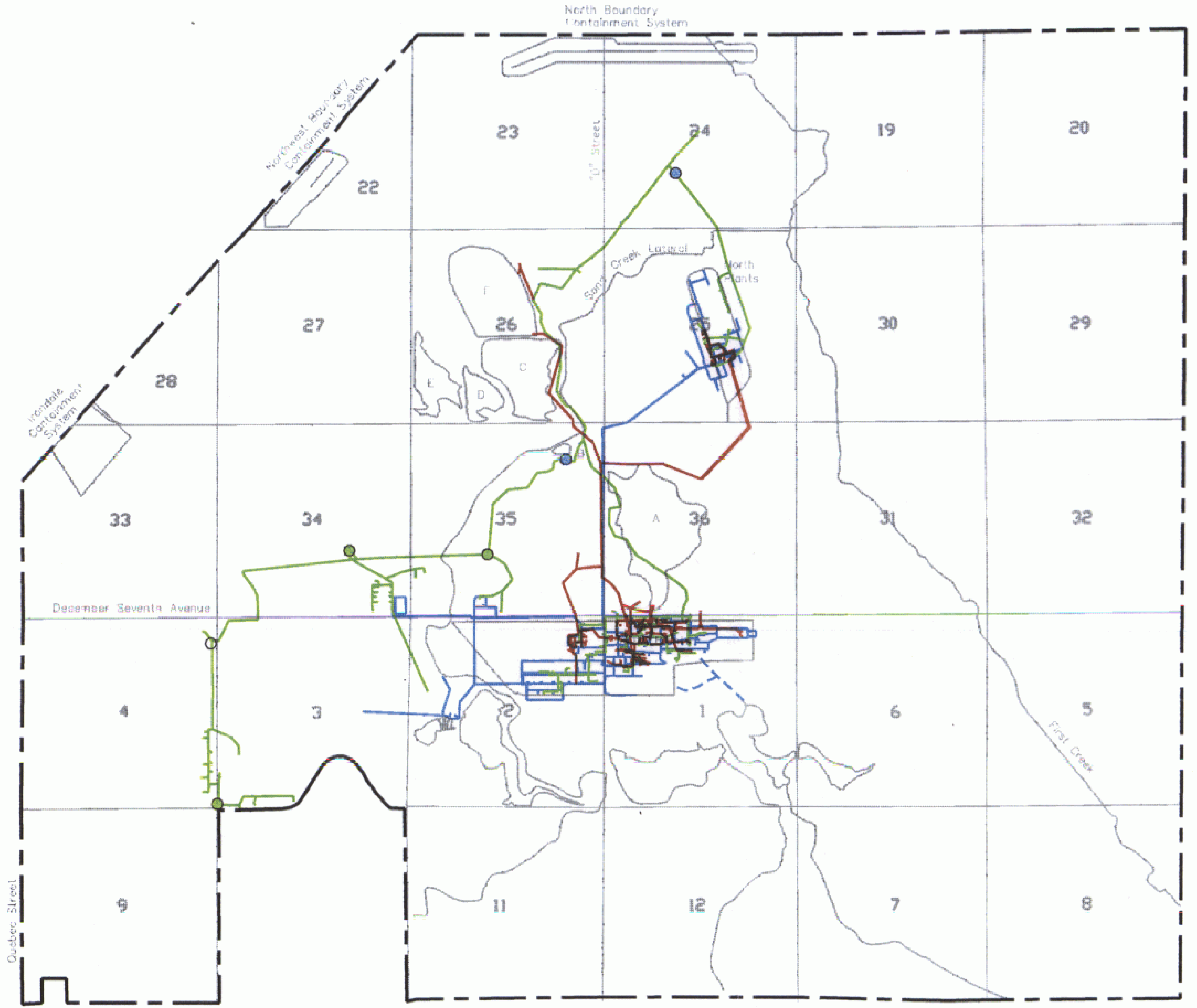


Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared: August 1991

FIGURE RISR A3.1-24
Distribution of ICP Metals
Greater than the Indicator Range
in Soils

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend:

- Rocky Mountain Arsenal Boundary
- Section Lines
- Streams
- Lakes
- Basins

Sewer Locations

- Chemical
- Sanitary
- Process Water
- Ditch

Detected Concentrations at Sampling Location

- ● > 10000 ug/g
- ● > 1000 – 10000 ug/g
- ● > 100 – 1000 ug/g
- ● > 10 – 100 ug/g
- ● CRL to 10 ug/g
- ○ BCRL

N

0 3000 Feet

Scale: 1" = 3000'

Prepared for:

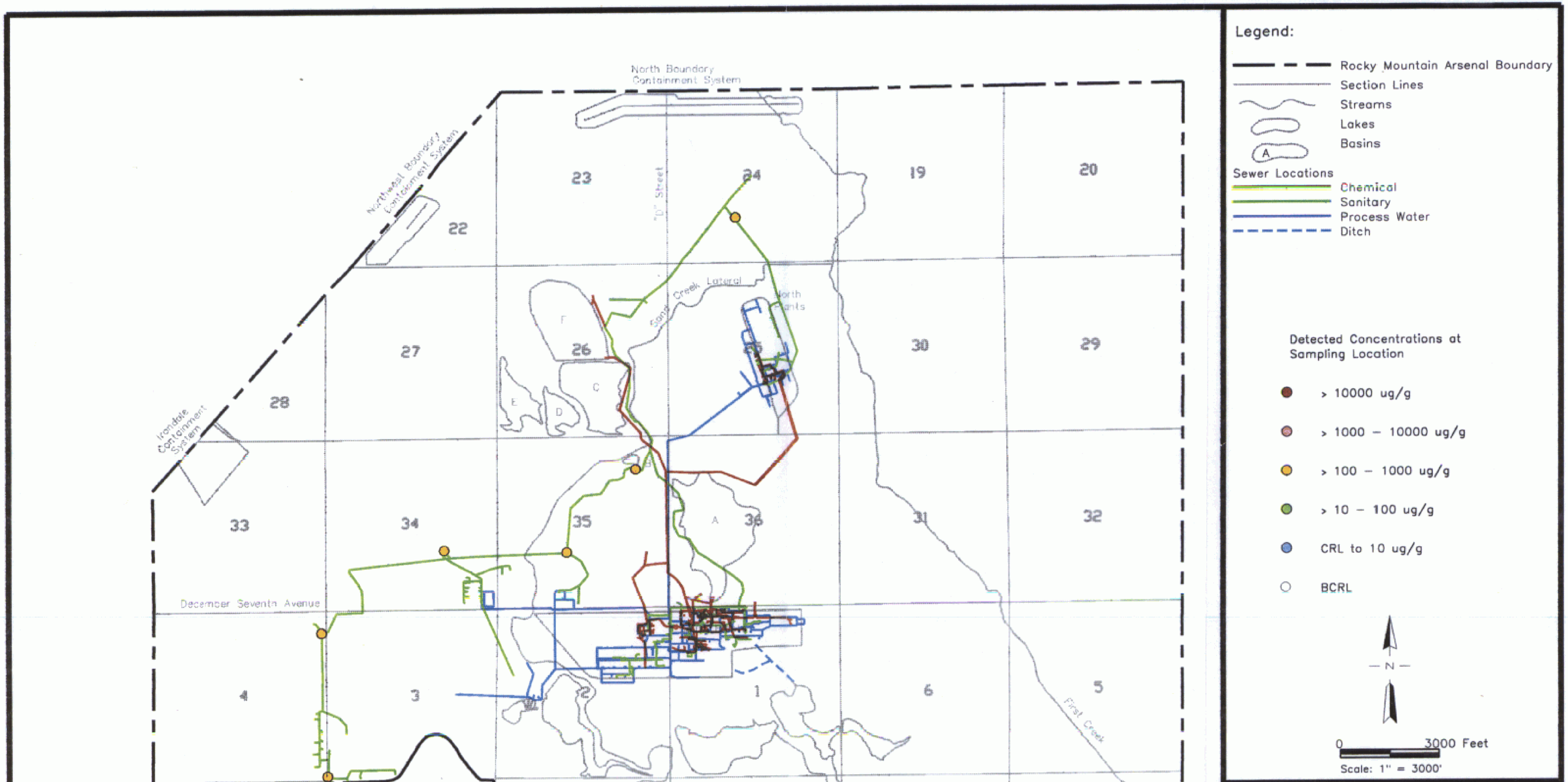
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A3.1–25

Results for Total Organic Analytes in Sediments from Sewers and Process Water Systems

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



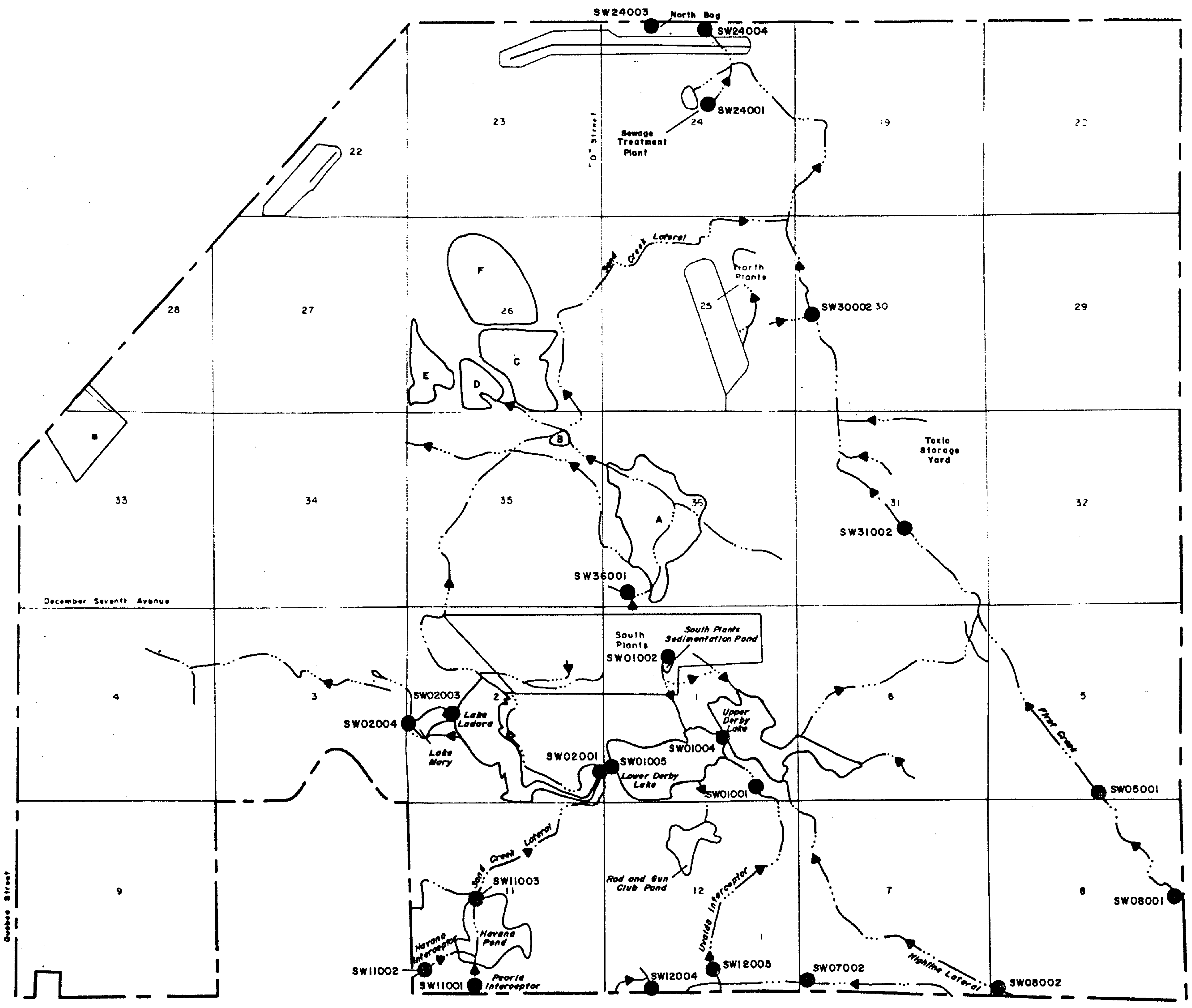
Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A3.1–26
Results for Total Inorganic Analytes
in Sediments from Sewers and Process
Water Systems

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Prepared for:

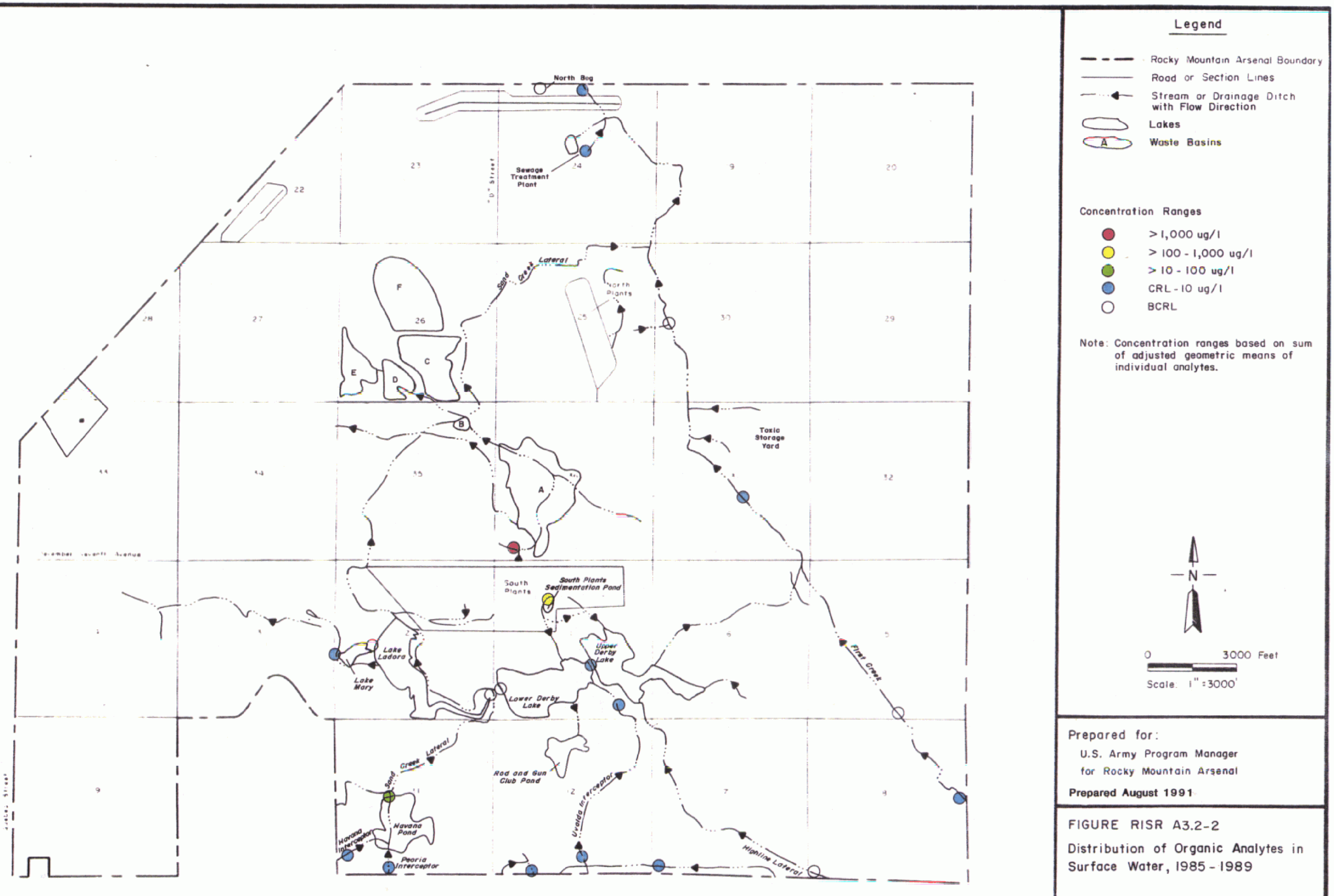
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A3.2-1

Surface Water Sampling Locations, 1985-1989

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



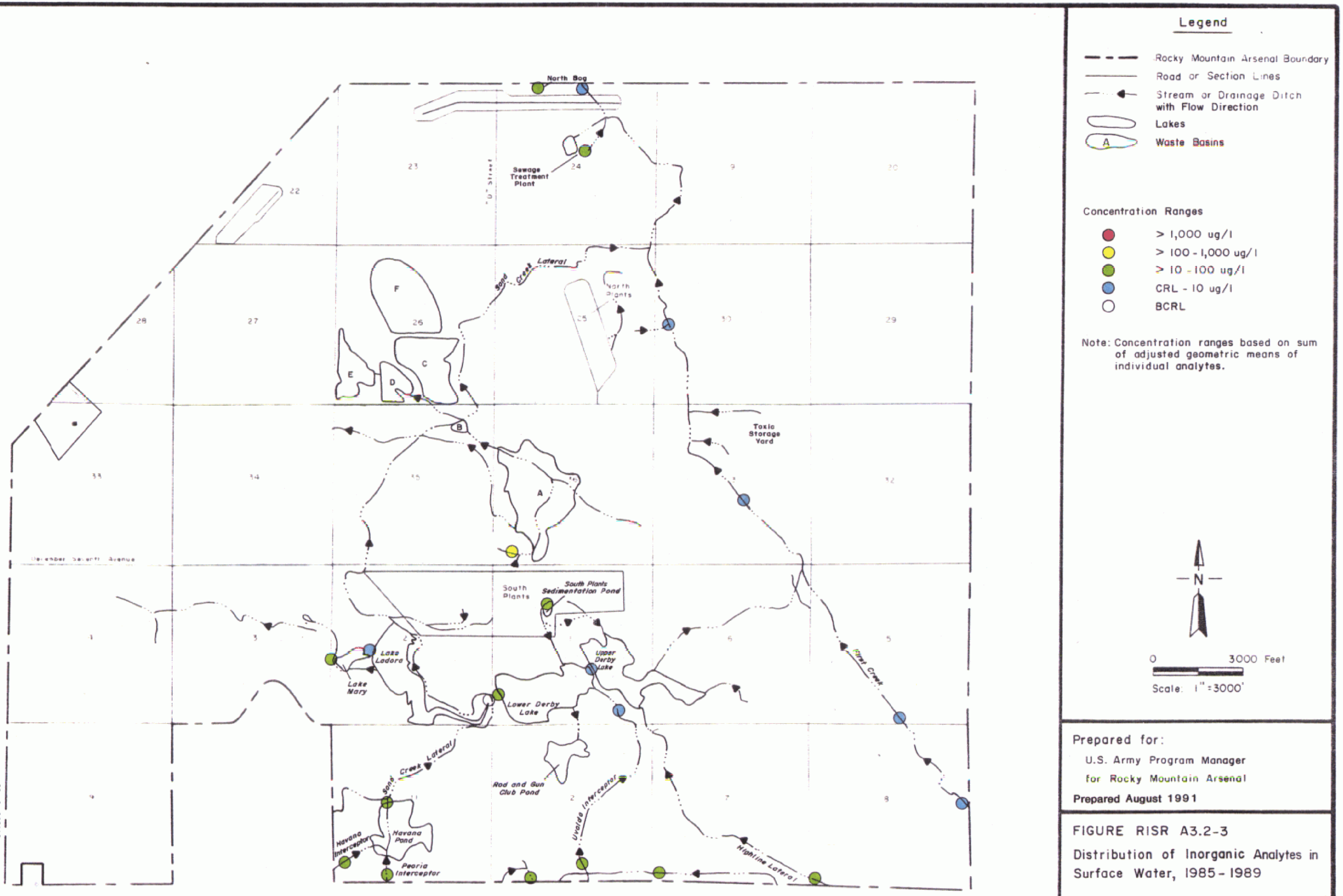
Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A3.2-2

Distribution of Organic Analytes in Surface Water, 1985 - 1989

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend

Rocky Mountain Arsenal Boundary

Road or Section Lines

Stream or Drainage Ditch with Flow Direction

Lakes

Waste Basins

Concentration Ranges

- 🔴 > 1,000 ug/l
- 🟡 > 100 - 1,000 ug/l
- 🟢 > 10 - 100 ug/l
- 🔵 CRL - 10 ug/l
- ○ BCRL

Note: Concentration ranges based on sum of adjusted geometric means of individual analytes.

Prepared for:

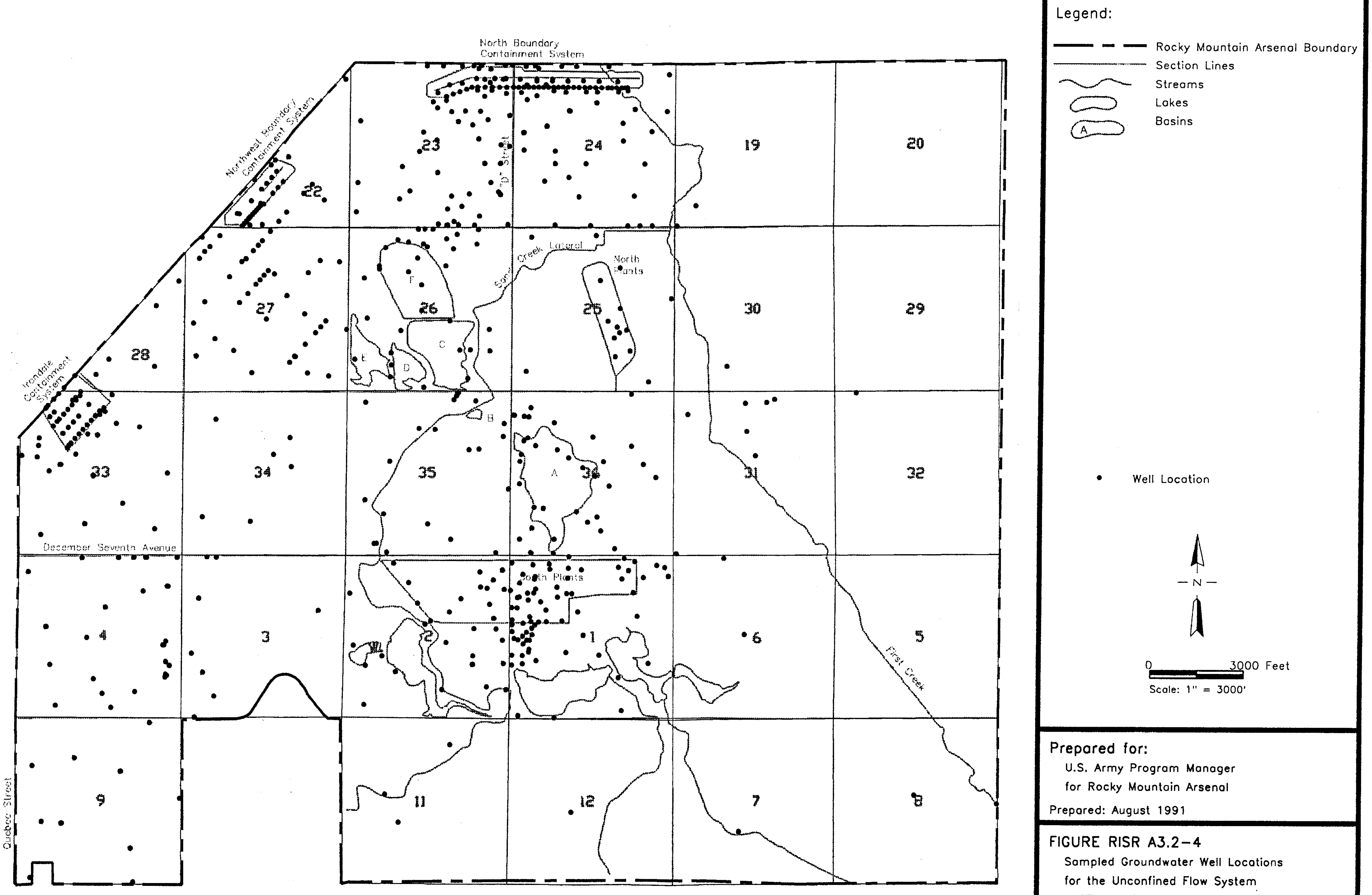
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A3.2-3

Distribution of Inorganic Analytes in Surface Water, 1985-1989

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

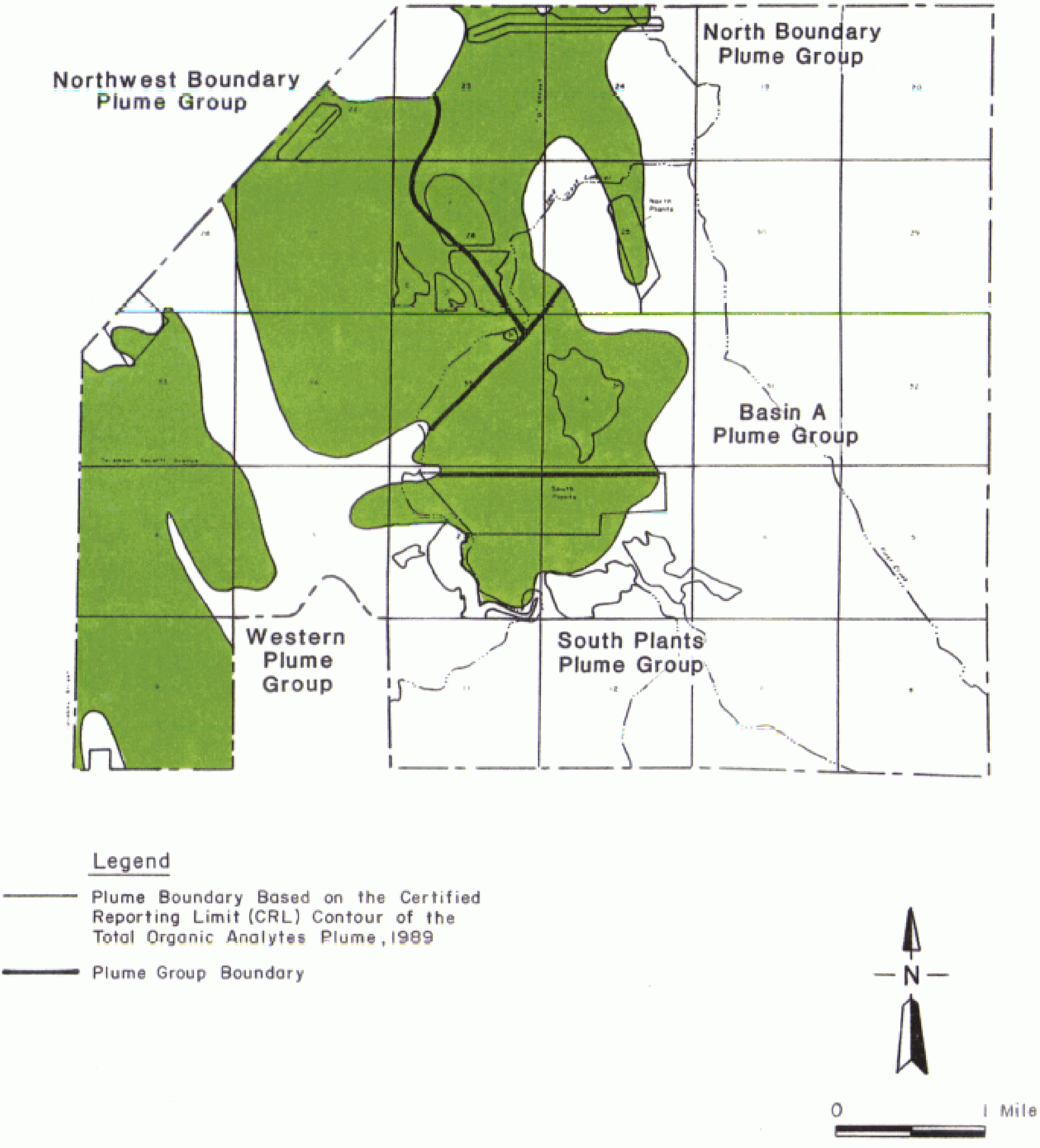


Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared: August 1991

FIGURE RISR A3.2-4
Sampled Groundwater Well Locations
for the Unconfined Flow System
1987 – 1989

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

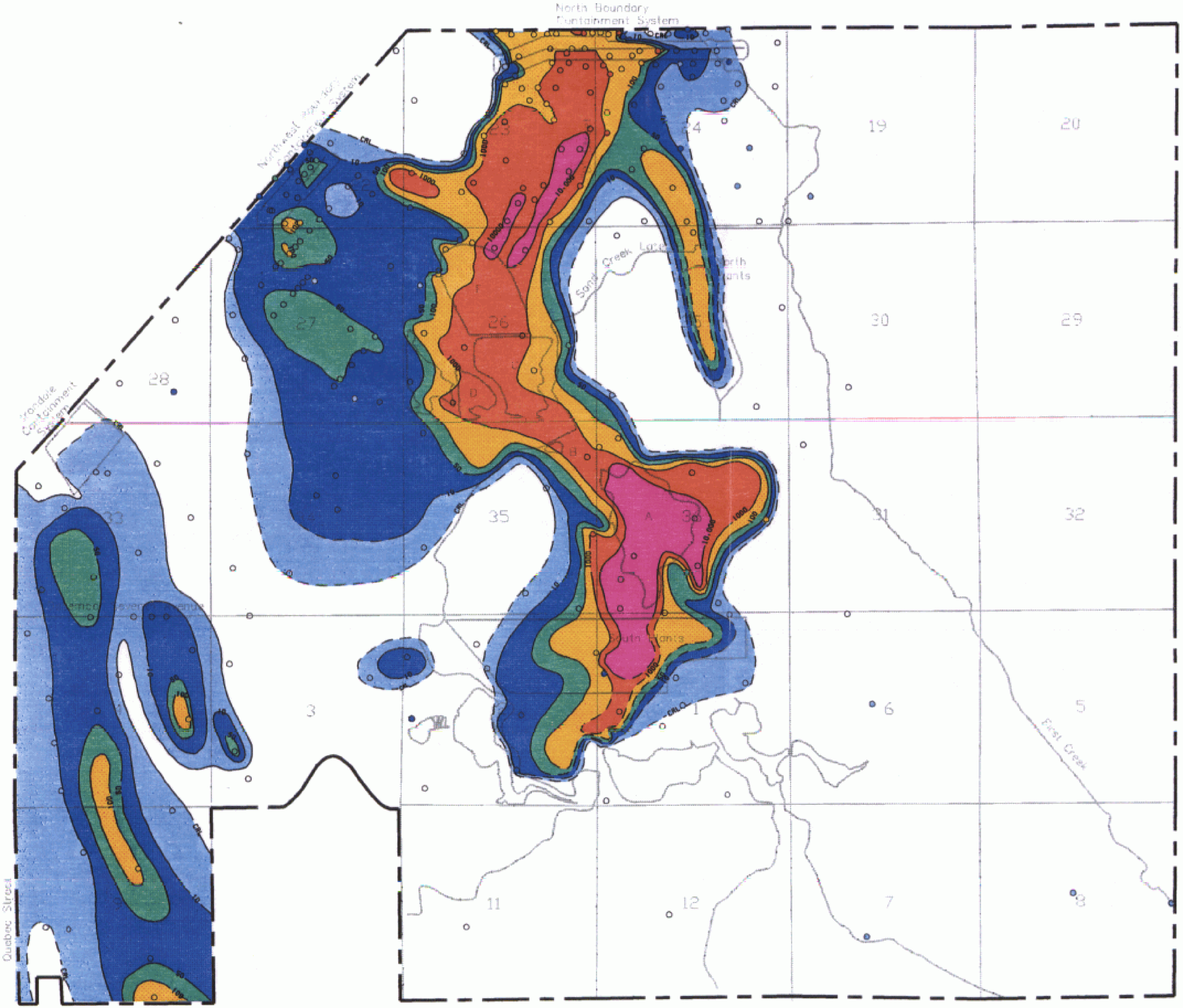
Prepared August 1991

FIGURE RISR A3.2-5

Regional Subdivisions of the Total Organic Analytes Plume - Unconfined Flow System

Rocky Mountain Arsenal

Prepared by: Ebasco Services Incorporated



Legend:

Rocky Mountain Arsenal Boundary
Section Lines
Streams
Lakes
Basins

Contour, dashed where inferred

Contour Intervals CRL; 10; 50; 100;
1000; 10,000 ug/l

Concentration Ranges

🟪 > 10,000 ug/l
🟥 > 1000 to 10,000 ug/l
🟧 > 100 to 1000 ug/l
🟩 > 50 to 100 ug/l
🟦 > 10 to 50 ug/l
🟦 CRL to 10 ug/l
○ BCRL

Note: Because certified reporting limits (CRLs) vary among analytes and analytical methods, there is no single value represented by the CRL contour.

N

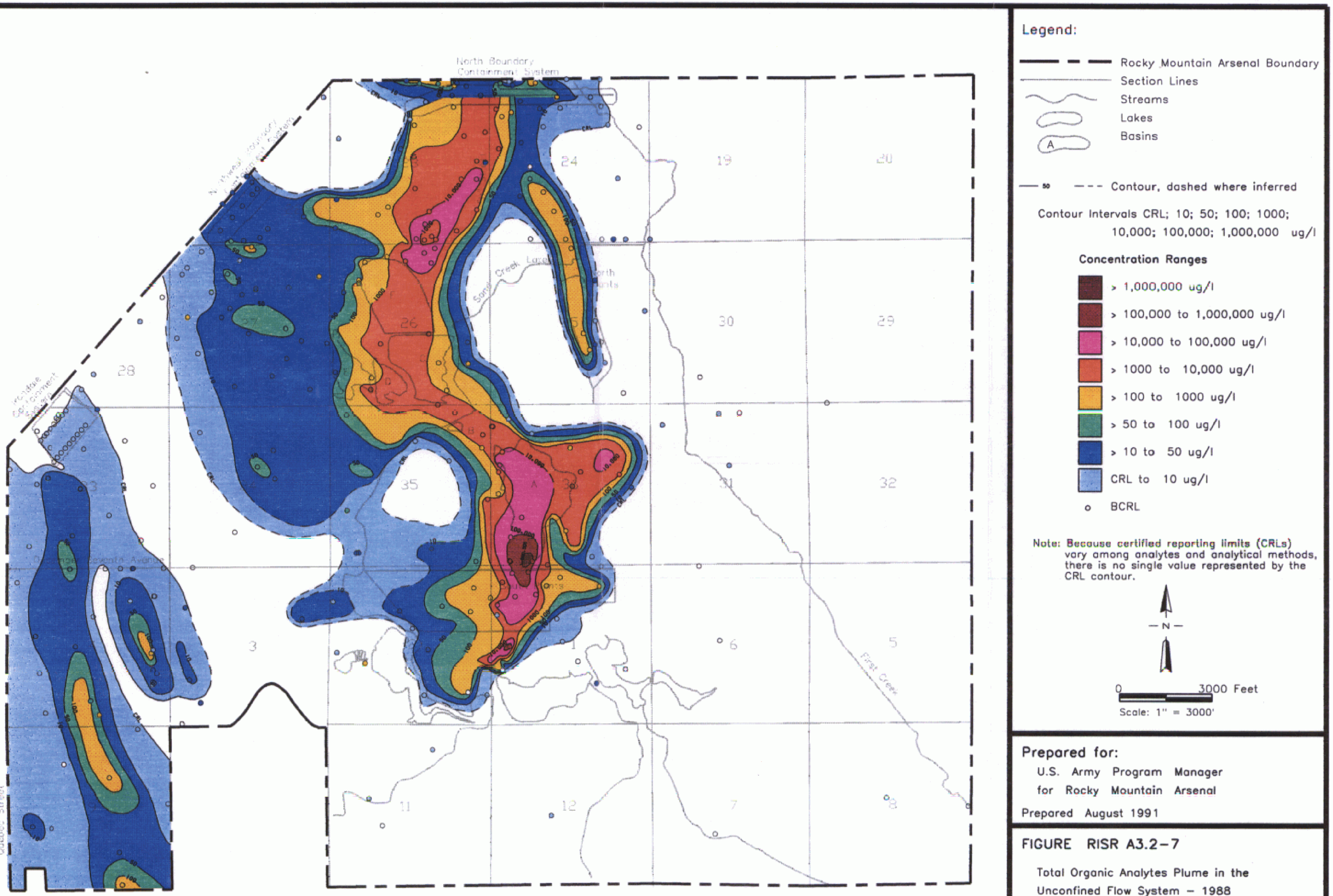
0 3000 Feet
Scale: 1" = 3000'

Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal
Prepared August 1991

FIGURE RISR A3.2-6

Total Organic Analytes Plume in the
Unconfined Flow System – 1987

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



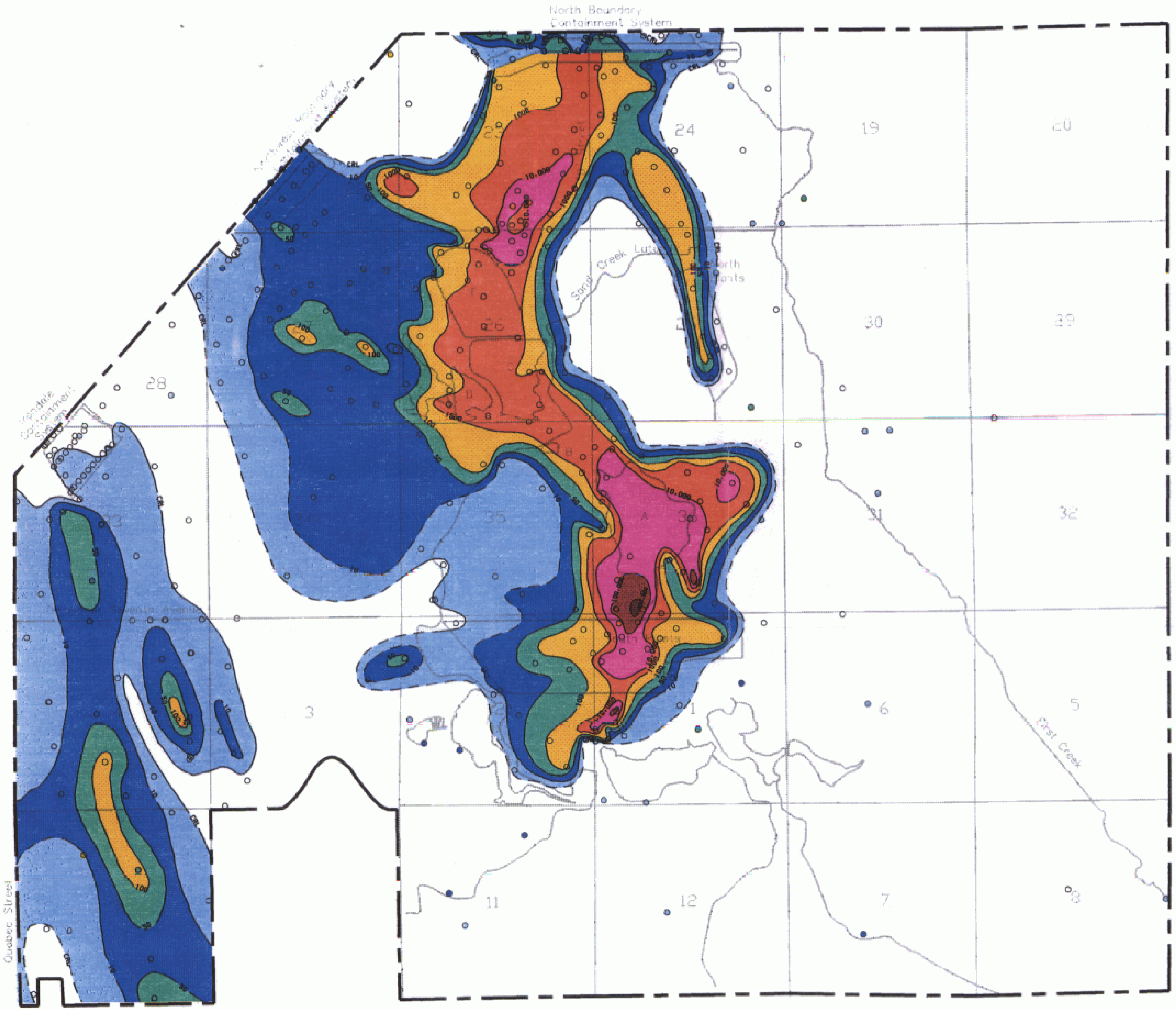
Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A3.2-7

Total Organic Analytes Plume in the
Unconfined Flow System – 1988

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend:

— — — Rocky Mountain Arsenal Boundary

Section Lines

Streams

Lakes

Basins

—50 - - - Contour, dashed where inferred

Contour Intervals CRL; 10; 50; 100;
1000; 10,000; 100,000 ug/l

Concentration Ranges

- 🟫 > 1,000,000 ug/l
- 🟫 > 100,000 to 1,000,000 ug/l
- 🟪 > 10,000 to 100,000 ug/l
- 🟥 > 1000 to 10,000 ug/l
- 🟧 > 100 to 1000 ug/l
- 🟩 > 50 to 100 ug/l
- 🟦 > 10 to 50 ug/l
- 🟦 CRL to 10 ug/l
- ○ BCRL

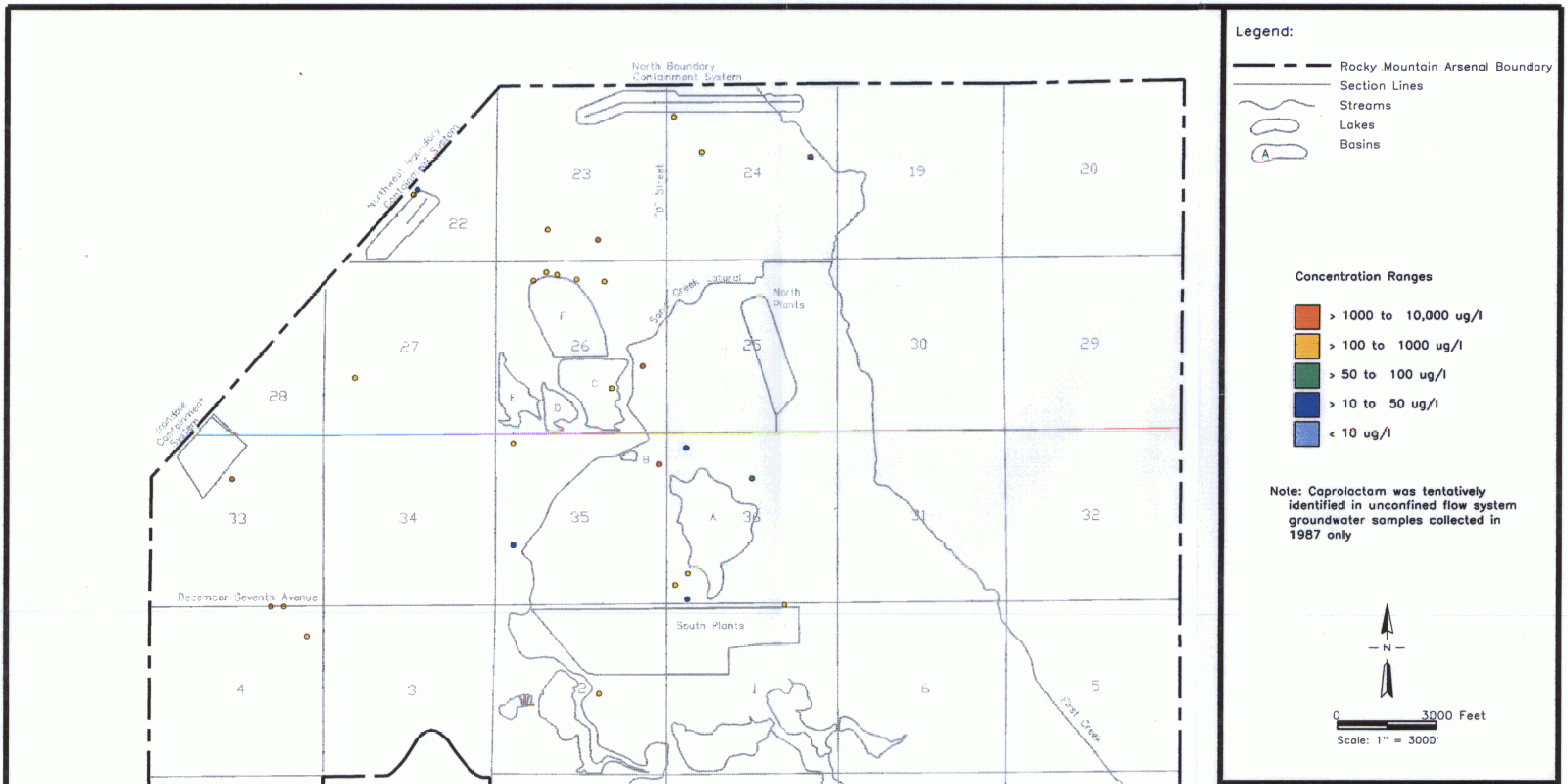
Note: Because certified reporting limits (CRLs) vary among analytes and analytical methods, there is no single value represented by the CRL contour.

Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal
Prepared August 1991

FIGURE RISR A3.2-8

Total Organic Analytes in the
Unconfined Flow System - 1989

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

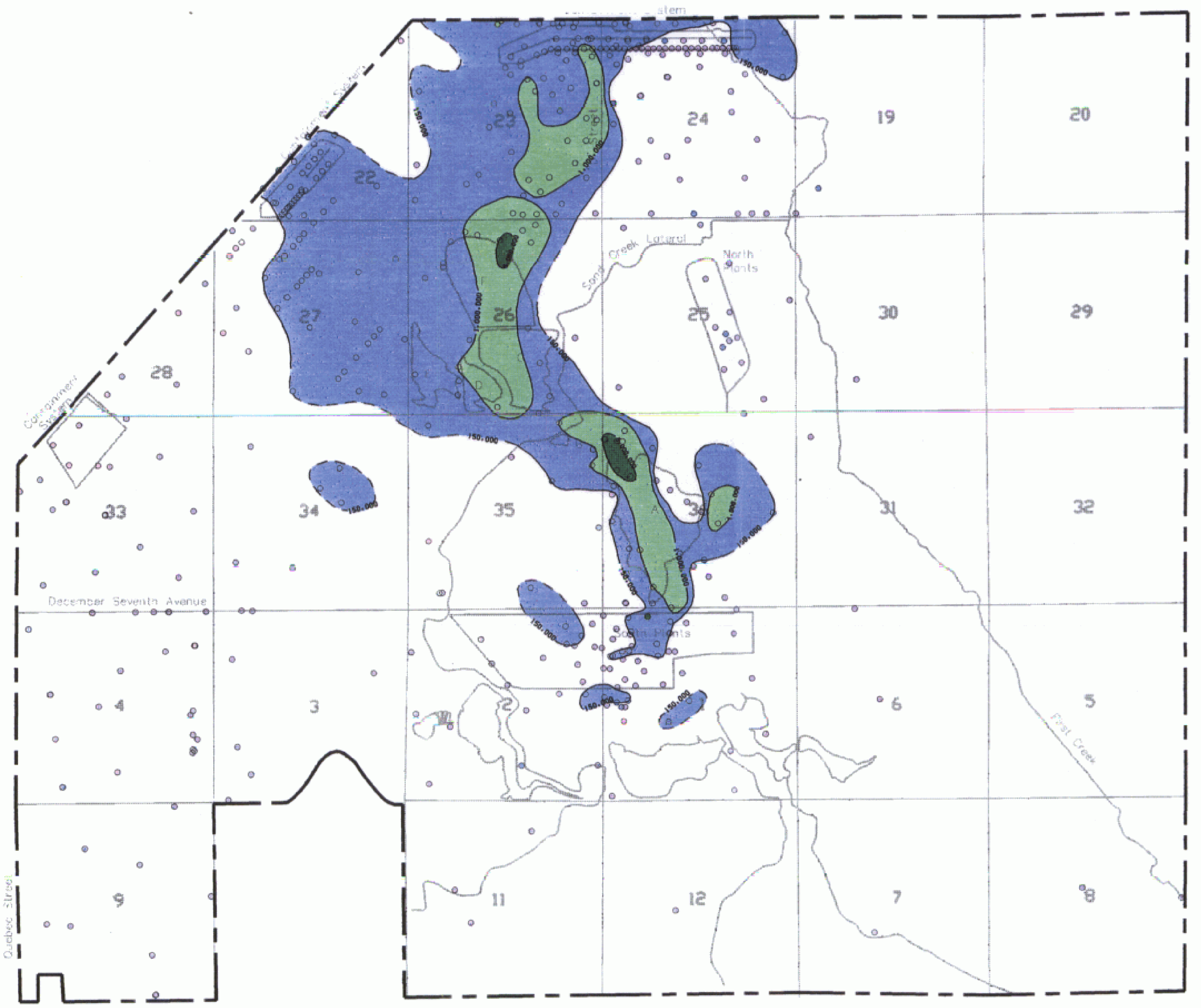


Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal
Prepared August 1991

FIGURE RISR A3.2-9

Locations of Caprolactam Detections
in the Unconfined Flow System, 1987

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend:

Rocky Mountain Arsenal Boundary

Section Lines

Streams

Lakes

Basins

150,000 Contour, dashed where inferred

Contour Intervals 150,000 ; 1,000,000 ;
5,000,000 ug/l

Concentration Ranges

■	> 5,000,000 ug/l
🟩	> 1,000,000 to 5,000,000 ug/l
🟦	> 150,000 to 1,000,000 ug/l
🟪	CRL to 150,000 ug/l
○	BCRL

Note: Concentration ranges based on
adjusted geometric means
for individual analyte.

N

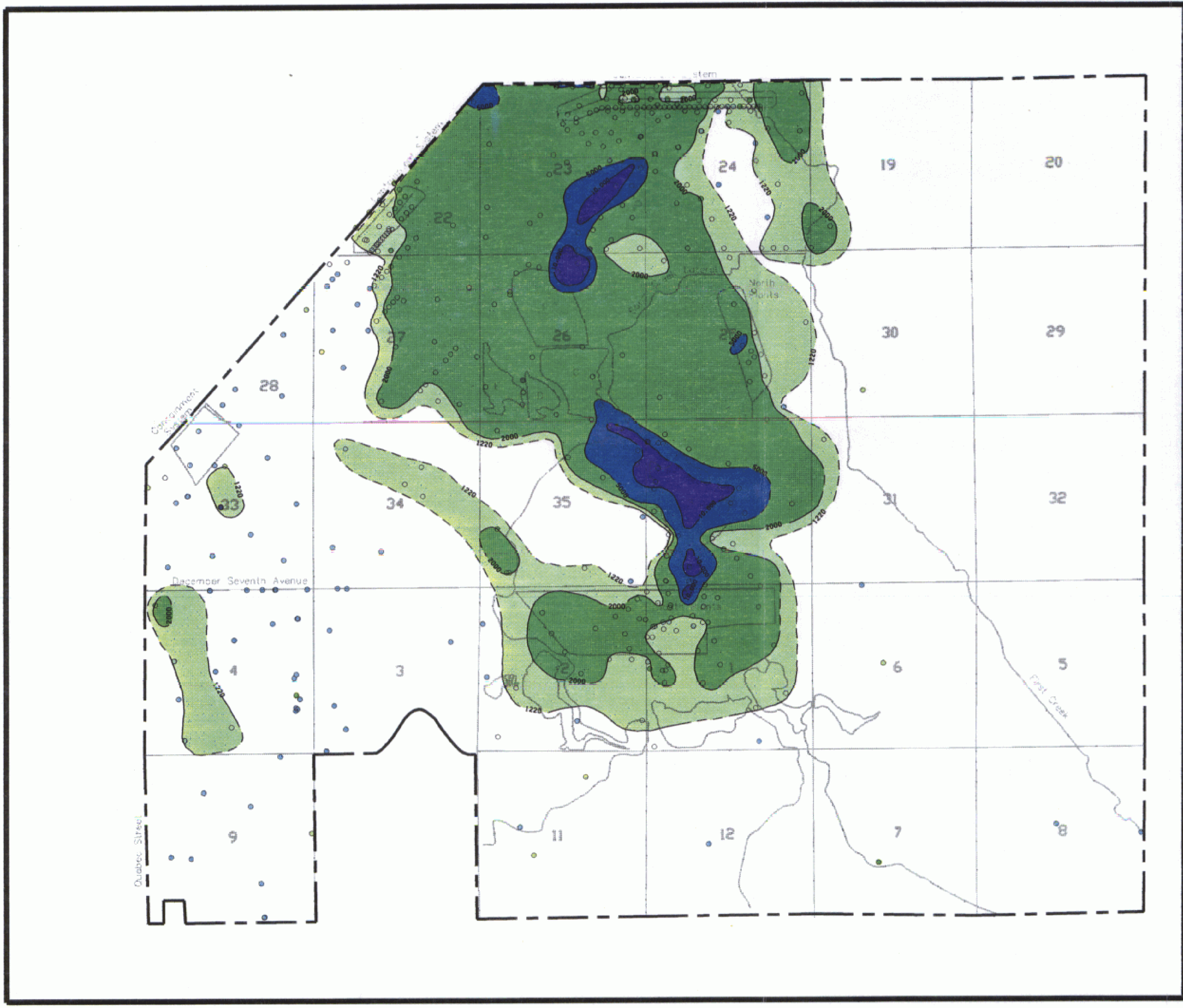
0 3000 Feet
Scale: 1" = 3000'

Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal
Prepared August 1991

FIGURE RISR A3.2-10

Chloride Plume in the Unconfined
Flow System, 1987-1989

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend:

Rocky Mountain Arsenal Boundary
Section Lines
Streams
Lakes
Basins

1220 Contour, dashed where inferred

Contour Intervals 1220; 2000; 5000; 10,000 ug/l

Concentration Ranges

- 🟪 > 10,000 ug/l
- 🟦 > 5000 to 10,000 ug/l
- 🟩 > 2000 to 5000 ug/l
- 🟩 > 1220 to 2000 ug/l
- 🟦 CRL to 1220 ug/l
- ○ BCRL

Note: Concentration ranges based on adjusted geometric means for individual analyte.

N

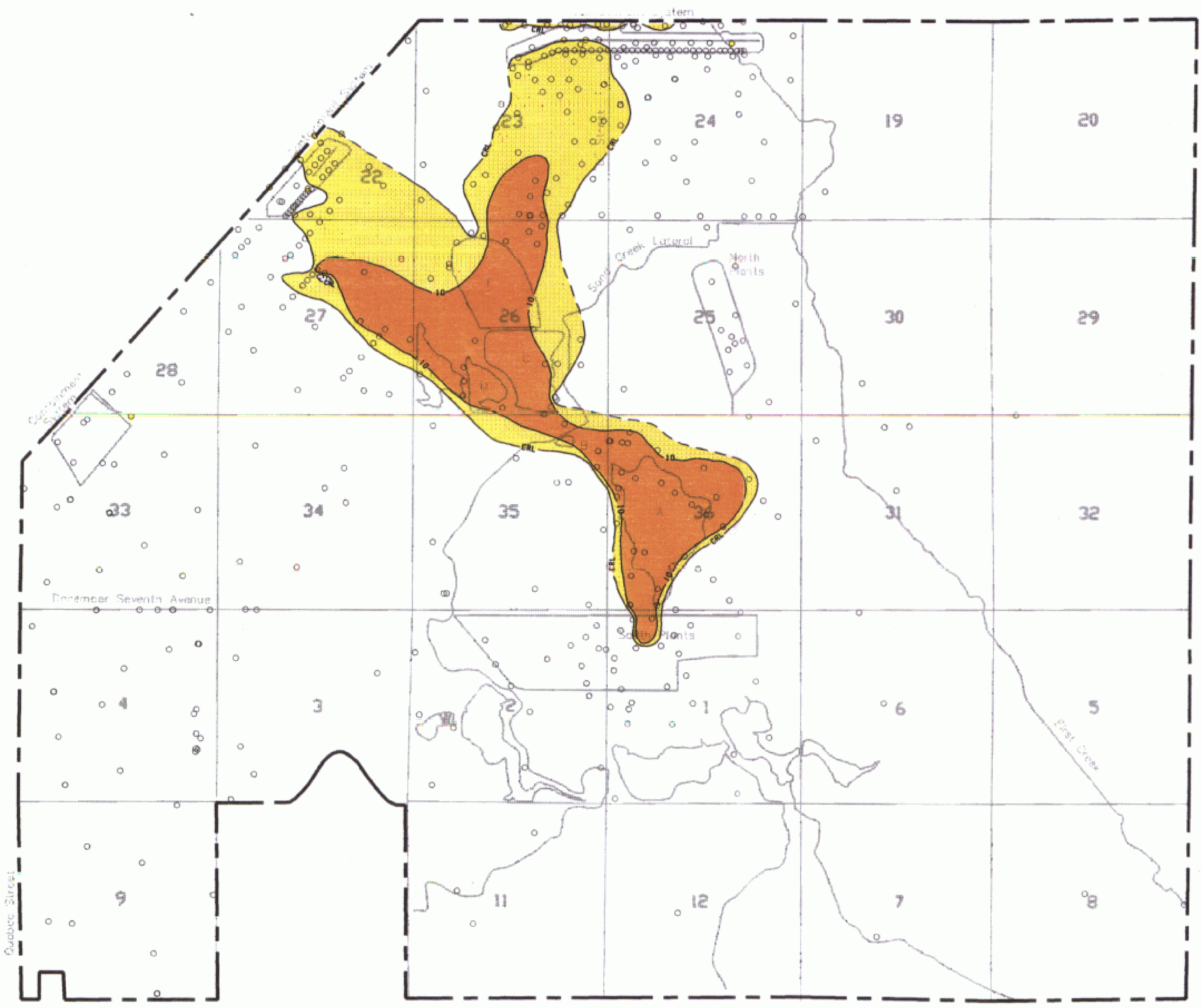
0 3000 Feet
Scale: 1" = 3000'

Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal
Prepared August 1991

FIGURE RISR A3.2–11

Fluoride Plume in the Unconfined
Flow System, 1987–1989

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend:

Rocky Mountain Arsenal Boundary
Section Lines
Streams
Lakes
Basins

10 Contour, dashed where inferred

Contour Intervals CRL, 10 ug/l

Concentration Ranges

🟧	> 10 ug/l
🟨	CRL to 10 ug/l
○	BCRL

Note: Concentration ranges based on adjusted geometric means for individual analyte.

N

0 3000 Feet

Scale: 1" = 3000'

Prepared for:

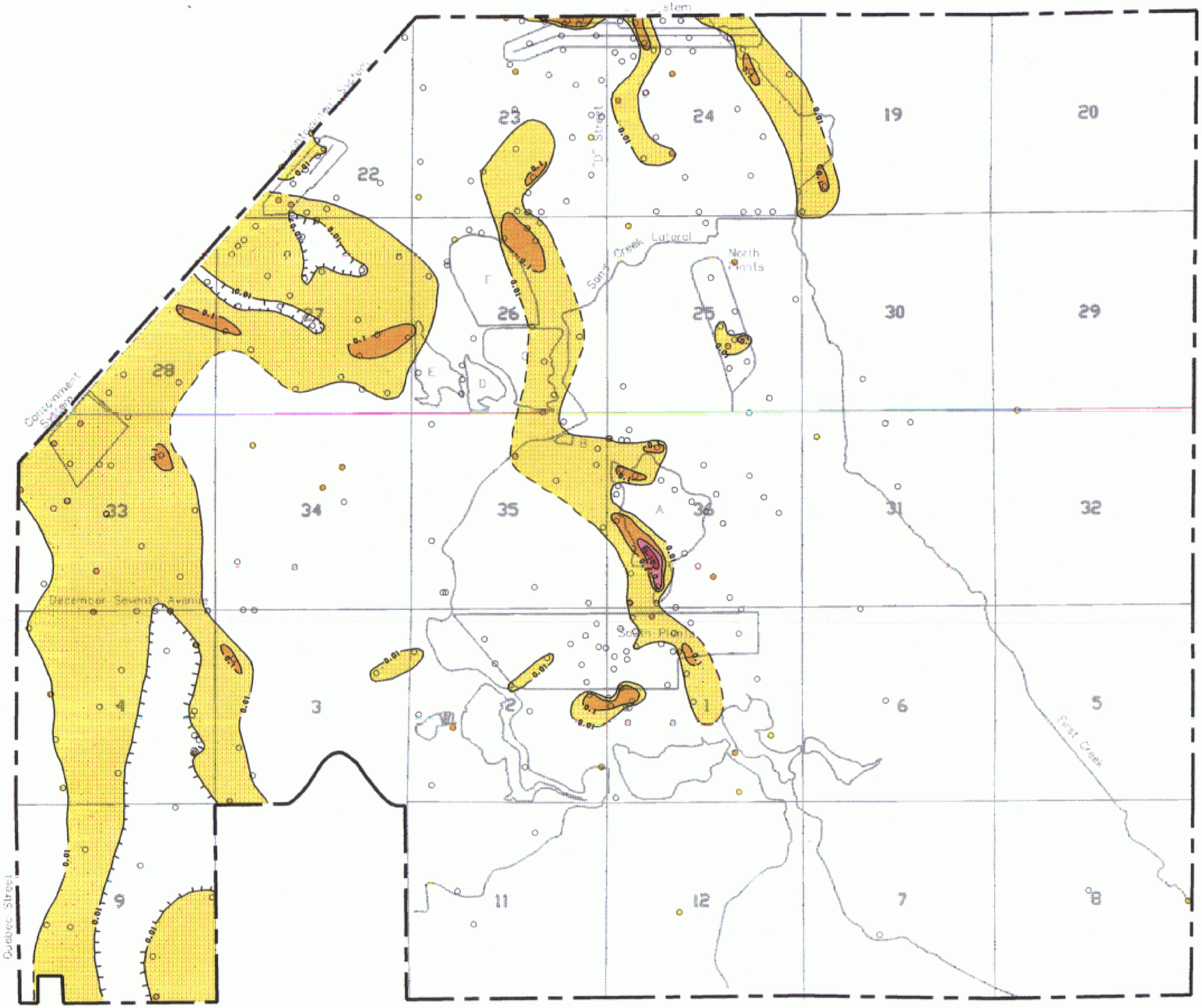
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A3.2-12

Arsenic Plume in the Unconfined Flow System, 1987-1989

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend:

- Rocky Mountain Arsenal Boundary
- Section Lines
- Streams
- Lakes
- Basins

0.01 — - - - Contour, dashed where inferred

Contour Intervals 0.01, 0.1, 1.0, 10 ug/l

Concentration Ranges

🟥 > 10 ug/l

🟥 > 1 to 10 ug/l

🟧 > 0.1 to 1 ug/l

🟨 > 0.01 to 0.1 ug/l

🟨 CRL to 0.01 ug/l

○ BCRL

Note: Concentration ranges based on adjusted geometric means for individual analyte.

N

0 3000 Feet

Scale: 1" = 3000'

Prepared for:

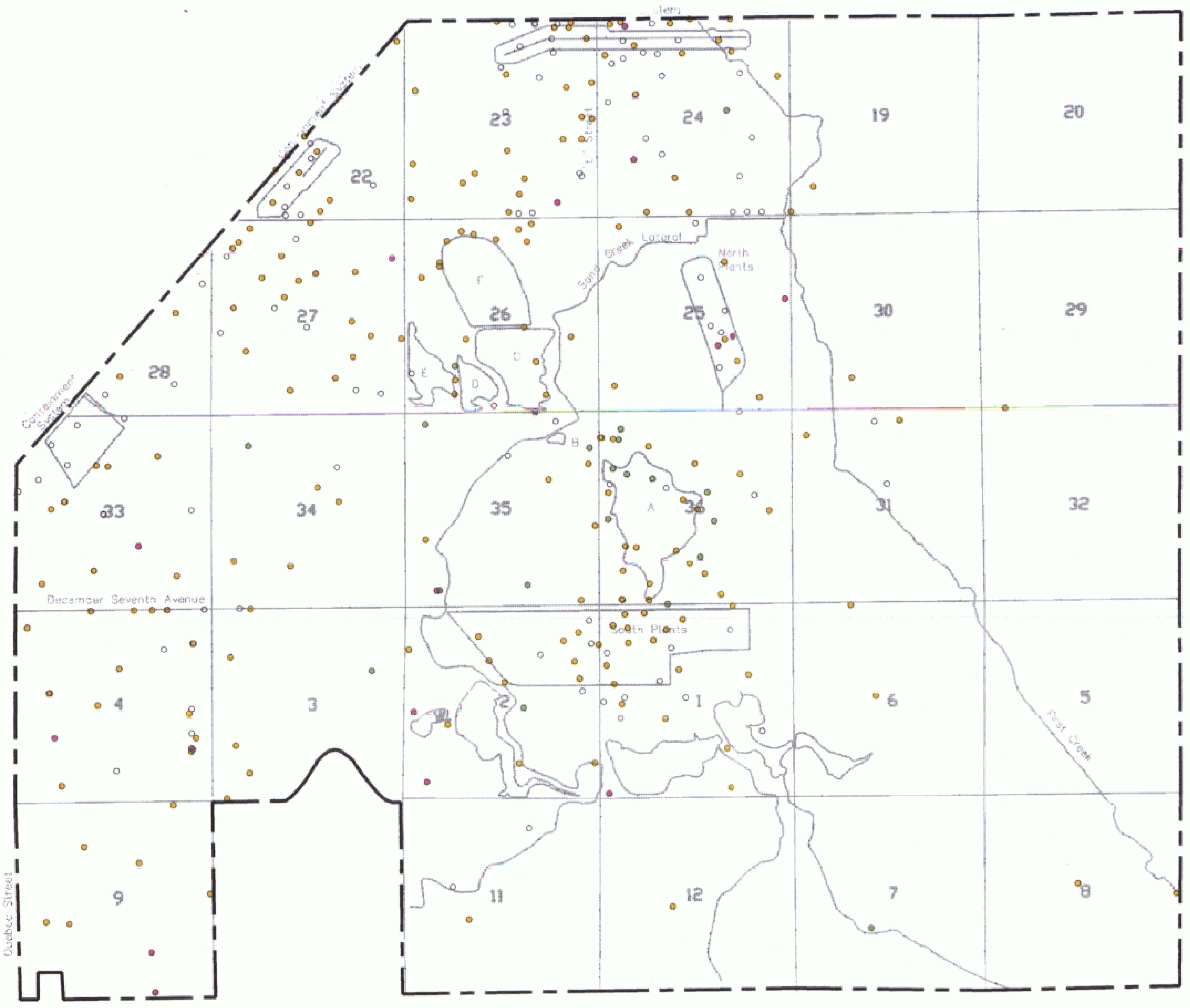
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A3.2-13

Mercury Plume in the Unconfined Flow System, 1987-1989

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



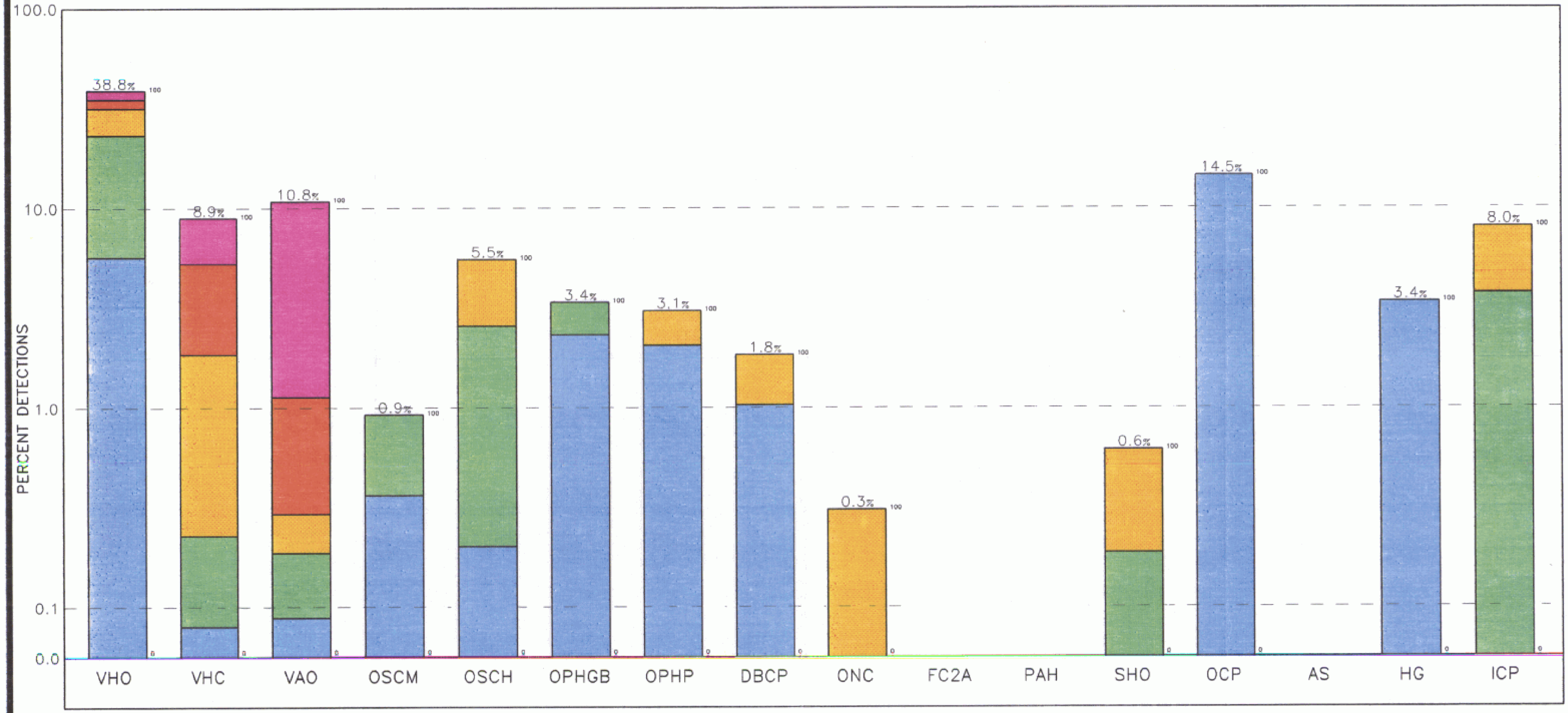
Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal
Prepared August 1991

FIGURE RISR A3.2-14

Total ICP Metals in the Unconfined
Flow System, 1987-1989

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

South Plants Plume Group

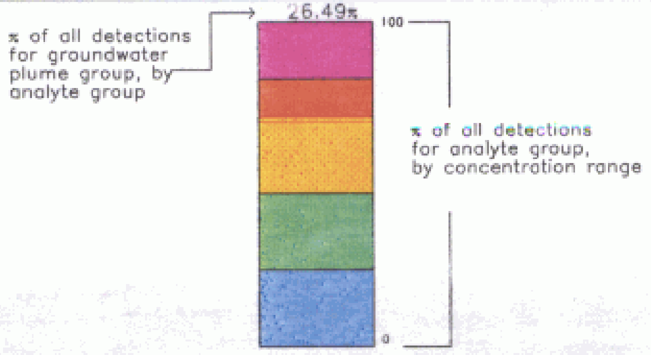


	VHO	VHC	VAO	OSCM	OSCH	OPHGB	OPHP	DBCP	ONC	FC2A	PAH	SHO	OCP	AS	HG	ICP
DETECTIONS	126	29	35	3	18	11	10	6	1	Not analyzed for in groundwater	0	2	47	0	11	26
ANALYSES	783	183	305	124	285	121	187	60	11		0	63	434	37	38	190

CONCENTRATION RANGES

- 🟪 >10,000 ug/l
- 🟥 >1,000 to 10,000 ug/l
- 🟨 >100 to 1000 ug/l
- 🟩 >10 to 100 ug/l
- 🟦 CRL to 10 ug/l

Total Detections all Analytes	325
Total Analyses all Analytes	2821



Prepared for:

U.S. Army Program Manager

for Rocky Mountain Arsenal

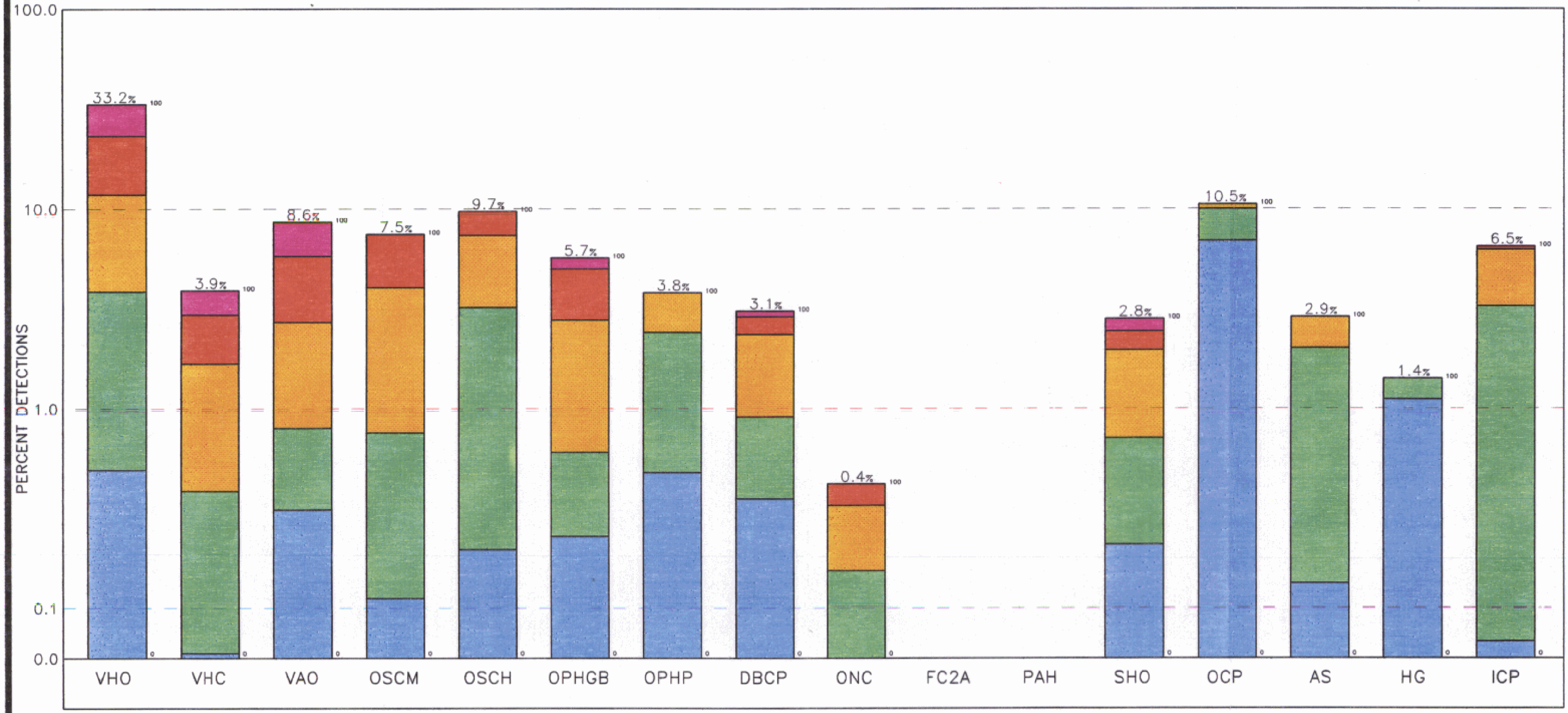
Prepared August 1991

FIGURE RISR A3.2–15

Analyte Group Detection Frequencies for the South Plants Plume Group, 1987–1989

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

Basin A Plume Group

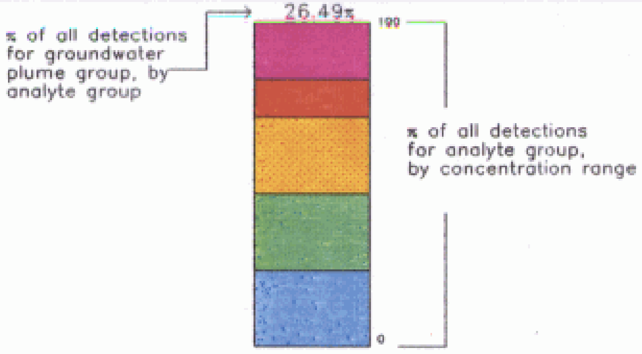


	VHO	VHC	VAO	OSCM	OSCH	OPHGB	OPHP	DBCP	ONC	FC2A	PAH	SHO	OCP	AS	HG	ICP
DETECTIONS	635	75	165	143	186	109	73	59	8	Not analyzed for in groundwater	0	54	201	55	27	124
ANALYSES	1837	458	733	357	793	348	515	194	39		0	192	1292	117	115	610

CONCENTRATION RANGES

- 🟪 >10,000 ug/l
- 🟥 >1,000 to 10,000 ug/l
- 🟧 >100 to 1000 ug/l
- 🟩 >10 to 100 ug/l
- 🟦 CRL to 10 ug/l

Total Detections all Analytes	1914
Total Analyses all Analytes	7600



Prepared for:

U.S. Army Program Manager

for Rocky Mountain Arsenal

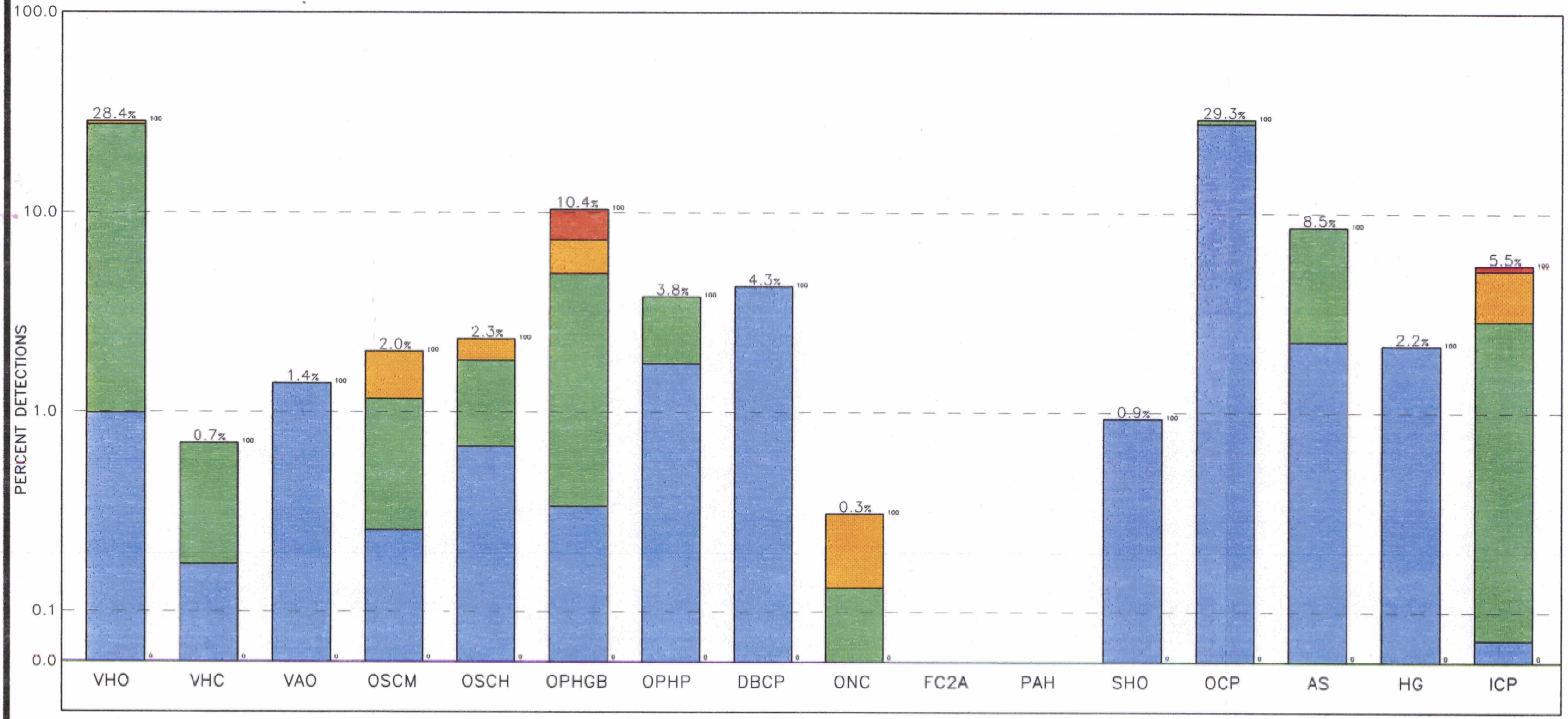
Prepared August 1991

FIGURE RISR A3.2-16

Analyte Group Detection Frequencies for Basin A Plume Group, 1987–1989

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

Northwest Boundary Plume Group



	VHO	VHC	VAO	OSCM	OSCH	OPHGB	OPHP	DBCP	ONC	FC2A	PAH	SHO	OCP	AS	HG	ICP
DETECTIONS	367	9	18	26	30	134	49	55	4	Not analyzed for in groundwater	0	12	378	110	28	71
ANALYSES	3457	687	1413	441	982	651	572	343	4		0	308	2336	268	125	644

CONCENTRATION RANGES

🟪	>10,000 ug/l
🟥	>1,000 to 10,000 ug/l
🟧	>100 to 1000 ug/l
🟩	>10 to 100 ug/l
🟦	CRL to 10 ug/l

Total Detections all Analytes	1291
Total Analyses all Analytes	12231

% of all detections for groundwater plume group, by analyte group

% of all detections for analyte group, by concentration range

Prepared for:

U.S. Army Program Manager

for Rocky Mountain Arsenal

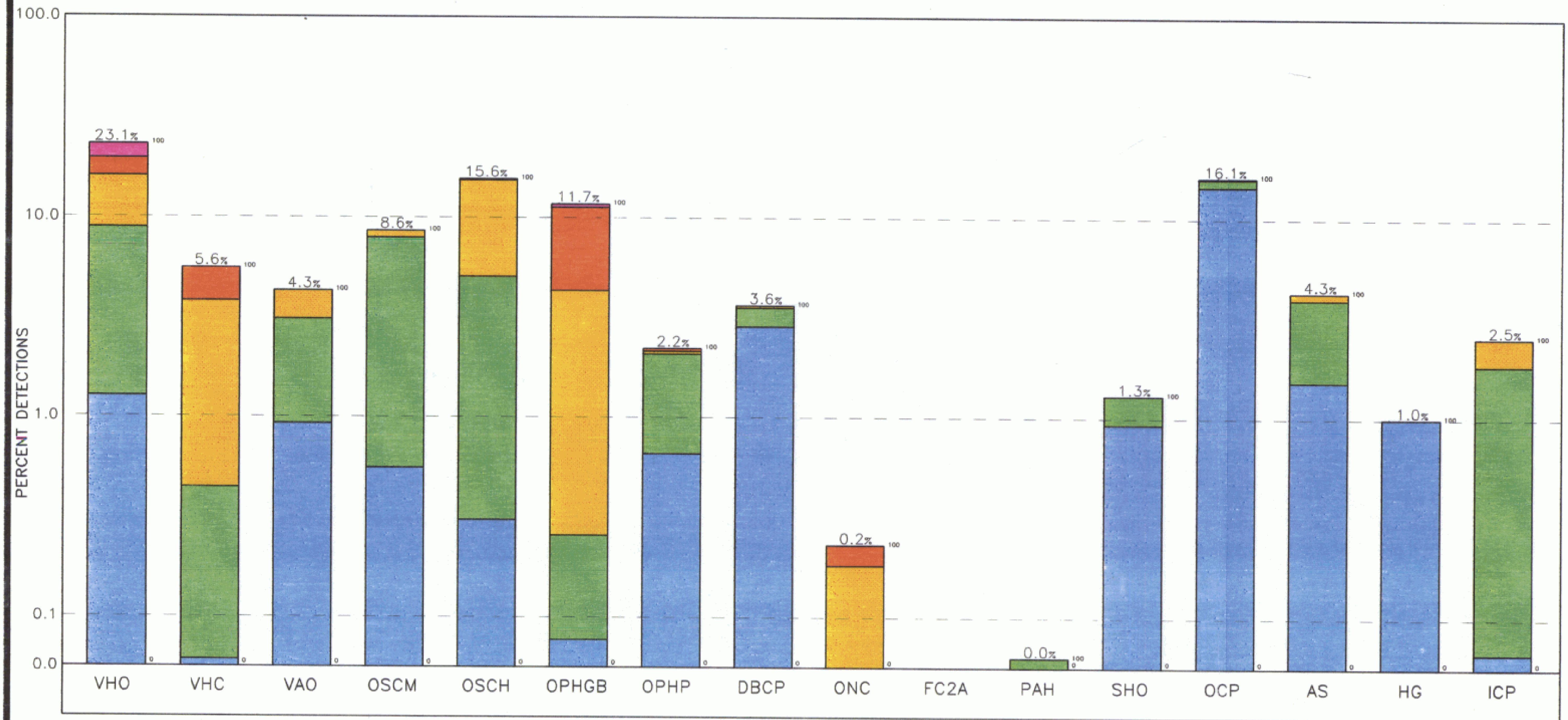
Prepared August 1991

FIGURE RISR A3.2-17

Analyte Group Detection Frequencies for the Northwest Boundary Plume Group, 1987-1989

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

North Boundary Plume Group

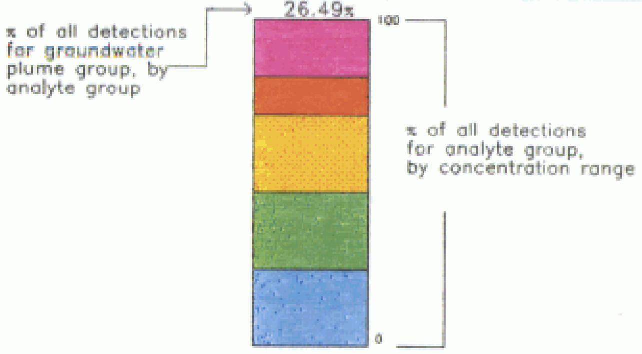


	VHO	VHC	VAO	OSCM	OSCH	OPHGB	OPHP	DBCP	ONC	FC2A	PAH	SHO	OCP	AS	HG	ICP
DETECTIONS	1197	289	223	445	808	606	115	189	12	Not analyzed for in groundwater	1	67	834	222	52	132
ANALYSES	7159	1529	2972	1349	3161	1366	1029	724	12		1	662	4786	560	238	1201

CONCENTRATION RANGES

- 🟪 >10,000 ug/l
- 🟥 >1,000 to 10,000 ug/l
- 🟨 >100 to 1000 ug/l
- 🟩 >10 to 100 ug/l
- 🟦 CRL to 10 ug/l

Total Detections all Analytes	5192
Total Analyses all Analytes	26749



Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

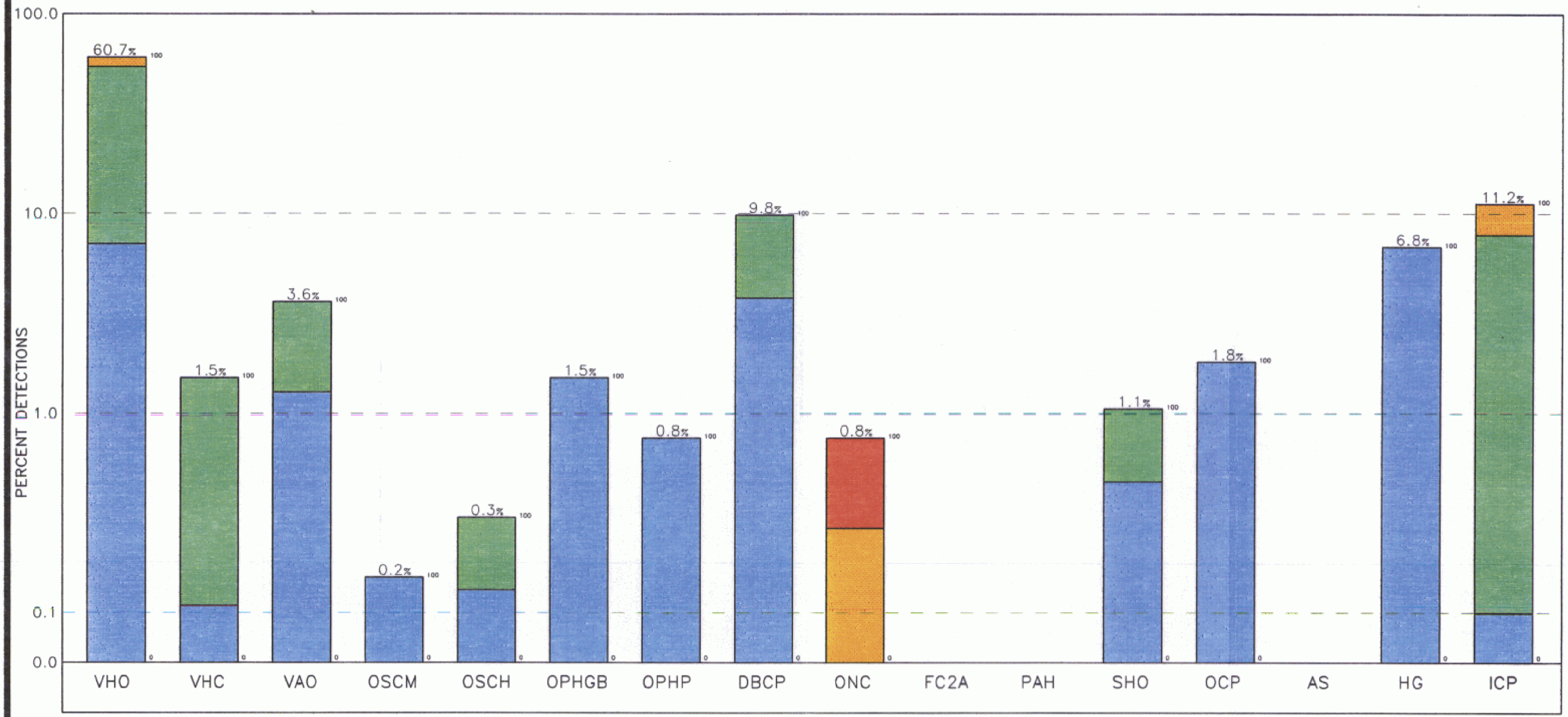
Prepared August 1991

FIGURE RISR A3.2-18

Analyte Group Detection Frequencies for the North Boundary Plume Group, 1987–1989

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

Western Plume Group



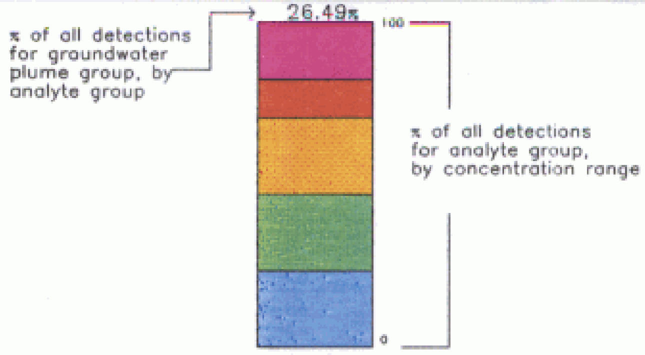
	VHO	VHC	VAO	OSCM	OSCH	OPHGB	OPHP	DBCP	ONC	FC2A	PAH	SHO	OCP	AS	HG	ICP
DETECTIONS	402	10	24	1	2	10	5	65	5	Not analyzed for in groundwater	0	7	12	0	45	74
ANALYSES	2224	510	880	417	966	379	478	252	5		0	199	1401	164	170	829

CONCENTRATION RANGES

🟪 >10,000 ug/l
🟥 >1,000 to 10,000 ug/l
🟧 >100 to 1000 ug/l
🟩 >10 to 100 ug/l
🟦 CRL to 10 ug/l

Total Detections all Analytes 662

Total Analyses all Analytes 8874



Prepared for:

U.S. Army Program Manager

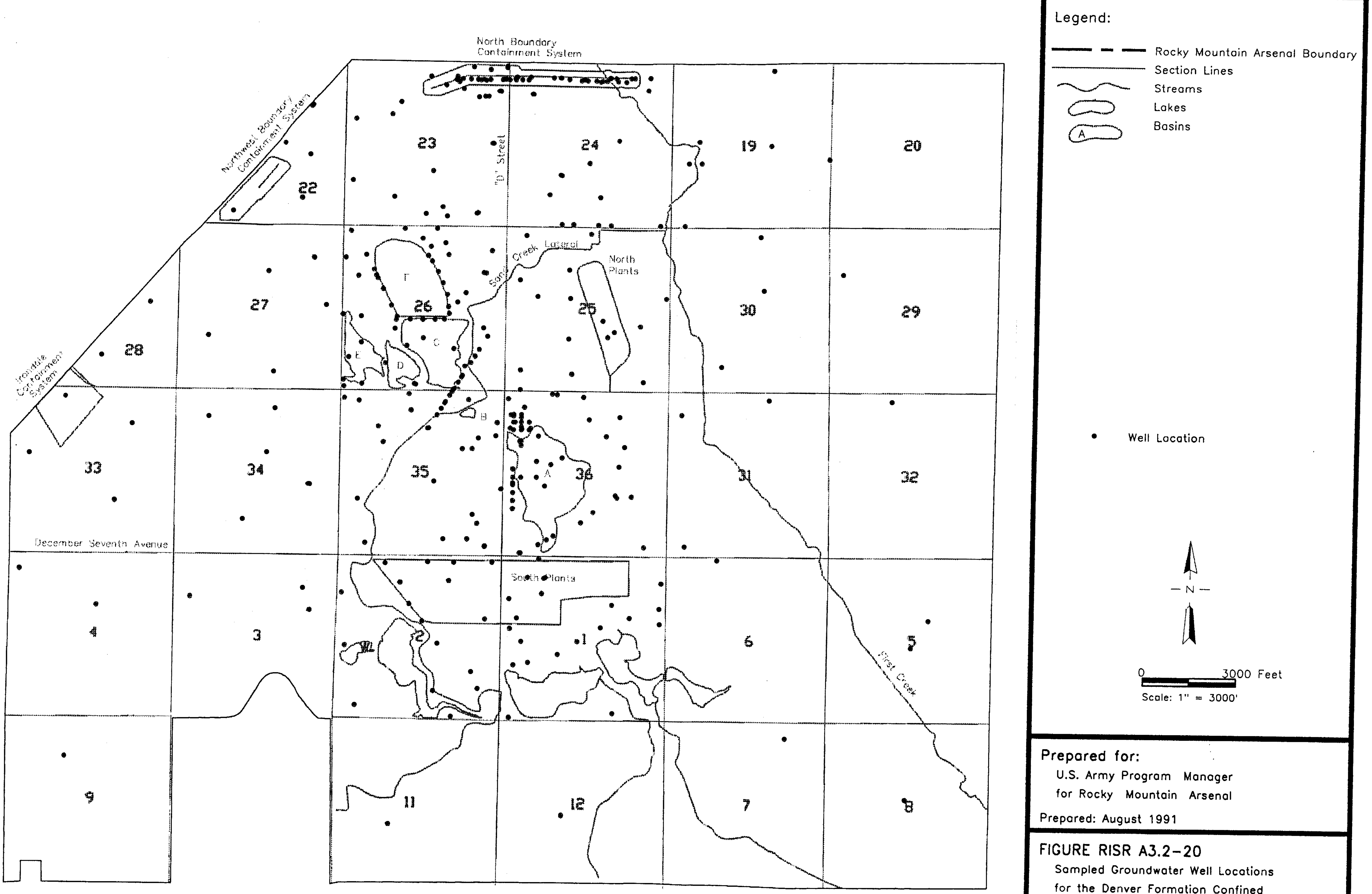
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A3.2-19

Analyte Group Detection Frequencies for the Western Plume Group, 1987-1989

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Prepared for:

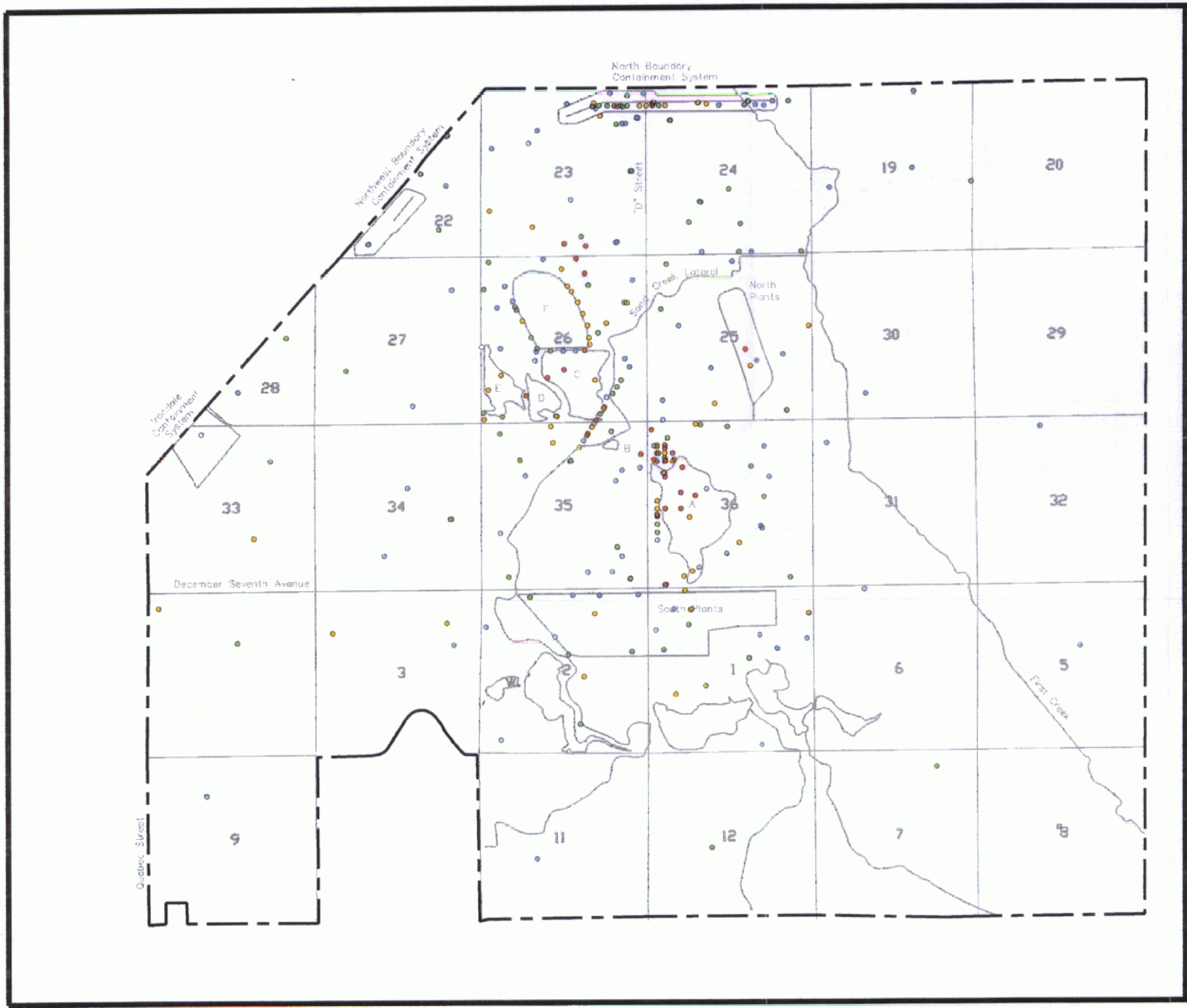
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared: August 1991

FIGURE RISR A3.2-20

Sampled Groundwater Well Locations
for the Denver Formation Confined
Flow System, 1975 - 1989

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend:

Rocky Mountain Arsenal Boundary

Section Lines

Streams

Lakes

Basins

Concentration Ranges

🟪	> 10,000 ug/l
🟥	> 1000 to 10,000 ug/l
🟧	> 100 to 1000 ug/l
🟩	> 10 to 100 ug/l
🟦	CRL to 10 ug/l

N

0 3000 Feet

Scale: 1" = 3000'

Prepared for:

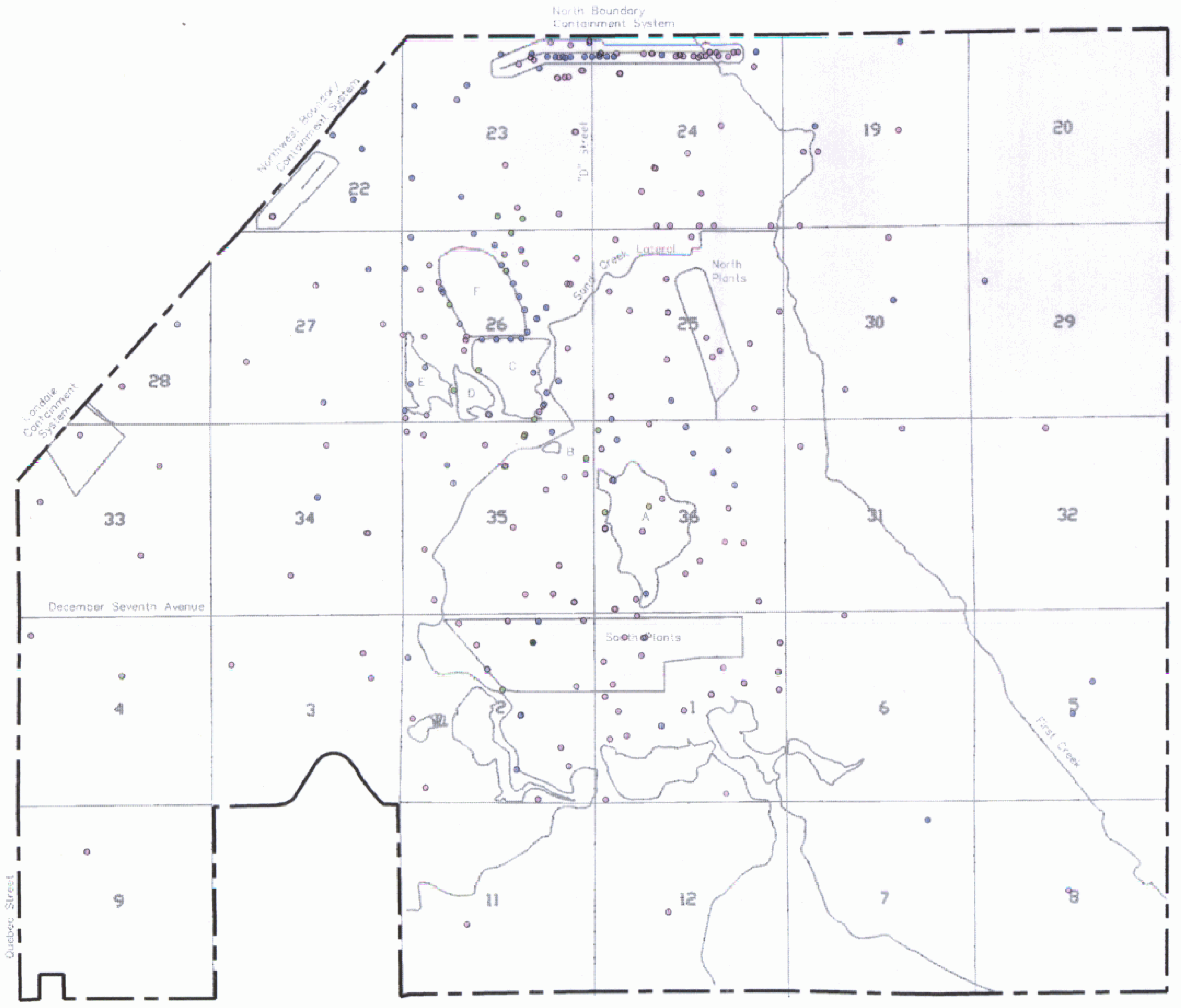
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared: August 1991

FIGURE RISR A3.2-21

Total Organic Analytes in the Denver Formation Confined Flow System, 1975 – 1989

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend:

Rocky Mountain Arsenal Boundary

Section Lines

Streams

Lakes

Basins

Concentration Ranges

- 🟩 > 5,000,000 ug/l
- 🟩 1,000,000 to < 5,000,000 ug/l
- 🟦 150,000 to < 1,000,000 ug/l
- 🟪 CRL to < 150,000 ug/l

N

0 3000 Feet

Scale: 1" = 3000'

Prepared for:

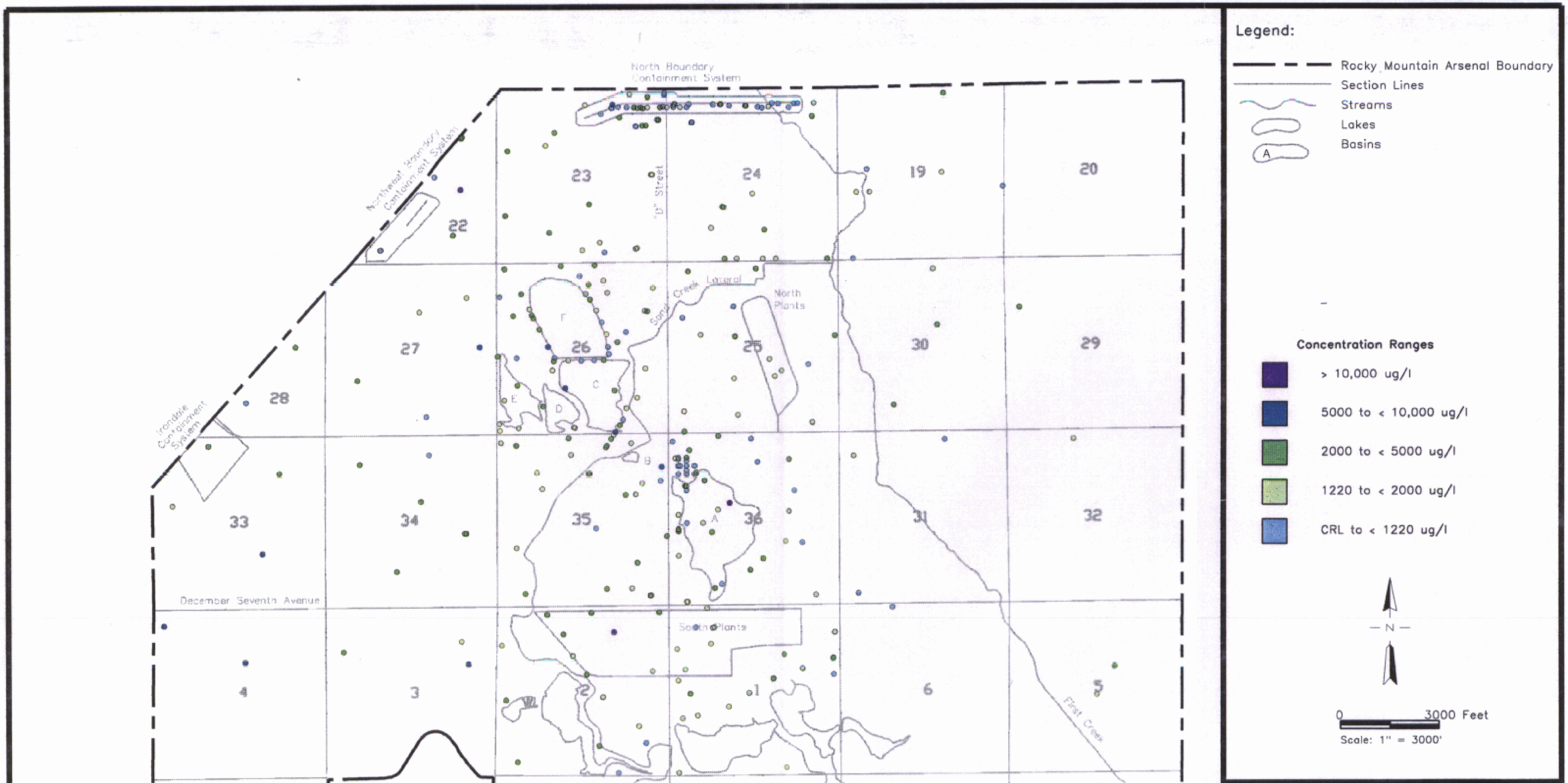
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared: August 1991

FIGURE RISR A3.2-22

Chloride in the Denver Formation
Confined Flow System, 1975 - 1989

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



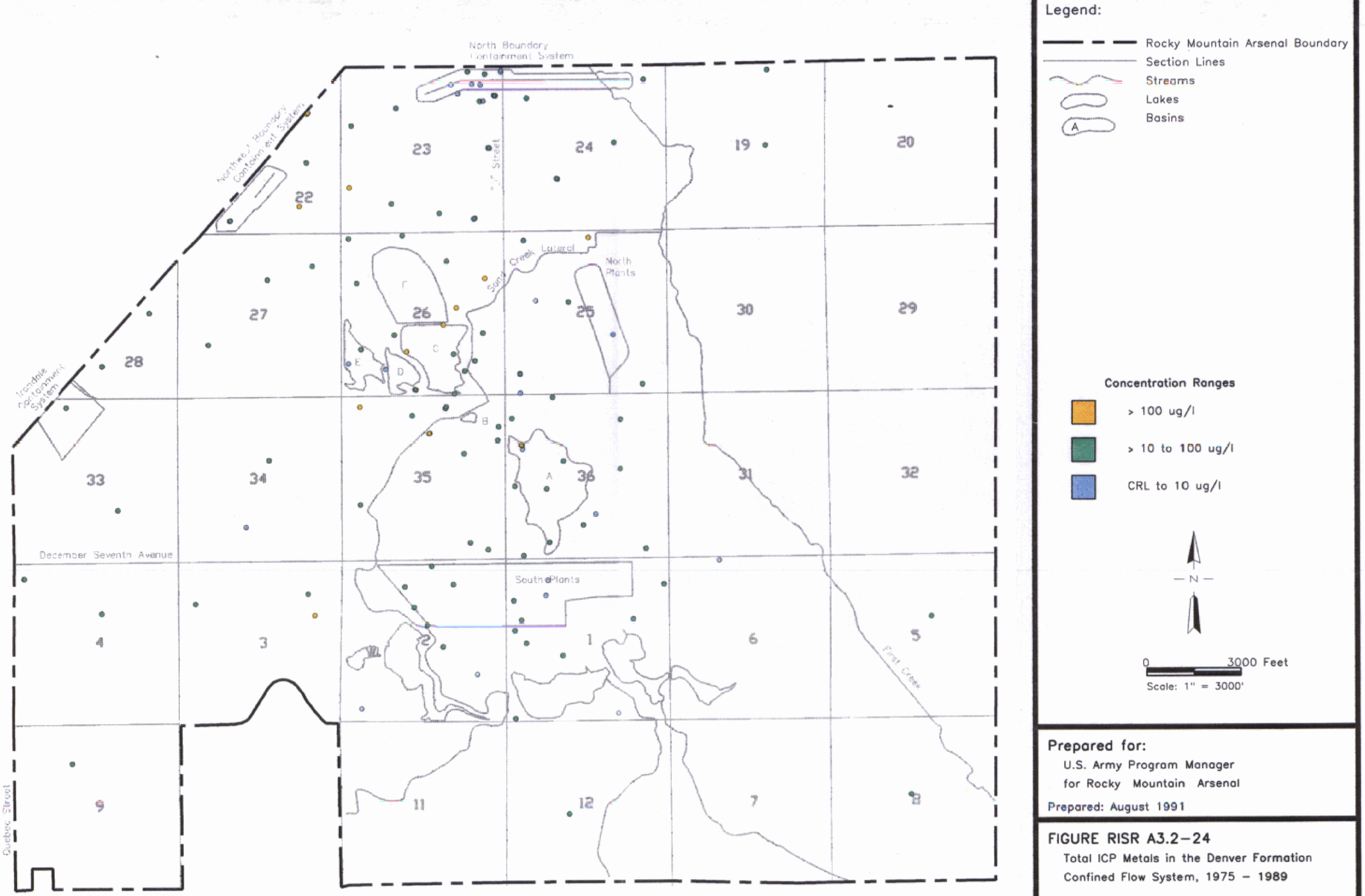
Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared: August 1991

FIGURE RISR A3.2-23

Fluoride in the Denver Formation
Confined Flow System, 1975 – 1989

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



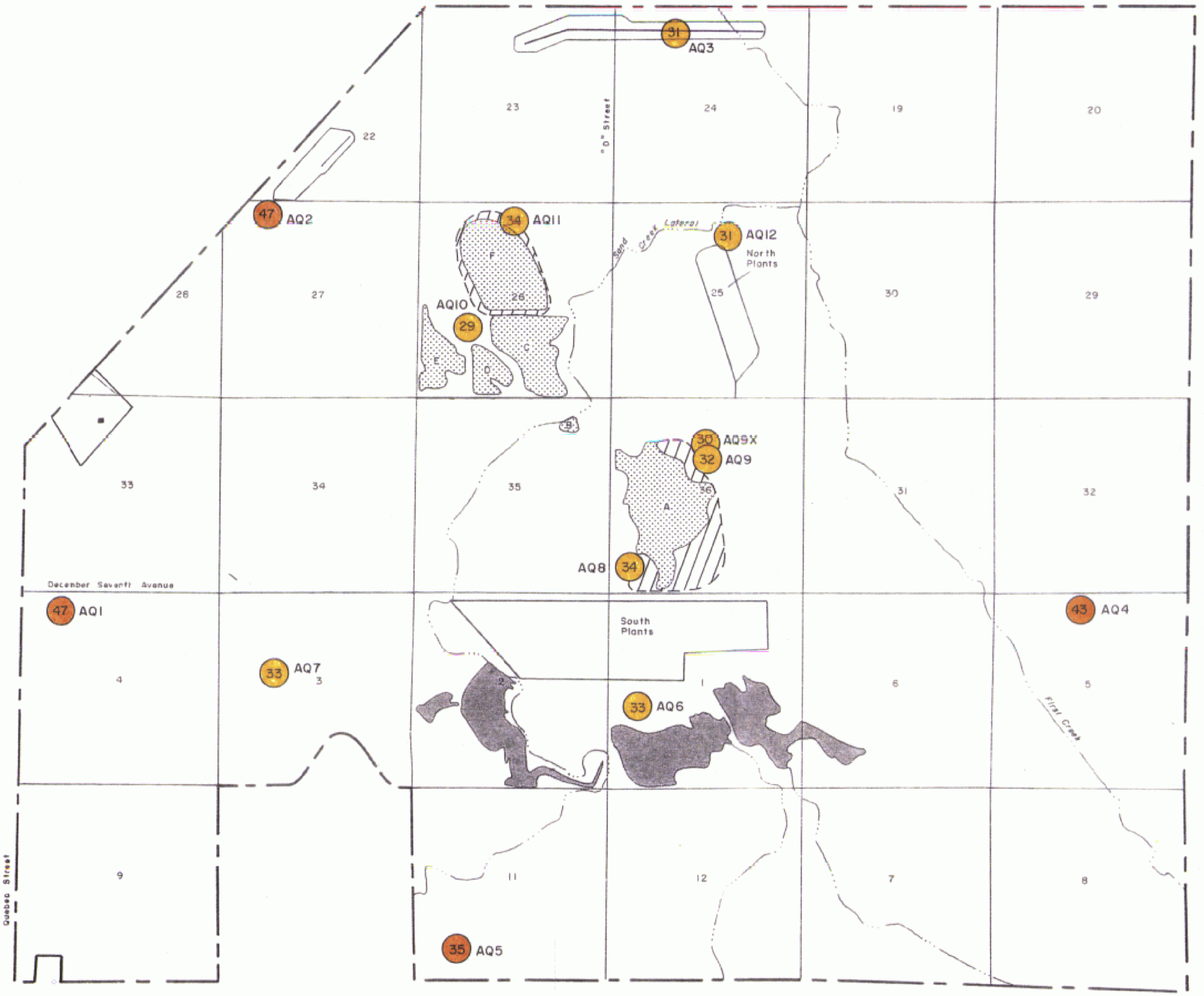
Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared: August 1991

FIGURE RISR A3.2-24

Total ICP Metals in the Denver Formation Confined Flow System, 1975 - 1989

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend

Rocky Mountain Arsenal Boundary
Road or Section Lines
Stream or Drainage Ditch
Lakes
A Waste Basins

37 ≥ 35 ug/m^3
29 0 - 34 ug/m^3

NOTE: Numerical value corresponds to actual TSP as reported in the Air Remedial Investigation (ESE, 1988)

47 AQ2 Air Quality Monitoring Station

▨ Area in which portable air monitoring stations were deployed during "event" sampling for VOCs and SVOCs.

N

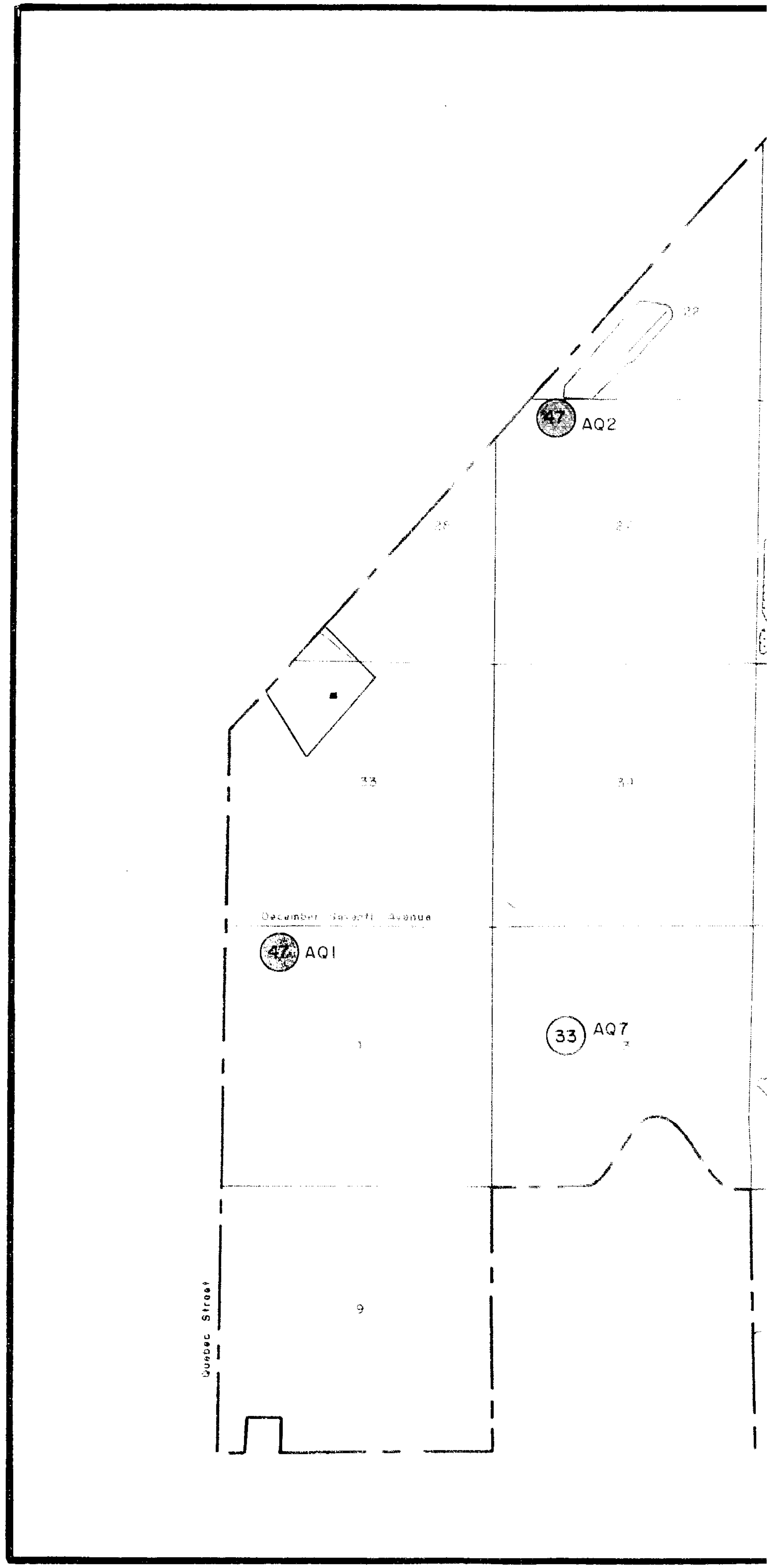
0 3000 Feet
Scale: 1" = 3000'

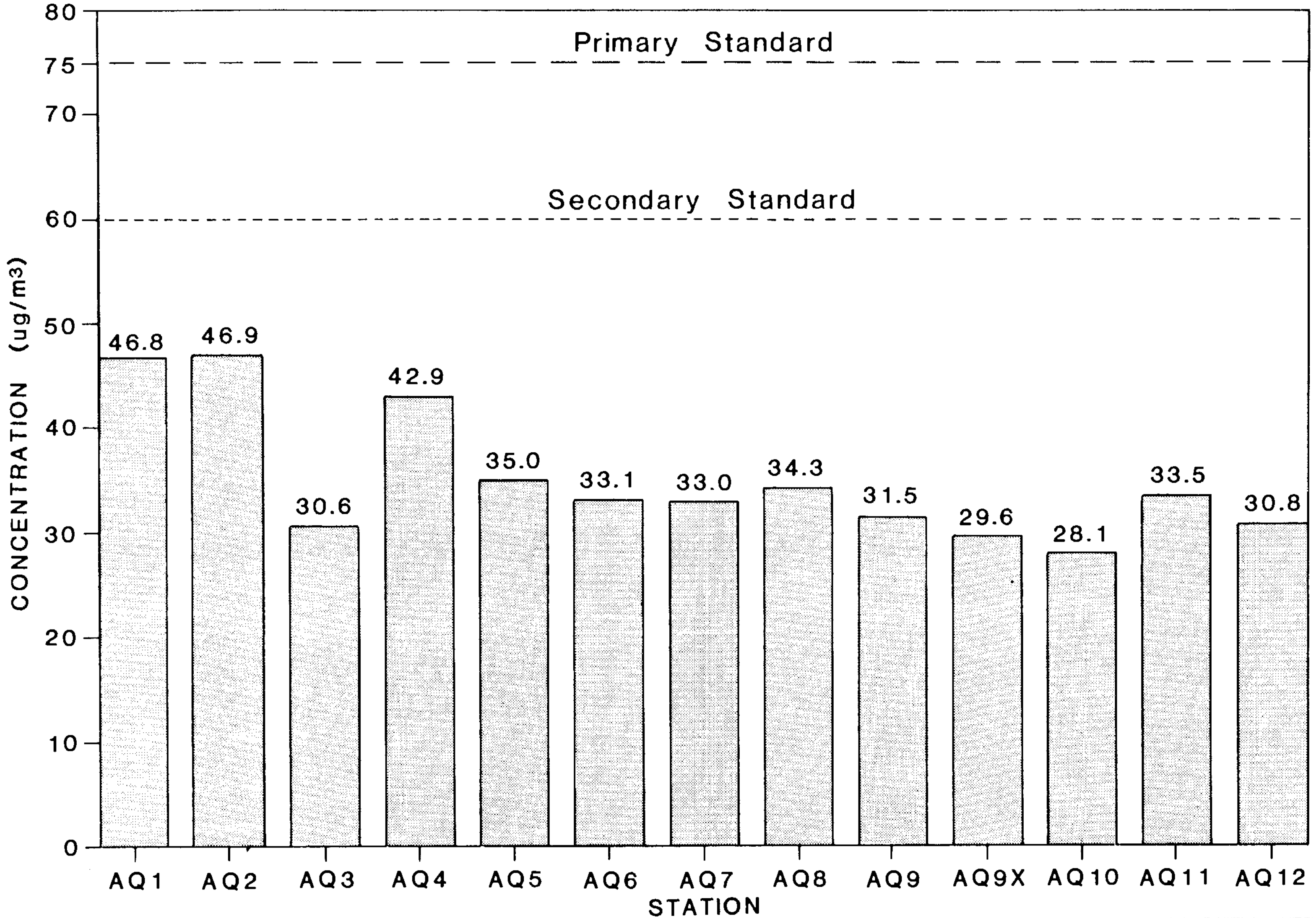
(ESE, 1988)

Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal
Prepared August 1991

FIGURE RISR A3.4-1
Distribution of Annual Geometric Means of Total Suspended Particulates in Air, June 1986 - June 1987

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated





Source: ESE,1988

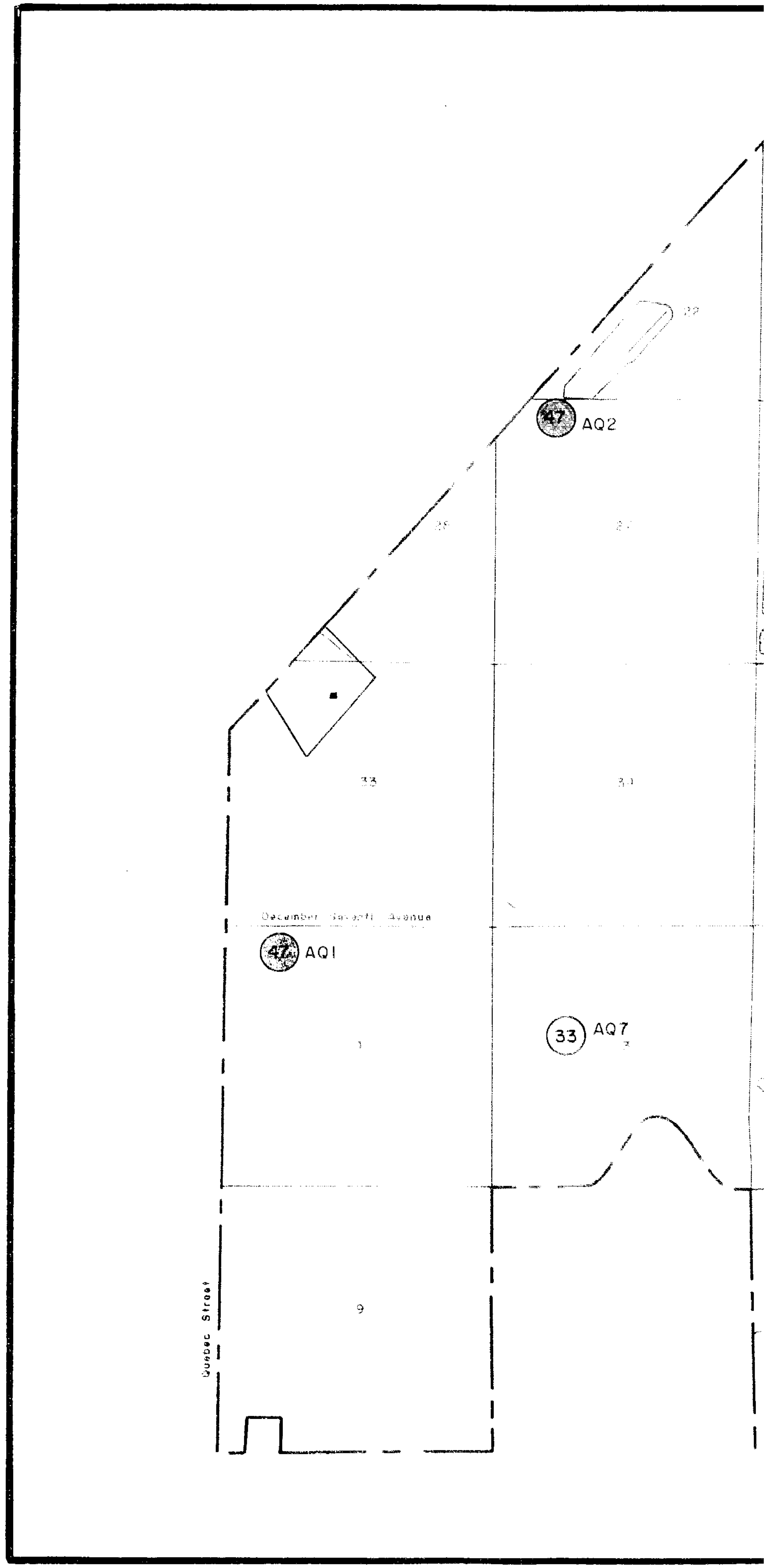
Prepared for:

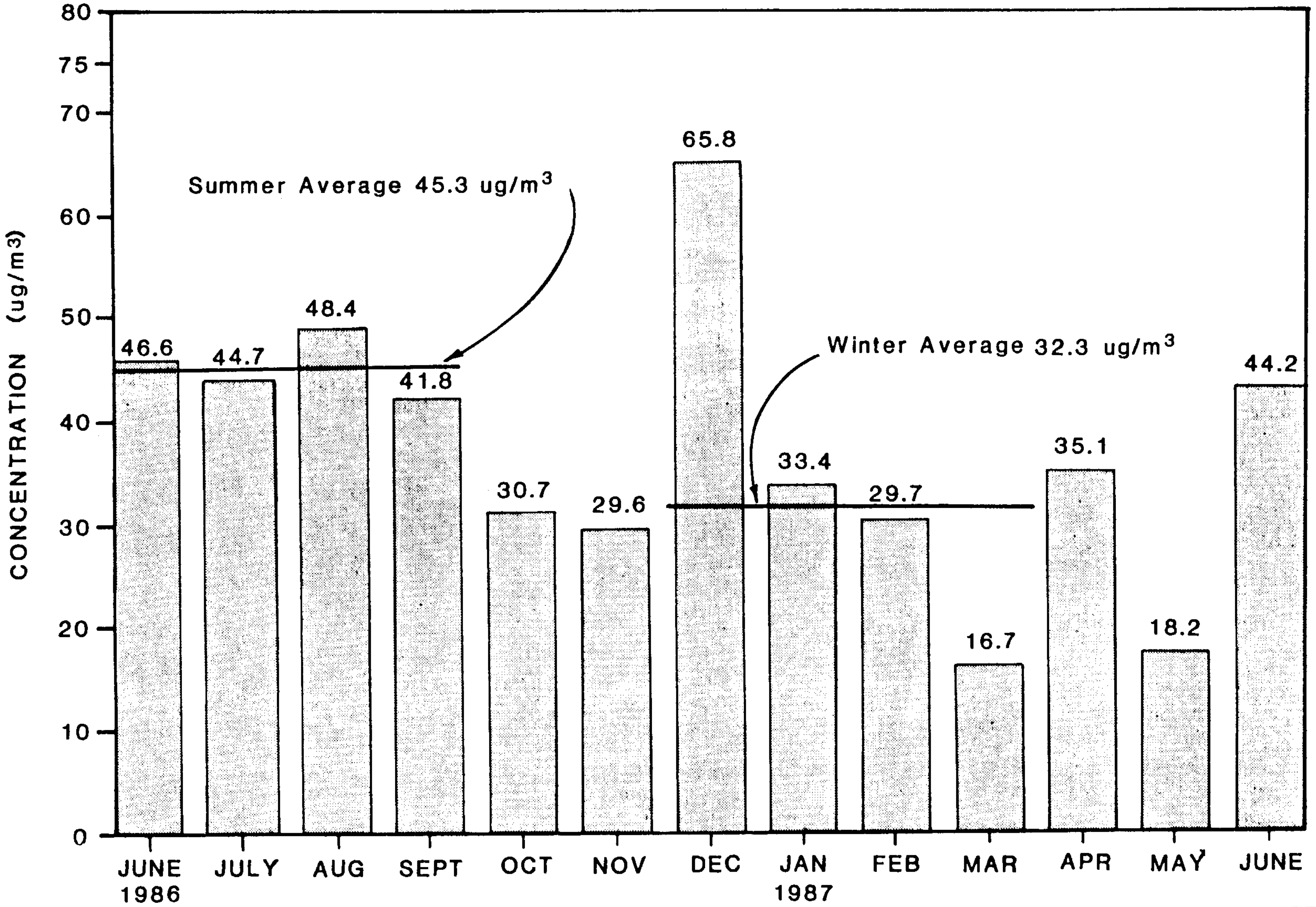
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A3.4-2
TSP Annual Geometric Mean
Concentration by Station,
June 1986 - June 1987

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated





Prepared for:

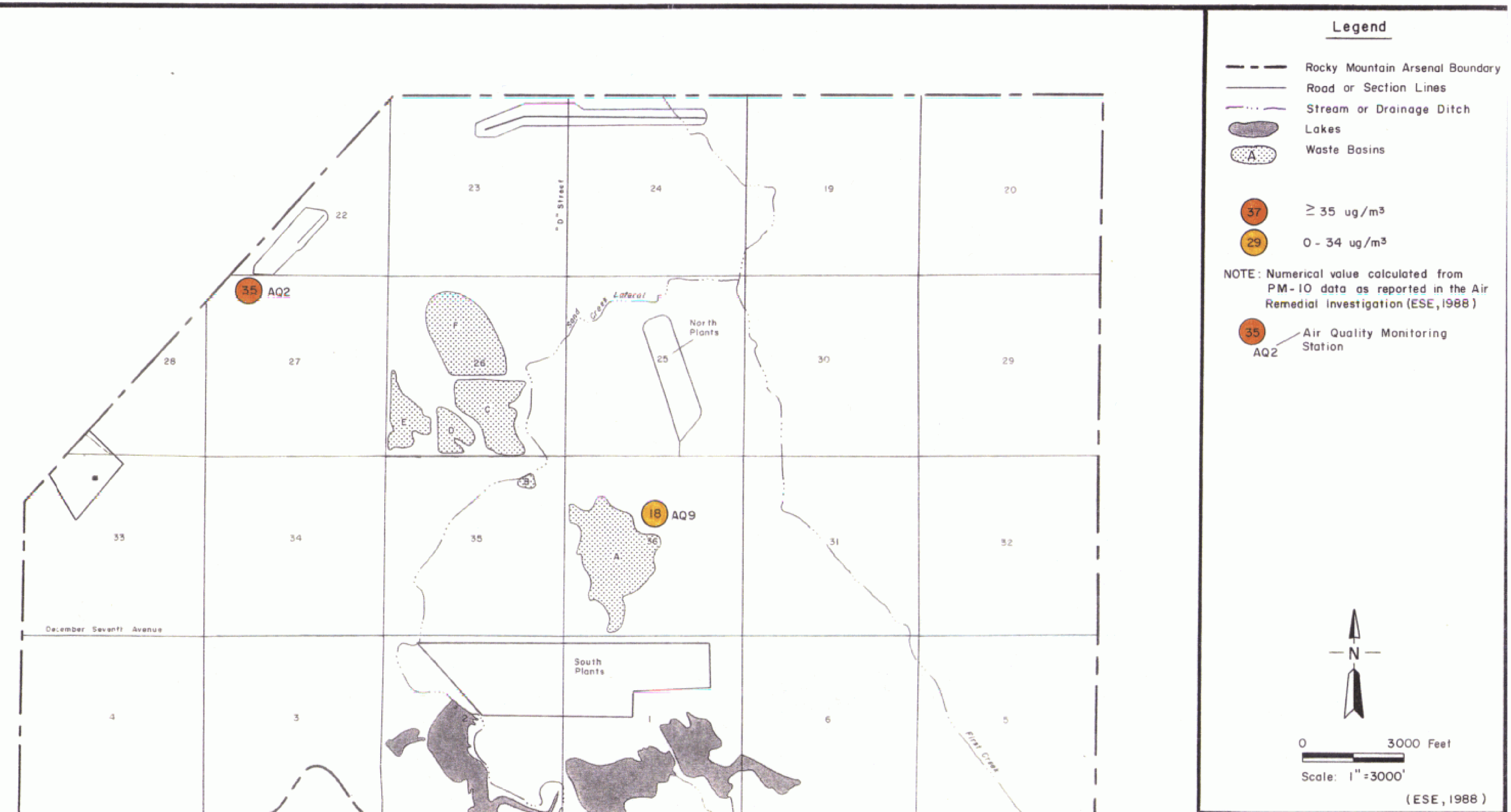
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A3.4-3

Geometric Mean Monthly TSP Concentrations for all Stations

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

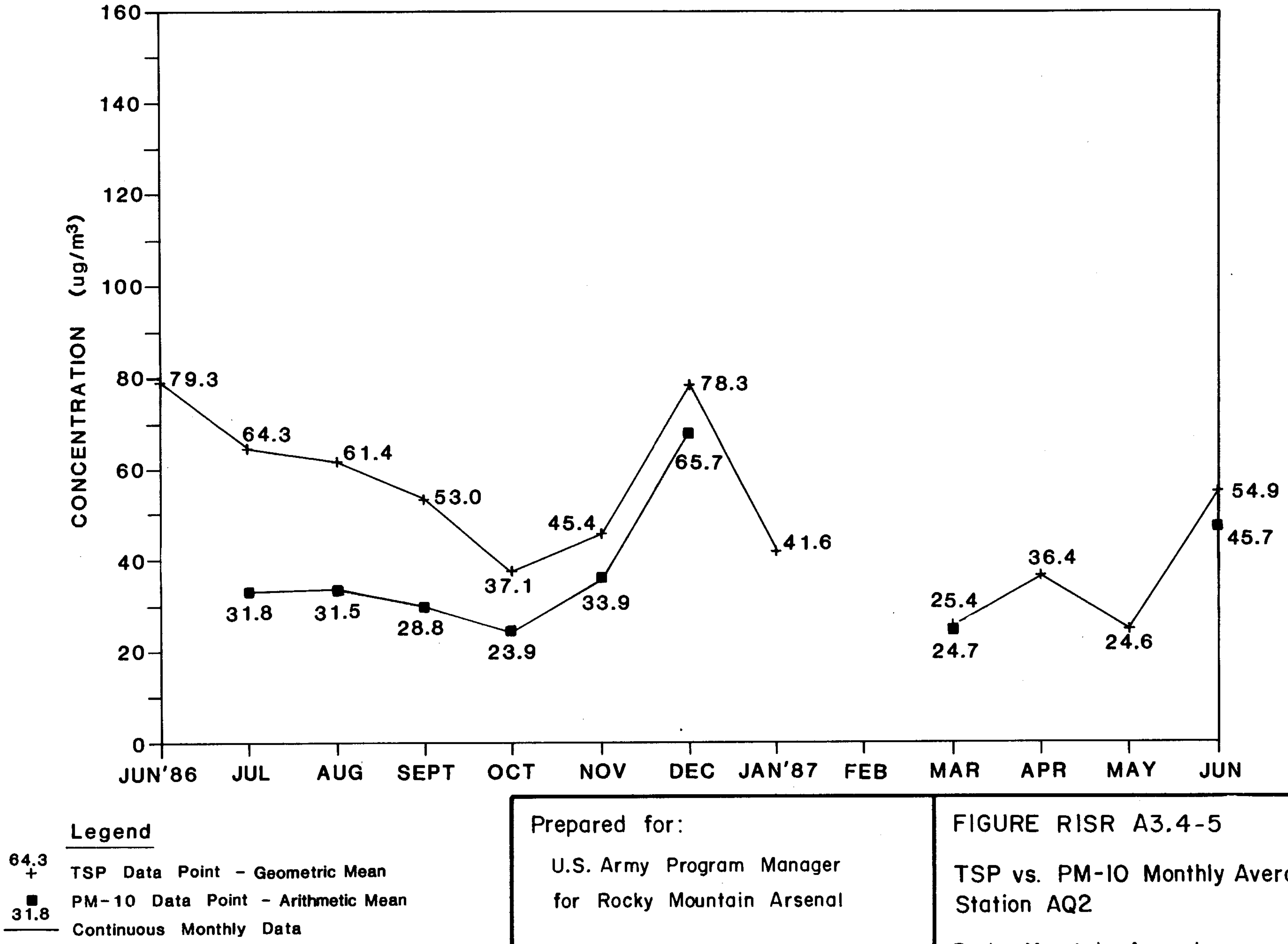
Prepared August 1991

FIGURE RISR A3.4-4

Distribution of Annual Arithmetic Means of Particulate Matter Less than 10 Microns (PM-10) in Air, June 1986 - June 1987

Rocky Mountain Arsenal

Prepared by: Ebasco Services Incorporated



Source: ESE, 1988

Prepared for:

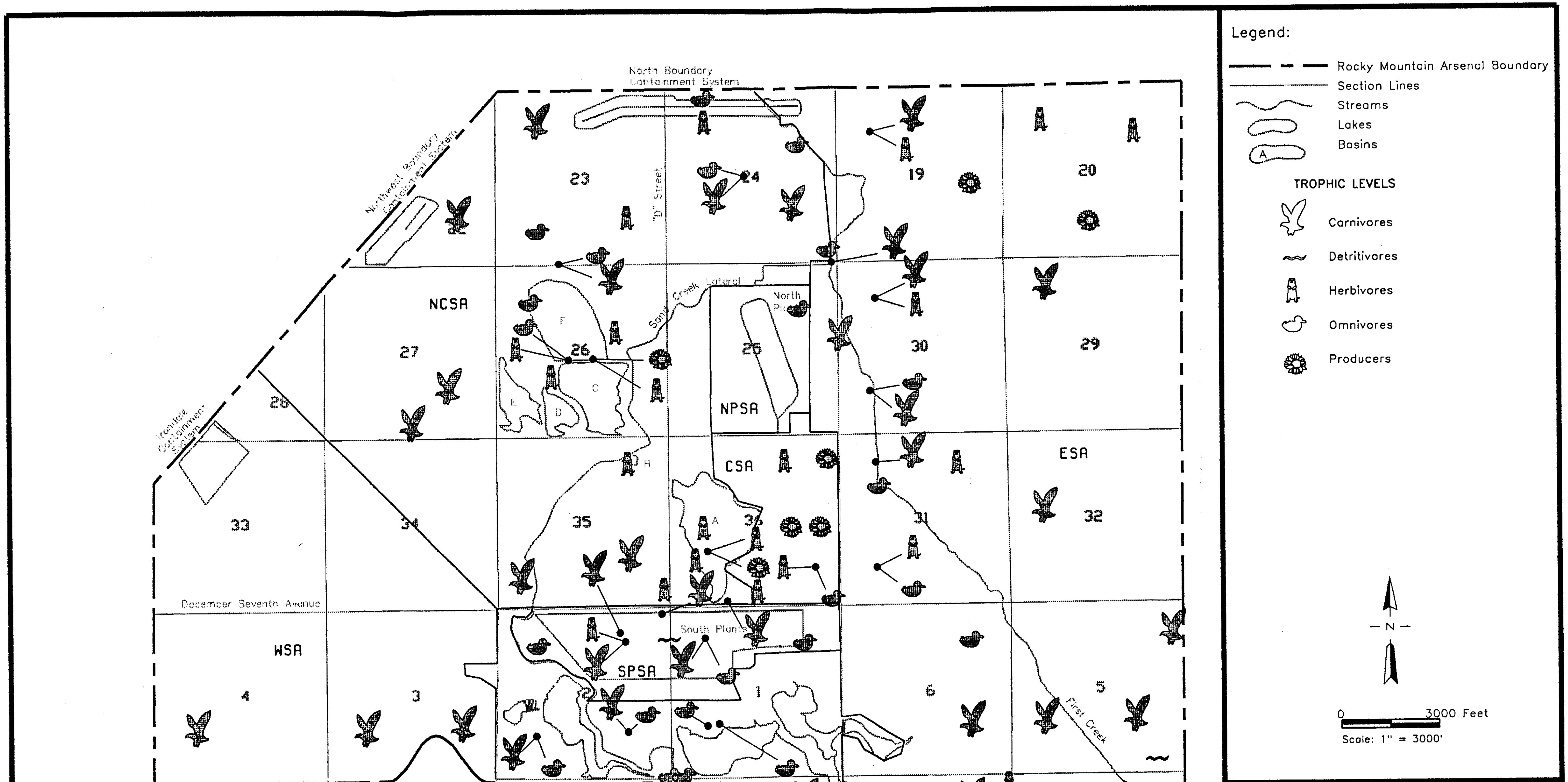
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A3.4-5

TSP vs. PM-10 Monthly Averages for Station AQ2

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



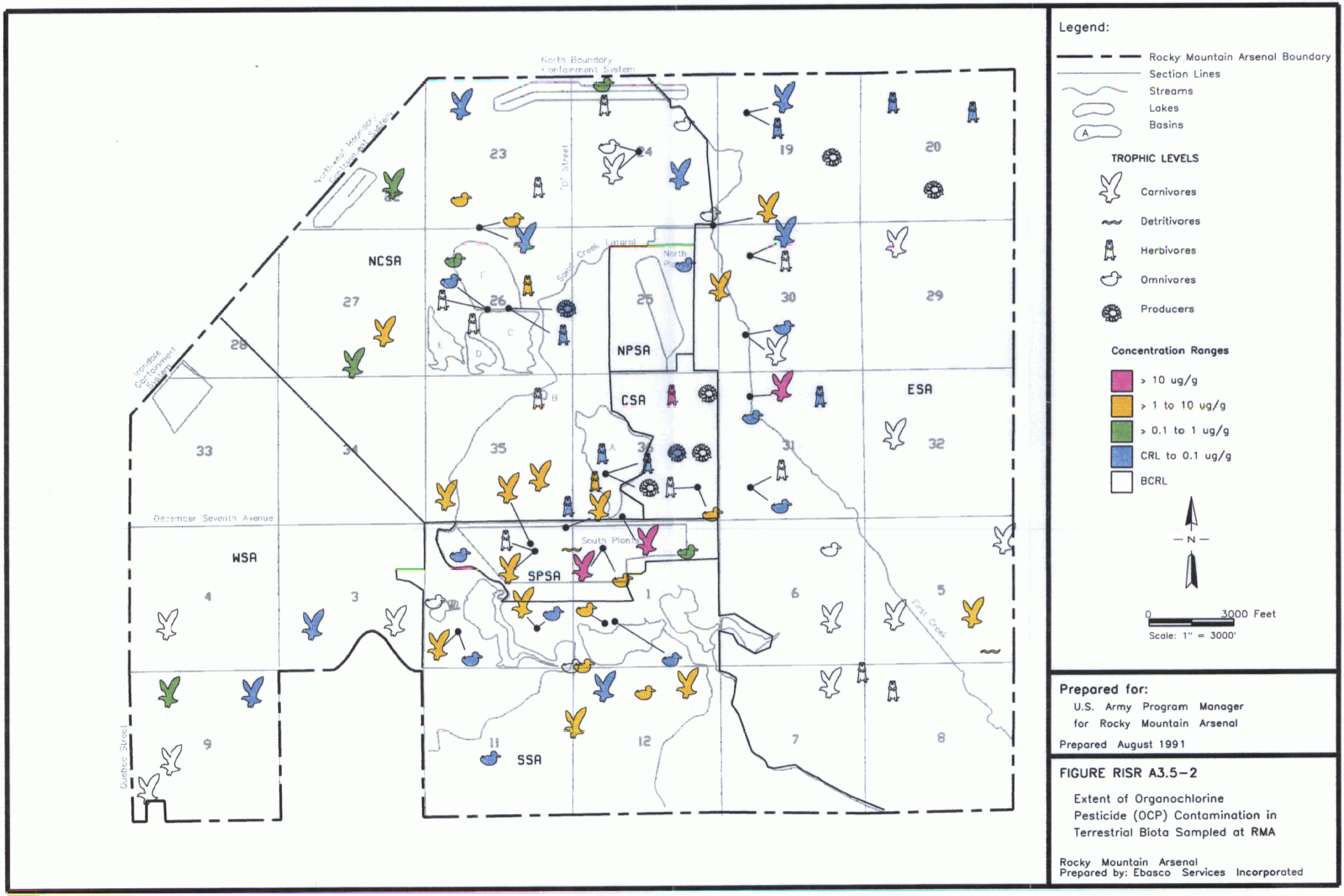
Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A3.5-1

Terrestrial Biota Sampling Locations by Trophic Level

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



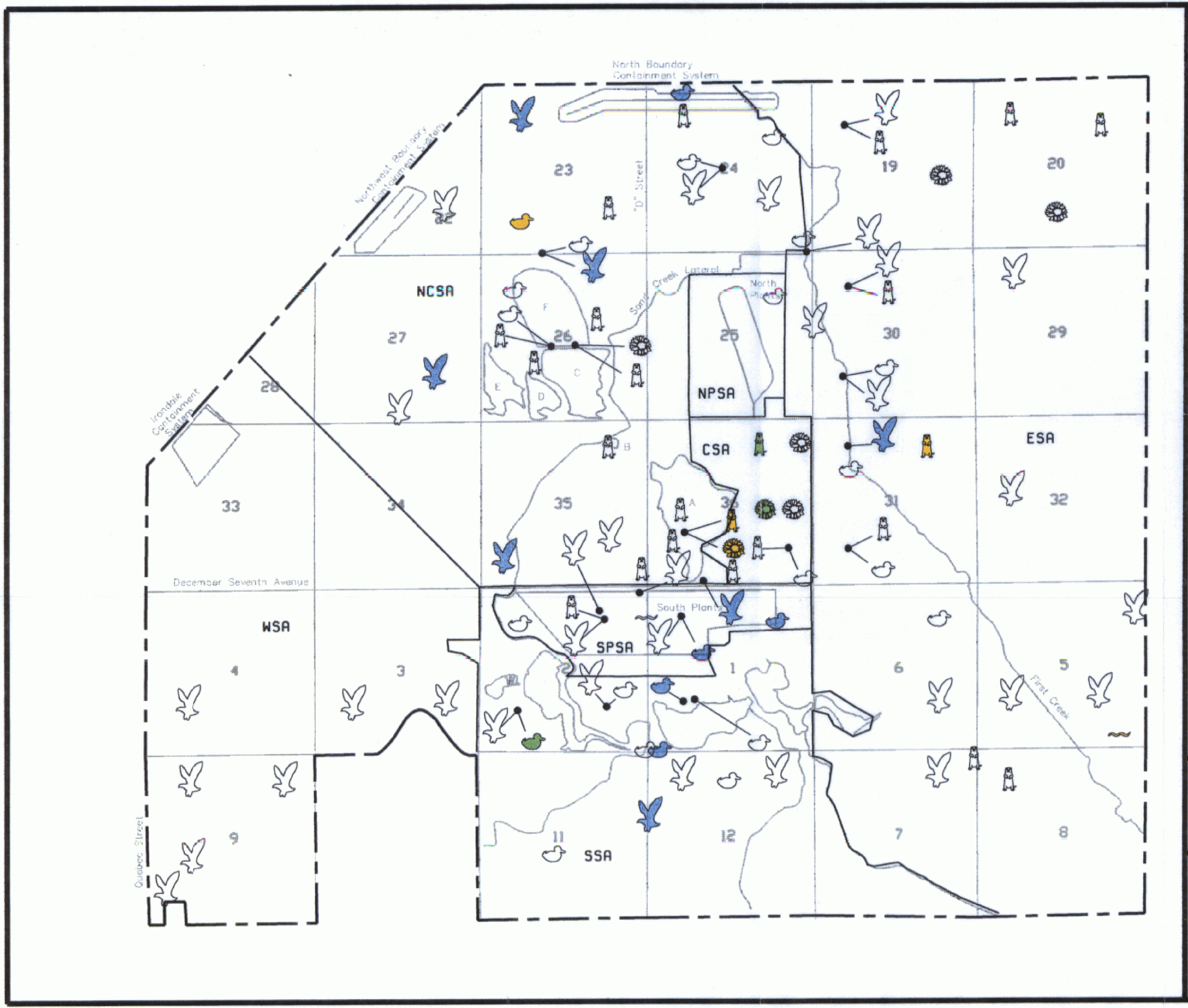
Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A3.5-2

Extent of Organochlorine Pesticide (OCP) Contamination in Terrestrial Biota Sampled at RMA

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend:

Rocky Mountain Arsenal Boundary
Section Lines
Streams
Lakes
Basins

TROPHIC LEVELS

Carnivores
Detritivores
Herbivores
Omnivores
Producers

Concentration Ranges

🟪 > 10 ug/g
🟧 > 1 to 10 ug/g
🟩 > 0.1 to 1 ug/g
🟦 CRL to 0.1 ug/g
⬜ BCRL

N

0 3000 Feet
Scale: 1" = 3000'

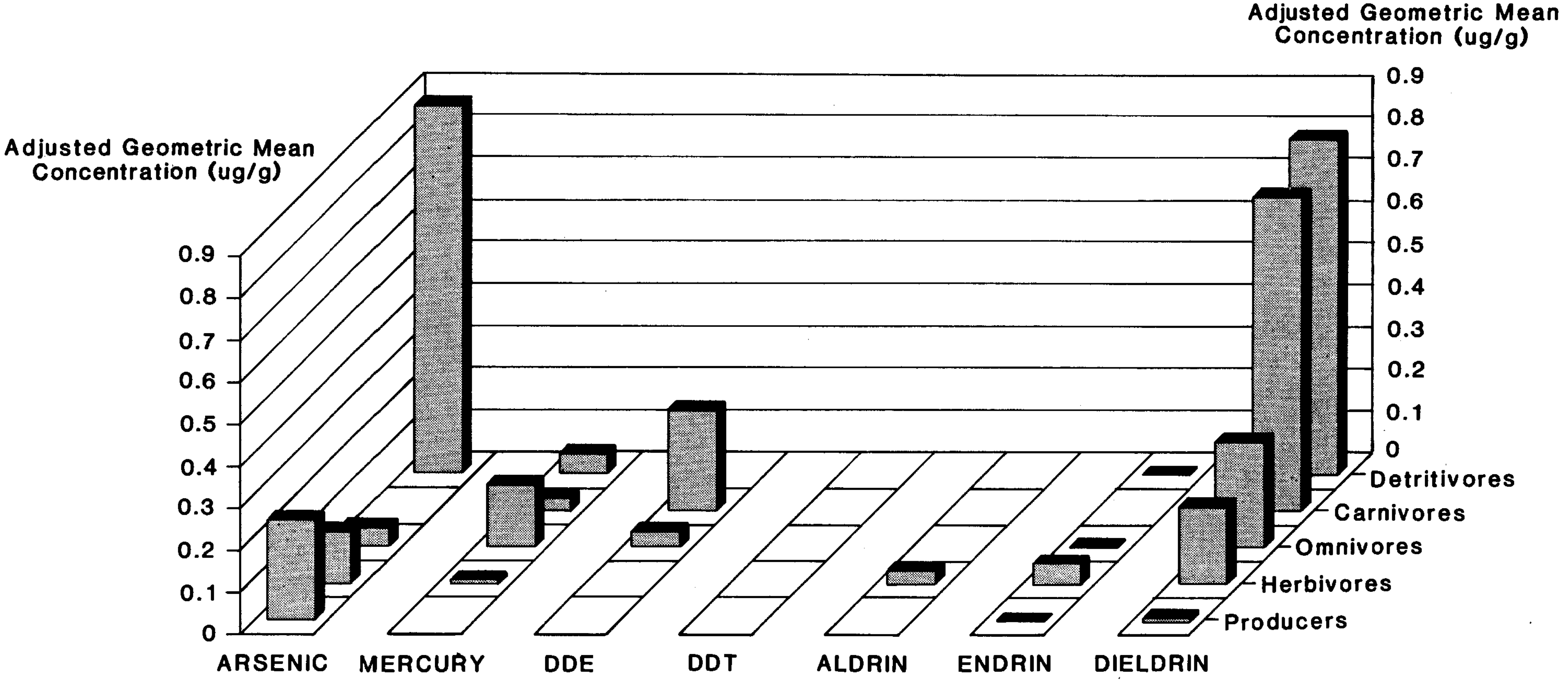
Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A3.5-3

Extent of Arsenic and Mercury
Contamination in Terrestrial Biota
Sampled at RMA

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

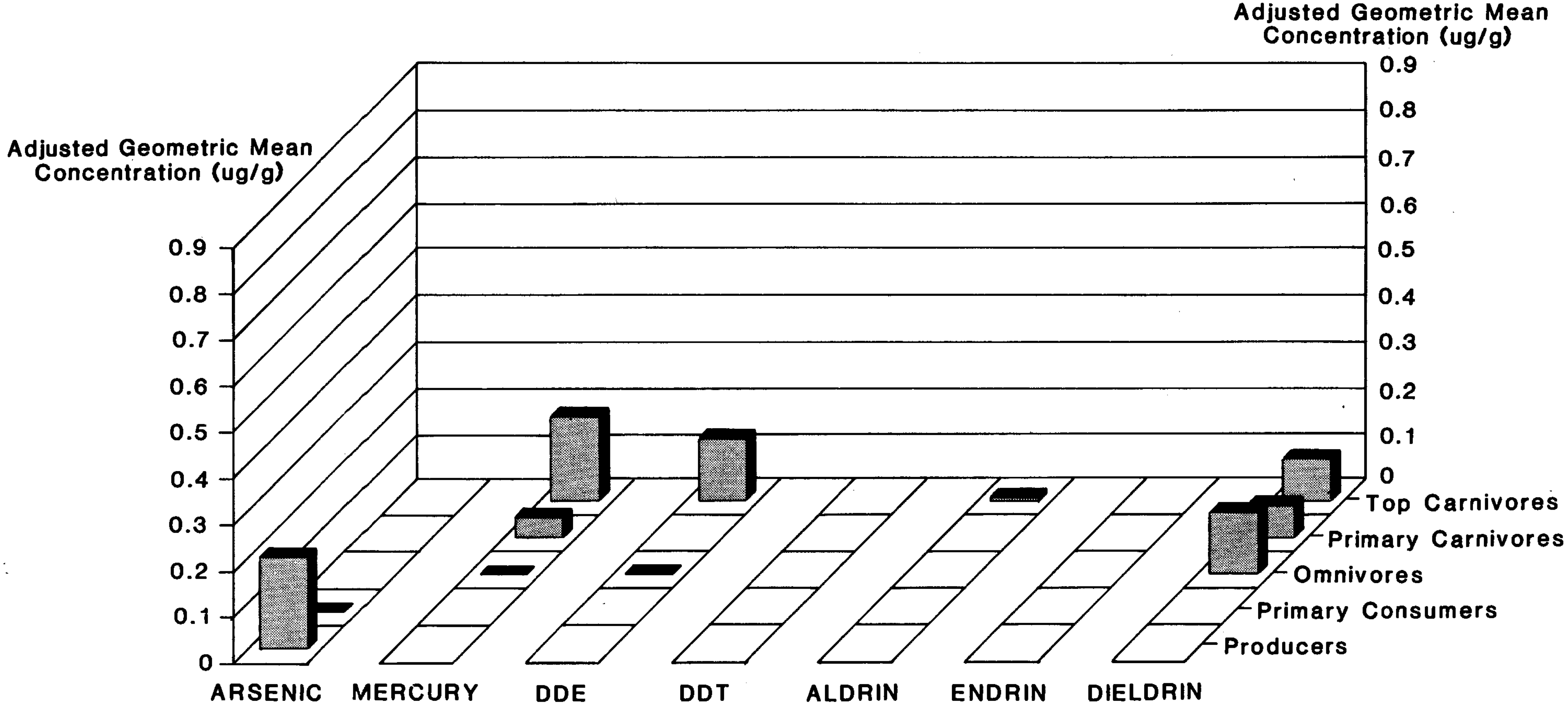
Prepared August 1991

FIGURE RISR A3.5-4

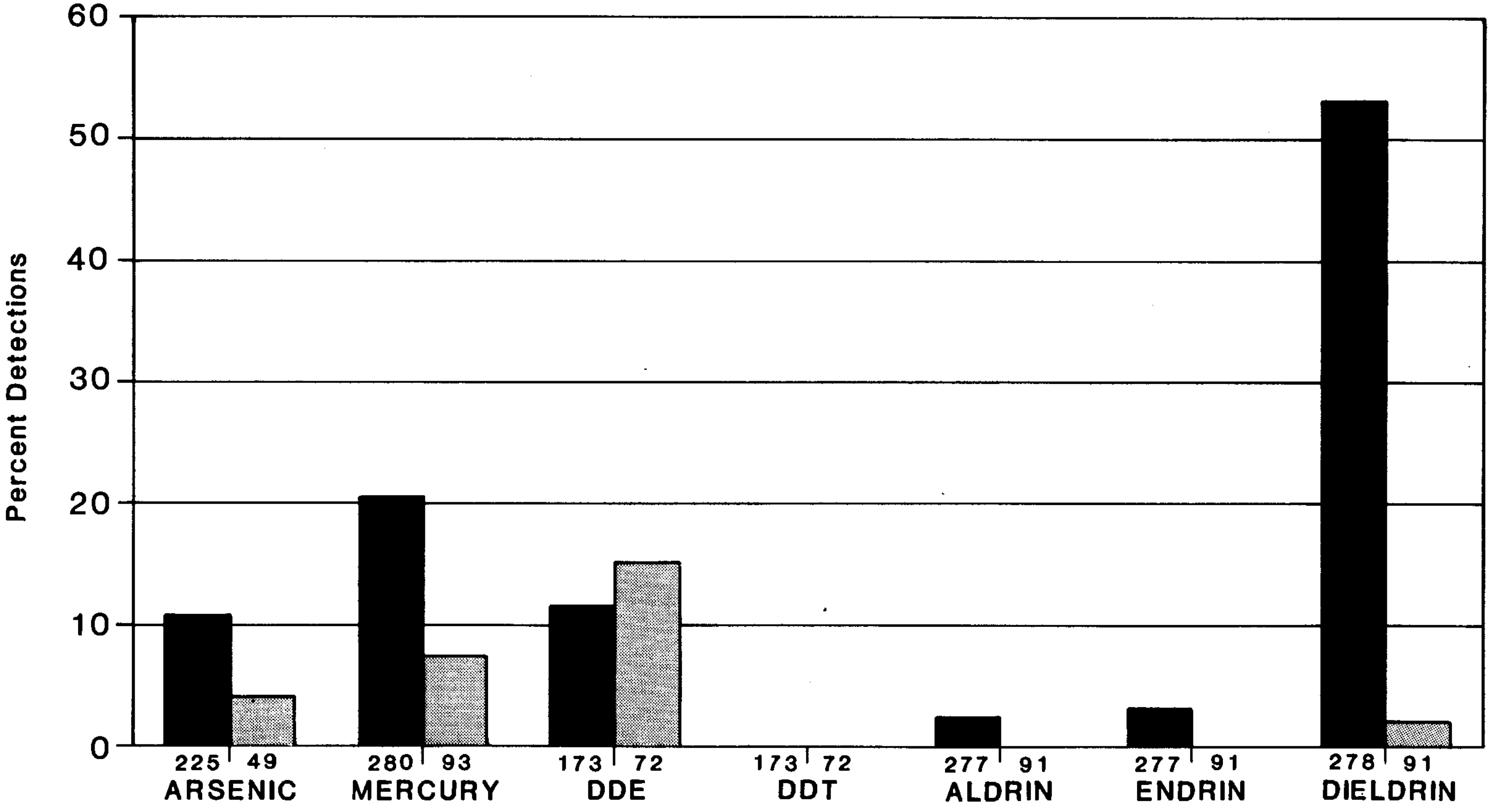
Terrestrial Trophic Analyte Concentrations, Adjusted Geometric Mean

Rocky Mountain Arsenal

Prepared by: Ebasco Services Incorporated



Prepared for:	FIGURE RISR A3.5-5
U.S. Army Program Manager for Rocky Mountain Arsenal	Aquatic Trophic Analyte Concentrations, Adjusted Geometric Mean
	Rocky Mountain Arsenal
Prepared August 1991	Prepared by: Ebasco Services Incorporated



BIOTA ANALYTES

■ RMA ▨ OFF POST

NOTE: Numbers at base of bars refer to total number of samples.

Prepared for:

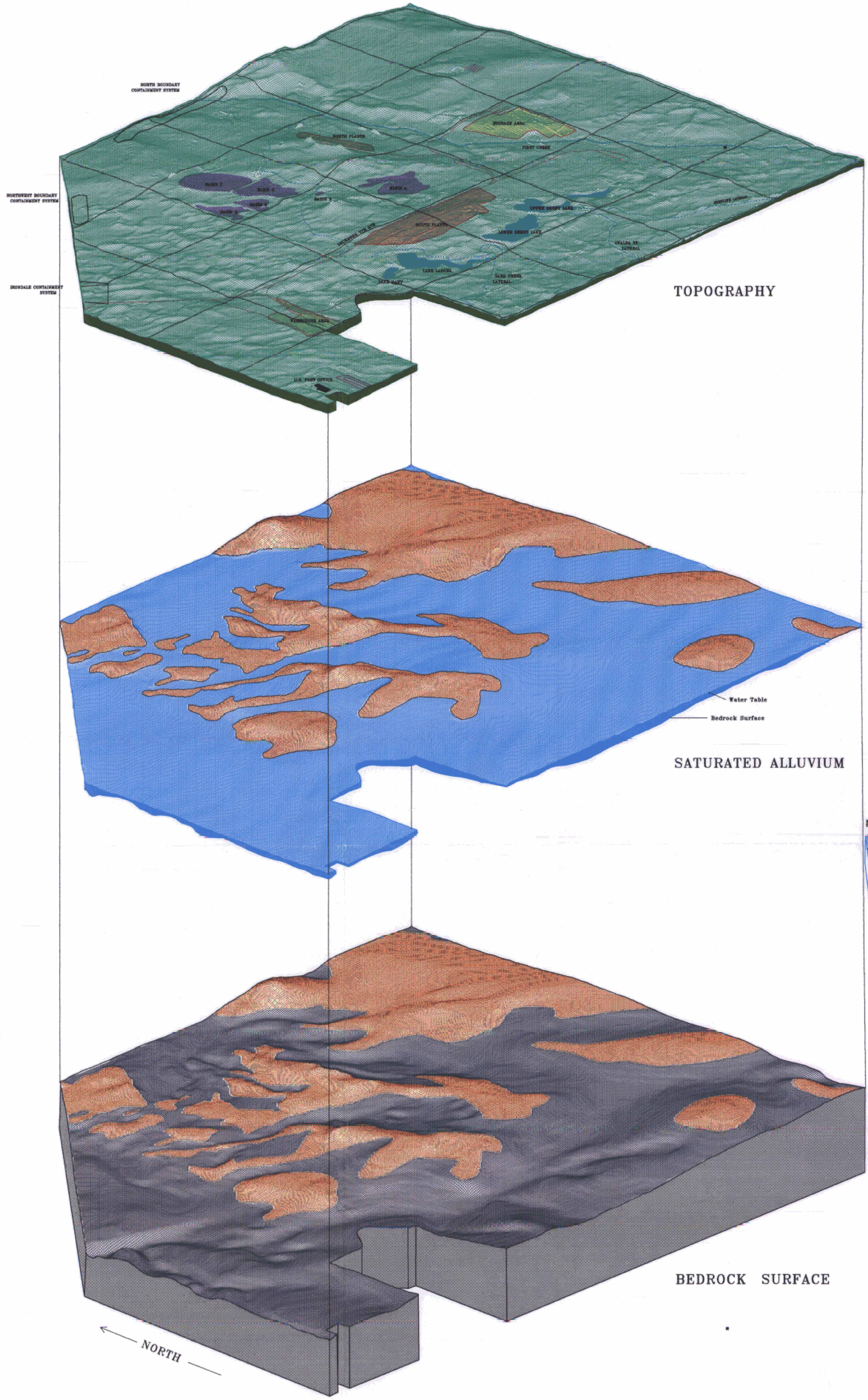
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A3.5-6

Biota Contaminant Detections
(On-Post vs. Off-Post Controls)

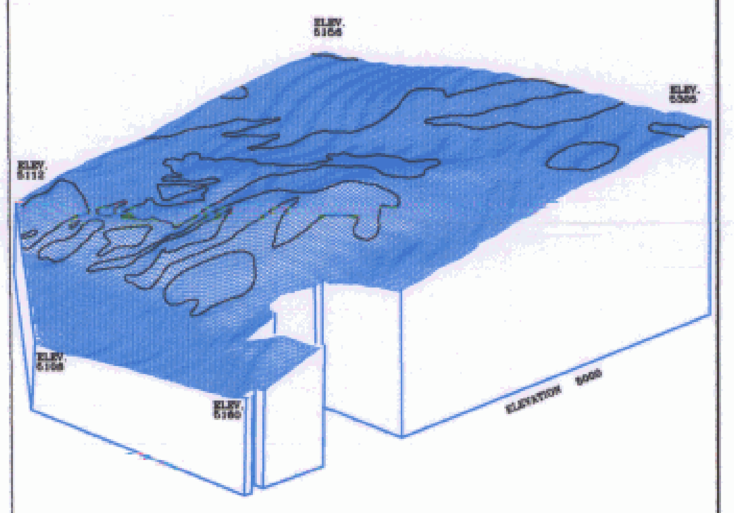
Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



EXPLANATION

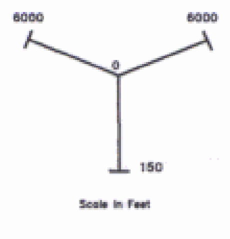
—	ROAD
—	RAILROAD
—	CONTAINMENT SYSTEM
—	STREAMS
- - - -	DRAINAGE – LATERALS
—	AIRPORT RUNWAY
🟧	PLANTS AREAS
🟪	BASINS
🟦	LAKES
🟨	STORAGE AREA
🟩	WAREHOUSE AREA
🟥	DEMOLITION AREA

🟦	REGION OF SATURATED ALLUVIUM
🟧	REGION OF UNSATURATED BEDROCK
⬛	REGION OF SATURATED BEDROCK

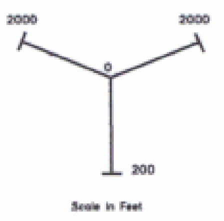


GROUNDWATER SURFACE *

VERTICAL EXAGGERATION: 40X



(* Generalized from potentiometric surface of the unconfined flow system, 4/87 – 6/87; Water Remedial Investigation Report, Figure 2.4; EBASCO, 1989d)



Vertical Exaggeration 10X

Prepared for:

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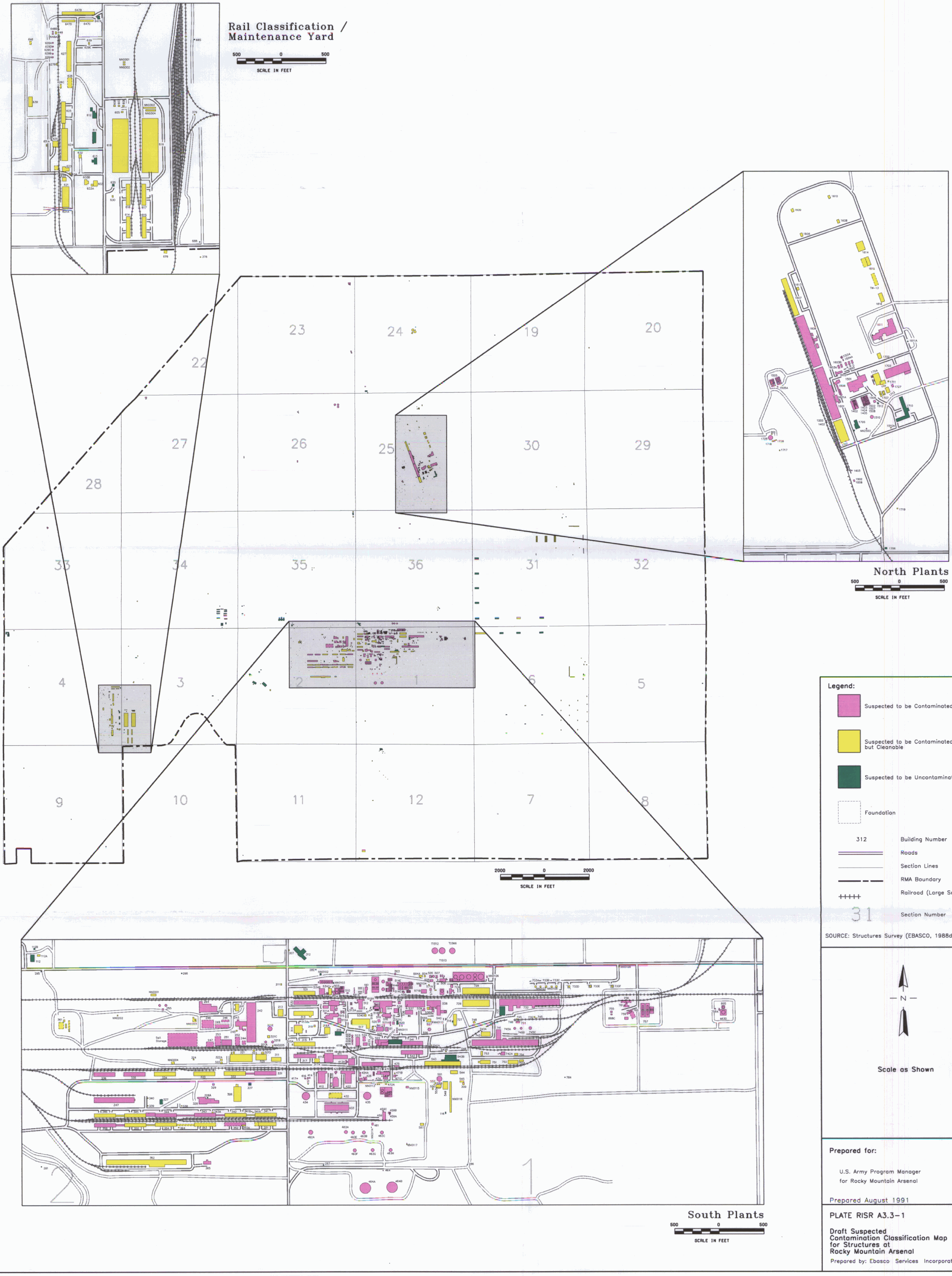
for Rocky Mountain Arsenal

Prepared August 1991

PLATE RISR A1.1–1

Isometric View of RMA

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Legend:

🟪	Suspected to be Contaminated
🟨	Suspected to be Contaminated but Cleanable
🟩	Suspected to be Uncontaminated
☐	Foundation
312	Building Number
═	Roads
─	Section Lines
─ ─	RMA Boundary
┼┼┼┼┼	Railroad (Large Scale)
31	Section Number

SOURCE: Structures Survey (EBASCO, 1988d)

N

Scale as Shown

Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

PLATE RISR A3.3-1

Draft Suspected
Contamination Classification Map
for Structures at
Rocky Mountain Arsenal

Prepared by: Ebasco Services Incorporated

92017R01
APPENDIX A
TEXT AND TABLES
1ST COPY

TECHNICAL SUPPORT FOR

ROCKY MOUNTAIN ARSENAL

FINAL
REMEDIAL INVESTIGATION SUMMARY REPORT
APPENDIX A - ENVIRONMENTAL SETTING, RI APPROACH, NATURE AND EXTENT OF CONTAMINATION - TEXT AND TABLES
VERSION 3.2

January 1992

Contract Number DAAA15-88-D-0024

PREPARED BY:

EBASCO SERVICES INCORPORATED
APPLIED ENVIRONMENTAL, INC.
CH2M HILL DATACHEM, INC.
R.L. STOLLAR AND ASSOCIATES

PREPARED FOR:

U.S. ARMY PROGRAM MANAGER FOR
ROCKY MOUNTAIN ARSENAL

THE INFORMATION AND CONCLUSIONS PRESENTED IN THIS REPORT REPRESENT THE OFFICIAL POSITION OF THE DEPARTMENT OF THE ARMY UNLESS EXPRESSLY MODIFIED BY A SUBSEQUENT DOCUMENT. THIS REPORT CONSTITUTES THE RELEVANT PORTION OF THE ADMINISTRATIVE RECORD FOR THIS CERCLA OPERABLE UNIT.

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TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

Section | Page

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Plate

Appendix A

Site Characterization, Methodology, and Findings of the Remedial Investigation

Remedial Investigation Summary Report

APPENDIX A - TABLE OF CONTENTS

APPENDIX A - TABLE OF CONTENTS
(continued)

Section Page

APPENDIX A - TABLE OF CONTENTS
(continued)

APPENDIX A - LIST OF TABLES

APPENDIX A - LIST OF TABLES
(continued)

APPENDIX A - LIST OF TABLES
(continued)

APPENDIX A - LIST OF FIGURES
(Note: Appendix A1 and A3 Figures are
bound separately with Appendix A Plates)

Figure

APPENDIX A - LIST OF FIGURES
(continued)

Figure

APPENDIX A - LIST OF FIGURES
(continued)

Figure

APPENDIX A - LIST OF FIGURES
(continued)

Figure

APPENDIX A - LIST OF FIGURES
(continued)

APPENDIX A - LIST OF FIGURES
(continued)

APPENDIX A - LIST OF PLATES

APPENDIX A - LIST OF ABBREVIATIONS

Analyte Groups and Selected Analytes

DBCP	Dibromochloropropane
DDE	Dichlorodiphenylethane
DDT	Dichlorodiphenyltrichloroethane
DIMP	Diisopropylmethyl phosphonate
GB	Nerve agent Sarin
ICP metals	Metals analyzed for by inductively coupled argon plasma spectroscopy; includes cadmium, chromium, copper, lead, and zinc
OCP	Organochlorine pesticides
ONC	Organonitrogen compounds
OPHGB	Organophosphorous compounds, GB-agent related
OPHP	Organophosphorous compounds, pesticide related
OSCH	Organosulfur compounds, herbicide related
OSCM	Organosulfur compounds, mustard-agent related
PAH	Polynuclear aromatic hydrocarbons
SHO	Semivolatile halogenated organics
SVOC	Semivolatile organic compounds
TCE	Trichloroethylene
VAO	Volatile aromatic organics
VHC	Volatile hydrocarbons
VHO	Volatile halogenated organics
VOC	Volatile organic compounds

National Acts and Organizations

AMC	U.S. Army Materiel Command
DOD	U.S. Department of Defense
EPA	U.S. Environmental Protection Agency
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USDA-SCS	U.S. Department of Agriculture - Soil Conservation Service
USFWS	U.S. Fish and Wildlife Service

Local Terminology

ACM	Asbestos-containing materials
AGM	Adjusted geometric mean
ANOVA	Analysis of variance test
AQ	Air quality (station)
BDL	Below detection limit

APPENDIX A - LIST OF ABBREVIATIONS
(continued)

BEMA	Bald Eagle Management Area
CAR	Contamination Assessment Report
CDH	Colorado Department of Health
CEC	Cation exchange capacity
CFS	Confined flow system
CMP	Comprehensive Monitoring Program
CO	Colorado
CRL	Certified reporting limit
DFA	Direct flow area
EA	Endangerment Assessment
ESA	Eastern Study Area
FS	Feasibility Study
FY	Fiscal year
GT	Greater than
ICS	Irondale Containment System
IR	Indicator range
IRA	Interim Response Action
ISP	Initial Sampling Program
LA	Lignite A (also LB, LC, LD)
LT	Less than
M	Meteorological data collection site
MDL	Method detection limit
N	Number of detections
NA	Not analyzed
N/A	Not applicable
NBCS	North Boundary Containment System
NC	Not calculated
NCSA	North Central Study Area
ND	None detected
NI	Not identified
NWBCS	Northwest Boundary Containment System
OAS	Organizations and State
PM-10	Respirable particulates
PMRMA	Program Manager for Rocky Mountain Arsenal
RI	Remedial Investigation
RIC	Rocky Mountain Arsenal Information Center
RI/FS	Remedial Investigation/Feasibility Study
RISR	Remedial Investigation Summary Report
RMA	Rocky Mountain Arsenal

APPENDIX A - LIST OF ABBREVIATIONS
(continued)

RMACCPMT	Rocky Mountain Arsenal Contamination Control Program Management Team
S	Number of samples analyzed
SAR	Study Area Report
SPSA	South Plants Study Area
TIC	Tentatively identified compound
TMP	Transitional Monitoring Program
TSP	Total suspended particulates
UFS	Unconfined flow system
USCS	Unified Soil Classification System
WRIR	Water Remedial Investigation Report
WSA	Western Study Area

Companies

CAL	California Analytical Laboratories, Inc.
EBASCO	Ebasco Services Incorporated
ENSE	ENSECO Inc. (formerly Rocky Mountain Analytical Laboratories)
ESE	Environmental Sciences and Engineering, Inc.
DataChem	DataChem, Inc. (formerly Utah Biomedical Test Laboratory, UBTL)
HB&A	Harland Bartholomew and Associates, Inc.
HITT	Hittman-Ebasco
MKE	Morrison-Knudsen Engineering
MRI	Midwest Research Institute
RCI	Resource Consultants, Inc.
RLSA	R.L. Stollar & Associates, Inc.
Shell	Shell Oil Company
WWE	Wright Water Engineers

Analytical Methods

AA	Atomic absorption spectroscopy
CVAA	Cold vapor atomic absorption spectroscopy
GC/ECD	Gas chromatography/electron capture detector
GC/FID	Gas chromatography/flame ionization detector
GC/FPD	Gas chromatography/flame photometric detector
GC/HECD	Gas chromatography/Hall electrolitic conductivity detector
GC/MS	Gas chromatography/mass spectrometry
GC/NPD	Gas chromatography/nitrogen phosphorous detector
GFAA	Graphite furnace atomic absorption spectroscopy

APPENDIX A - LIST OF ABBREVIATIONS
(continued)

HPLC	High pressure liquid chromatography
ICP	Inductively coupled argon plasma spectroscopy
IONCHROM	Ion chromatography
SPEC	Spectrophotometry

<u>Measurements, Quantities, and Parameters</u>

a_N	Concentration of the Nth detection
atm	Atmosphere
atm-m^3/mol	Atmospheres-cubic meters per mole
cfs	Cubic feet per second
°F	Degrees Farenheit
ft	Foot, feet
ft^2	Square feet
K_d	Soil-water partition coefficient
mg/l	Milligrams per liter
ml/g	Milliliters per gram, a measure of aqeous solubility
mm Hg	Millimeters mercury, a measure of vapor pressure
msl	Mean sea level
pH	A measure of acidity or alkalinity
sq mi	Square mile(s)
yd^3	Cubic yards
µg/g	Micrograms per gram (equivalent to parts per million)
µg/l	Micrograms per liter (equivalent to parts per billion)
µg/m^3	Micrograms per cubic meter

Appendix A1

Environmental Setting
Text

Remedial Investigation Summary Report

A1 ENVIRONMENTAL SETTING

The Rocky Mountain Arsenal (RMA) covers 27 square miles (sq mi) in western Adams County, CO, approximately 8 miles northeast of Denver. Areas bordering RMA exhibit varied land use. To the north and east the land is primarily agricultural, although a great deal of business and residential activity is anticipated because the new Denver airport site is located adjacent to the eastern boundary of RMA. The southern boundary is adjacent to the Denver residential, commercial, and industrial community of Montbello and to Stapleton International Airport. Commerce City borders RMA on the west, where land use is also residential, commercial, and industrial.

A1.1 PHYSIOGRAPHY

RMA is located at the western edge of the Colorado plains, near the foothills of the Rocky Mountains. It occupies an area of rolling terrain characterized by grasslands, shrublands, wetlands, aquatic habitats, and extensive weedy areas, and supports a variety of plant and wildlife species. The elevation above mean sea level ranges from 5,330 feet (ft) at the southeastern boundary of RMA to approximately 5,130 ft at the northwestern boundary. Maximum local topographic relief in the area is approximately 200 ft. An exaggerated isometric view of RMA surface topography is shown in Plate RISR A1.1-1.

Regional surface drainage is toward the northwest into the South Platte River, which flows parallel to the northwest boundary of RMA and eventually joins the North Platte River in Nebraska. The land surface of the RMA has been largely shaped by fluvial processes associated with the South Platte River and its tributaries. Alluvial terraces dominate the landscape, and are accompanied by steeper sloped terrace escarpments. Eolian sand deposits mantle and obscure the alluvial land surface in many areas, particularly in the southern and western portions of RMA. Landforms in these areas include stabilized dunes and water-reworked eolian plains with poorly integrated and partially buried drainage channels (J.P. Walsh, 1988).

A1.2 CLIMATE

Climatic data were collected at a National Weather Service meteorology station at Stapleton International Airport. Because of the close proximity and relatively uniform topography between the airport and RMA, the meteorological conditions are similar at the two sites. The area is generally classified as mid-latitude and semi-arid. The climate is characterized by low relative humidity, abundant sunshine, relatively low rainfall, moderate to high winds, and a wide daily range in temperature.

The mean maximum temperatures range from 43°F in January to 88°F in July; mean minimum temperatures range from 16°F in January to 59°F in July. The average diurnal fluctuation is about 28°F. Fluctuations of 20° to 35°F may occur in just a few hours during the winter due to warm, high intensity "chinook" winds caused by migrating air masses.

A summary of precipitation data at Stapleton is given in Figure RISR A1.2-1. Annual precipitation averages approximately 15 inches. Average monthly precipitation is highest in May and lowest from December through February. The maximum precipitation events are heavy localized thunderstorms that occur during late spring and summer. Tornadoes may develop during frontal activity and convective instability commonly associated with intense thunderstorm activity. Several work trailers and buildings at RMA were damaged by tornadoes in the summer of 1986. Tornadoes touched down but did little damage in the summers of 1987 and 1988. Severe hailstorms may also occur in association with intense thunderstorm activity. Snowfall normally occurs from September through May, although snow has also been recorded in June and August. July is the only month with no recorded snowfall. Annual snowfall averages 63 inches. Average monthly snowfall is highest in March when snow also tends to have the highest moisture content. Snow generally melts rapidly at RMA and normally does not cover the ground for extended periods.

RMA wind data are presented in the form of a wind rose in Figure RISR A1.2-2. The length of the bars indicates the percent of time that the wind blows from each of the indicated directions, and the coded segments along each bar depict the relative frequency of each wind speed category. The figure shows that prevailing winds originate in the south and the south-southwest. Annual mean wind speed is approximately 9 miles per hour (mph). In summer the strongest winds are associated with thunderstorms. In other seasons the strongest winds are generally from the northwest quadrant and are downslope "chinook" winds. During the 1951 to 1980 time period, the highest windspeed recorded at Stapleton as a 1-minute average was 44 mph from the northwest.

A1.3 CULTURAL FEATURES

The prominent cultural features at RMA are shown on Plate RISR 1.3-1. RMA was established in 1942 to produce and test chemical warfare agents and incendiary munitions. Most military and industrial activities occurred at three sites: North Plants, South Plants, and the Rail Classification/Maintenance Yard, and most of the structures at RMA are found at these sites. The primary roads at RMA form a grid with 1-mile spacing corresponding to Section lines.

According to the Structures Survey Report, there are 982 structures on RMA. Of these, 524 are buildings and foundations; 239 are tanks, tank farms, and piperuns; and 219 are electrical substations. Most of these structures (53 percent) are located in the South Plants area (Sections 1 and 2), 12 percent are located in the North Plants area (Section 25), 8 percent are located in the Rail Classification/Maintenance Yard (Sections 3 and 4), and the remaining 27 percent occur individually or in small clusters throughout RMA. Information on specific structures can be found in the Structures Survey Report (EBASCO, 1988c/RIC 88306R02).

There are five former disposal basins at RMA. Basin A (Section 36) was originally developed as an unlined evaporation basin for disposal of mustard and lewisite aqueous waste. Basin B (Section 35) was used as a holding pond for overflow from Basin A. Basins C, D, and E (Section 26) were created from natural depressions to hold overflow aqueous wastes from pre-existing basins. Basin F (Section 26) was a lined evaporative disposal basin constructed in 1956. An interim response action (IRA) for Basin F to containerize the liquids and stabilize soils and sludges in a waste pile was completed in May 1989. A discussion of the Basin F IRA is presented in Appendix C.

Three groundwater interception/treatment systems, the North Boundary Containment System (NBCS), the Northwest Boundary Containment System (NWBCS), and the Irondale Containment System (ICS) are present at RMA. These systems are designed to treat and to control the migration of groundwater contamination to offpost areas. The NBCS is located in Sections 23 and 24. It was constructed in June 1978 and expanded in January 1982. The NWBCS, located in Section 22, was completed in October 1984. The ICS, located at the northwest boundary in Sections 28 and 33, was completed in December 1981. Each groundwater interception/treatment system consists of an array of extraction wells, water treatment facilities, an array of injection wells, and, at the NBCS, recharge trenches (ESE, 1988i/RIC 89024R02). Recent or pending IRA activities at the boundary systems include installation of fine recharge trenches at the NBCS; extension of the slurry wall and installation of extraction, injection, and monitoring wells at the NWBCS; and at the ICS, installation of extraction, injection, and monitoring wells and improvements to the treatment facilities to allow for increased flow from the Rail Classifications Yard/Motor Pool Area to the ICS.

A1.4 GEOLOGY

RMA is located in the Denver Basin, an asymmetrical structural depression that formed approximately 67 million years ago as the present Rocky Mountains began to rise. The basin is approximately 300 miles long and 200 miles wide. The eastern flank of the basin dips very gently, while the western flank of the basin dips steeply along the Colorado Front Range, exposing most of the sedimentary section underlying RMA. RMA is situated near the structural axis of the basin. The uppermost sediments beneath RMA dip gently to the southeast at less than one degree. The sedimentary rocks in the Denver Basin are over 10,000 ft thick and contain units that range in age from Cambrian (approximately 500 million years old) to Recent. In addition to the surficial soils, only the two uppermost units are of interest for the purpose of the remedial investigation (RI) because, based on existing information, only they are potentially affected by RMA contamination in either soils or groundwater. These units are the Quaternary unconsolidated alluvium and the underlying Tertiary/Cretaceous Denver Formation, a member of the Dawson Group. Figure RISR A1.4-1 presents a general geologic map of the RMA vicinity.

A1.4.1 Soils

Soil associations at RMA were originally described and mapped by the U.S. Department of Agriculture Soil Conservation Service (USDA-SCS) (Sampson et al., 1974/RIC 81266R54). Shell and Morrison-Knudsen Engineering (MKE) recently remapped the soils because of observed discrepancies and lack of detail in previous studies. Soils maps in the study area reports (SARs) and in this report are based on the new data from this investigation (J.P. Walsh, 1988). Unified Soil Classification System (USCS) designations, used throughout the RI, are textural terms that generally correspond to Walsh's (1988) soil series and classifications.

Figure RISR A1.4-2 is a generalized map showing the distribution of RMA soils. The soils include three subgroups (Typic Haplustolls, Aquic Haplustolls, and Petrocalcic Paleustolls), six series (Bresser, Weld, Ascalon, Nunn, Satanta, and Truckton), and one undifferentiated soil (Disturbed Lands). Disturbed Lands comprise undifferentiated soils, fill and borrow materials, and industrial structures. Three phases of disturbed lands were recognized by Walsh (1988), based on texture of the soil series that likely occurred prior to the disturbance, and were classified accordingly as sandy, loamy, or clayey. Waste basins fit the concept of disturbed lands, but were mapped separately (J.P. Walsh, 1988) and are designated as such on the soils map.

Several physical, hydrological, and chemical properties of soil series and subgroups were identified that may influence contaminant migration. Cation exchange capacities (CECs) tend to be highest in soils containing argillic, or clay, horizons. The Weld, Satanta, and Nunn series, and to a lesser extent, the Aquic and Typic Haplustolls, contain clayey soils with high CECs. Clay minerology is primarily double-latticed smectites that could potentially absorb inorganic and some organic contaminants more strongly than single lattice clays. The infiltration potential of these clayey soils is low, and is conducive to runoff.

Sandier soils include the Ascalon, Bresser, and Truckton series. These soils have low clay percentages throughout their respective soil profiles, retain less water then do the clayey soils, and have fairly low bulk densities. Consequently, the infiltration potential of contaminants through the soil profile is enhanced. Soil pH ranges from slightly acid to strongly alkaline across RMA, and tends to increase with depth. Soil pHs above 7 tend to inhibit vertical migration of metals by enhancing the tendency for metals to precipitate. Alkaline soils include the Petrocalcic Paleustolls, and to a lesser extent, the Bresser and Satanta series.

A1.4.2 Alluvium

Virtually all of RMA is covered with unconsolidated Quaternary alluvial and eolian sediments that may locally reach thicknesses of up to 130 ft (Lindvall, 1980a; Lindvall, 1980b). Figure RISR A1.4-3 presents an isopach map of alluvium thickness across RMA. Eight distinct alluvial units are recognized; from oldest to youngest these are: the Verdos, Slocum, Louviers, Broadway, Loess, Eolian, Piney Creek, and Post Piney Creek. These units can be correlated with Pleistocene and Holocene glacial and interglacial (e.g. eolian) stages. The older Verdos, Slocum, Louviers, and Broadway units have a coarse texture indicative of high-energy, alluvial-fluvial depositional environments. These units generally coarsen westward. The remaining units are fine-grained, indicating eolian or low-energy fluvial environments (EBASCO, 1989h/RIC 89166R07; ESE, 1988h/RIC 88344R01). Figure RISR A1.4-4 illustrates the varied and heterogeneous nature of the materials composing the alluvium. Due to the nature of alluvial deposition and erosion and the irregular bedrock surface on which the alluvium lies, there is little lateral continuity in the alluvial units, and the spatial relationships between them are complex.

A1.4.3 Alluvium - Bedrock Contact

The unconformable contact between alluvium and Denver Formation bedrock is irregular but distinct. The coarser sandy and gravelly materials constituting the alluvium contrast sharply with the much finer grained sandstones, siltstones, and claystones of the Denver Formation. The bedrock surface is weathered in places at the contact and varies from friable, fractured and jointed, and heavily altered to more lithified, compacted material. The weathered portion of the Denver Formation is typically less than 10 ft thick, however, recent information collected subsequent to the RI indicates that it may locally extend to as much as 45 to 65 ft thick, particularly on bedrock topographic highs. Weathered bedrock depths are typically on the order of 15 ft at bedrock highs, and 5 ft at bedrock lows. The contact is irregular because deep paleochannels were incised in the bedrock surface and subsequently infilled with coarse-grained alluvium (ESE, 1988h/RIC 88344R01). Principal paleochannels are identified in Figure RISR A1.4-5, the bedrock surface contour map. Plate RISR A1.1-1 presents an exaggerated isometric view of the bedrock topography. The paleochannels facilitate groundwater migration and influence the direction and rate of movement of groundwater contaminant plumes at RMA.

A1.4.4 Denver Formation

The Late Cretaceous to Paleocene Denver Formation was deposited following the broad downwarp of the Denver Basin in Laramide time (67 million years ago). Tertiary and Quaternary erosion removed up to 700 ft of Denver Formation in the RMA area and incised deep channels in its erosional surface (MKE, 1988). At RMA the Denver Formation is exposed in only a few isolated outcrops and has been characterized almost entirely by subsurface data. The unit ranges from approximately 200 ft to 500 ft in thickness and is separated from the underlying Arapahoe Formation by a 30- to 50-ft-thick relatively impermeable claystone interval referred to by some hydrogeologists working in the Denver Basin as the "buffer zone" (Romero, 1976). Detailed lithologic and stratigraphic study of the Denver Formation has resulted in the identification of several sandstone-lignite/claystone sequences or "zones." Although sedimentary facies in the Denver Formation vary widely, they are generally interpreted as representing a low-energy fluvial depositional environment.

Stratigraphic relationships of the Denver Formation zones within RMA are illustrated in Figures RISR A1.4-6, A1.4-7, and in detailed cross-sections in the SARs (EBASCO, 1989a-c, e-h/RIC 89166R01 through 89166R07). The nomenclature scheme for the Denver Formation stratigraphy used in the RI reports is based on the occurrence of a thick, laterally continuous lignitic interval identified as Lignite A (LA). Subsequent lignitic intervals were designated LB, LC, and LD down-section from this marker. Using LA as the marker bed, Denver Formation zones were assigned a number based on proximity to this unit. The Denver Formation zone immediately below LA is called the number 1 upper (1U) zone, and is, in turn, underlain by the number 1 through 9 zones. Denver Formation zones above LA were assigned a letter designation based on proximity to the lignite marker, with the A zone immediately above LA. Above zone A is a volcaniclastic interval and an associated clay-rich stratigraphically equivalent zone. Zone B is the uppermost zone of the Denver Formation at RMA (ESE, 1988h/RIC 88344R01). Sandstone units within these stratigraphic zones are designated with an "S" prefix, as shown in Figure RISR A1.4-6.

A1.5 HYDROLOGY

Flow of surface water at RMA occurs through a network of streams and lakes and by infiltration and percolation into the unsaturated zone. Groundwater flow occurring within the alluvium and the uppermost part of the Denver Formation has been designated as the unconfined flow system (UFS). Within the Denver Formation, the series of bedrock strata that composes the Denver aquifer is designated as the confined flow system (CFS). Depending on site-specific hydrologic characteristics, varying degrees of hydraulic interchange are possible between surface water and groundwater and between the UFS and CFS.

A1.5.1 Surface Water

Five principal drainage basins and three smaller subcatchments are recognized within RMA and include the First Creek, Irondale Gulch, South Platte, Sand Creek, and Second Creek Drainage Basins, and the Basin A, Basin F, and Sand Creek Lateral subcatchments. Lakes, ditches, and creeks also exist within smaller subcatchments. Surface water features and monitoring and gaging station locations are shown in Figure RISR A1.5-1.

First Creek drains approximately 27 sq mi upstream of the Arsenal and 12 sq mi on RMA. Flow is northwest to the confluence of First Creek and O'Brian Canal north of the RMA boundary. In dry years, flow in First Creek is continuous only during spring runoff and during major storms (RLSA, 1990). Soil infiltration capacities are low to moderate in the drainage basin off post, and moderate on post (RCI, 1982/RIC 82096R01). As First Creek traverses RMA, several tributaries have the potential of contributing to its flow, including tributaries draining Upper Derby Lake in Section 6, the old Toxic Storage Yard in Section 31, and North Plants in Section 30. The Sand Creek Lateral joins First Creek in Section 25; however, because of infrequent flows and infiltration, water in the lateral normally has not reached the confluence in several years. Effluent from the Sewage Treatment Plant enters First Creek in Section 24, and just before First Creek crosses the north boundary, it intercepts a small channel which drains overflow from the North Bog. North Bog is a 2.7-acre body of water, located in the northwest corner of Section 24, that was used as a natural recharge for treated groundwater from the NBCS (RLSA, 1990).

Irondale Gulch drains 11.5 sq mi upstream from RMA and 6.5 sq mi within the southern portion of RMA. Flow is to the northwest. Four lakes (Upper Derby Lake, Lower Derby Lake, Lake Ladora, and Lake Mary) and two ponds (Rod and Gun Club Pond and Havana Pond) lie within the Irondale Gulch Drainage Basin. Surface areas for these water bodies range from 5 acres at the ponds to 94 acres at Lower Derby Lake. Average depths range from 3 ft at Rod and Gun Club Pond to 10 ft at Lower Derby Lake (RLSA, 1990). The Havana, Peoria, and Uvalda Interceptors and the Highline and Sand Creek Laterals originate south of RMA and flow north to the lakes in the Irondale Gulch drainage. The Sand Creek

Lateral continues northward across RMA and empties into First Creek in Section 25. Because the Sand Creek Lateral intercepts surface flow within the Irondale drainage, it is considered a subcatchment area (RLSA, 1990).

The South Platte Drainage Basin includes 6 sq mi in the northwestern corner of RMA. It is characterized by a large number of natural depressions and no distinct channel, similar to the Sand Creek Drainage Basin (RLSA, 1990). Soil infiltration capacities are high in the central portions of the drainage basin, low in the northern portions, and moderate elsewhere. Two subcatchment areas, Basin A and the Sand Creek Lateral, have been delineated because they intercept surface flow within the South Platte drainage (RLSA, 1990). Formerly, Basin F comprised a third subcatchment, however, as a result of the IRA activities completed in 1988 (see Appendix A of this report), Basin F is no longer present and the site is graded to drain to the northwest.

The Sand Creek Drainage Basin includes 2.2 sq mi of the Arsenal in the southwestern corner. Lack of channelized flow in the Sand Creek drainage has been attributed to high infiltration capacities of the soils in the area, which are mostly sandy Bresser and Truckton series soils (RCI, 1982/RIC 82096R01). Many natural depressions in the basin intercept runoff, so that surface flow tends to be local. The Sand Creek drainage is also interrupted by the airport runways and drainage system that extend into Section 10 adjacent to RMA.

Only a small portion of the Second Creek Drainage Basin is present in the northeast corner of RMA (0.6 sq mi out of a total drainage area of 20.6 sq mi). The main stream channel crosses RMA at the extreme northeast corner (RLSA, 1990). Drainage is to the northwest. Soils of the Second Creek drainage have low infiltration capacities off post (upstream) and low to moderate infiltration capacities on post. The more incised and sinuous nature of the channels in this drainage, in comparison with that of First Creek, may be attributed to the lower infiltration rates exhibited by the soils in this drainage basin (RCI, 1982/RIC 82096R01).

Streamflow at RMA is highly variable. Seasonal variations in stream discharge are generally greater than average year-to-year variations and are strongly affected by the amount of urban runoff, released or diverted flow, and direct precipitation. Streams on RMA are generally intermittent, and highest flows tend to occur during spring runoff and during major storms. Streams with highest discharge are the Havana and Uvalda Interceptors and First Creek. During the period 1986 to 1988, while the RI was being conducted, a maximum of 6 cubic feet per second (cfs) was measured in the Havana Interceptor in April 1988. Maximum discharges in First Creek south and the Uvalda Interceptor during this same period were 5 cfs and 25 cfs, respectively. Both measurements were taken in April 1986. Water levels in the lakes are less variable than stream discharge and are regulated. Peak storage volumes usually occur in spring or early summer.

According to a study of flooding potential at RMA (COE, 1983/RIC 84066R01), a 100-year flood would cover the projected floodplain illustrated in Figure RISR A1.5-2. This study was based on existing development and existing drainage facilities; however, continued urban development of areas south of RMA would cause flooding potential to increase if detention facilities were not constructed. Recent studies of flood potential at RMA incorporated consideration of continuing urban development in areas to the south to define flood peaks and volumes for runoff from the 2-, 5-, 10-, and 100-year floods for various development conditions. These included existing development and existing drainage facilities, future development and existing drainage facilities, and future development and proposed drainage facilities (WWE, 1988a/RIC 88188R01; WWE, 1988b/RIC 89111R01). Flood hazards were determined for the watersheds based on comparisons of the system's capacity to projected flood peaks. It was concluded that, whereas many of the channels could convey the flood peaks, the increase in depth and velocity of flow would cause extensive channel bank and bed erosion. Various alternatives were considered and an outfall system plan was developed to increase channel capacity and storage volume in the First Creek, Irondale Gulch, and Direct Flow Area (DFA) 0055 systems (WWE, 1990a/RIC 90115R02; WWE, 1990b/RIC 90115R01).

A1.5.2 Unsaturated Zone

The unsaturated zone consists of unsaturated material between the land surface and the water table. Interconnected pore spaces in this zone serve either as conduits through which fluid migrates toward the saturated zone or as areas in which water is retained. The interaction between surface and subsurface fluids is significantly impacted by the thickness of the unsaturated zone. Thickness ranges from less than 5 ft in the area of the lakes, Basin A, and First Creek and the northcentral portion of South Plants to greater than 60 ft in the Western Tier area and part of Section 19 (Figure RISR A1.5-3).

Soils at RMA have been grouped into areas of low to high infiltration capacity based on USDA-SCS maps and published values of permeability and hydraulic conductivity. In general, highly permeable soils are located in the southwestern part of RMA (within Irondale Gulch Drainage Basin) while less permeable soils tend to be present in the northeastern part of RMA.

Fluid movement through the unsaturated zone varies seasonally. Soil moisture content generally increases during winter when plant transpiration is low and during spring when precipitation is high. Increased soil moisture increases the likelihood of percolation and groundwater recharge. During periods of snow melt or high precipitation, local runoff may cause ponding in low lying areas, enhancing the opportunity for movement through the unsaturated zone.

A1.5.3 Unconfined Flow System

The UFS includes saturated alluvium, eolian deposits, and permeable subcrops and of the Denver Formation. Impermeable clay zones in the Denver Formation occur at the base of the UFS. Saturated thickness varies from less than 10 ft to approximately 70 ft (Figure RISR A1.5-4). Horizontal hydraulic conductivity estimates from aquifer tests in the UFS range from 0.2 ft/day in the Denver Formation to greater than 900 ft/day in alluvial terrace gravels (EBASCO, 1989d/RIC 89186R01). Hydraulic conductivities in the alluvial portions of the UFS are approximately two orders of magnitude greater than those in the Denver

Formation portions. A potentiometric surface map of the UFS shows groundwater flow toward the north and northwest (Figure RISR A1.5-5). Spatial variations in hydraulic gradients may be attributed to variations in saturated thickness, hydraulic conductivity, locations of recharge and discharge, and configuration of the bedrock surface. Hydraulic gradients in areas of saturated alluvium are typically 0.002 to 0.009 ft/ft (EBASCO, 1989d/RIC 89186R01). Gradients are typically larger in the Denver Formation portions of the UFS. Water table fluctuations at RMA generally average 1 to 3 ft; however, seasonal fluctuations as large as 7 ft have been measured beneath South Plants. Fluctuations in the water table are artificially induced in the vicinity of the boundary containment systems and near the western RMA boundary, where the water table drops approximately 11 ft during the summer due to withdrawal of water from nearby Adams County Water and Sanitation District public water supply system wells. Currently, no production wells obtain water from the UFS on RMA.

Historical water level data indicate that hydraulic heads in the vicinity of Basin C and Basin F were 20 to 30 ft higher when the basins were in use than they are today (Smith et al., 1963/RIC 84324R02). The water table in these areas has continued to drop in recent years. Long-term water level fluctuations have been small in other areas of RMA.

Present-day recharge to the UFS occurs as infiltration of precipitation, seepage from lakes, reservoirs, streams, canals, and buried pipelines, and flow from the underlying CFS. Discharge occurs as seepage to lakes, underflow to off-post areas north and west of RMA, and as downward flow into the CFS.

Mass balance calculations have been used to estimate rates of hydraulic interchange between the lakes and basins and the UFS. Results indicate that Lower Derby Lake, Havana Pond, and Basin C are areas of groundwater recharge, whereas Lake Ladora, Lake Mary, and Basin A receive groundwater in upgradient areas and lose it in downgradient areas. Recharge-discharge conditions at Upper Derby Lake depend on lake level. Streamflow loss and gain studies indicate that all streams and canals at RMA lose water to the UFS over the course of a water year. However, actual recharge or discharge rates vary substantially in response to changes in stream discharge and aquifer head (EBASCO, 1989d/RIC 89186R01).

A1.5.4 Confined Flow System

The CFS consists of strata within the Denver Formation collectively referred to as the Denver aquifer, where water residing in permeable sandstone or lignite horizons is confined above and below by relatively impermeable shale or claystone horizons. The confining effect of the claystones and upgradient off-post recharge of the Denver aquifer produces artesian conditions in much of the CFS underlying RMA. That is, the potentiometric surface is above the upper confining horizons.

In other areas the potentiometric surface is below the water table of the UFS, allowing recharge of the CFS by leakage from the overlying UFS. Water enters the CFS by vertical leakage from the overlying UFS in areas where bedrock is predominantly shale or claystone. Rates of leakage per unit area are small but may be enhanced by movement through fractures. Both head difference and vertical hydraulic conductivity influence rates of leakage. Water also enters the CFS by underflow from areas south and east of RMA. These relationships are more fully explained in the Water RI Report (EBASCO, 1989d/RIC 89186R01).

Adjacent sand zones within the CFS are hydraulically connected. Hydraulic conductivity estimates vary spatially and reflect variations in lithology: estimates range from 10^{-4} to 10^{-2} feet per day (ft/day) for shale and claystone to 0.03 to 4 ft/day for sandstone (Figure RISR A1.5-6). In areas where hydraulic interchange is relatively unrestricted, water levels in adjacent sand zones tend to be similar. In areas where hydraulic interchange is small, water levels tend to be unrelated.

Discharge from the CFS probably occurs by lateral flow into the UFS locally where transmissive strata of the Denver aquifer contact the UFS and may occur by leakage to the Arapahoe aquifer. Currently, no production wells obtain water from the CFS on RMA.

A1.6 BIOLOGICAL HABITAT

RMA lies within the High Plains District of the North Temperate Grassland biome (Shelford, 1963). The region is dominated by a mosaic of grassland communities with a diverse component of wildflowers. Tall grass species are common in moist areas and short grass species prevail in dry areas. Historical patterns of land use have altered the original vegetation. Much of the off-post area north and east of RMA is used either as cropland or pasture. Most of the areas to the south and west of RMA are heavily urbanized. On-post human activity has resulted in vegetation dominated by weedy species and early successional colonists typical for the region.

Regional wildlife is dominated by species of prairie, steppe, and savannah communities. The wildlife species inhabiting RMA are those found in similar habitats off-post. RMA supports large populations of some species such as deer, hawks, and eagles. In contrast to surrounding areas where these species are hunted or are sensitive to human presence, RMA provides an oasis for wildlife. Its large acreage of diverse open habitats interspersed with lakes, small wooded areas, a mixture of native grasses and tall weedy forbs, along with a lack of hunting pressure and disturbance, have contributed to an abundance of many wildlife species greater than occurs off post. The abundance and availability of prey species attracts avian and mammalian predators.

A1.6.1 Vegetation

Vegetation at RMA is dominated by five broad community types: weedy forbs, cheatgrass/weedy forbs, cheatgrass/perennial grassland, native perennial grassland, and crested wheatgrass (Figure RISR A1.6-1) (ESE, 1989b/RIC 89173R02). Trees, shrubs, and minor communities occur within these five broad communities, providing support for diverse plant and animal species. Minor community types include sand sagebrush shrubland, rubber rabbitbrush shrubland, yucca grassland, cottonwood/willow stands, bottomland meadows, cattail marshes, and ornamental trees and shrubs. More detailed information on vegetation is available in the Biota RI Report (ESE, 1989b/RIC 89173R02).

A1.6.2 Wildlife

The wildlife component of RMA and the control areas contain the major species and most of the less common species found in similar habitats elsewhere in the region.

A1.6.2.1 Reptiles, Amphibians, and Fish

The most conspicuous reptiles at RMA are bullsnakes, which are frequently observed sunning themselves along roads. Other snakes commonly encountered are the western hognose snake in sandy terrain, the common gartersnake and plains gartersnake near water, and the yellow-bellied racer and plains rattlesnake in a variety of habitats. Three species of lizards are known to inhabit RMA; the lesser earless lizard, short-horned lizard, and the many-lined skink.

The northern chorus frog is probably the most abundant amphibian on RMA. It breeds in cattail stands and intermittent wet areas near Upper Derby Lake, Rod and Gun Club Pond, Havana Pond, and the North Bog. Bullfrogs and northern leopard frogs have been observed in wet areas near Lake Mary, Lake Ladora, and the North Bog. Upper Derby Lake, Rod and Gun Club Pond, Havana Pond, and the North Bog provide habitat for Woodhouses's toads, great plains toads, and plains spadefoot toads. Tiger salamanders are found in the North Bog (ESE, 1989b/RIC 89173R02).

First Creek supports plains killifish, fathead minnows, and some green sunfish. North Bog supports carp and fathead minnows. Largemouth bass, bluegill, bullhead, channel catfish, and northern pike are found in Lower Derby Lake, Lake Mary, and Lake Ladora. Sport fishing in the lakes is catch and release only.

A1.6.2.2 Birds

Waterfowl are conspicuous at RMA. Canada geese and various ducks (mallard, gadwall, blue-winged teal, and green-winged teal) are all known nesters. Other dabbling (surface-feeding) ducks include the northern shoveler, cinnamon teal, and American widgeon. All of these species are common on small ponds and lakes at RMA. Diving ducks prefer large waterbodies such as Lake Ladora and Lower Derby Lake and include the canvasback, redhead, ringnecked duck, lesser scaup, common goldeneye, bufflehead, ruddy duck, and the common and hooded mergansers. Only the redhead has been documented as an RMA breeder. Coots and grebes are nesters and migrants on RMA and are also found on large water bodies. Wading birds observed at RMA are the great blue heron and black-crowned night heron. 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. The most commonly observed gulls and shorebirds are herring and ring-billed gulls, killdeer, American avocets, willets, greater and lesser yellowlegs, long-billed dowitchers, and spotted sandpipers. Wilson's phalaropes, white-faced ibis, Virginia rails, and soras are also observed. Killdeer and avocets nest on post in small numbers and the Virginia rail and the sora apparently nest along the inlet of Lake Ladora, near Rod and Gun Club Pond, and on First Creek northeast of the North Plants. White pelicans and double-crested cormorants are occasionally seen in the summer.

Prevalent breeding songbirds of open habitats at RMA are the horned lark, western meadowlark, grasshopper sparrow, lark sparrow, and lark bunting. Deciduous trees along roadsides or in clumps are used for nesting by northern flickers, eastern and western kingbirds, black-billed magpies, American robins, loggerhead shrikes, northern orioles, lesser goldfinches, and lark sparrows. Ornamental and shade trees near buildings are attractive to house finches, house sparrows, Brewer's blackbirds, common grackles, and starlings. Denser tree stands with more diverse understory in riparian areas provide nesting habitat for the downy woodpecker, western wood-pewee, tree swallow, black-capped chickadee, gray catbird, red-eyed vireo, warbling vireo, yellow warbler, black-headed grosbeak, and indigo bunting. Also found in this habitat on post are house wrens, ruby-crowned kinglets, Swainson's thrushes, brown thrashers, orange-crowned warblers, yellow-rumped warblers, Wilson's warblers, chipping sparrows, white-crowned sparrows, Lincoln's sparrows, American goldfinches, and pine siskins.

Other common songbirds nesting at RMA include red-winged blackbirds, yellow-headed blackbirds, common yellowthroats, and song sparrows in cattail marshes. Rock doves, Say's phoebes, and barn swallows are common around abandoned buildings. RMA supports breeding populations of several species that breed only locally or rarely on the eastern plains: the short-eared owl, tree swallow, northern mockingbird, sage thrasher, and orchard oriole. Common winter birds are the western meadowlark, horned lark, and water pipit in open areas; the American tree sparrow, dark-eyed junco, and white-crowned sparrow in brushy areas; and the black-capped chickadee, brown creeper, and white-breasted nuthatch in wooded areas. Other prominent winter species include northern shrikes and Townsend's solitaires, and year-round residents such as house finches, house sparrows, starlings, and magpies (ESE, 1989b/RIC 89173R02).

A1.6.2.3 Raptors

The high density of raptors observed during the winter at RMA is attributable to the abundance of prey and perching habitat and the lack of human disturbance. Rough-legged hawks, ferruginous hawks, and red-tailed hawks are common during winter, as are golden eagles. Wintering owls include long-eared, short-eared, barn, and great horned.

Two species of high Federal concern, the bald eagle and the ferruginous hawk, are common winter residents. The Bald Eagle Management Area (BEMA) is a 6,700-acre area in the eastern and southern portions of RMA (Figure RISR A1.6-2). The BEMA is managed and maintained by the U.S. Fish Wildlife Service (USFWS) during the winter (October through April) and provides a roosting area for the bald eagle. More than 20 bald eagles wintered in the region during 1986-1987, and 1987-1988. Food habit studies have indicated bald eagle preference for a diet consisting primarily of prairie dogs and rabbits, many of which are stolen from ferruginous hawks. Eagles were rarely observed fishing on the RMA lakes during the winters of 1988 and 1987 (ESE, 1988g/RIC 88293R09).

Abundant suitable nesting habitat contributes to large breeding populations of hawks and owls. During the summer, Swainson's hawks and American kestrels are common and dominant breeders; great-horned, long-eared, short-eared, and burrowing owls are common breeders; and red-tailed hawks are also prevalent. Less common raptor species on RMA include Cooper's and sharp-shinned hawks, prairie falcons and merlins, and occasionally turkey vultures and osprey (ESE, 1989b/RIC 89173R02).

A1.6.2.4 Mammals

Coyotes are the largest and most conspicuous carnivores inhabiting RMA. The species is widespread on post, particularly in and near prairie dog towns. Badgers are also common and have been frequently observed in prairie dog towns during night surveys. Red fox, gray fox, swift fox, raccoon, striped skunk, and long-tailed weasel are other carnivores present at RMA.

Both mule deer and white-tailed deer are common and conspicuous at RMA. Ground counts conducted at RMA in 1986-1987 revealed up to 350 mule deer and 125 white-tailed deer. Such counts are high for the region, and both species are more abundant at RMA than off post (ESE, 1989b/RIC 89173R02).

Desert cottontails and black-tailed jackrabbits are abundant throughout RMA. Eastern cottontails and white-tailed jack-rabbits also occur in small numbers in thickets and riparian areas.

Black-tailed prairie dogs are the most conspicuous mammal at RMA. Aerial photographs and a literature review suggest colonies have expanded in recent years. Extensive colonies were documented in 1986 and 1987. An outbreak of silvatic plague at RMA in the winter of 1988 markedly decreased the number of prairie dogs; such occurrences are cyclic. Other rodents observed at RMA include thirteen-lined ground and spotted squirrels in open habitats, fox squirrels in riparian woodlands, muskrats on all permanent bodies of water, and pocket gophers throughout RMA. Small mammal trapping efforts in 1988 resulted in identification of deer mouse, plains harvest mouse, western harvest mouse, northern grasshopper mouse, prairie vole, meadow vole, Ord's kangaroo rat, hispid pocket mouse, and silky pocket mouse. Tall weedy forbes, yucca, sand sagebrush, and cattails are the most productive habitats for small rodents.

A1.6.3 Conservation and Management of Fish and Wildlife Resources

Conservation and management of fish and wildlife resources is accomplished through a cooperative agreement between the USFWS and the Army. The USFWS has three areas of responsibility under this agreement: contaminants, conservation and mitigation, and public relations. Under the first area of responsibility, the USFWS reviews contaminant-related studies including the Comprehensive Monitoring Program (CMP), remedial investigation/ feasibility study (RI/FS), and IRA documents; identifies ways to minimize contaminant exposure to fish and wildlife; and makes recommendations concerning contaminant exposure to the CMP, RI/FS, and IRA programs. Under the second area of responsibility, the USFWS conserves and protects wildlife and mitigates habitat losses during cleanup. Providing public relations support on wildlife issues is the third area of responsibility. Included in this area is a program that enables the public to learn more about the natural resources at RMA through wildlife tours and other activities involving the local community.

Appendix A2

RI Approach: Strategies of Media Sampling and Analysis Program

Text, Tables, and Figures

Remedial Investigation Summary Report

A2 RI APPROACH: STRATEGIES OF MEDIA SAMPLING AND ANALYSIS PROGRAMS

The strategies developed to assess the nature and extent of contamination in each of the media at the RMA were directed by the characteristics of the media and the objectives of the various sampling and analytical programs. One of the initial steps in assessing the contamination involved the selection of target analytes (organic compounds and metals) for laboratory analysis within each of the media. From the analyses performed, nontarget analytes were also tentatively identified, if possible. A summary explanation of the target and nontarget analytes is presented below, followed by specific discussions of the strategies for collecting and analyzing samples of the soils and sewers, water, structures, air, and biota media.

In order to manage, evaluate, interpret, and present the array of information collected by the RI in an accessible manner, the many hundreds of analytes and their breakdown products that were identifiable by the certified analytical methods used at RMA were organized into "target" and "nontarget" analytes. "Target" analytes are those that were identified in advance of the field investigations, and were deemed to have a high likelihood of being present at RMA based on knowledge of the activities that occurred there. For each of the media, the basis for designating a target analyte, the list of target analytes, and the analytical methods are presented in the media-specific discussions below.

The "nontarget" analytes are compounds that were not expected to be present at RMA in large quantities and that were not analyzed for specifically by a U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) certified method. However, some of the analytical methodologies employed for soil, water, liquid, and air samples permitted identification of nontarget analytes. Depending on the analytical method, detected concentration, matrix effects, background noise level, and other factors, nontarget analytes were identified at varying levels of confidence. The nontarget analytes that could be identified were called tentatively identified compounds (TICs).

The TICs were identified using gas chromatography/mass spectrometry (GC/MS) techniques. A gas chromatogram and a mass spectrum were produced for each separated compound detected at a concentration sufficient to generate a signal in the GC/MS instrument. The spectra obtained from the samples were compared with those stored in a computer library and best matches were recorded. This method was applied to all compounds with a GC peak area response greater than 10 percent of the internal standard's response. The spectral identifications were further reviewed by the analyst to produce a final tentative identification based on analyst experience and "best fit" of the data. In cases where spectral information was less complete, only a structural skeleton and general compound class were reported. In some cases, insufficient information was available from both the GC and MS data, and an identification could not be made.

The TICs differ from the target analytes in the degree of certification attached to the qualitative identification. This is discussed in detail in Section 1.4 of the Chemical Index (EBASCO, 1988b/RIC 88357R01), Section 2.2.2 of the Introduction to the Contamination Assessment Reports (CARs) (ESE, 1987a/RIC 88204R02), Section 2.1.1 of the SARs (EBASCO, 1989a-c, e-h/RIC 89166R01 through 89166R07), Section 2.2.2 of the Overall Soil Assessment and Groundwater Integration Technical Plan (ESE, 1988b/RIC 88203R05), and in various USATHAMA Certified Methods Manuals. Many of the TICs are uniquely identified; others are only generally described. All TICs are less confidently identified than are the target analytes and comprise a subset of the nontarget analytes. The TICs for each of the media are listed in the following media-specific discussions.

A2.1 SOILS AND SEWERS

In order to increase program efficiency at sites designated as potentially contaminated, the primary soil sampling and analysis program of the RI was conducted in two phases. The Phase I program was designed to identify the presence of potential contaminants within designated sites and surrounding areas. The objective of the Phase II program was to more precisely estimate the areal and vertical extent of contaminated soil within designated sites.

Separate sampling strategies were executed for potential source and nonsource areas. Potential source areas, as defined by the Rocky Mountain Arsenal Contamination Control Program Management Team (RMACCPMT, 1983/RIC 83326R01), were assigned to designated site investigation programs for in-depth study. Nonsource areas, defined as regions where no known disposal practices had occurred, were also investigated. The nonsource area investigations were designed to confirm historical records as well as to screen for previously unrecognized site activities. Both portions of the soil program provided for analysis of a wide variety of potential contaminants.

For each phase, a geotechnical strategy, a chemical identification plan, and an analytical strategy were formulated. Detailed descriptions of the soil sampling program, including physical sample collection and handling techniques, are presented in the technical plans for the individual tasks (referenced in Section 1.4 of this report) and the Phase I Introduction to the CARs (ESE, 1987a/RIC 88204R02). Details of the sampling and analytical results for individual sites, including any variations to the original plan, are included in the CARs and the Phase II Data Addenda, which have been cited in Section 1.4 of this report. Sediment and soil sampling of the sewers was primarily conducted in a single phase and is discussed in Section A2.1.3.

In addition to the two-phase soil program and the sewers investigation, other sampling and analytical programs were conducted to address specific concerns related to soil contamination. These programs are discussed below following discussions of the Phase I and II programs, and the sewers investigation.

A2.1.1 Phase I

The Phase I program was developed to investigate the suspected contamination of designated sites identified by the RMACCPMT, and previously unidentified sites. The designated sites, which were shown on the "Tricolor Map," were areas in which contamination was suspected to occur based on historical records, aerial photographs, and interviews with RMA and Shell personnel (RMACCPMT, 1984/RIC 84034R01). The scope of the Phase I program included an investigation of nonsource areas that comprised large portions of RMA with no known history of manufacturing, waste handling, or waste disposal. To these ends, a geotechnical strategy, chemical identification plan, and analytical strategy were developed.

A2.1.1.1 Geotechnical Strategy

Soil boring and sampling was conducted on all designated sites under Phase I investigations. These designated sites were identified through review of historical records by the RMACCPMT (1983, RIC 83326R01). Geophysical or soil gas investigations were included on a site-specific basis dependent on the nature of the site and on the applicability of these screening techniques. These data were used whenever possible to help design Phase I soil sampling efforts by directing sample collection to areas with a high potential for contamination. Integration of geophysical, soil gas, and sampling techniques produced the most cost-effective Phase I soil sampling program.

Although a wide variety of chemicals were handled at RMA, large portions of the site appear to have never been used for the manufacture or disposal of hazardous materials. This fact has been documented by several methods including interpretation of historical aerial photographs, examination of RMA records, examination of litigation interrogatories, and interviews with RMA and Shell personnel. Portions of RMA that had no historical evidence of manufacturing, waste handling, or waste disposal were designated as nonsource areas for the RI.

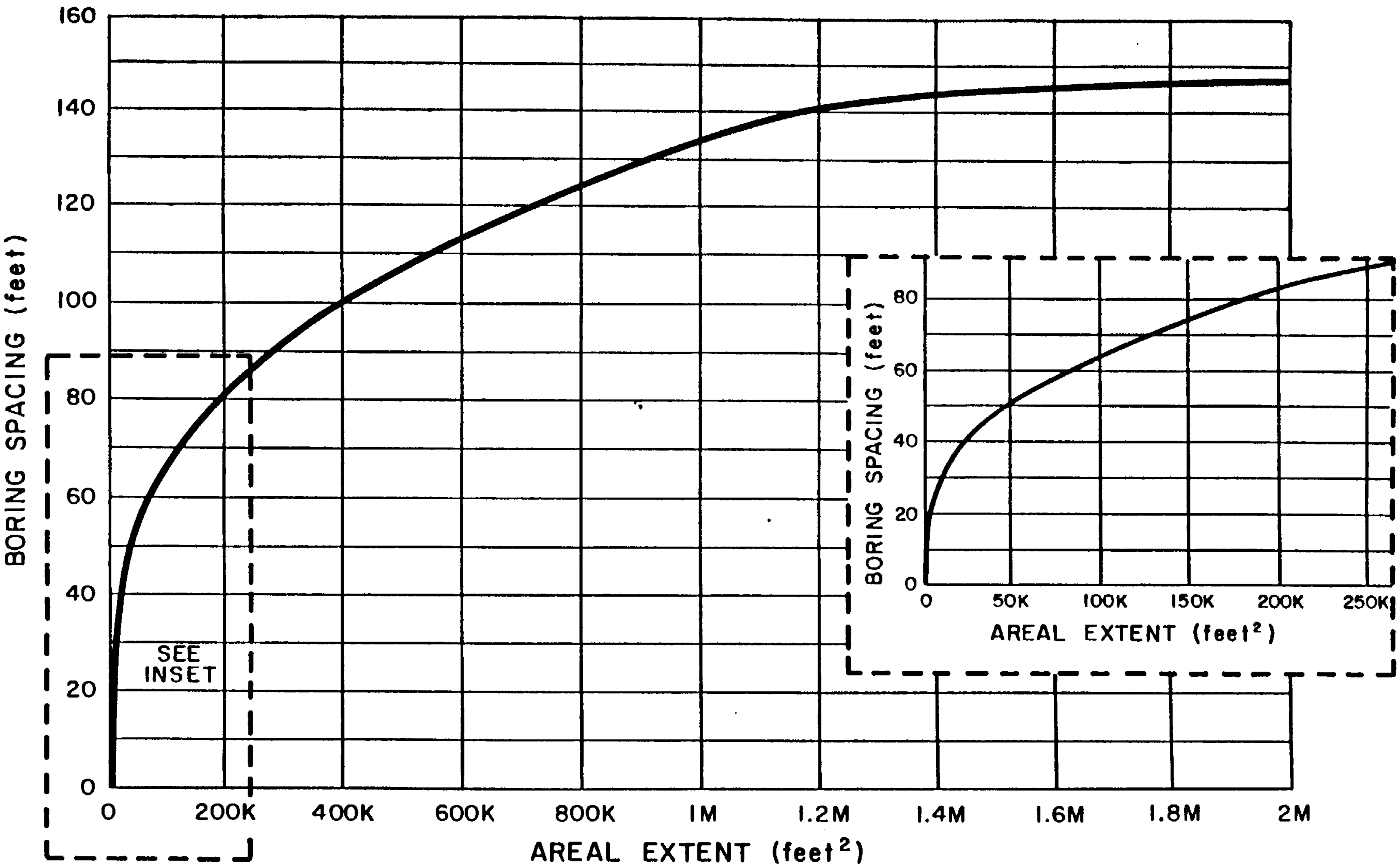
During the period when manufacturing and disposal occurred at RMA, attempts were made to leave a mile-wide buffer zone between RMA operations and the RMA boundary. Preliminary investigations indicate that the buffer was maintained, as sections located along the perimeter of RMA contain few potential contamination sites. Most manufacturing and disposal sites occur in interior sections of RMA, and the vast majority of potentially contaminated soils occur within these sections. Large portions of some of these interior sections, however, may not have been affected by RMA operations.

Nonsource areas were investigated under the RMA Phase I program to confirm the absence of contaminants. The Phase I program for nonsource areas involved soil boring, collection of soil samples, and chemical analysis of the collected samples. If contaminants were detected, the area in question was either included within the boundary of an existing site or designated as an additional site and subjected to an appropriate Phase I or Phase II investigation.

Boring Density

A rigorous statistical approach to sampling program design was considered early in the Phase I planning stages, but was found to be neither practical nor cost effective. The size and complexity of the RMA site, and the large number of potential sources of contamination, made the use of a statistically rigorous approach impossible. Therefore, a sampling program was designed using best professional judgment and considering all available historical information. The selected program design removed some of the bias associated with designing sampling programs for different types and sizes of contaminant sources by establishing a systematic approach based on the estimated areal extent of the source. The program relied on soil boring techniques for collection of samples in both designated sites and nonsource areas. Drilling was generally organized in a flexible grid pattern. The program included uniform sampling intervals so that the vertical extent of contamination could be calculated.

The density of Phase I borings at each designated site was determined through the use of empirical relationships based on past site experience. A boring density curve, shown in Figure RISR A2.1-1, was developed based on knowledge of soil investigation data from other hazardous waste sites throughout the country, historical data concerning contaminant disposal practices, and the estimated areal extent of each site. The curve provides closer borehole spacing at smaller sites, allowing multiple sample collections at even the smallest sites.



Source: ESE, 1985

Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A2.1-1

Borehole Spacing for Designated Sites Based on Site Areal Extent

Rocky Mountain Arsenal

Prepared by: Ebasco Services Incorporated

During the soil program design phase, the curve was used to estimate the total number of Phase I and II soil borings and to allow preliminary estimates of required effort and schedule. Exceptions to this initial design of the program were allowed for site-specific reasons.

Nonsource areas defined as the balance of the area within each of the 1-square-mile sections of RMA, excluding the designated sites within that section, were investigated by sampling on a more or less evenly spaced sampling grid. Borehole spacing was selected based on the occurrence of designated sites within the nonsource area. A closer borehole spacing was chosen for nonsource areas with a greater number of designated sites in the section, based on the greater potential for contamination in these areas. Once the grid was established, actual bore locations were adjusted based on field inspection to ensure that samples were collected from areas most likely to contain or concentrate contaminants (e.g., depressions, scarred areas, and similar features).

Boring and Sampling Methods

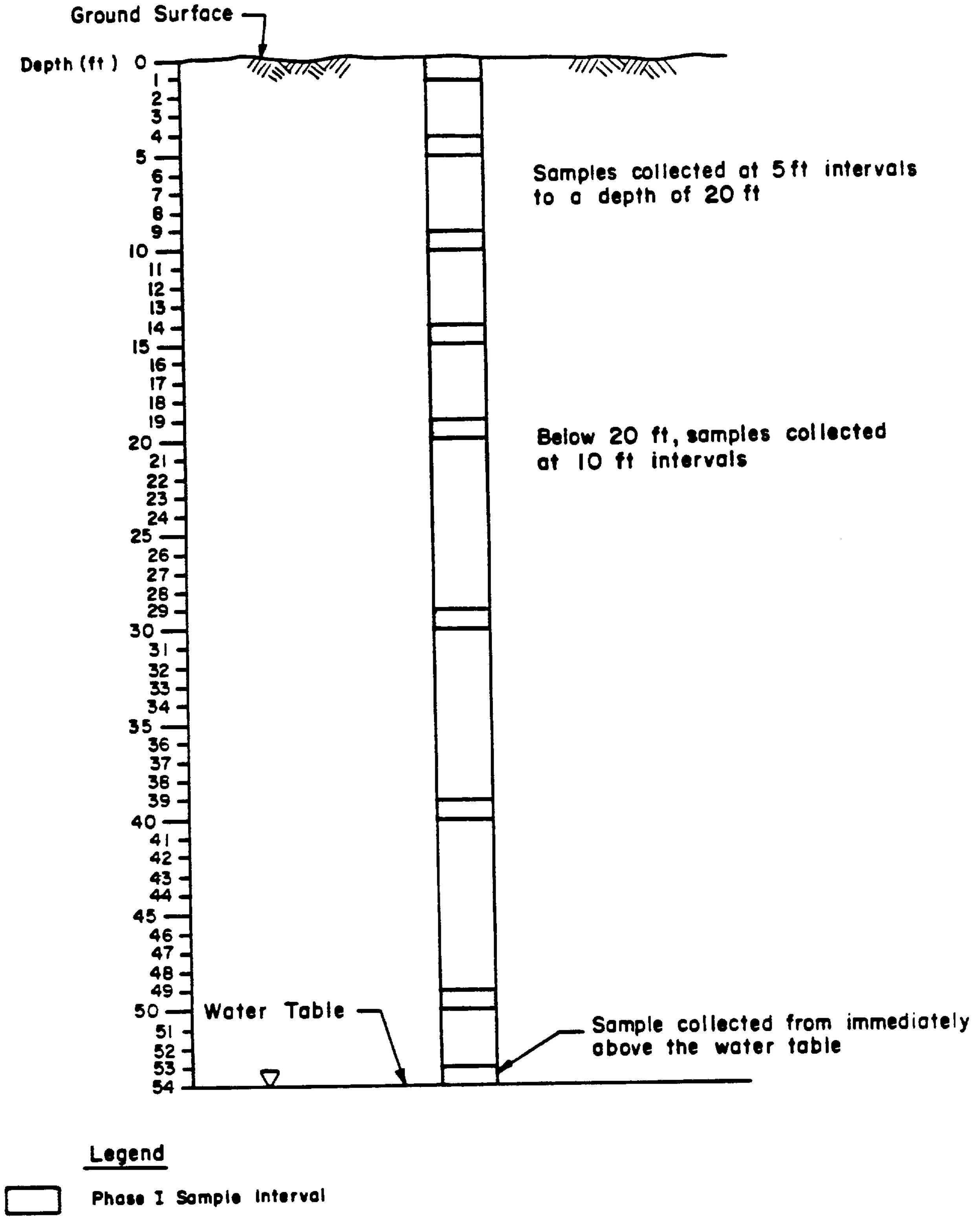
Soil borings were sampled using a continuous core augering technique. A core barrel containing a clear polybutyrate tube was placed inside a hollow-stem auger such that the soil core entered the tube as the auger advanced. The entire core was examined by the field geologist in order to determine geologic conditions, and generally samples were collected from standard depth intervals. Zones with visible evidence of potential contamination were sometimes substituted for, or added to, the standard intervals. A photoionization detector was used during boring to screen the borehole and breathing zone for volatile organics. In areas that were inaccessible to the drilling rig, samples were obtained by hand auger.

In areas where chemical warfare agents were anticipated based on site history, agent screening was conducted both in the field, for health and safety reasons, and in the laboratory at RMA. Field screening techniques included using portable chemical warfare agent test kits in the field primarily to ensure the health and safety of field personnel and not to assess contamination. Small subsamples were obtained from each core and composited over a sampling day to be analyzed by the RMA laboratory for chemical warfare agents. This screening by the RMA laboratory was conducted to prevent agent-contaminated materials from leaving RMA.

Sampling Depths

Standard depth intervals were selected for sampling to maintain consistency and facilitate spatial interpretation of contaminant concentration data for all sites. Selected intervals were 0- to 1-ft, 4- to 5-ft, 9- to 10-ft, 14- to 15-ft, and 19- to 20-ft below ground surface. Below 20 ft, soil samples were typically collected at 10-ft intervals to the maximum borehole depth. Figure RISR A2.1-2 illustrates these standard sampling intervals. Field personnel typically deviated from the standard sampling procedure when visual evidence of potential contamination was observed, high readings of organic vapors were noted on field monitoring equipment, the water table was encountered, or drilling became difficult. In these instances, samples were collected at nonstandard intervals. Exceptions to the uniform sampling approach and the reasons for the exception are listed in Table RISR A2.1-1. Site-specific exceptions are explained in the Phase I CARs. Phase I sampling was conducted primarily in the unsaturated zone. Approximately 30 percent of the Phase I borings were drilled to the water table, with deeper borings located near the center of sources or in areas suspected to host deep contamination. In some cases, because of changes in the water table, previously dry trench or disposal sites were saturated during the RI. In these areas, samples were collected from below the water table to the maximum estimated depth of trenching or disposal activities.

In nonsource areas, samples were collected at 0- to 1-ft and 4- to 5-ft depths to investigate the possibility of shallow and deep contamination of the type observed elsewhere in the designated sites. The 0- to 1-ft interval was selected to detect the presence of contaminants, such as organochlorine pesticides or trace metals, that may have been disposed of surficially or transported by wind. The 4- to 5-ft interval was selected to screen for the presence of deeper contamination associated with previously unidentified waste burial activities. The purpose of nonsource area sampling was to screen for the presence or absence of target analytes, rather than to quantify the concentrations of these contaminants. Consequently, the



Samples collected at 5 ft intervals to a depth of 20 ft

Below 20 ft, samples collected at 10 ft intervals

Sample collected from immediately above the water table

Note: Depths of actual borings varied. The water table generally represented the maximum depth of boring.

Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A2.1-2

Typical Soil Sampling Depth Intervals for Phase I Borings in Designated Sites

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

Table RISR A2.1-1. Examples of Exceptions to Uniform Soil Sampling Approach. Page 1 of 1.

Site	Exception	Reason for Exception
Lakes and Ponds	Boreholes not advanced to design depths and samples not obtained from standard intervals.	Able to penetrate and recover only shallow bottom sediments due to compacted, wet clays.
Ditches	Borehole spacing of 100 to 1,000 ft along ditch, rather than uniform grid sampling, depending on probability of encountering contamination, proximity to known sources, and physical configuration.	Linear physical dimensions not conducive to uniform grid sampling. Uniform sampling does not allow for locating borings where highest potential for contamination exists.
Sewers, removed	Average borehole spacing of 200 to 500 ft within backfill of former sewer location, rather than uniform grid sampling. Spacing based on estimated length, proximity to discharge or effluent point, and whether a chemical or sanitary sewer.	Linear physical dimensions not conducive to uniform grid sampling. Uniform sampling does not allow for locating borings where highest potential for contamination exists.

0- to 1-ft sample and the 4- to 5-ft sample from each boring were composited for chemical analysis. This approach provided an efficient and cost-effective method to screen the nearly 20 sq mi of nonsource areas, although this procedure had the potential of doubling certified analytical reporting limits. That is, if a sample with no contamination were composited with a contaminated sample, the concentration of the contaminated sample would have to be at least two times the certified reporting limit in order for any detection to be quantified. This loss of sensitivity was deemed acceptable, given the relatively low probability of finding new contamination sources, and the need to maximize the effectiveness of limited analytical resources.

Geophysical Methods

Geophysical methods were used in the Phase I program for several purposes. Metal detectors, and in some cases magnetometer surveys, were used to clear boring locations where contamination was suspected in order to limit the risk of encountering buried unexploded ordnance or metal debris while drilling. Magnetometers were employed to locate boundaries of geophysical anomalies potentially associated with waste disposal.

A2.1.1.2 Chemical Identification

Prior to implementation of the Phase I program, procedures were developed to select the chemicals associated with RMA that should be included in the list of target analytes. Three mechanisms were used to ensure consideration of all potential contaminants.

First, a review of available literature describing past activities conducted by the Army and tenants during the entire history of RMA was performed. An extensive list of 333 chemicals used by the Army or lessees at RMA was developed and is presented in the RMA Chemical Index (EBASCO, 1988b/RIC 88357R01). The following criteria were used as general guidelines for evaluation of chemicals on the list and the selection of the target analytes:

1) The analyte was produced or disposed of in large quantities at RMA

2) The analyte is toxic

3) The analyte is persistent in the environment

4) The analyte is an Army agent material, or degradation product of an agent material, still likely to be present in the RMA environment

5) The analyte was included in ongoing monitoring and investigatory programs being carried out at and in the vicinity of RMA.

Emphasis was placed on the second and third criteria listed above, which were interpreted in a broad sense. Any analyte not obviously benign was considered potentially toxic, and any analyte maintaining its integrity in the environment for more than a few days was considered potentially persistent. If an analyte met the first, fourth, or fifth criterion listed above but did not meet the second or third criterion, it was generally not included on the target analyte list. Forty-eight analytes were selected as the initial targets.

Next, in response to comments from concerned parties, all GC/MS data from the Phase I program were examined to ensure that nontarget compounds warranting inclusion into the target list were not overlooked. Frequency of detection and the range and mean of detected concentrations were tabulated, and the physical properties, probable origin, and toxicity of each nontarget compound was determined.

Finally, as the Phase I program progressed, analytes were added to the initial target list based on recommendations from parties involved in the investigation. These additional analytes included Army agent degradation compounds and organonitrogen compounds. Some Army agents were added later due to difficulties associated with developing acceptable analytical methodologies.

The Phase I target analytes for soil are organized into the analyte groups presented in the SARs, and are listed in Table RISR A2.1-2.

Table RISR A2.1-2. Phase I Target Analytes for Soil Samples.

Analytes
Volatile Halogenated Organics (VHOs)
1,1-Dichloroethane
1,2-Dichloroethane
trans-1,2-Dichloroethylene
1,1,1-Trichloroethane
1,1,2-Trichloroethane
Carbon tetrachloride
Chlorobenzene
Chloroform
Methylene chloride
Tetrachloroethylene
Trichloroethylene
Volatile Hydrocarbons (VHCs)
Bicycloheptadiene
Dicyclopentadiene
Methylisobutyl ketone
Volatile Aromatic Organics (VAOs)
Benzene
Ethylbenzene
m-Xylene
o- and p-Xylene
Toluene
Organosulfur Compounds, Mustard-Agent Related (OSCMs)
1,4-Oxathiane
Dithiane
Thiodiglycol*
Chloroacetic acid*
Organosulfur Compounds, Herbicide Related (OSCHs)
Chlorophenylmethyl sulfide
Chlorophenylmethyl sulfone
Chlorophenylmethyl sulfoxide
Dimethyldisulfide
Organophosphorous Compounds, GB-Agent Related (OPHGBs)
Diisopropylmethyl phosphonate
Dimethylmethyl phosphonate
Isopropylmethyl phosphonic acid*
Methylphosphonic acid*

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*Analytes added to the target analyte list during later Phase I investigations.

Analytes
Organophosphorous Compounds, Pesticide Related (OPHPs)
Atrazine
Malathion
Parathion
Supona
Vapona
Dibromochloropropane (DBCP)
Organonitrogen Compounds (ONCs)
Hydrazine*
Methylhydrazine*
n-Nitrosodimethylamine*
n-Nitrosodi-n-propylamine*
Unsymmetrical dimethylhydrazines*
Fluoroacetic acid*
Semivolatile Halogenated Organics (SHOs)
Hexachlorocyclopentadiene
Organochlorine Pesticides (OCPs)
Aldrin
Chlordane
Dichlorodiphenylethane
Dichlorodiphenyltrichloroethane
Dieldrin
Endrin
Isodrin
Arsenic
Mercury
ICP Metals
Cadmium
Chromium
Copper
Lead
Zinc

*Analytes added to the taget analyte list during later Phase I investigations.

Source: ESE, 1985.

A2.1.1.3 Analytical Strategy

Phase I analytical methods were selected to provide versatile screening capabilities with the potential to provide semiquantitative information on a wide variety of potential contaminants. Interpretation of Phase I data was performed to estimate the concentrations of target and nontarget analytes present at each source area, and to provide information on the approximate vertical and areal extent of detectable target compounds. The analytical methods for the Phase I samples are presented in Table RISR A2.1-3. An exception to this standard suite of analyses was made with respect to volatile organic compound (VOC) analyses. Because volatilization processes were expected to have eliminated VOCs in surface soils, VOCs were not analyzed for in 0- to 1-ft samples. In areas where site history indicated that volatiles had not been disposed, only 10 percent of the samples collected from deep intervals were analyzed for VOCs.

The analytical methods for Phase I were chosen to provide positive identification of the target analytes. Semiquantitative and quantitative methods were used to determine the level of organic contaminants, and quantitative methods were used to determine the level of inorganic contaminants. The semiquantitative results for organic compounds identified in the GC/MS analyses are due to the use of a one level standard for calibration as compared to a calibration curve of multiple standards. The one level calibration standard contains all of the target analytes being screened for in the method. The injection of surrogate compounds into all samples before being extracted allows for analyte extraction efficiencies to be determined, thus lending a higher level of confidence to the data. Use of this semiquantitative GC/MS analysis is an efficient way to produce a positive identification for all target analytes; these data are typically not reported to the same level of precision (number of significant figures) as are the atomic absorption (AA) and inductively coupled argon plasma (ICP) spectroscopy results. With few exceptions, all target analytes were screened in samples collected during Phase I. Analytical methods certified for discrete groups of compounds were used in a few later Phase I investigations, as indicated in Table RISR A2.1-3. These quantitative methods were also used in Phase II investigations.

Table RISR A2.1-3. Summary of Phase I Analytical Methods for Soil Sampling.

Analyte Group	Analytical Method
Volatile and Semivolatile Organic Compounds (VOCs and SVOCs)	Gas Chromatography/Mass Spectrometry
Organosulfur Compounds, Mustard-Agent Related (OSCMs) Chloroacetic acid* Thiodiglycol*	High Performance Liquid Chromatography
Organophosphorous Compounds, GB-Agent Related (OPHGBs) Isopropylmethylphosphonic acid* Diisopropylmethyl phosphonate* Dimethylmethyl phosphonate*	Ion Chromatography Gas Chromatography/Flame Photometric Detector
Dibromochloropropane (DBCP)	Gas Chromatography/Electron Capture Detector Gas Chromatography/Mass Spectrometry
Organonitrogen Compounds (ONCs) n-Nitrosodimethylamine* n-Nitrosodi-n-propylamine*	Gas Chromatography/Nitrogen Phosphorous Detector
Hydrazines (ONCs) Hydrazine* Methylhydrazine* Unsymmetrical dimethylhydrazine*	Spectrophotometry
Arsenic	Graphite Furnace Atomic Absorption Spectroscopy
Mercury	Cold Vapor Atomic Absorption Spectroscopy
Metals (ICPs)	Inductively Coupled Argon Plasma Spectroscopy

*Samples collected in later Phase I investigations were analyzed for these compounds.

For each of the analytical methods discussed above, analyte concentrations can be quantified within a specified concentration range. The lower limit of this range was designated by USATHAMA as the lower certified reporting limit (CRL). This estimate for each analyte is numerically and philosophically different from the method detection limit (MDL) estimated by U.S. Environmental Protection Agency (EPA) protocols. The CRLs and MDLs are discussed and compared in Development and Evaluation of Analytical Methodologies used in RMA Soil Investigations (EBASCO, 1988a/RIC 88127R02). A greater degree of confidence is obtained by using CRLs as opposed to MDLs because the method of CRL determination accounts for normal variability associated with day-to-day variations, the range expected for real samples, and uncertainties in the calibration function. The CRL estimates from the USATHAMA procedure were believed to be better representations of what would be achieved in long-term programs conducted by contractor laboratories. In addition, there is a range of concentrations below the CRL where signals can be detected. Although a large uncertainty is associated with signals detected in this range, the raw data can be used to supplement reported results where there may be ambiguities or contradictory analyses.

The reporting limits for each of the target analytes are method-, laboratory-, and instrument-specific. Six laboratories performed analyses on the Phase I soil samples. The lower CRLs for each laboratory and for each analyte are listed in Table RISR A2.1-4. For comparison purposes, this table also includes the CRLs for the Phase II investigation which will be discussed in Section A2.1.2. The CRLs generally vary between laboratories, with a range of CRLs established by the most and least sensitive methods used by the different laboratories.

Data from GC/MS analyses performed for target analytes during Phase I were also examined to tentatively identify any other organic compounds present in the sample. This tentative identification of nontarget compounds was undertaken to ensure the identification of major contaminants present, whether or not they were included in the target list. The overall procedures used for identification of nontarget compounds involved the review of all instrument response peaks meeting the response criteria. Available GC/MS libraries were

Table RISR A2.1-4 Phase I and II Analytes, Methods, and Certified Reporting Limits (CRLs) for Soil Samples. **Page 1 of 6**

Analytical Groups/Analytes	Phase I Certified Reporting Limits (µg/g) Laboratory							Phase II Certified Reporting Limits (µg/g) Laboratory				
	Method	CAL	ESE	MRI	DataChem	HITT	ENSE	Method	CAL	RMA	ESE	DataChem
Volatile Halogenated Organics (VHOs)												
1,1-Dichloroethane	GC/MS	0.9	0.3	0.5	2	-	2	GC/HECD	–	-	0.055	0.074
1,2-Dichloroethane	GC/MS	0.3	0.3	0.4	0.6	-	2	GC/HECD	–	-	0.071	0.085
1,1-Dichloroethylene	GC/MS	–	–	–	–	-	-	GC/HECD	–	-	0.051	0.24
trans-1,2-Dichloroethylene	GC/MS	0.3	0.3	0.8	2	-	2	GC/HECD	–	-	0.063	0.26
1,1,2,2-Tetrachloroethane*	GC/MS	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.6*	GC/MS	–	-	*0.3*	*0.3*
1,1,1-Trichloroethane	GC/MS	0.3	0.3	0.5	0.4	-	1	GC/HECD	–	-	0.040	0.088
1,1,2-Trichloroethane	GC/MS	0.3	0.3	0.6	0.4	-	1	GC/HECD	–	-	0.081	0.26
Carbon tetrachloride	GC/MS	0.3	0.3	0.4	0.3	-	1	GC/HECD	–	-	0.044	0.12
Chlorobenzene	GC/MS	0.3	0.3	0.3	1	-	1	GC/HECD	–	-	0.026	0.20
Chloroform	GC/MS	0.3	0.3	0.7	0.3	-	1	GC/HECD	–	-	0.038	0.068
Methylene chloride	GC/MS	0.7	0.3	–	2	-	2	GC/HECD	–	-	0.083	3.7
Tetrachloroethylene	GC/MS	0.3	0.3	0.5	0.3	-	1	GC/HECD	–	-	0.045	0.27
Trichloroethylene	GC/MS	0.3	0.3	0.6	0.5	-	1	GC/HECD	–	-	0.049	0.14
Trichloropropene*	GC/MS	*0.3*	*0.3*	*0.3*	*0.3*	-	-	GC/MS	–	-	*0.3*	*0.3*
Volatile Hydrocarbons (VHCs)												
2-Butoxyethanol*	GC/MS	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	-	GC/MS	–	-	*0.3*	*0.3*
4-Hydroxy-4-methyl-2-pentanone*	GC/MS	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	-	GC/MS	–	-	*0.3*	*0.3*
1-Methyl-1,3-cyclopentadiene*	GC/MS	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	-	GC/MS	–	-	*0.3*	*0.3*
2,2-Oxybisethanol*	GC/MS	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	-	GC/MS	–	-	*0.3*	*0.3*
2-Pentanone*	GC/MS	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	-	GC/MS	–	-	*0.3*	*0.3*
Bicycloheptadiene	GC/MS	0.3	0.3	0.8	0.4	-	1	GC/FID	–	-	5.1	1.1
Dicyclopentadiene	GC/MS	0.3	0.3	0.3	0.7	1.0	1	GC/FID	–	-	4.27	0.45
Methylcyclohexane*	GC/MS	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	-	GC/MS	–	-	*0.3*	*0.3*
Methylisobutyl ketone	GC/MS	0.3	0.5	0.4	0.7	-	2	GC/FID	–	-	4.61	0.64

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** = *Ortho- and para- (o-and p-) Xylenes coelute under the GC conditions specified in this method*
\+ = *Caprolactam never detected in soil samples*

Note: *CRLs for significant former nontarget compounds are italicized.*

Table RISR A2.1-4 Phase I and II Analytes, Methods, and Certified Reporting Limits (CRLs) for Soil Samples.

	Phase I Certified Reporting Limits (µg/g)	Laboratory						Phase II Certified Reporting Limits (µg/g)	Laboratory			
Analytical Groups/Analytes	**Method**	**CAL**	**ESE**	**MRI**	**DataChem**	**HITT**	**ENSE**	**Method**	**CAL**	**RMA**	**ESE**	**DataChem**
Volatile Aromatic Organics (VAOs)												
Benzene	GC/MS	0.3	0.3	1	0.3	-	1	GC/PID	–	-	0.081	0.085
Ethylbenzene	GC/MS	0.3	0.3	0.4	0.4	-	2	GC/PID	–	-	0.043	0.16
m-Xylene	GC/MS	0.7	0.3	0.3	0.8	-	1	GC/PID	–	-	0.053	0.26
o- and p-Xylene**	GC/MS	0.3	0.5	0.5	5	-	3	GC/PID	–	-	0.086	0.39
Toluene	GC/MS	0.3	0.3	0.3	0.3	-	1	GC/PID	–	-	0.096	0.19
Organosulfur Compounds, Mustard-Agent Related (OSCMs)												
1,4-Oxathiane	GC/MS	6	0.3	0.5	0.3	0.9	1	GC/FPD	–	-	0.90	1.7
Chloroacetic acid	HPLC	–	18	–	36	-	-	HPLC	–	-	18	36
Dithiane	GC/MS	7	0.3	2	0.4	0.3	1	GC/FPD	–	-	1.5	1.4
Thiodiglycol	HPLC	–	2.6	–	4.2	-	-	HPLC	–	-	3.9	4.2
Organosulfur Compounds, Herbicide Related (OSCHs)												
Benzothiazole		–	–	–	–	-	-	GC/FPD	–	-	1.1	2.0
Chlorophenylmethyl sulfide	GC/MS	4	0.3	0.3	0.9	0.5	1	GC/FPD	–	-	1.1	4.4
Chlorophenylmethyl sulfone	GC/MS	0.6	0.3	0.4	0.3	0.6	0.8	GC/FPD	–	-	2.4	9.0
Chlorophenylmethyl sulfoxide	GC/MS	7	0.4	1	0.3	0.7	0.4	GC/FPD	–	-	2.3	4.8
Dimethyldisulfide	GC/MS	0.8	0.3	4	20	-	3	GC/FPD	–	-	0.70	3.1

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** = *Ortho- and para- (o-and p-) Xylenes coelute under the GC conditions specified in this method*

\+ = *Caprolactam never detected in soil samples*

Note: *CRLs for significant former nontarget compounds are italicized.*

Table RISR A2.1-4 Phase I and II Analytes, Methods, and Certified Reporting Limits (CRLs) for Soil Samples.

Analytical Groups/Analytes	Phase I Certified Reporting Limits (µg/g) Method	Laboratory CAL	ESE	MRI	DataChem	HITT	ENSE	Phase II Certified Reporting Limits (µg/g) Method	Laboratory CAL	RMA	ESE	DataChem
Organophophorous Compounds, GB-Agent Related (OPHGBs)												
Diisopropylmethyl phosphonate	GC/MS	0.3	0.5	0.3	1	0.8	0.4	GC/FPD	0.050	-	0.11	–
Dimethylmethyl phosphonate	GC/MS	–	2	–	–	2	0.6	GC/FPD	0.050	-	0.13	–
Isopropylmethyl phosphonic acid	IONCHROM	5	2	–	–	-	-	IONCHROM	4.7	-	2.1	–
Methylphosphonic acid	IONCHROM	–	2.0	–	–	-	-	IONCHROM	–	-	2.0	–
Phosphoric acid, tributyl ester*	GC/MS	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	-	GC/MS	*0.3*	-	*0.3*	
Phosphoric acid, triphenyl ester*	GC/MS	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	-	GC/MS	*0.3*	-	*0.3*	
Organophosphorous Compounds, Pesticide Related (OPHPs)												
Atrazine	GC/MS	0.3	0.7	0.5	0.3	3	0.4	GC/NPD	–	-	0.25	–
Malathion	GC/MS	0.3	0.6	2	0.7	0.4	0.3	GC/NPD	–	-	0.25	–
Parathion	GC/MS	0.4	0.7	2	0.9	0.6	0.6	GC/NPD	–	-	0.25	–
Supona	GC/MS	0.3	0.5	0.9	0.6	0.3	0.6	GC/NPD	–	-	0.25	–
Vapona	GC/MS	0.3	0.3	0.3	3	0.6	1	GC/NPD	–	-	0.70	–
Dibromochloropropane (DBCP)	GC/MS	0.3	0.3	0.6	0.3	0.3	1	GC/ECD	0.014	-	0.0050	0.0050
	GC/ECD	0.014	0.0050	-	0.0050	-	-	-	-	-	-	-
Organonitrogen Compounds (ONCs)												
Caprolactam*+		–	–	–	–	-	-	GC/MS	*0.3*	-	*0.3*	*0.3*
Hydrazine	SPEC	–	–	–	50	-	-	SPEC	–	-	–	50
Methylhydrazine	SPEC	–	–	–	200	-	-	SPEC	–	-	–	200
n-Nitrosodimethylamine	GC/NPD	–	–	–	0.26	-	-	GC/NPD	–	-	0.11	0.26
n-Nitrosodi-n-propylamine	GC/NPD	–	–	–	0.10	-	-	GC/NPD	–	-	0.16	0.10
Unsymmetrical dimethylhydrazine	SPEC	–	–	–	200	-	-	SPEC	–	-	–	200

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** = *Ortho- and para- (o-and p-) Xylenes coelute under the GC conditions specified in this method*

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Table RISR A2.1-4 Phase I and II Analytes, Methods, and Certified Reporting Limits (CRLs) for Soil Samples.

	Phase I Certified Reporting Limits (µg/g) Laboratory							Phase II Certified Reporting Limits (µg/g) Laboratory				
Analytical Groups/Analytes	Method	CAL	ESE	MRI	DataChem	HITT	ENSE	Method	CAL	RMA	ESE	DataChem
Fluoroacetic Acid	IONCHROM	–	2.0	–	–	-		IONCHROM	–	-	2.0	–
Polynuclear Aromatic Hydrocarbons (PAHs)												
Fluoranthene*	GC/MS	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	-	GC/MS	*0.3*	-	*0.3*	*0.3*
Methylnaphthalene*	GC/MS	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	-	GC/MS	*0.3*	-	*0.3*	*0.3*
Phenanthrene*	GC/MS	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	-	GC/MS	*0.3*	-	*0.3*	*0.3*
Pyrene*	GC/MS	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	-	GC/MS	*0.3*	-	*0.3*	*0.3*
Semivolatile Halogenated Organics (SHOs)												
Hexachlorobenzene*	GC/MS	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	-	GC/MS	*0.3*	-	*0.3*	*0.3*
Hexachlorobutadiene*	GC/MS	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	-	GC/MS	*0.3*	-	*0.3*	*0.3*
Hexachlorocyclopentadiene	GC/MS	0.3	1	1	0.6	0.3	1	GC/ECD	–	-	0.0026	0.0018
Pentachlorobenzene*	GC/MS	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	-	GC/MS	*0.3*	-	*0.3*	*0.3*
Tetrachlorobenzene*	GC/MS	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	-	GC/MS	*0.3*	-	*0.3*	*0.3*
Trichlorobenzene*	GC/MS	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	-	GC/MS	*0.3*	-	*0.3*	*0.3*
Organochlorine Pesticides (OCPs)												
Aldrin	GC/MS	0.3	0.9	0.5	0.3	0.6	0.3	GC/ECD	–	-	0.0018	0.0019
Chlordane	GC/MS	0.6	1	6	2	2	2	GC/ECD	–	-	0.11	0.023
Dichlorodiphenylethane (DDE)	GC/MS	0.3	0.3	0.5	0.6	0.9	0.3	GC/ECD	–	-	0.0010	0.0024
Dichlorodiphenyltrichloroethane (DDT)	GC/MS	0.6	0.4	2	0.5	0.3	0.5	GC/ECD	–	-	0.0023	0.0020
Dieldrin	GC/MS	0.3	0.3	0.6	0.3	0.8	0.3	GC/ECD	–	-	0.0012	0.0033
Endrin	GC/MS	0.3	0.7	4	0.5	0.6	0.7	GC/ECD	–	-	0.0010	0.0058
Isodrin	GC/MS	0.3	0.3	0.6	0.3	0.5	0.3	GC/ECD	–	-	0.0011	0.0011

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** = *Ortho- and para- (o-and p-) Xylenes coelute under the GC conditions specified in this method*

\+ = *Caprolactam never detected in soil samples*

Note: CRLs for significant former nontarget compounds are italicized.

Table RISR A2.1-4 Phase I and II Analytes, Methods, and Certified Reporting Limits (CRLs) for Soil Samples.

Analytical Groups/Analytes	Phase I Certified Reporting Limits (µg/g) Laboratory Method	CAL	ESE	MRI	DataChem	HITT	ENSE	Phase II Certified Reporting Limits (µg/g) Laboratory Method	CAL	RMA	ESE	DataChem
Arsenic	GFAA	5.0	4.7	2.5	2.5	-	2.0	GFAA	5.0	-	4.7	2.5
Mercury	CVAA	0.060	0.050	0.070	0.050	-	0.037	CVAA	0.060	-	0.050	0.050
ICP Metals												
Cadmium	ICP	0.66	0.90	0.51	0.74	-	0.31	ICP	0.66	-	0.90	0.74
Chromium	ICP	5.2	7.2	7.4	6.5	-	2.5	ICP	5.2	-	7.2	6.5
Copper	ICP	4.9	4.8	4.9	4.7	-	3.4	ICP	4.9	-	4.8	4.7
Lead	ICP	13	17	16	8.4	-	8.0	ICP	13	-	17	8.4
Zinc	ICP	9.5	16	28	8.7	-	12.8	ICP	9.5	-	16	8.7
Agent Compounds - Phase I and Phase II												
Mustard	GC/FPD	-	-	-	-	-	-	-	-	2.0	-	-
Lewisite	GC/ECD	-	-	-	-	-	-	-	-	5.0	-	-
Sarin	GC/FPD	-	-	-	-	-	-	-	-	0.075	-	-
VX	GC/FPD	-	-	-	-	-	-	-	-	5.0	-	-

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** = *Ortho- and para- (o-and p-) Xylenes coelute under the GC conditions specified in this method*

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Table RISR A2.1-4 Phase I and II Analytes, Methods, and Certified Reporting Limits (CRLs) for Soil Samples.

		Phase I Certified Reporting Limits (µg/g)							Phase II Certified Reporting Limits (µg/g)			
Analytical Groups/Analytes	Method	CAL	ESE	MRI	DataChem	HITT	ENSE	Method	CAL	RMA	ESE	DataChem

Notes:

CAL = California Analytical Laboratory, W. Sacramento, CA.
DataChem = formerly UBTL, Salt Lake City, UT.
ENSE = ENSECO Inc., formerly Rocky Mountain Analytical Laboratories, Arvada, CO.
ESE = Environmental Science and Engineering, Inc., Gainesville, FL.
HITT = Hittman-Ebasco, Columbia, MD.
MRI = Midwest Research Institute, Kansas City, MO.
RMA = Rocky Mountain Arsenal Laboratory, Rocky Mountain Arsenal

Method:

CVAA = Cold vapor atomic absorption.
GC/ECD = Gas chromatography/electron capture detector.
GC/FID = Gas chromatography/flame ionization detector.
GC/FPD = Gas chromatography/flame photometric detector.
GC/HECD = Gas chromatography/Hall electrolytic conductivity detector.
GC/MS = Gas chromatography/mass spectrometry.
GC/NPD = Gas chromatography/nitrogen phosphorous detector.
GC/PID = Gas chromatography/photoionization detector.
GFAA = Graphite furnace atomic absorption.
HPLC = High performance liquid chromatography.
ICP = Inductively coupled argon plasma spectroscopy.
IONCHROM = Ion chromatography.
SPEC = Spectrophotometry.

searched to develop the best three computer-aided identifications. Once this was complete, a GC/MS expert reviewed all data to determine which, if any, of these three matches best fit the data. In some cases, none of the computer matches adequately fit the data. For other samples, the spectra were of inadequate quality to allow characterization. The expert then attempted an identification based on his or her analytical experience and training. Wherever possible, the best fit identification was made. While examining the mass spectra, the expert made note of any unusual patterns that might indicate the presence of oil, other petroleum products, or other chemicals common to hazardous waste areas.

These TICs are listed in the Phase I CARs, and comments are provided there to explain the presence of certain chemicals that may have been naturally occurring or artificially introduced during sampling and analysis. These compounds will be discussed in more detail in the review of the Phase II program presented in Section A2.1.2.

TICs have no CRL because the method used for identification is not USATHAMA-certified. Therefore, the lower limit of detection was assumed to correspond to 10 percent of the internal standard for the GC/MS method used. For the purposes of this report, a value of 0.3 µg/g was used.

In a few cases Phase I samples required dilution to facilitate analysis, and the dilution may have potentially masked the presence of some compounds by raising the effective detection level. These situations were examined individually, and comparisons were made with data from surrounding areas. If necessary, an expanded suite of Phase II analyses and/or additional GC/MS analyses were used to ensure that all target analytes were examined.

In some cases, based on the analytical procedure or results, an extended Phase I program was performed. These circumstances included the following:

- The sporadic detection of one or more of the analytes at a particular site led to the uncertainty that these measurements were true detections.

- Concentrations detected were very close to background concentration levels or the method detection limit.

- Adherence to the Phase I protocol was not complete.

- A field sampling or laboratory analysis error during the Phase I program possibly affected the analytical results.

- Further characterization of the site was necessary using investigative methods other than sampling and analysis, such as geophysics.

Results of these extended Phase I programs were included in the CARs for the individual sites investigated.

A2.1.2 Phase II

The goal of the Phase II sampling program was to estimate the areal and vertical extent of contamination initially identified during Phase I, and to more precisely quantify the contaminants present. Therefore, the investigative approach in Phase II was strongly influenced by the results of Phase I sampling.

Phase II soils investigation sampling patterns, boring densities, and boring numbers were determined individually for each site upon evaluation of Phase I results. The Phase II boring programs were designed by a committee comprising personnel from the contracting teams, the Program Manager for RMA (PMRMA), EPA, and EPA's contractors.

A2.1.2.1 Geotechnical Strategy

Phase II programs were implemented for all Phase I sites where organic compounds were detected. Concentrations of target organic analytes in Phase I above the CRL were considered indicative of contamination. The Phase II program was designed to further determine the extent of this contamination.

Phase II investigations were generally not conducted at sites where only inorganics were detected if the inorganic concentrations were within or below the indicator range (IR). The IR is defined as the range of concentrations in soils of a particular analyte considered indicative of natural occurrences. Concentrations above the upper end of the IR are typically considered to indicate possible contamination. For the organic analytes, since these compounds are not naturally occurring, the upper end of the IR, or indicator level, is the CRL. For the inorganic analytes (arsenic, mercury, and the ICP metals) the IRs were established both by reference to the published literature for background concentrations in soils in similar areas and by evaluation of data collected at RMA and off-post areas (ESE, 1987a/RIC 88204R02).

The IRs for the inorganic analytes are:

Metal	Concentration (ug/g)
Arsenic	CRL - 10
Mercury	CRL - 0.10
Cadmium	CRL - 2.0
Chromium	CRL - 40
Copper	CRL - 35
Lead	CRL - 40
Zinc	CRL - 80

While natural occurrences of the metals and many hydrocarbon compounds are documented in surface water and groundwater, no IRs for the water medium or any other environmental media have been established at RMA.

During Phase II, site boundaries were revised based on the extent of contamination suggested by Phase I results and other available data. Boundaries were adjusted to include sites of similar contamination or disposal history and to accommodate physical features and adjacent sources.

Although the design of the Phase II sampling program was site specific, general guidelines were established to standardize sampling rationale for sites with similar characteristics. Generalized soil sampling locations for areas investigated in Phase II are summarized in Table RISR A2.1-5. The soil sampling program in Phase II was organized to complement the network established in Phase I. Basically, Phase II soil borings were positioned to determine the extent of contamination identified by Phase I detections. An example of the Phase II methodology used to refine the Phase I extent-of-contamination estimates is illustrated in Figure RISR A2.1-3.

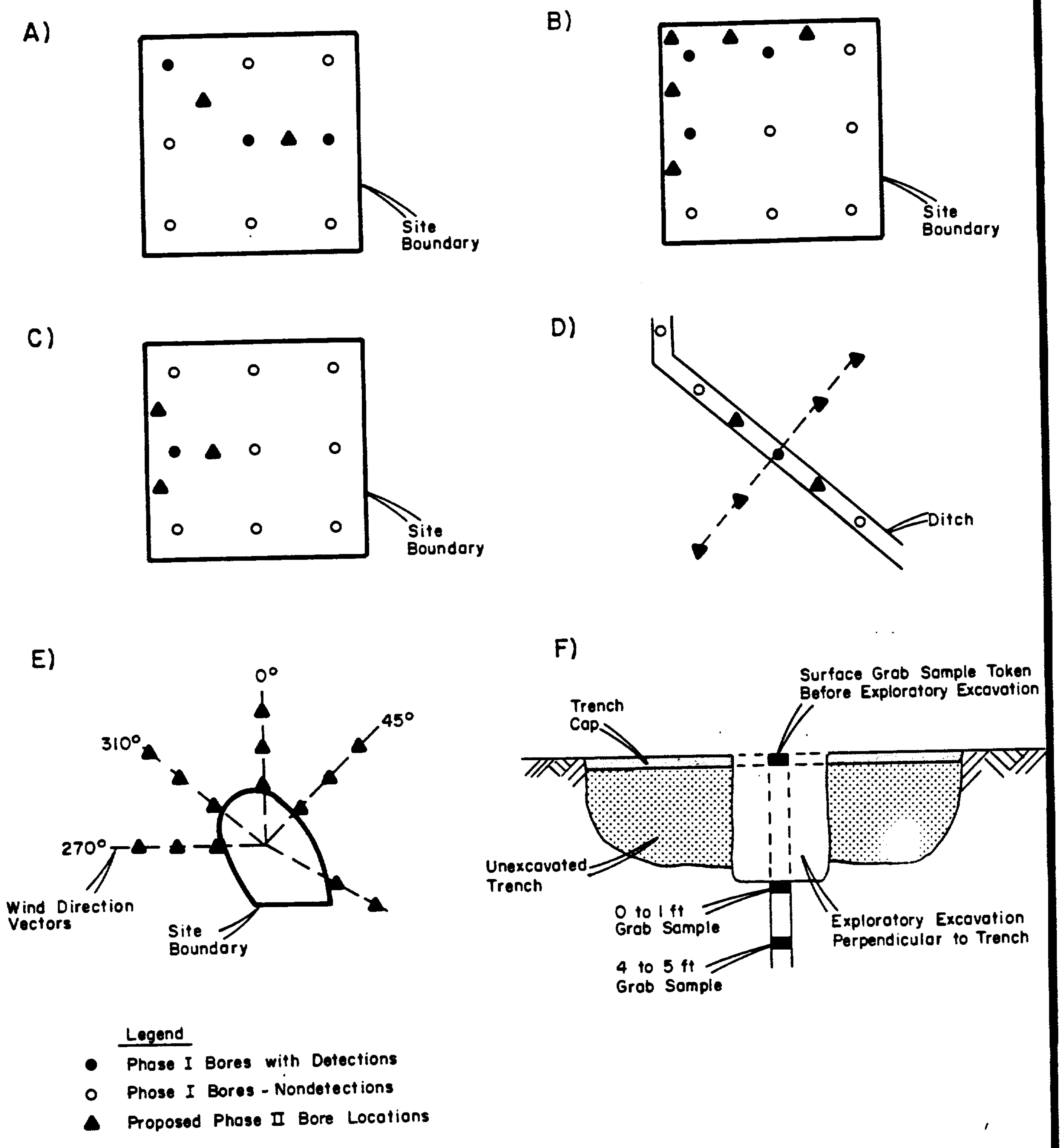
Uniform sampling intervals were proposed for Phase II site investigations with the stipulation that these could be altered or augmented by the site geologist depending on field observations. Sampling intervals were either the same as those used in Phase I or were selected to bracket Phase I target analyte detections by sampling above and below the interval. Sampling intervals were not composited in Phase II sampling. An example of the depth intervals sampled in Phase II is illustrated in Figure RISR A2.1-4. This method was chosen to provide better vertical definition where necessary.

The maximum depth of Phase II soil sampling was determined based on contaminant distributions and the depth to the water table at each site. Generally, Phase II soil samples were collected in unsaturated soils. However, soil samples were collected in Phase II from both the saturated and unsaturated zones where contaminants were present in significant concentrations immediately above the water table, where the water table appeared to have risen since contaminant disposal, or where liquids were disposed into unlined basins and the depth to water table was shallow. These samples were collected to investigate the potential for downward contaminant migration and degradation of groundwater quality suggested by the Phase I results.

In the bottoms of steep-sided ditches or drainages where drilling was logistically impossible, borings were placed as close to the edge of the feature as possible. The first soil sample was

Table RISR A2.1-5. General Soil Sampling Locations for Areas Investigated in Phase II.

Description of Area	Soil Sampling Location	Purpose for Location
Elevated levels of organics and/or metals detected over large areas of a site.	Locate borings approximately halfway between Phase I borings with detections. (Figure RISR A2.2-3A)	More accurately define the extent of contamination within the site.
Analytes sporadically detected in outermost boreholes of a site.	Skew sampling towards the site boundary. Figure RISR A2.2-3B)	More accurately define the site boundary.
Isolated detections (i.e., a boring with detections surrounded by borings with no detections).	Locate three borings in a triangular pattern around isolated boring and approximately 10 ft to 50 ft away. (Figure RISR A2.2-3C)	Determine the areal extent of contamination.
Linear features (i.e., ditches) with isolated analyte detections.	Locate borings approximately halfway between or at regularly spaced intervals between Phase I borings, in line with feature. (Figure RISR A2.2-3D)	Determine extent of contamination along linear feature.
Elevated levels of organics and/or metals within a linear feature.	Locate borings in a perpendicular transect to central alignment of feature approximately 5 ft to 20 ft from center. (Figure RISR A2.2-3D)	Determine extent of contamination beyond physical boundaries of linear feature.
Areas around Basin F and Basin A with detections of potentially windblown analytes in surficial soil.	Locate shallow borings along wind direction vectors emanating from the basins. (Figure RISR A2.2-3E)	Determine if surficial contaminants have been transported by the wind from Basin F and Basin A and deposited in surface soils of adjacent areas.
Trenches used for burning or disposal that may contain metal or unexploded ordnance debris.	Construct narrow, shallow excavations perpendicular to site trench and obtain grab samples from soil; if possible, collect sample from 0- to 1-ft interval and 4- to 5-ft interval below the bottom of the trench. (Figure RISR A2.2-3F)	Determine soil quality in areas unsafe for drilling; determine the vertical extent of contamination below the trenches; and estimate width, spacing, and number of trenches.



Prepared for:

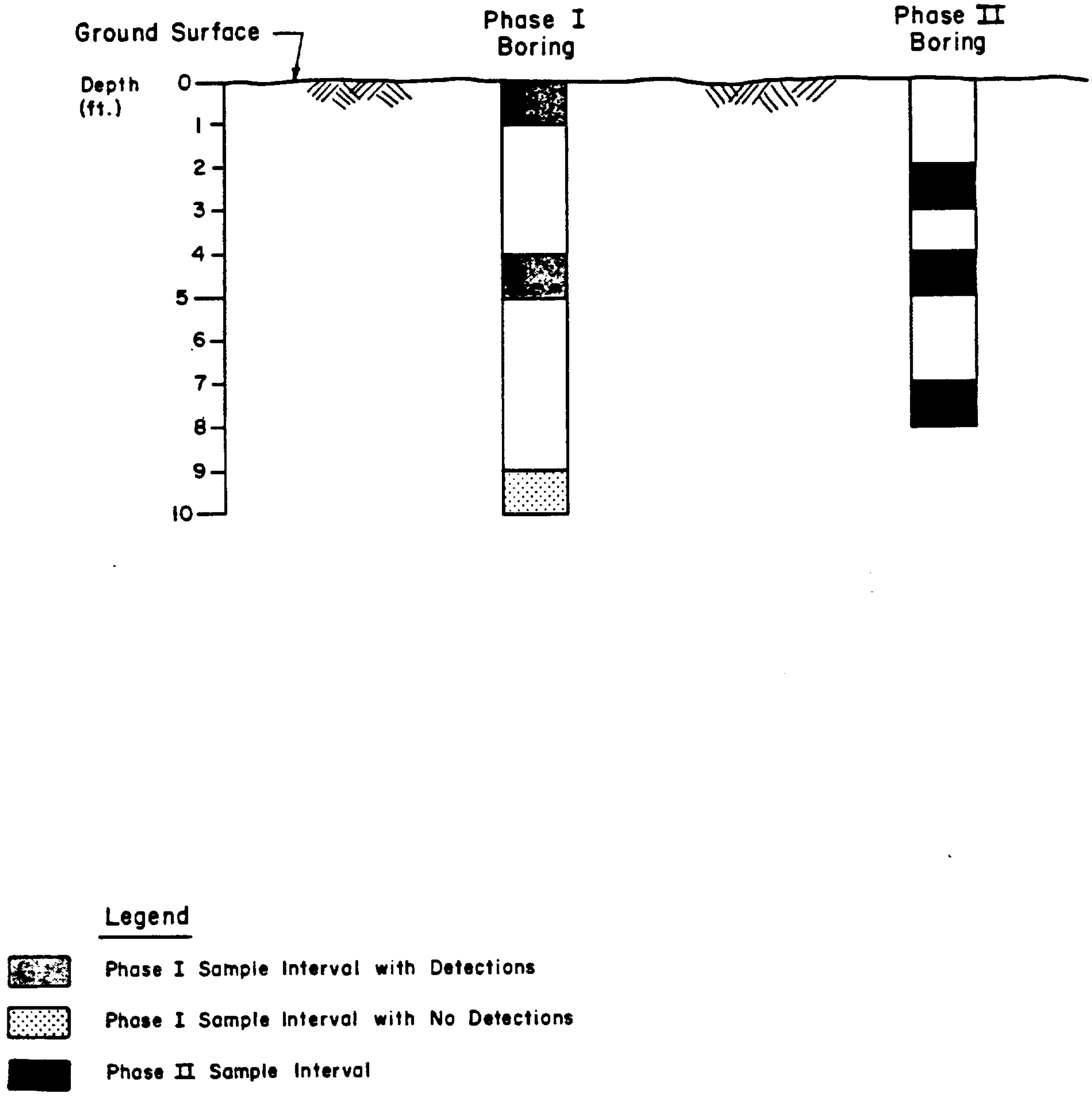
U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A2.1-3

Methodologies for Phase II Soil Sampling

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



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U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A2.1-4

Example of Phase II Soil Sampling Depth Intervals

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

then obtained from approximately the same horizon as surface sediment within the bottom of the drainage or ditch, and subsequent samples were obtained from intervals below this horizon.

Geophysical and soil gas surveys were included in the Phase II program design when necessary to help locate Phase II boreholes, and when historical information indicated that these methods would perform suitably. Standard soil sampling alone may not give the continuous, detailed assessment of contamination extent that geophysical and soil gas surveys can provide. Geophysical surveys were particularly useful in defining the boundaries of trench and burn sites, which are poorly suited to a grid sampling program. Soil gas was emphasized where sources of volatile or semivolatile contaminants observed in groundwater were uncertain. In such instances, soil sampling was used to confirm the results of geophysical and soil gas surveys and identify specific contaminants of concern.

A2.1.2.2 Chemical Identification

During Phase II, specific analytical parameters were selected for individual sites based on results of the Phase I investigation and on additional historical document searches, field inspections, results of groundwater sampling, and other factors. These parameters were chosen in order to further quantify and define the extent of contamination by analytes detected in Phase I. The Phase II analytical suite included Phase I analytes listed in Table RISR A2.1-2, as well as 1,1-dichloroethylene and benzothiazole. Benzothiazole was recommended for inclusion by the parties involved in the investigation.

An examination of the TICs from Phase I and Phase II investigations was conducted to determine whether specific chemicals should be incorporated in the list of target analytes to be considered by the RI and the endangerment assessment (EA). Some or all of the following criteria were used as the basis for upgrading nontarget compounds:

- Confidently identified according to analytical technique
- Clearly arsenal-activity or fuel-component related, rather than naturally occurring

- Moderate to high carcinogenicity and/or toxicity, as outlined in the Chemical Index (EBASCO, 1988b/RIC 88357R01)
- Frequency of occurrence and concentration
- Co-occurrence with target analytes on a site-by-site basis.

A summary list of TICs compiled from the Phase I CARs and the Phase II Data Addenda is presented in Table RISR A2.1-6. The 20 compounds indicated on this list by an asterisk were elevated to target analyte status by the criteria listed above. These 20 compounds, discussed in the SARs and evaluated by the EA, are frequently referred to as significant nontarget compounds. The summary list also includes naturally occurring compounds, suspected laboratory contaminants, and compounds not specifically identified.

To facilitate discussions of soil and water contamination in the SARs, the analytes were organized by analyte groups. Each analyte group is comprised of several analytes with similar composition, use, chemical behavior, and/or history of origin and disposal. The chemical analytes and analyte groups for soil and water samples, used in the SARs, are outlined in Table RISR A2.1-7. Significant nontarget compounds that were reviewed and added to the list of target analytes in the SARs, are noted in Table RISR A2.1-7 with an asterisk.

These analyte groupings are convenient to facilitate summary data presentations, but in some cases, represent fairly broad associations of compounds. For example, dimethylmethyl phosphonate is grouped with the GB-related organophosphorous compounds (OPHGBs) as a possible by-product of GB agent manufacture, but it could also be grouped with the pesticide-related organophosphorous compounds (OPHP) as a by-product of pesticide manufacture (EBASCO, 1988b/RIC 88357R01).

Table A2.1-6. Summary of Tentatively Identified Compounds in Phase I and Phase II Soils Samples. Page 1 of 8.

Compound	Comments
Chlorinated Compounds:	
1,1,2-Trichloro-1,2,2-trifluoroethane	Also known as freon 113; used in manufacturing of button and sandwich bombs.
1,2-Dichloropropane	Used in manufacture of d-d soil fumigant for nematodes.
1,2-Dichloro-1,1-difluoroethane	------
1-Chloro-4(methylsulfonyl)-benzene	------
2-Chlorophosphate ethanol (3:1)	------
Aldrin isomer	------
Amines	------
Chlorinated compound	------
Chlorinated compound	------
Chlorobenzene	Raw chemical used in RMA operations and solvent in thionyl chloride synthesis.
Chlorocyclohexane	------
Chlorocyclohexanol	------
2-Chlorocyclohexanone	------
Chloroethane	------
Chloromethane	Raw material used in Planavin manufacture.
2-Chloro-1-phenyl-ethanone	------
Chlorophenylmethyl sulfide isomer	------
Chlorophenylmethyl sulfoxide isomer	------
Cyclobutane, 1,2-dichloro-3,4-bis(dichloromethylene)	------
1,3-Cyclopentadiene, 1,2,3,4-tetrachloro-5-(dichloromethane)	------
Dichlorobenzene	Raw material used in Akton manufacture.
1,2-Dichloro-3,4-bis(dichloromethane) cyclobutane	------
Dichlorodiphenylethane isomer	------
Dichlorodiphenyltrichloroethane isomer	------
Dichlorocyclohexane	------
Dichlorofluoromethane	------
2,2-Dichloro-3-hydroxyl-1-phenyl-propanone	------
Dichloromethylbutane isomer	
Dichloromethylene tetrachloropentadiene	Chlorinated compound possibly related to OCP.
Dichloro-1,5-naphthyridine isomer	------
1,3-Dichloro-2-propane	------
1,3-Dichloro-2-propanone	------
Dichloro-2-propanone isomer	------
Dieldrin isomer	------
Dimethylmethylphosphonate isomer	------
Endrin intermediate	------

---

* Significant former nontarget compound

Compound	Comments
Ethylhexyl trichlorophenoxyethanoate	Chlorinated compound possibly related to OCP.
Heptachlor	Produced prior to 1952.
Heptachlorinated compound	------
Heptachlorobicycloheptene	Endrin intermediate.
Heptachlorobornene	Possible endrin intermediate?
Hexachlorinated compound	------
Hexachlorobenzene*	Placed in SHO analyte group.
Hexachlorobicycloheptene	------
Hexachlorobutadiene*	Placed in SHO analyte group.
Hexachlorocyclopentadiene impurity	------
Hexachlorobicycloheptadiene	Isodrin and endrin intermediate.
Hexachloroethane	Chlorination by-product, minor use in insecticides.
Hexachloromethane	------
Isodrin isomer	------
Nanochlorinated compound	------
Octachlorinated compound	------
Octachlorocyclopentene	------
Octachlorodibenzofuran	------
Octachloropentafulvalene	------
Octachloropentafulvalene/ octachlorobiphenyl	------
Pentachlorinated compound	------
Pentachloro octahydromethanycyclo-propapentalene	------
Pentachlorobenzene*	Placed in SHO analyte group.
Pentachloro (trichloroethenyl) benzene	Chlorinated compound possibly related to OCP.
Pentachlorocyclopentene	Possible HCCPD impurity.
Perchlorobiphenyl	Chlorinated compound possibly related to OCP.
Polycyclic chlorinated biphenyl	PCB.
Tetrachlorinated compound	------
Tetrachlorobenzene*	Placed in SHO analyte group.
Tetrachlorocyclopentadiene	OCP impurity?
Tetrachlorocyclopentene	HCCPD impurity.
Tetrachloro(dichloromethylene)cyclo-pentadiene	Possible HCCPD impurity.
1,1,2,2-Tetrachloroethane*	Placed in VHO analyte group.
1,1,2,3-Tetrachloroethane	------
1,1,3,3-Tetrachloro-2-propanone	------
Trichlorinated compound	------
Trichloroaniline	------
Trichlorobenzene*	Placed in SHO analyte group, raw material used in Gardona manufacture.
Trichlorobenzenamine	Possible product of anilines in high chloride environment, or reactive intermediates; possibly pesticide related.
Trichlorobiphenyl isomer	PCB.
Trichlorocyclopentene	------
Trichlorofluoroethane	Possibly freon 113; used in manufacture of button and sandwich bombs.

---

* Significant former nontarget compound

Table A2.1-6. Summary of Tentatively Identified Compounds in Phase I and Phase II Soil Samples.

Compound	Comments
Trichlorophenol	Commonly used fungicide, bactericide.
1,2,3-Trichloropropane	------
Trichloropropene isomer	------
Trichloropropene*	Placed in VHO analyte group.
1,1,2-Trichloro-1-propene	------
1,1,3-Trichloro-1-propene	------
Other Compounds:	
1,2-Dihydroacenaphthalene	In petroleum residues, used as insecticide.
1,2-Dimethylcyclopentane	------
1,3,5-Cycloheptatriene	------
1,3-Butanediol	Intermediate in manufacture of polyester plasticizers, mold inhibitor.
1,3-Cyclopentadiene	Raw material used in aldrin, dieldrin, and heptachlor manufacture.
1-Phenylethanone	Possibly related to Ciodrin manufacture?
17-Pentatriacontene	------
2,3-Dimethylpentane	------
2-Ethylhexyldiphenylphosphonate	Breakdown of parathion/malathion?
2-Hydroxy-1-phenyl-ethanone	------
3-Ethylpentane	------
3-Methylhexane	------
4-Oxide-1,4-oxathiane	Probable mustard degradation product.
5-Methyl-2-hexane	------
Acenaphthylene	A polynuclear aromatic hydrocarbon compound.
Acetate-1-heptadecanol	------
Acetate-1-hexadecanol	------
Acetone	Solvent associated with Azodrin and Planavin production.
Acetylhydroxydimethylpyridinone	Ketone.
Alkyl acid	------
Alkyl benzene	------
Alpha-methy-benzene methanol	------
Aminophenol	Intermediate in manufacture of dyes.
Anthracene	A polynuclear aromatic hydrocarbon compound.
9,10-Anthracenedione	------
Benzaldehyde	Used in manufacture of dyes, perfumery, cinnamic and mandelic acids, as solvent.
7H-Benz[DE]anthracene-7-one	------
1,3-Benzediol monobenzoate	------
1,3-Benzenediolimonobenzoate	------
Benzo[a]anthracene	------
Benzocoumarin	Possibly related to rodenticide or pesticide?
Benzo[b]fluoranthene	------
Benzo[k]fluoranthene	------
Benzoic acid	------
2H-1-Benzopyran-2-one	------

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* Significant former nontarget compound

Compound	Comments
Benzothiazole	A heterocyclic aromatic compound, prevalent in manufacturing pesticides.
Bicycloheptadiene	Process intermediate during aldrin and dieldrin manufacture.
Bicycloheptane	------
Bicyclo[3,1,0]hex-2-ene, 4-methyl-1-(methylethyl)	------
Bicyclo(2,2,2)oct-5-en-2-ol or isomer	------
Biphenyl	------
bis(2-Methylpropyl) ester-2-butenedioic acid	------
Bromocyclohexane	------
2-Butanone	------
2-Butoxyethanol*	Placed in VHC analyte group.
Butyl ester of 4-methyl benzene, sulfonic acid	------
Butyl-p-toluene sulfonate	------
Caprolactam*	Placed in ONC analyte group.
Carbazole	------
Carbon sulfide	------
Carboxylic acid	------
Chalcone	------
Chlordene	Human waste.
Chrysene	A polynuclear aromatic hydrocarbon compound.
Chrysophenol	Possible natural compound?
Cyclobutanediylbenzene	Related to solvent or burning fuel.
Cyclohexane	Solvent for lacquers and resins.
Cyclohexanone	------
Cyclohexene	Alkylation component.
Cyclohexenol isomer	------
2-Cyclohexen-1-one	Raw material used in Landrin manufacture.
1,3-Cyclooctadiene	------
1,3,5,7-Cyclooctatetraene	------
Cyclopentaphenanthrene	------
Cyclotetradecane	------
Decahydromethylnaphthalane	Related to solvent or burning fuel.
Decamethy(cyclopentasiloxane)	------
Dibenzofuran	Related to benzocoumarin?, rodenticide?, or pesticide?
n-n-Dibutyl-1-butanamine	------
Diethylbenzene	------
Diethylmethylphosphorothioate	Insecticide?
Difluorobenzene isomer	------
Dihydroacenaphthylene	A polynuclear aromatic hydrocarbon compound; fuel burning residue related.
Dimethoxy methane	------
Dimethyl benzene	Also known as xylene, used as solvent and in manufacture of dyes and other organics.
a-Dimethylcyclohexane	------

---

* Significant former nontarget compound

Table A2.1-6. Summary of Tentatively Identified Compounds in Phase I and Phase II Soil Samples. Page 5 of 8.

Compound	Comments
Dimethylethylbenzene	------
2,6-Dimethylheptane	------
2,2-Dimethylhexane	------
7,11-Dimethyl-3-methylene-1,6,10-dodecatriene	------
1,6-Dimethyl-4-(1-methylethyl) naphthalene	------
Dimethylnaphthalene	------
3,7-Dimethyl-2,6-octadien-1-ol	------
Dimethylphenanthrene	------
Dimethylpropylcyclohexane	A polynuclear aromatic hydrocarbon compound; tar or creosote related, burn product.
Dimethyltetrahydromenthoindine	------
Dimethyltrithialane	An organosulfur compound.
Dioctyl adipate	------
Diphenylethanedione	------
Diphenyl methanone	------
1,1-Diphenyl-2-propanone	------
1,1-Diphenyl-1-propene-2-thiol	------
Dodecanamide	------
1,6,10-Dodecatriene-7,11-dimethyl-3-methylene	------
9-Dodecyltetradecahydrophenanthrene isomer	------
Endo,exo,endo-octahydrodimethane benze(f)indene	------
Endosulfan	------
Endrin ketone	Endrin transformed by sunlight to form ketone.
2,2(1,2-Ethanediyl-bis) oxybis ethanol	------
Ethendiylbisbenzene	------
Ethylbenzene isomer	------
Ethylcyclohexane	------
Ethyldimethyl azulene	------
Ethane-diyl-bis oxybis ethanol	------
3-Ethyl-3-heptane	------
Ethylmethylbenzene	Related to solvent or burning fuel?
Ethylmethylcyclohexane	------
Ethylnaphthalene	------
Ethylpropylcyclohexane	Related to solvent or burning fuel? Possibly related to CBDP.
Fuel/oil hydrocarbons	------
Fluoranthene*	Placed in PAH analyte group.
Fluorene	A polynuclear aromatic hydrocarbon compound.
9H-Fluoren,9-methylene	------
Fluorenone	A polynuclear aromatic hydrocarbon compound.
9H-Fluoren-9-one	------

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* Significant former nontarget compound

Compound	Comments
Fumanic acid, diisobutyl ester	------
Glycolacetate	------
Hexachlorepoxide	Possible degradation product of heptachlor (produced by Hyman).
Hexachlorethane	Used as solvent and in explosives.
Hexadecane	------
Hexandiocic acid, mono (2-ethyl hexyl)ester	------
Hexane	Solvent associated with Ciodrin and Nudrin.
Hexathiapane	------
2-Hexenal	------
2-Hydrobenzaldehyde	------
4-Hydroxy-4-methyl-2-pentanone*	Placed in VHC analyte group.
Hydroxyphenyltrimethylammonium hydroxide	------
Isobenzofurandione	Related to solvent or burning fuel.
Isobutyl butenediol	------
Isobutyl butenoate	------
1-Isocyanonaphthalene	------
1H-Isoindole-1,3(2H)-dione, 2-hydroxymethyl	------
Junipene	Related to turpentine/solvents?
Methano-3h-cyclobuta(cd)pentaten-3-one	------
Methoxybenzenemethanamine	------
1-Methoxy-2-(methoxymethoxy)ethane	------
2-Methylanthracine	------
Methylanthracine isomer	------
4-Methylbenzene-sulfonic acid butyl ester	------
Methylbromocyclohexane	------
3-Methyl-2-butanone	------
Methylcyclohexane*	Placed in the VHC analyte group.
Methylcyclopentane	------
2-Methylcyclopentenol	------
1-Methyl-1,3-cyclopentadiene*	Placed in the VHC analyte group; chemical used by Shell at RMA.
2-Methylcyclopentanone	------
4-Methyldibenzylfuran	------
Methyl ester acetic acid	------
Methylethylbenzene	------
a-(Methylethyl)-dimethyl naphthalene	------
Methyl hexanone	------
Methylhexane	------
2-Methyl-3-hydroxy-2,4,4-trimethyl pentyl ester of propanoic acid	------
5-Methyl-2-(1-methylethylidene) cyclohexanone	------

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* Significant former nontarget compound

Compound	Comments
Methyl-(methylethyl)napthalene	------
Methylnaphthalene*	Placed in the PAH analyte group; natural sources are coal and petroleum.
Methylnaphthalene isomer	------
2-Methyl-1-naphthalenol or isomer	------
Methylpentanediol	------
2-Methyl-1-penten-3-yne or isomer	------
Methylphenanthrene isomer	------
Methyl phenol isomer	------
4-Methyl phenol	------
1-Methyl-2-pyrrolidinone	------
Methylsulfonyldinitrodipropylbenzenamine (planavin)	An organophosphorous compound; pesticide.
4-Methyl-4H-1,2,4-triazole	------
Mirex	Insecticide.
Molecular sulfur	Related to mustard production.
Monobenzoate,1-3benzenediol	------
Monobenzoatebenzenediol	Related to resorcinol.
Mustard	Army surety compound, possible interference from detected mustard degradation product.
Naphthacene	------
Naphthalene	A polynuclear aromatic hydrocarbon compound.
1-Naphthalene acetonitrile	------
1H-3H-Naphtho[1,8-CD]pyran-1,3-dione	------
Nitrophenol	Hydrolysis product of ethyl parathion and methyl parathion.
Nonadecane	------
Nonanedioic acid, diester	------
Nonanedioic acid, tributyl ester	------
o,o-Diethyl-o-methyl phosphorothioate	Insecticide?
Octadecadienyloxyethanol	------
9-Octadecanamide	------
Octadecenyloxyethanol	------
Octahydromethenecyclobutapentalene	------
Octane	------
1,4-Oxathiane,4-oxide	Decomposition product of mustard.
Oxatricyclooctanone	OCP impurity?
Oxidboxathiane	Probable mustard degradation product.
Oxybisbenzene	Used as heat transfer medium and in organic synthesis.
2,2-Oxybisethanol*	Placed in VHC analyte group.
1,1,1,3,3-Pentachloro-2-propanone	------
Pentadecane	------
2-Pentanol,4-hydroxy-4-methyl	------
2-Pentanone*	Placed in the VHC analyte group.
Pentatriancontane	------
Phenanthrene*	Placed in the PAH analyte group.
Phenylbenzoate	------
Phenylethylphenol	Naturally occurring? - phenols are widely used in cleaning agents.
Phenylnaphthalene	A polynuclear aromatic hydrocarbon compound; fuel/burning residue related.
Phenylnaphthalene isomer	------
1-Phenyl-1,2-propanone	------
Phosphoric acid, tributyl ester*	Placed in the OPHGB analyte group.
Phosphoric acid, triphenyl ester*	Placed in the OPHGB analyte group.

---

* Significant former nontarget compound

Table A2.1-6. Summary of Tentatively Identified Compounds in Phase I and Phase II Soil Samples. Page 8 of 8.

Compound	Comments
Photodieldrin	Decomposition product associated with dieldrin.
Phthalate	Ubiquitous, plasticizer.
Propanediylbisbenzene	------
Propanoic acid, 2-methyl-2,2-dimethyl-1-(2-hydroxy-1-methyl) propylester	------
Propanoic acid, 2-methyl,3-hydroxy-2,4,4-trimethyl pentyl ester	Solvent?
1,2,3-Propantril,triacetate	------
2-Propenyl benzene	------
4-Propyl heptane	------
Pyrene*	Placed in the PAH analyte group.
Silicone	------
1,1-Sulfonylbis benzene	------
Terphenyl	------
Tetraazatricyclodecane	------
Tetrahydrofuran	Solvent for polyvinyl chloride, vinyl chloride copolymers, and vinylidene copolymers.
Tetrahydromethanoindene	Raw material used in aldrin and endrin manufacture
2,2,3,3-Tetramethylbutane	------
Tetramethylhexadecane	------
Tetramethylpentadecane	Lubricant, anti-corrosion agent.
Triethylester of phosphorodithioic acid	------
Tributylamine	Used as a stabilizer in production of GB.
Tributylester	------
Tricycloheptane	------
Trimethylbenzene	Occurs in coal tar and in petroleum crudes.
Trimethylester of phosphorodithioic acid	------
Trimethylnaphthalene	A polynuclear aromatic hydrocarbon compound; tar or creosote related, burn product.
Trimethylpentadecane	------
Triphenylene	A polynuclear aromatic hydrocarbon compound; fuel/burning residue related.

---

* Significant former nontarget compound

Table RISR A2.1-7. Chemical Analytes and Analyte Groups for Soil Samples.

Analyte Groups/Analytes

Volatile Halogenated Organics (VHOs)
- 1,1-Dichloroethane
- 1,2-Dichloroethane
- 1,1-Dichloroethylene
- trans-1,2-Dichloroethylene
- 1,1,2,2-Tetrachloroethane*
- 1,1,1-Trichloroethane
- 1,1,2-Trichloroethane
- Carbon tetrachloride
- Chlorobenzene
- Chloroform
- Methylene chloride
- Tetrachloroethylene
- Trichloroethylene
- Trichloropropene*

Volatile Hydrocarbons (VHCs)
- 2-Butoxyethanol*
- 4-Hydroxy-4-methyl-2-pentanone*
- 1-Methyl-1,3-cyclopentadiene*
- 2,2-Oxybisethanol*
- 2-Pentanone*
- Bicycloheptadiene
- Dicyclopentadiene
- Methylcyclohexane*
- Methylisobutyl ketone

Volatile Aromatic Organics (VAOs)
- Benzene
- Ethylbenzene
- m-Xylene
- o- and p-Xylene
- Toluene

Organosulfur Compounds, Mustard-Agent Related (OSCMs)
- 1,4-Oxathiane
- Chloroacetic acid
- Dithiane
- Thiodiglycol

---

* Significant former nontarget compound

Analyte Groups/Analytes

Organosulfur Compounds, Herbicide Related (OSCHs)
- Benzothiazole
- Chlorophenylmethyl sulfide
- Chlorophenylmethyl sulfone
- Chlorophenylmethyl sulfoxide
- Dimethyldisulfide

Organophosphorous Compounds, GB-Agent Related (OPHGBs)
- Diisopropylmethyl phosphonate
- Dimethylmethyl phosphonate
- Isopropylmethylphosphonic acid
- Methylphosphonic acid
- Phosphoric acid, tributyl ester*
- Phosphoric acid, triphenyl ester*

Organophosphorous Compounds, Pesticide Related (OPHPs)
- Atrazine
- Malathion
- Parathion
- Supona
- Vapona

Dibromochloropropane (DBCP)

Organonitrogen Compounds (ONCs)
- Caprolactam*
- Hydrazine
- Methylhydrazine
- n-Nitrosodimethylamine
- n-Nitrosodi-n-propylamine
- Unsymmetrial dimethylhydrazine

Fluoroacetic Acid

Polynuclear Aromatic Hydrocarbons (PAHs)
- Fluoranthene*
- Methyl naphthalene*
- Phenanthrene*
- Pyrene*

---

* Significant former nontarget compound

Analyte Groups/Analytes

Semivolatile Halogenated Organics (SHOs)
- Hexachlorobenzene*
- Hexachlorobutadiene*
- Hexachlorocyclopentadiene
- Pentachlorobenzene*
- Tetrachlorobenzene*
- Trichlorobenzene*

Organochlorine Pesticides (OCPs)
- Aldrin
- Chlordane
- Dichlorodiphenylethane (DDE)
- Dichlorodiphenyltrichloroethane (DDT)
- Dieldrin
- Endrin
- Isodrin

Arsenic

Mercury

ICP Metals
- Cadmium
- Chromium
- Copper
- Lead
- Zinc

---

* Significant former nontarget compound

A2.1.2.3 Analytical Strategy

Phase II analytical methods were specifically developed and certified for use in quantifying the concentration of target analytes identified in Phase I. The Phase II analytical techniques for organics were GC methods, which were certified for discrete groups of analytes that were generally, but not always, at lower CRLs than the less sensitive GC/MS methods used in Phase I. A summary of Phase II analytical methods for soil sampling is presented in Table RISR A2.1-8. The quantitative analytical methods for metals, arsenic, and mercury remained the same as in Phase I. The analytical methods and CRLs for specific Phase II analytes are listed in Table RISR A2.1-4. For the majority of organics, CRLs in Phase II were lower than in Phase I, providing a more precise quantification of the concentration of target organic analytes.

The Phase II investigation contained provisions for GC/MS confirmation of GC findings to ensure that analytes were being correctly identified. Approximately 10 percent of the positive GC findings were selected for confirmation by GC/MS. These were selected according to site and sample location to ensure the confirmation of significant analytes at all sites.

Field samples were examined for laboratory-induced contamination primarily by comparing analytical results for these samples with the associated laboratory blank sample. A blank sample was analyzed along with each lot of field samples. When a target or nontarget analyte was detected in the blank sample at concentrations similar to those in the field sample, the presence of that analyte was generally attributed to laboratory contamination. In some instances, determination of laboratory contamination was made by the laboratory analyst based on other factors. Methylene chloride was frequently suspected to be a laboratory-introduced contaminant during the RI due to its widespread use as a laboratory solvent. Toluene and tetrachloroethylene were suspected laboratory contaminants in samples from the Section 31 toxic storage yard plots because an inferior lot of sealing caps were used in the laboratory.

Table RISR A2.1-8. Summary of Phase II Analytical Methods for Soil Sampling. Page 1 of 1.

Analyte Types and Groups	Analytical Method
Volatile Organic Compounds (VHOs, VAOs, some VHCs)	Gas Chromatography/Mass Spectrometry Gas Chromatography/Photoionization Detector Gas Chromatography/Hall Electrolyte Conductivity Detector
Volatile Hydrocarbon Compounds (VHCs)	Gas Chromatography/Flame Ionization Detector
Semivolatile Organic Compounds (OCPs, OSCHs, OPHPs, DBCPs, VHCs, OPHGBs, OSCMs, PAHs*, SHOs)	Gas Chromatography/Mass Spectrometry Gas matography/Electron Capture Detector Detector
Organosulfur Compounds (OSCMs, OSCHs)	Gas Chromatography/Flame Photometric Detector High Performance Liquid Chromatography
Organophosphorous Compounds (OPHGBs, OPHPs)	Gas Chromatography/Flame Photometric Detector Gas Chromatography/Nitrogen Phosphorous Detector Ion Chromatography
Organonitrogen Compounds (ONCs)	Gas Chromatography/Nitrogen Phosphorous Detector
Fluorocetic Acid	Ionchromatography
Organochlorine Pesticides and DBCP (OCPs)	Gas Chromatography/Electron Capture Detector
Hydrazines (ONCs)	Spectrophotometry
Arsenic	Graphite Furnace Atomic Absorption Spectroscopy
Mercury	Cold Vapor Atomic Absorption Spectroscopy
Metals (ICPs)	Inductively Coupled Argon Plasma Spectroscopy

* Significant former nontarget analyte

A2.1.3 Sewers

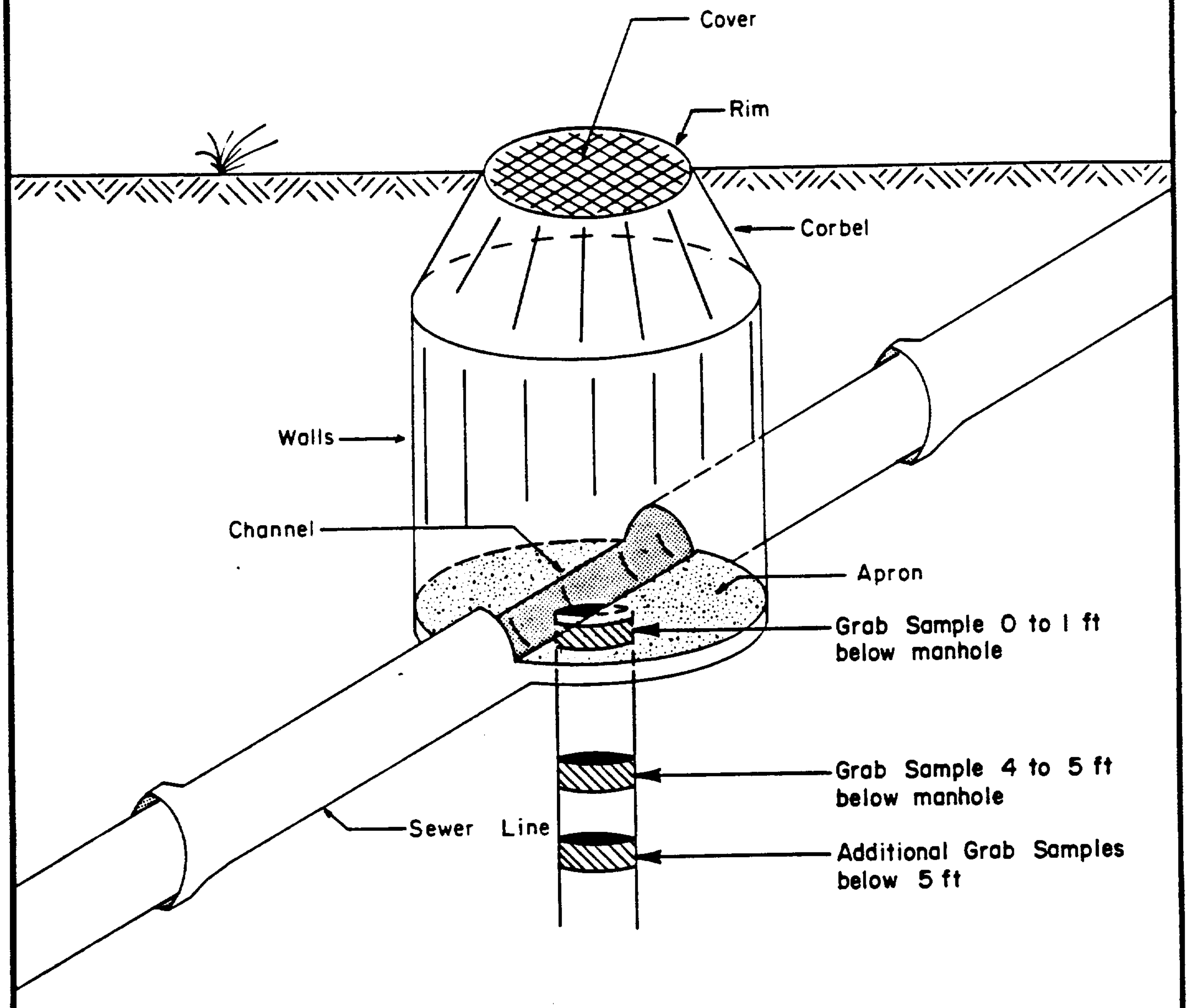
Included in the previous discussions of Phase I and Phase II soil sampling programs are the investigative strategy for sewer lines that have been previously removed, and ditches that comprised portions of the process water system. Chemical identification and analytical strategy for sewer sampling is the same as that discussed in Sections A2.1.1.2 and A2.1.1.3. For existing portions of the sewers systems, the rationale used for sewer sampling was based on the physical nature of the systems. Sediment and soil samples were collected from manholes and beneath manholes to determine which portions of the system were possibly contaminated, and soil samples were collected beneath trenches excavated along potentially contaminated segments of the system. These two aspects of sampling are summarized below. Specific details of these sampling methodologies are provided in the Task 10 Technical Plan (EBASCO, 1987/RIC 87336R03) and in several CARs referenced in Section 1.4 of this report.

A2.1.3.1 Sampling at Sewer Manholes

The objectives of sampling at sewer manholes were to locate leaks, estimate the vertical and horizontal extent of contamination in the soil beneath the manholes, and examine portions of the sewer systems where contamination was anticipated. A reconnaissance survey was conducted initially to select manholes for sampling. Sediment grab samples were collected from manholes at strategic locations along the system. Borings were drilled through the bottoms of selected manholes and soil samples were obtained from the 0- to 1-ft and 4- to 5-ft depth intervals below each drilled manhole (Figure RISR A2.1-5). Additional samples were collected at greater than 5-ft depths in drilled manholes along segments of the sanitary sewer and in all drilled manholes along the chemical sewers because historical information suggests that these systems transported contaminants.

A2.1.3.2 Sampling Beneath Excavated Trenches

Trenches were excavated along segments of the sewer lines that may have contributed to soil contamination as determined by historical data review, visual observation of manholes, and tracer dye tests. The tracer dye tests involved injecting a dye solution into an isolated



Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A2.1-5

Example of Soil Sampling
at Manholes

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

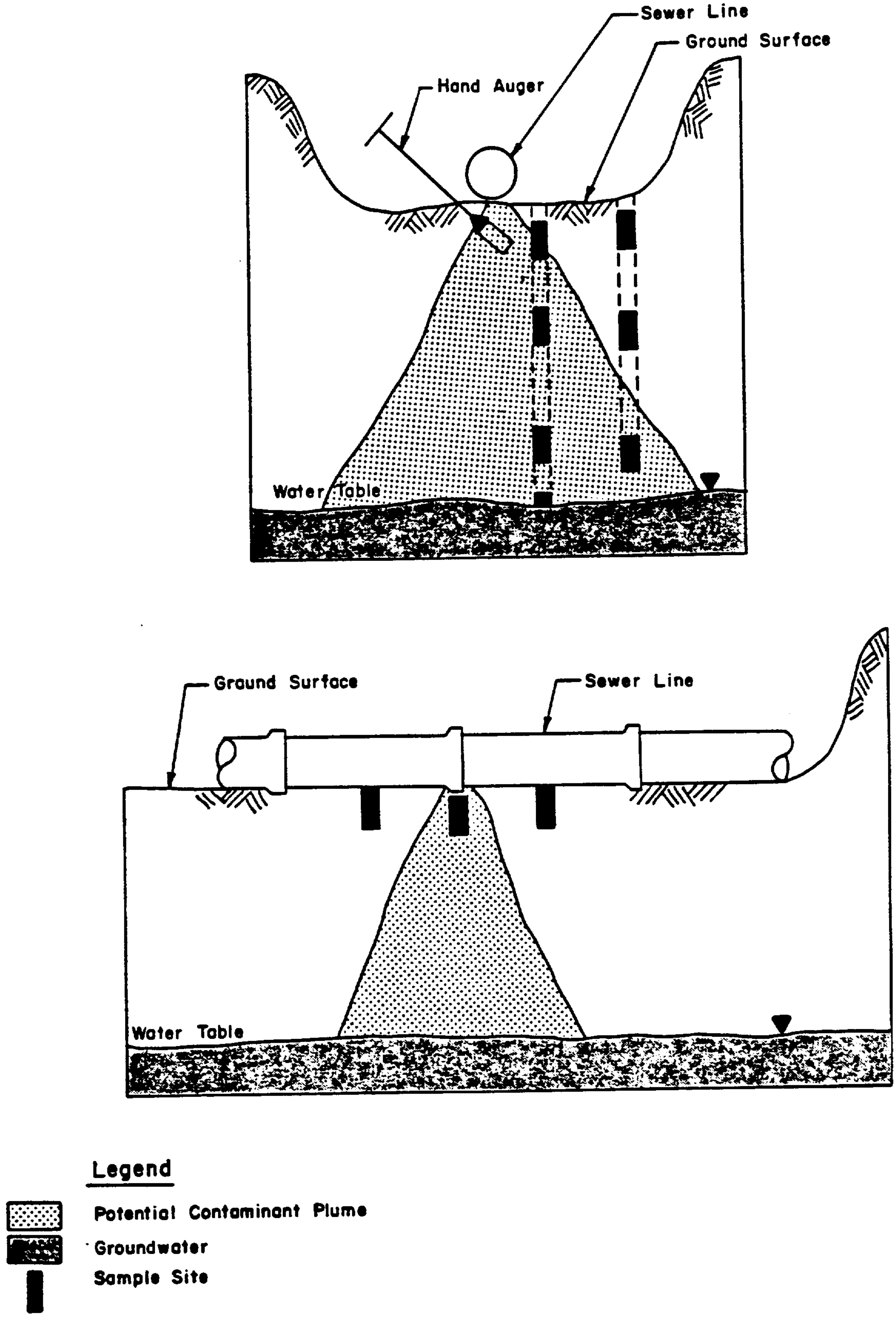
segment of pipe, excavating around the pipe, and examining the soil for evidence of leakage. Generally, a backhoe was used to remove soil down to approximately 6 inches above the pipe and 5 ft on one or both sides of the pipe. The remaining soil around the pipe was removed manually with shovels to avoid disturbing or damaging the pipe. To avoid the potential for spreading contamination, excavations were conducted to expose only those sections of the pipe necessary for sampling, and all excavations were backfilled with the excavated materials.

Figure RISR A2.1-6 illustrates the soil sampling scheme at excavation sites. The number of borings drilled or hand augered within the trenches and the number of samples collected was determined by the degree of observed damage of the pipe, or the results of the tracer dye tests. Samples were typically collected from directly beneath exposed pipe joints and from the 1-ft-depth interval below the pipe joints. In some cases, samples were collected from a boring on one side or both sides of the pipe, approximately 1 ft away from the joint. In instances where tracer dye studies were used and joints exhibited significant leakage, samples were collected from directly beneath and at 1-ft and 5-ft distances from the joints, on one or both sides of the pipe. To provide additional information on the extent of contamination, samples were collected in some excavations from beneath the midpoint of the pipe sections located on either side of a leaking joint, as illustrated in Figure RISR A2.1-6.

Borings 1 ft away from the pipes were, if possible, drilled to the water table, and borings 5 ft away were drilled to the water table or 15 ft, whichever was encountered first. The purpose of sampling at these depths was to estimate both the vertical and lateral extent of contamination associated with leaks.

A2.1.4 Other Soil Programs

Additional soil sampling and analysis programs were conducted to rectify observed data deficiencies and to assist in the assessment of the RI data. Detailed explanations of these programs can be found in the documents cited in the following subsections.



Source: Ebasco, 1987

Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A2.1-6

Example of Soil Sampling at Excavation Sites

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

A2.1.4.1 Partitioning Study

A field investigation was conducted in Section 36 of RMA to examine the partitioning of selected contaminants between soil and water, quantified as the partition coefficient K_d (ESE, 1988h/RIC 88344R01). This document also summarizes and cites other RMA partitioning studies.

A2.1.4.2 Soil Gas Programs

Soil gas sampling programs conducted at RMA included a pilot program and a program to sample spill sites in South Plants. The pilot program (EBASCO, 1986/RIC 86239R03) was conducted to determine the effectiveness of soil gas methods in detecting the presence of VOCs in groundwater and in the unsaturated zone. Areas in the western portion of RMA and in South Plants were tested where VOCs, particularly trichloroethylene (TCE) and dibromochloropropane (DBCP), were known or suspected to be present in the groundwater or vadose zone. Soil gas surveys were conducted at spill sites in South Plants (EBASCO, 1989e/RIC 89166R04) in order to place soil borings in locations with the highest probability of contamination.

A2.1.4.3 Soil Characterization Studies

Investigations of the surficial soil units on RMA have been conducted by MKE for Shell (MKE, 1987; MKE, 1988; and J.P. Walsh, 1988). These studies were performed to examine the physical, chemical, and hydrologic properties of the surficial soil types at RMA.

A2.2 WATER

The water quality sampling program at RMA has evolved through a series of investigations that began with the 360° Monitoring Program in 1976. Water quality programs were developed to provide a regional monitoring network, to define contaminant contribution from specific source areas, and to assist in the operation and maintenance of active remediation systems. These goals were addressed by a series of sampling and analysis programs which were each designed to complement the information collected by the others. While objectives for each investigation have varied and sampling networks have been tailored to meet those objectives, results of earlier investigations were used to improve the design of later investigations. For example, new information about contaminant sources frequently resulted in the addition of new sampling locations. Similarly, as understanding of hydrologic and geologic conditions has increased, data-collection networks have been revised to improve the monitoring of contaminant distribution. Table RISR A2.2-1 provides a summary of water sampling programs conducted as part of the RI.

A2.2.1 Surface Water

While the 360° Monitoring Program was initiated in 1976 primarily to characterize groundwater quality (see Section A2.2.2 Groundwater), surface water monitoring was also included in the program. Initially, 12 on-post and 10 off-post surface water locations were monitored on a quarterly basis. Surface water quality monitoring continued through 1985 with minor changes and ended in 1986. Beginning in 1982, stream gaging stations were installed at ten on-post locations, stage and discharge data were collected, and rating curves were developed.

Surface water monitoring in 1985 was conducted as part of the Task 4 Water Quantity and Quality Survey Program. Stream stage and discharge were measured at the existing on-post gaging stations. Water diverted from Lake Ladora and effluent from the Sewage Treatment Plant were also measured. Surface water elevations of Upper Derby Lake, Lower Derby Lake, Lake Ladora, and Lake Mary were recorded weekly. Stream stage at gaging stations was continuously recorded. Water quality samples were initially obtained on a quarterly basis at 16 designated on-post locations. This program was subsequently expanded to include 25 on-post locations by the completion of Task 4 in 1986.

The objective of Task 39 was to complete RI work initiated under the off-post contamination assessment study. Eleven off-post surface water sites were sampled. The results of the Task 39 Investigation are presented in the "RMA Off-post Operable Unit Remedial Investigation and Chemical Specific Applicable or Relevant and Appropriate Requirements Final Report" (ESE, 1988f/RIC 89173R01).

Table RISR A2.2-1. Summary of 1985 to 1989 Water Sampling Programs. Page 1 of 2.

Task/ Program	Sampling Period	Sampling Frequency	Number of Wells Sampled	Number of Wells Installed[1]	Number of Surface-Water Stations Sampled
4[2]	ISP[3]: October 1985 to March 1986	Single event	321	0	25
	3rd & 4th Quarter: April to September 1986	Quarterly[4]	3rd Quarter: 180 4th Quarter: 182	0	3rd: 30 4th: 30
11	1986	Single event	12	2	0
	1988	Single event	13	0	0
25	September 1986 to December 1987	Quarterly	117[5]	10	0
36	June 1987 to October 1987	Quarterly	97	18	0
38	December 1986 to September 1987	Quarterly	52[5]	31	0
39	June 1987 to October 1987	Quarterly	73	15	11
42	January 1988	Single event	6	6	0

[1] Additional wells completed under soils tasks included in the Composite Well Program Report (ESE, 1988d/RIC 88244R02).

[2] Third and fourth quarter program contained an additional 43 off-post wells and 11 off-post samples in the 360° Monitoring Program; numbers not included in well totals.

[3] Initial Screening Program.

[4] Quarters by 3-month increments, with October to December = first quarter, etc.

[5] Number of wells sampled in third quarter (April-June) 1987; see task reports for number of wells sampled during other quarters.

[6] Dates of well installation: May 1987-January 1988.

[7] Comprehensive Monitoring Program.

Source: Modified from EBASCO, 1989d/RIC 89186R01.

Table RISR A2.2-1. Summary of 1985 to 1989 Water Sampling Programs. Page 2 of 2.

Task/ Program	Sampling Period	Sampling Frequency	Number of Wells Sampled	Number of Wells Installed[1]	Number of Surface-Water Stations Sampled
44	September 1986 to March 1987	Quarterly	55	0	41
	April 1987 to June 1987	Single event	311	0	37
	July 1987 to September 1987	Single event	55	22[6]	27
Shell South Plants	February 1988 to April 1988	Single event	95	0	0
RIFS2	October 1988 to February 1989	Single event	75	41	0
CMP[7]	Winter 1987/88	Annually	255	0	0
	Spring 1988	Semi-annually	307	0	14
	Summer 1988	Quarterly	46	0	13 (annual) 4 (storm) 2 (special)
	Fall 1988	Annually	488	0	12
	Winter 1989	Quarterly	62	0	0

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[1] Additional wells completed under soils tasks included in the Composite Well Program Report (ESE, 1988d/RIC 88244R02).

[2] Third and fourth quarter program contained an additional 43 off-post wells and 11 off-post samples in the 360° Monitoring Program; numbers not included in well totals.

[3] Initial Screening Program.

[4] Quarters by 3-month increments, with October to December = first quarter, etc.

[5] Number of wells sampled in third quarter (April-June) 1987; see task reports for number of wells sampled during other quarters.

[6] Dates of well installation: May 1987-January 1988.

[7] Comprehensive Monitoring Program.

Source: Modified from EBASCO, 1989d/RIC 89186R01.

Task 44 was initiated in 1986 to monitor changes in water quality, assess regional distribution and concentration of contaminants, and identify areas of potential public exposure. A total of 41 on- and off-post locations were monitored quarterly for water quality from September 1986 to March 1987. Water quality samples were obtained in the third and fourth quarters of fiscal year (FY) 87 from 37 and 27 sites, respectively. Stream discharge and lake levels previously monitored on post under Task 4 continued to be monitored under Task 44. Results of Tasks 4 and 44 monitoring are summarized as part of the Water Remedial Investigation Report (WRIR) (EBASCO, 1989d/RIC 89186R01). The WRIR includes discussions of water balances, stream-aquifer and lake-aquifer interactions, and surface water quality data from fall 1985 to fall 1987.

Since 1988 surface water data have been obtained and interpreted as part of the Comprehensive Monitoring Program (CMP). Although not a part of the RI, the CMP is designed to provide continual long-term verification monitoring of environmental conditions at RMA. Continued monitoring serves, in part, to verify data collected and results obtained in the RI. Emphasis has been placed on refining and extending rating curves for stream gages by increased monitoring of peak flow periods, collecting stream-sediment data, and improving estimates of stream-aquifer and lake-aquifer interactions. A total of 35 sites have been designated for on- and off-post sampling. CMP data for the period extending through February 1989 are incorporated into the evaluation of contamination presented in this report.

A2.2.2 Groundwater

The 360° Monitoring Program was initiated in 1976 to provide regional monitoring of groundwater quality. Fifty-five on-post and 20 off-post wells were initially included in the well sampling network. The well sampling network was expanded as contaminant distribution became better defined. Approximately 130 wells were monitored quarterly from 1976 until 1985. The on-post portion of the 360° Monitoring Program was replaced by the Task 4 program in 1985, and the off-post wells were incorporated into the Task 44 program in 1986. The Task 4 program was designed to provide verification of historical results collected under the 360° Monitoring Program by using approved USATHAMA sample collection and analytical methodologies, and by comparing current, rigorously collected data to earlier sampling results. This verification effort was required in order to avoid the loss of these valuable historical records of groundwater and surface water quality, and to ensure the suitability of these records for use in the RI. Other monitoring programs conducted concurrently with the 360° Monitoring Program included:

- Basin F Monitoring Program - Initiated to evaluate potential leakage from Basin F (10 wells sampled quarterly from 1975 to 1985). Monitoring of this site was incorporated into Tasks 4 and 44.
- NBCS and NWBCS Monitoring - Initiated in 1978 and 1981, respectively, to assess effectiveness of the boundary containment systems (80 and 45 wells sampled quarterly, respectively). Monitoring was continued under Tasks 25 and 36.
- ICS Monitoring - Analyses for DBCP were conducted on quarterly samples between 1981 and 1986 (approximately 58 wells).
- U.S. Army Corps of Engineers, Waterways Experiment Station Monitoring Program - Groundwater samples were collected in four on-post areas referred to as the Northwest Boundary, South Plants, Basin A Neck, and Eastern Arsenal (approximately 245 wells sampled between 1980 and 1983).

Regional groundwater monitoring was conducted between October 1985 and September 1986 as part of Task 4. Initial sampling of 321 on-post wells was conducted and results were presented in the Initial Screening Program Report (ESE, 1987c/RIC 87253R01). As part of the Initial Screening Program, well completion information was reviewed. This review formed the basis for selecting wells to include in a sampling network. Sampling was conducted for two additional quarters (April-June 1986 and July-September 1986) for approximately 180 wells each quarter, and results were presented in the Final Screening Program Report (ESE, 1988a/RIC 88173R06).

Regional groundwater monitoring continued during 1987 as part of Task 44. Data collection for the task included installation of 22 wells, quarterly sampling of 55 wells from September 1986 to March 1987, a single sampling event of 311 on-post wells from April to June 1987, and a single sampling event of 55 wells from July 1987 to September 1987. The well network used in Task 44 was based on the network used in the Initial Screening Program.

However, minor modifications of the network resulted from previous sampling results. Results of the Task 44 program formed the basis of the WRIR.

A number of subregional monitoring programs were conducted concurrently with Tasks 4 and 44. Monitoring of the NBCS and NWBCS was conducted as part of Tasks 25 and 36 (ESE, 1988i/RIC 89024R02; ESE, 1988j/RIC 88344R02). Quarterly sampling of UFS and CFS wells upgradient and downgradient of the boundary systems was conducted under these tasks between September 1986 and December 1987. Task 38 was designed specifically to characterize the distribution of trichloroethylene and related contaminants in the western tier of RMA (EBASCO, 1989a/RIC 89166R03). Thirty-one wells were installed, and 52 wells were sampled quarterly between December 1986 and September 1987. The Shell South Plants Monitoring Program was conducted to obtain water quality data from the UFS in the vicinity of South Plants (EBASCO, 1989e/RIC 89166R04). The program was undertaken from February to April 1988 and included the sampling of 95 wells. Additional site-specific monitoring was conducted as part of Task 39 (Off-Post Remedial Investigation, ESE, 1988f/RIC 89024R01), Task 42 (North Plants, EBASCO, 1989f/RIC 89166R05), and Task 11 (Hydrazine Facility, EBASCO, 1989e/RIC 89166R04).

Since the completion of Task 44, regional groundwater monitoring has been conducted in conjunction with the SARs under the RIFS2 task and as part of the CMP. Data collection for RIFS2 included installation of 41 wells and a single sampling event of 75 on-post wells from October 1988 to February 1989. The groundwater element of the CMP is designed to maintain regional and project groundwater monitoring programs for regulatory database maintenance, RI/FS verification, and system operational purposes. Groundwater quality and hydrology are monitored to assess changes in the rate and extent of contaminant migration and the distribution of contaminants both in on- and off-post areas. The well network used for regional monitoring in the CMP is based on the network used in Task 44. However, additional wells have been installed in areas where greater detail is needed. Subregional monitoring, using a greater density of wells than required for regional monitoring, is also included within the CMP. Monitoring is conducted in specific areas requiring further evaluation of contaminant distribution. Wells monitored on a quarterly basis provide water quality data to support ongoing IRA projects in the Basin F area. CMP data collected through February 1989 are incorporated into the evaluation of contamination included in this report.

The Transitional Monitoring Program (TMP) was the first annual sampling round conducted under the CMP. It was designed to provide continuity with the previous regional and boundary systems monitoring programs conducted under the RI/FS contracts. A total of 255 wells were sampled under this program in winter 1987-1988. Additional wells were sampled for Tasks 25 and 44 during this time period. The semiannual well network consisted of 307 wells, and quarterly sampling was conducted for 46 wells. During the FY 89 CMP, 488 wells were monitored in the fall of 1988 and 62 wells were monitored in the winter of 1989. Water quality monitoring was conducted after this date for the CMP; however, with the exception of the total organic analyte plume maps presented in Appendix A3 of this report, data collected after February 1989 are not discussed.

Several investigations have been conducted recently or are planned to investigate light, non-aqueous phase liquids (LNAPLs), dense, non-aqueous phase liquids (DNAPLs), and absorbed contamination. In the South Tank Farm Area of Sections 1 and 2, LNAPL investigations have been conducted to determine the extent, composition, and thickness of the LNAPL, monitor the leading edge, and characterize the hydrogeologic sitting (Shell, 1989/RIC 89216R01; 1989/RIC 89264R01; 1990/RIC 91002R06). In addition, there is a current study designed to evaluate the applicability and effectiveness of soil vapor extraction (SVE) processes for cleaning LNAPL contaminated soil and free product in the weathered Denver Formation (Shell, 1990/RIC 91002R01). Field investigations conducted at the Shell Section 36 trenches indicated the presence of a DNAPL in one well (Shell, 1989/RIC 90262R05). Installation of monitoring wells are planned to investigate the extent of the DNAPL (Shell, 1990/RIC 91002R04). An investigation designed to characterize rates of desorption from the unsaturated alluvium is planned to be conducted north of Basin F in Section 23. Multiple well tests and laboratory analyses will be performed to monitor elution rates and the potential that dissolved organic matter might contribute to contaminant mobilities (RLSA, pending). Other investigations of NAPLs in the South Plants area are included in the Phase II FS Field Data Collection Program. Results of these investigations are forthcoming.

A2.2.3 Analytical Programs

The number and types of contaminants included in recent groundwater and surface water monitoring programs have increased substantially from the number and types included in29 earlier monitoring programs. The 360° Monitoring Program, which extended from 1976 to 1986, included diisopropylmethyl phosphonate (DIMP), DBCP, aldrin, dieldrin, endrin, isodrin, dithiane, oxathiane, chlorophenylmethyl sulfide, chlorophenylmethyl sulfoxide, chlorophenylmethyl sulfone, and major inorganic constituents. Results of the Regional Groundwater Study of RMA conducted during the early 1980s (Spaine et al., 1984/RIC 85133R04) indicated the presence of volatile organics including toluene, xylene, benzene, chlorobenzene, chloroform, methylene chloride, carbon tetrachloride, dichloroethylene, trichloroethylene, and tetrachloroethylene. Historical information was combined with results of an evaluation of contaminant source characteristics at RMA and a review of compounds attributable to historical activity to derive the list of analytes used in Tasks 4 and 44 monitoring programs. Target analytes for Task 44 included those analyzed in Task 4, and benzothiazole and chlordane. The CMP target analytes were similar to those analyzed in Task 44. Additional CMP analyses include thiodiglycol, phenols, cyanide, and the pesticide-related organophosphorous compounds (OPHPs) (atrazine, malathion, parathion, supona, and vapona). The RIFS2 program was similar to the CMP, with the exception of thiodiglycol and nitrate/nitrite analyses. The target analytes selected to fulfill the individual task and program objectives are listed in Table RISR A2.2-2. In general, target analytes for each site-specific program were selected on the basis of site history and previous investigations. Analytical methods for these analytes did not tend to differ between programs. Rationale for the selection of specific analytes is discussed in the task and program reports. General criteria used as guidelines for selecting target analytes at RMA are presented in Section A2.1 of this report.

Table RISR A2.2-2. Target Analytes for Water Sampling Programs, 1985 to 1989. Page 1 of 3.

	Tasks									
Analyte	4	11	25	36	38	39	42	44	RIFS2	CMP
<u>Volatile Halogenated Organics (VHOs)</u>										
1,1-Dichloroethane	X	-	X	X	X	X	X	X	X	X
1,1-Dichloroethylene	X	-	X	X	X	X	X	X	X	X
1,2-Dichloroethane	X	-	X	X	X	X	X	X	X	X
trans-1,2-Dichloroethylene	X	-	X	X	X	X	X	X	X	X
1,1,1-Trichloroethane	X	-	X	X	X	X	X	X	X	X
1,1,2-Trichloroethane	X	-	X	X	X	X	X	X	X	X
Carbon tetrachloride	X	-	X	X	X	X	X	X	X	X
Chlorobenzene	X	-	X	X	X	X	X	X	X	X
Chloroform	X	-	X	X	X	X	X	X	X	X
Methylene chloride	X	-	X	X	X	X	X	X	X	X
Tetrachloroethylene	X	-	X	X	X	X	X	X	X	X
Trichloroethylene	X	-	X	X	X	X	X	X	X	X
<u>Volatile Hydrocarbons (VHCs)</u>										
Bicycloheptadiene	-	-	-	-	-	-	X	-	X	X
Dicyclopentadiene	X	-	X	X	-	X	X	X	X	X
Methylisobutyl ketone	X	-	X	X	-	X	X	X	X	X
<u>Volatile Aromatic Organics (VAOs)</u>										
Benzene	X	-	X	X	X	X	X	X	X	X
Ethylbenzene	X	-	X	X	X	X	X	X	X	X
m-Xylene	X	-	X	X	X	X	X	X	X	X
o- and p-Xylene	X	-	X	X	X	X	X	X	X	X
Toluene	X	-	X	X	X	X	X	X	X	X
<u>Organosulfur Compounds, Mustard-Agent Related (OSCMs)</u>										
1,4-Oxathiane	X	-	X	X	-	X	X	X	X	X
Dithiane	X	-	X	X	-	X	X	X	X	X
Thiodiglycol	-	-	-	-	-	-	X	-	-	X
<u>Organosulfur Compounds, Herbicide Related (OSCHs)</u>										
Benzothiazole	-	-	X	X	-	X	X	X	X	X
Chlorophenylmethyl sulfide	X	-	X	X	-	X	X	X	X	X
Chlorophenylmethyl sulfone	X	-	X	X	-	X	X	X	X	X
Chlorophenylmethyl sulfoxide	X	-	X	X	-	X	X	X	X	X
Dimethyldisulfide	X	-	X	X	-	X	X	X	X	X
<u>Organophosphorous Compounds, GB-Agent Related (OPHGBs)</u>										
Diisopropylmethyl phosphonate	X	-	X	X	-	X	X	X	X	X
Dimethylmethyl phosphonate	X	-	X	X	-	X	X	X	X	X

Table RISR A2.2-2. Target Analytes for Water Sampling Programs, 1985 to 1989. Page 2 of 3.

	Tasks									
Analyte	4	11	25	36	38	39	42	44	RIFS2	CMP
<u>Organophosphorous Compounds Pesticide Related (OPHPs)</u>										
Atrazine	-	-	-	-	-	-	X	-	X	X
Malathion	-	-	-	-	-	-	X	-	X	X
Parathion	-	-	-	-	-	-	X	-	X	X
Supona	-	-	-	-	-	-	X	-	X	X
Vapona	-	-	-	-	-	-	X	-	X	X
<u>Dibromochloropropane (DBCP)</u>	X	-	X	X	-	X	X	X	X	X
<u>Organonitrogen Compounds (ONCs)</u>										
Hydrazine	-	X	-	-	-	-	-	-	-	-
Methylhydrazine	-	X	-	-	-	-	-	-	-	-
n-Nitrosodimethylamine	-	X	-	-	-	-	-	-	-	-
Unsymmetrical dimethylhydrazine	-	X	-	-	-	-	-	-	-	-
<u>Semivolatile Halogenated Organics (SHOs)</u>										
Hexachlorocyclopentadiene	X	X	X	-	X	X	X	X	X	X
<u>Organochlorine Pesticides (OCPs)</u>										
Aldrin	X	-	X	X	-	X	X	X	X	X
Chlordane	-	-	X	X	-	X	X	X	X	X
Dichlorodiphenylethane	X	-	X	X	-	X	X	X	X	X
Dichlorodiphenyltrichloroethane	X	-	X	X	-	X	X	X	X	X
Dieldrin	X	-	X	X	-	X	X	X	X	X
Endrin	X	-	X	X	-	X	X	X	X	X
Isodrin	X	-	X	X	-	X	X	X	X	X
<u>Arsenic</u>	X	-	X	X	-	X	X	X	X	X
<u>Mercury</u>	X	-	-	X	-	-	X	X	X	X
<u>ICP Metals</u>										
Cadmium	X	-	-	X	-	-	X	X	X	X
Chromium	X	-	-	X	-	-	X	X	X	X
Copper	X	-	-	X	-	-	X	X	X	X
Lead	X	-	-	X	-	-	X	X	X	X
Zinc	X	-	-	X	-	-	X	X	X	X

Table RISR A2.2-2. Target Analytes for Water Sampling Programs, 1985 to 1989. Page 3 of 3.

	Tasks									
Analyte	4	11	25	36	38	39	42	44	RIFS2	CMP
Anions and Cations										
Calcium	X	-	-	X	-	-	X	X	X	X
Chloride	X	-	X	X	-	X	X	X	X	X
Fluoride	X	-	X	X	-	X	X	X	X	X
Magnesium	X	-	-	X	-	-	X	X	X	X
Nitrate	X	-	-	X	-	-	-	X	-	X
Potassium	X	-	-	X	-	-	X	X	X	X
Sodium	X	-	-	X	-	-	X	X	X	X
Sulfate	X	-	X	X	-	X	X	X	X	X
Phenols	-	-	-	-	-	-	-	-	-	X
Cyanide	-	-	-	-	-	-	-	-	-	X

Several laboratories, certified using USATHAMA protocols, performed analyses of water samples collected during the RI at RMA. Analyses were conducted by five primary laboratories: California Analytical Laboratories, Inc. (CAL); Environmental Science and Engineering, Inc. (ESE)-Gainesville; ESE-Denver; DataChem, Inc. (DataChem, formerly Utah Biomedical Test Laboratory); and ENSECO, Inc. (ENSE, formerly Rocky Mountain Analytical Laboratories). The CRLs for water varied, as they are method-, analyte-, laboratory-, and instrument-specific. Ranges of CRLs for the target analytes in surface water and groundwater samples from 1985 through 1989 are listed in Table RISR A2.2-3. Additional information on CRLs for groundwater samples is presented in Appendix B.

In addition to the quantitative analyses performed for target compounds in Tasks 4 and 44, RIFS2, and CMP, a representative number of samples were analyzed by GC/MS techniques in an effort to identify previously unrecognized compounds not included on the target analytical schedules. The nontarget compounds that were tentatively identified in water samples are summarized in Table RISR A2.2-4. In order to determine whether specific chemicals should be incorporated in the list of target analytes, the TICs in water samples were reviewed by the same criteria as the TICs in soil samples (Section A2.1.2.2).

The compounds elevated to target analyte status, indicated by an asterisk in Table RISR A2.2-4, were discussed in the SARs and evaluated by the EA.

The target and former nontarget analytes used in assessing the nature and extent of soil contamination in the SARs and in this report are listed in Table RISR A2.1-7. As previously noted, the analytes are organized into analyte groups by similar chemical behaviors and histories of usage, origin, and disposal.

A2.3 STRUCTURES

Prior to the structures survey conducted in 1987 as part of the RI (EBASCO, 1988c/RIC 88306R02), ten smaller-scale surveys had been undertaken at RMA. Table RISR A2.3-1 summarizes the results of the 1987 structures survey and previous structures surveys/

Table RISR A2.2-3. CRL Ranges for Target Analytes in Water Samples, 1985 to 1989.

Analyte Groups/Analytes	CRLs (ug/l)	
	Surface Water	Groundwater
Volatile Halogenated Organics (VHOs)		
1,1-Dichloroethane	0.730-2.40	0.730-12.0
1,1-Dichloroethylene	1.00-1.85	1.00-1.85
1,2-Dichloroethane	0.610-2.07	0.610-7.40
trans-1,2-Dichloroethyelene	0.760-5.00	0.760-5.00
1,1,1-Trichloroethane	0.760-1.70	0.760-6.80
1,1,2-Trichloroethane	0.780-1.68	0.780-7.10
Carbon tetrachloride	0.990-2.40	0.990-6.30
Chlorobenzene	0.580-1.36	0.580-5.10
Chloroform	0.500-1.88	0.500-1.88
Methylene chloride	1.00-7.40	1.00-7.40
Tetrachloroethylene	0.750-2.76	0.750-9.40
Trichloroethylene	0.560-1.40	1.00-5.20
Volatile Hydrocarbons (VHCs)		
Bicycloheptadiene	1.20-5.90	1.00-5.90
Dicyclopentadiene	1.50-9.31	1.10-9.31
Methylisobutyl ketone	1.00-12.9	1.00-12.9
Volatile Aromatic Organics (VAOs)		
Benzene	1.00-1.92	1.00-6.10
Ethylbenzene	0.620-1.40	0.620-11.0
m-Xylene	1.00-2.00	1.00-14.0
o- and p-Xylene	1.34-3.20	1.34-19.0
Toluene	1.00-2.80	1.00-7.80
Organosulfur Compounds, Mustard-Agent Related (OSCMs)		
1,4-Oxathiane	1.35-27.0	1.35-27.0
Dithiane	1.11-21.0	1.11-21.0
Thiodiglycol	None	6.69-65.9
Organosulfur Compounds, Herbicide Related (OSCHs)		
Benzothiazole	1.14-5.00	1.14-5.00
Chlorophenylmethyl sulfide	1.08-17.0	1.00-17.0
Chlorophenylmethyl sulfone	2.24-7.46	2.24-11.5
Chlorophenylmethyl sulfoxide	1.98-29.0	1.98-29.0
Dimethyldisulfide	0.550-13.5	0.550-13.5

Table RISR A2.2-3. CRL Ranges for Target Analytes in Water Samples, 1985 to 1989.

Analyte Groups/Analytes	CRLs (ug/l)	
	Surface Water	Groundwater
Organophosphorous Compounds, GB-Agent Related (OPHGBs)		
Diisopropylmethyl phosphonate	0.392-21.0	0.392-21.0
Dimethylmethyl phosphonate	0.188-130	0.188-130
Organophosphorous Compounds, Pesticide Related (OPHPs)		
Atrazine	0.790-5.90	0.790-14.3
Malathion	0.373-21.0	0.373-21.2
Parathion	0.250-37.0	0.250-37.0
Supona	0.680-19.0	0.680-19.0
Vapona	0.384-17.0	0.384-17.3
Dibromochloropropane (DBCP)	0.130-12.0	0.0400-19.0
Organonitrogen Compounds (ONCs)		
Hydrazine	—	31
Methylhydrazine	—	3000
n-Nitrosodimethylamine	—	2.6-300
Unsymmetrical dimethylhydrazine	—	22
Semivolatile Halogenated Organics (SHOs)		
Hexachlorocyclopentadiene	0.0489-54.0	0.0480-54.0
Organochlorine Pesticides (OCPs)		
Aldrin	0.0500-13.0	0.0500-13.0
Chlordane	0.0950-37.0	0.0950-37.0
Dichlorodiphenylethane	0.0460-14.0	0.0460-14.0
Dichlorodiphenyltrichloroethane	0.0490-18.0	0.0490-18.0
Dieldrin	0.0500-26.0	0.0500-26.0
Endrin	0.0500-18.0	0.0500-18.0
Isodrin	0.0510-7.80	0.0510-7.80
Arsenic	2.50-3.88	2.35-3.88
Mercury	0.100-0.500	0.100-0.500
ICP Metals		
Cadmium	4.09-8.40	4.09-8.40
Chromium	4.44-24.0	4.44-24.0
Copper	6.20-26.0	6.20-26.0
Lead	18.6-74.0	18.6-74.0
Zinc	5.35-22.0	5.35-22.0

Table RISR A2.2-3. CRL Ranges for Target Analytes in Water Samples, 1985 to 1989.

Analyte Groups/Analytes	CRLs (ug/l) Surface Water	 Groundwater
Anions and Cations		
Calcium	22.6-500	22.6-500
Chloride	114-4800	114-4800
Fluoride	50.0-1220	50.0-1220
Magnesium	110-500	89.2-500
Nitrate/Nitrite	10.0	10.0
Potassium	250-1256	250-1256
Sodium	91.3-940	91.3-940
Sulfate	175-10,000	175-10,000
Phenols	2.20-9.20	2.20
Cyanide	2.50-5.00	2.50-8.90

Table RISR A2.2-4 Summary of Tentatively Identified Compounds in Water Samples.

Compound	Comments
Compounds with 10 or more occurrences:	
1,1,2,2-Tetrachloroethane*	Placed in VHO analyte group; also called acetylene tetrachloride; in laundry operations 1942-62.
2,6,10,14-Tetramethylhexadecane	---
2,6,10-Trimethylpentadecane	---
bis(2-Ethylhexyl)phthalate	---
Caprolactam*	Placed in ONC analyte group; also called 2H-Azepin-2-one, hexahydro.
Tetrahydrofuran	A solvent for polyvinyl chloride, vinyl chloride copolymers, and vinylidene chloride copolymers; used by Shell.
Compounds with fewer than 10 occurrences:	
1,1-Bismethylthiolethane	---
1,2,3,4,5,7,7-Heptachlorobornene	---
1,2-Dichloroethylene	Solvent for fats, phenol, camphor, etc.; retards fermentation.
1,2-Dichloropropene	Used in manufacture of d-d soil fumigant.
1,3-Cyclopentadiene	Raw material used in aldrin, dieldrin, and heptachlor manufacture.
1,3,6-Dioxathiolane	---
1,3-Dithiolane	---
1,4-Cyclooctadiene	---
1,4-Dithiane	---
1-Propamine	---
1-(4-Hydroxy-3-methoxyphenol)ethanone	---
2-Butoxyethanol*	Placed in VHC analyte group
2-Propanone	---
2,2,2-Trichloroethanol	---
2,3-Dichloro-2-methylbenzyl alcohol	---
2,4-Imidiazolidinedione	---
2,6,10,14-Tetraethylhexadecane	---
2,6,10,14-Tetraethylpentadecane	---
2,6,10,14-Tetramethylhexadiene	---
2,6,10,14-Tetramethylpentadecane	---
2,6,10,14-Tetramethylpentadiene	---
2-Cyclohexen-1-one	Raw material used in Landrin manufacture.
2-Methylcyclopentanone	---
2-Methyl,1-(1,1-dimethylethyl)-2-methyl-(1,3-propanediylpropionate)	---
2-Methyl-2,4-pentanol	Solvent?
2-Propanol	Also called allyl alcohol; raw material for synthesis of Nemagon soil fumigant.
2-(4-Methyl-2-furyl)-2-cyclopenten-1-one	---
2,6-1-Butyl-4-methylphenol	---

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* Significant former nontarget compound

Compound	Comments
3,3,5-Trimethylcyclohexanone	---
3,5-Dimethyl-1,2,4-trithiolane	---
3-Methyl-1,3,5-hexatriene	---
4-Hydroxy-4-methyl-2-pentanone*	Placed in VHC analyte group
5-Ethyl-5-secanyl-2,4,6(1h,3h,5h)-pyrimidinetrione	---
5-Methyl-1,3-oxathiane	---
8-Oxatricyclo(2,2,2,0,2,6)-octan-7-ol	---
Acetophenone	Decomposition product of Ciodrin.
Azidobenzene	---
Benzamine	---
Benzothiazine	---
Bicyclodihydropentadiene	---
Bicyclohydropentadiene	---
Bicyclo(2,2,1)hept-2-en-7-ol	---
Biphenyl-ol	---
bis(isopropyl)urea	---
Butyloctadecanoate	---
Butylglycolacetate	---
Chloromethylphenol	---
Chloromethylsulfoxylamide	---
Chlorophenylmethylsulfide isomer	---
Cholest-3-ene	---
Cyclohexanone	---
Cyclopenten-1-on	---
Dehydropyram	---
Dichlorobenzene	Raw material used in Akton manufacture
Diheptylphthalate	---
Dihydroxymethyl benzoate	---
Dimethoxymethane	---
Dimethylphthalate	---
Dimethylsulfide	---
Dimethyl trithialane	An organosulfur compound.
Diphenyl ether	---
Dimethylmethylphosphonate	Byproduct of GB manufacture.
Docosane	---
Dodecanamide	---
Ethylbenzene	Component of leaded and unleaded gasoline.
Ethyldimethylbenzene	---
Ethylmethylbenzene	---
Freon	Used in button and sandwich bomb production.
Heptachlorobicycloheptene	Endrin intermediate.

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* Significant former nontarget compound

Compound	Comments
Heptachlorobicyclo(2,2,1)hept-2-ene	Endrin intermediate.
Heptanone	---
Hexachlorocyclo(2,2,1)hepta-2-one	---
Hexachlorobutadiene*	Placed in SHO analyte group.
Hexadecanamide	---
Hexanoic acid	---
Hexanol	---
Hexanone	---
Isobutyloctadecanoate	---
Isobutylbenzene	---
Limonene	---
Methoxybenzaldehyde	---
Methyl ester of dihydroxybenzoic acid	---
Methyl octane	---
Methyl benzylamine	---
Methylethyl benzene	Related to solvent or burning fuel?
Methyl naphthalene*	Placed in PAH analyte group; natural sources are coal and petroleum.
Methylsulfoxyl benzene	---
Methylthio-1-butanone	---
Methyltricyclo(3,2,1,0,2,7)oct-3-ene-5-carboxylate	---
Methyl-2,4-pentanediol	Solvent.
m-Mentha-4,8-diene	---
n-Methyl lutidon	---
Naphthalene	A polynuclear aromatic hydrocarbon compound.
Nonanal	---
Nonane	---
n,n-Dibutylacetamide	---
n,n-Dimethylbenzylamide	---
n-Hexylacetamide	---
n-Methylmethanamide	Raw material used in Bidrin manufacture.
n-Nitrosodipropylamide	---
n,n-bis(1,-Methylethyl)urea	---
n-Propylpropamine	---
n-Tridecane	---
Octadecanamide	---
Octadecanaethiol	---
Octanoic acid	---
Oxatricyclooctane	OCP impurity
Pentachlorophenol	Shell waste; used for slime and algae control in herbicide formulations.
Phenanthrene*	Placed in PAH analyte group.
Phenol	A common chemical and ingredient in cleaning agents, reportedly contained in petroleum oil extract.

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* Significant former nontarget compound

Table RISR A2.2-4 Summary of Tentatively Identified Compounds in Water Samples.

Compound	Comments
Phosphorithidic acid	---
Propamine amide	---
Propanedinitryl	---
Propanil	---
Propanoic acid	---
Propylbenzene	---
p-Isopropylbenzaldehyde	---
Silosane	---
Sulfur	Raw material used in production of sulfur chloride and sulfur dichloride; used at mustard distillation plant.
Tetrachlorobenzene*	Placed in SHO analyte group.
Tetrachlorophenol	---
Tetrachlorotannane	---
Tetrachlorocycloheptane	---
Tetradecanoic acid	---
Tetradecanol	---
Thiophene	---
Trichlorobenzene*	Placed in SHO analyte group; raw material used in Gardona manufacture.
Trichlorocyclopentene	---
Tricyclo(2,2,21,2,6)-heptan-3-ol	---
Triethylester of phosphoric acid	---
Triethyl phosphate	Decomposition product of Supona.
Trimethyl ester of phosphorothioic acid	---
Trimethylbenzene	Occurs in coal tar and petroleum crudes.
Trimethylcyclohexane	---

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* Significant former nontarget compound

Table RISR A2.3-1. Summary of Results of Structures Surveys/Inventories. Page 1 of 1.

Study/Date	Number of Structures Surveyed	Location	Estimated Area of Structures	Number of Contaminated Structures	Estimated Volume of Contaminated Material
EBASCO, 1987	763	RMA-wide	2,600,00 ft^2	655*	240,000 yd^3
EBASCO, 1985	89	Sections 1 & 2	N/A	49	N/A
RMACCPMT, 1984	Not specified	Sections 1, 2, & 25	N/A	30+ (Unspecified number in North Plants)	65,010 yd^3
Green, 1983	381	RMA-wide	N/A	N/A	N/A
HB&A, 1983	381	RMA-wide	N/A	N/A	N/A
HB&A, 1982	103	Sections 1 & 2 (Shell lease-hold only)	N/A	N/A	N/A
USATHAMA, 1977	400	RMA-wide	N/A	87	N/A
DOD, 1974	N/A	RMA-wide	2,206,171 ft^2	N/A	N/A
AMC, 1973	Approximately 278	Sections 1, 2, 3, 4, 6, 11, 24, 25, & 31	N/A	43	N/A
RMA, 1966	N/A	RMA-wide	2,157,218 ft^2	N/A	N/A
Unauthored, undated	N/A	RMA-wide	2,204,053 ft^2	N/A	N/A

Source: EBASCO, 1988c/RIC 88306R02.

*Includes suspected to be contaminated but cleanable structures.

N/A - Not applicable or Not available

inventories. The purpose of the structures survey portion of the RI was to develop comprehensive physical inventories of the structures at RMA, estimate the volume of materials contained in the buildings, and assess the nature of contamination in RMA structures. Historical usage, visual inspection of structures, and sampling results were the basis for evaluating the nature of contamination within RMA structures.

A2.3.1 Historical Usage

No generally recognized structure sampling procedures or acceptable levels for contamination found in structural materials exist. Therefore, the structures survey used historical records as a basis for conservatively assigning preliminary contamination classifications. Structures used for process or chemical storage functions were classified as "suspected to be contaminated, with contamination possible throughout the structure;" structures used for warehouse, maintenance, utility, or laboratory functions were classified as "suspected to be contaminated but cleanable, with contamination possible but likely to be confined to one part of the structure;" and structures used for administrative functions were classified as "suspected to be uncontaminated, with contamination unlikely." Structures with histories indicating more than one use were categorized according to the use with the highest potential for contamination.

A2.3.2 Visual Inspection

The field reconnaissance program was conducted in order to determine the location of every structure at RMA and prepare accurate location maps; complete physical descriptions of each building that included dimensions, physical condition, contents, presence of process equipment, presence of standing liquid, and potential existence of asbestos; note current usage and status of each structure; and verify the historical usage-based contamination classification. Information from the field reconnaissance program was used to build a database containing basic physical description, use, status, and contamination classification information for each structure. In addition, the field measurements and observations were used to provide quantitative estimates of the area of each structure and the volume of construction materials within each structure (e.g., concrete/brick, wood, or other).

A2.3.3 Sampling

Standing liquid and asbestos sampling programs were used to supplement the contamination classification. Standing liquid was sampled from sumps, pits, and basements where contamination was suspected and where sampling was not being conducted by other tasks. Fifty-three samples of standing liquid discovered during the initial field reconnaissance were collected from 14 building locations. The samples were analyzed to define the nature of contamination and to verify the historical contamination classifications.

The analyses conducted were chosen based on the history of use of the structures (EBASCO, 1988c/RIC 88306R02.) Liquid samples from all buildings were screened for VOCs and semivolatile organic compounds (SVOCs) using semiquantitative GC/MS analytical methods. Liquid samples from selected buildings in North Plants and South Plants were analyzed for Army agent breakdown products, arsenic, mercury, and the ICP metals (cadmium, chromium, copper, lead, and zinc), as their histories dictated. Liquid from one building in South Plants used for the manufacture and storage of pesticides was analyzed for organochlorine pesticides (OCPs) and OPHPs. The target analytes, analytical methods, and CRLs for the liquid sampling program are listed in Table RISR A2.3-2. Laboratories used for sample analysis were CAL, DataChem, and ESE. CRLs listed are from one of these three laboratories.

Nontarget compounds were tentatively identified from GC/MS analyses of the liquid samples. These compounds are discussed in the Structures Survey Report (EBASCO, 1988c/RIC 88306R02), and a summary list is presented in Table RISR A2.3-3.

Drummed sludge from a chemical sump in a building in North Plants was also analyzed. Details concerning the sampling, analysis, and analytical results are provided in the North Plants SAR (EBASCO, 1989f/RIC 89166R05).

Thirteen types of structural materials were identified at RMA that could possibly contain asbestos. Eighteen samples were collected with at least one from each of the thirteen material types, and the samples were analyzed for the presence of asbestos. The intent of this

Table RISR A2.3-2 Target Analytes, Analytical Methods, and CRLs for Liquid Sampling in Structures

Page 1 of 3.

Analyte Groups/Analytes	Analytical Method+	CRL (ug/l)
<u>Volatile Organic Compounds</u>		
1,1-Dichloroethane	GC/MS	2
1,2-Dichloroethane	GC/MS	1
1,1,1-Trichloroethane	GC/MS	1
1,1,2-Trichloroethane	GC/MS	1
Benzene	GC/MS	1
Bicycloheptadiene	GC/MS	1
Carbon tetrachloride	GC/MS	2
Chlorbenzene	GC/MS	1
Chloroform	GC/MS	1
Dibromochloropropane*	GC/MS	3
Dicyclopentadiene*	GC/MS	2
Dimethyldisulfide	GC/MS	10
Ethylbenzene	GC/MS	1
m-Xylene	GC/MS	1
Methylene chloride	GC/MS	4
Methylisobutyl ketone	GC/MS	1
o- and p-Xylene	GC/MS	1
Tetrachloroethylene	Gc/MS	1
Toluene	GC/MS	1
trans-1,2-Dichloroethylene	GC/MS	1
Trichloroethylene	GC/MS	1
<u>Semivolatile Organic Compounds</u>		
1,4-Oxathiane	GC/MS	8
Dichlorodiphenylethane*	GC/MS	6
Dichlorodiphenyltrichloroethane*	GC/MS	9
Aldrin*	GC/MS	8
Atrazine	Gc/MS	6
Chlordane*	GC/MS	9
Chlorophenylmethyl sulfide	GC/MS	20
Chlorophenylmethyl sulfone	GC/MS	7
Chlorophenylmethyl sulfoxide	GC/MS	30

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*Compounds analyzed for under more than one compound classification

+Analytical Methods:

GC/MS = Gas chromatography/mass spectrometry
GC/FPD = Gas chromatography/flame photometric detector
GC/ECD = Gas chromatography/electron capture detector
HPLC = High pressure liquid chromatography
ICP = Inductively coupled argon plasma spectroscopy
GFAA = Graphite furnace atomic absorption
CVAA = Cold vapor atomic absorption

Table RISR A2.3-2 Target Analytes, Analytical Methods, and CRLs for Liquid Sampling in Structures

Page 2 of 3.

Analyte Groups/Analytes	Analytical+ Method	CRL (ug/l)
Dibromochloropropane*	GC/MS	20
Dicyclopentadiene*	GC/MS	7
Dieldrin*	GC/MS	5
Diisopropylmethyl phosphonate	GC/MS	20
Dimethylmethyl phosphonate	GC/MS	30
Dithiane	GC/MS	20
Endrin*	GC/MS	8
Hexachlorocyclopentadiene*	GC/MS	20
Isodrin*	GC/MS	4
Malathion	GC/MS	10
Parathion	GC/MS	20
Supona	GC/MS	9
Vapona	GC/MS	20
Organophosphorous Compounds		
Diisopropylmethyl phosphonate	GC/FPD	29
Dimethylmethyl phosphonate	GC/FPD	19
Organochlorine Pesticides		
Dichlorodiphenylethane	GC/ECD	0.054
Dichlorodiphenyltrichloroethane	GC/ECD	0.049
Aldrin*	GC/ECD	0.050
Endrin*	GC/ECD	0.52
Isodrin*	GC/ECD	0.51
Dieldrin*	GC/ECD	0.50
Hexachlorocyclopentadiene*	GC/ECD	0.048
Chlordane*	GC/ECD	0.095
Organosulfur Compounds, Mustard-Agent Related		
Thiodiglycol	HPLC	66
Thiodiglycolic acid	HPLC	53

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*Compounds analyzed for under more than one compound classification

+Analytical Methods:

GC/MS = Gas chromatography/mass spectrometry
GC/FPD = Gas chromatography/flame photometric detector
GC/ECD = Gas chromatography/electron capture detector
HPLC = High pressure liquid chromatography
ICP = Inductively coupled argon plasma spectroscopy
GFAA = Graphite furnace atomic absorption
CVAA = Cold vapor atomic absorption

Table RISR A2.3-2 Target Analytes, Analytical Methods, and CRLs for Liquid Sampling in Structures

Analyte Groups/Analytes	Analytical+ Method	CRL (ug/l)
ICP Metals		
Cadmium	ICP	8.4
Calcium	ICP	500
Chromium	ICP	24
Copper	ICP	26
Lead	ICP	74
Magnesium	ICP	500
Potassium	ICP	250
Sodium	ICP	940
Zinc	ICP	22
Arsenic	GFAA	2.5
Mercury	CFAA	0.10

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*Compounds analyzed for under more than one compound classification

+Analytical Methods:

GC/MS = Gas chromatography/mass spectrometry
GC/FPD = Gas chromatography/flame photometric detector
GC/ECD = Gas chromatography/electron capture detector
HPLC = High pressure liquid chromatography
ICP = Inductively coupled argon plasma spectroscopy
GFAA = Graphite furnace atomic absorption
CVAA = Cold vapor atomic absorption

Table RISR A2.3-3 Summary of Tentatively Identified Compounds in Liquid Samples in Structures.

Page 1 of 1.

Compound	Comments
0,0-Diethyl 0[6-methyl-2-(1-methylethyl)-4-pyr]; phosphothioic acid	------
1-Ethylidene-1h-indene	------
1-Phenyl-2(1H)-pyridinone	------
1-Terpineol	------
1h-Purine-2,6-dione,3,7-dihydro-3,7-dihydro-1,3,7-trimethyl	------
1,1,2-Trifluoro-1,2-dichloroethane	------
2-Butoxyethanol, phosphate (3:1)	------
2-[(4-Chloro 6-(ethylameno)]-1,3,5-triazine-2-yl) aminol; propanenitrile	------
4-Nonyl phenol	------
5-Bromo-6-methyl-3-(1-methylpropyl)-2,(1H,3H)-pyrimidinedione	------
Acetone	Solvent associated with Azodrin and Planavin production.
Alkylated benzene	------
Alpha-terpineol	------
Bromodichloromethane	------
Bromoform	------
Camphor	------
Chlorophenol isomer	------
Cyclic olefin	------
Cyclohexanone	------
Dibromochloromethane	------
Diethyl benzene isomer	------
Dimethylnapthalene isomer	------
d-Limonene mixture	------
Ethyl dimethyl benzene isomer	------
Ethylmethyl benzene isomer	------
Ethyl ester benzoic acid	------
Propyl benzene	------
Tetramethylbutyl phenol isomer	------
Trichlorofluoromethane	------
Trimethylnaphthalene isomer	------
Trimethylsilanol	------

sampling program was to identify likely asbestos-containing materials. Samples were analyzed for five varieties of asbestos: amosite, chrysotile, crocidolite, actinolite/tremolite, and anthophyllite.

Dust or residue samples were collected and analyzed from 80 buildings under the Task 2 program in 1985. Samples were composites of material collected from several sampling points within a building. One composite sample was obtained from each building. Analyses were conducted for organic residues, toxic metals, and asbestos. The list of target analytes, analytical methods, and CRLs for the dust samples are presented in Table RISR A2.3-4.

Dust samples were also analyzed from six buildings on RMA in a 1978 study conducted prior to the RI structures survey. Analytical results from RMA samples were compared to results of dust samples taken from two households in Aurora. These results are discussed in Appendix A3 of this report.

A2.4 AIR

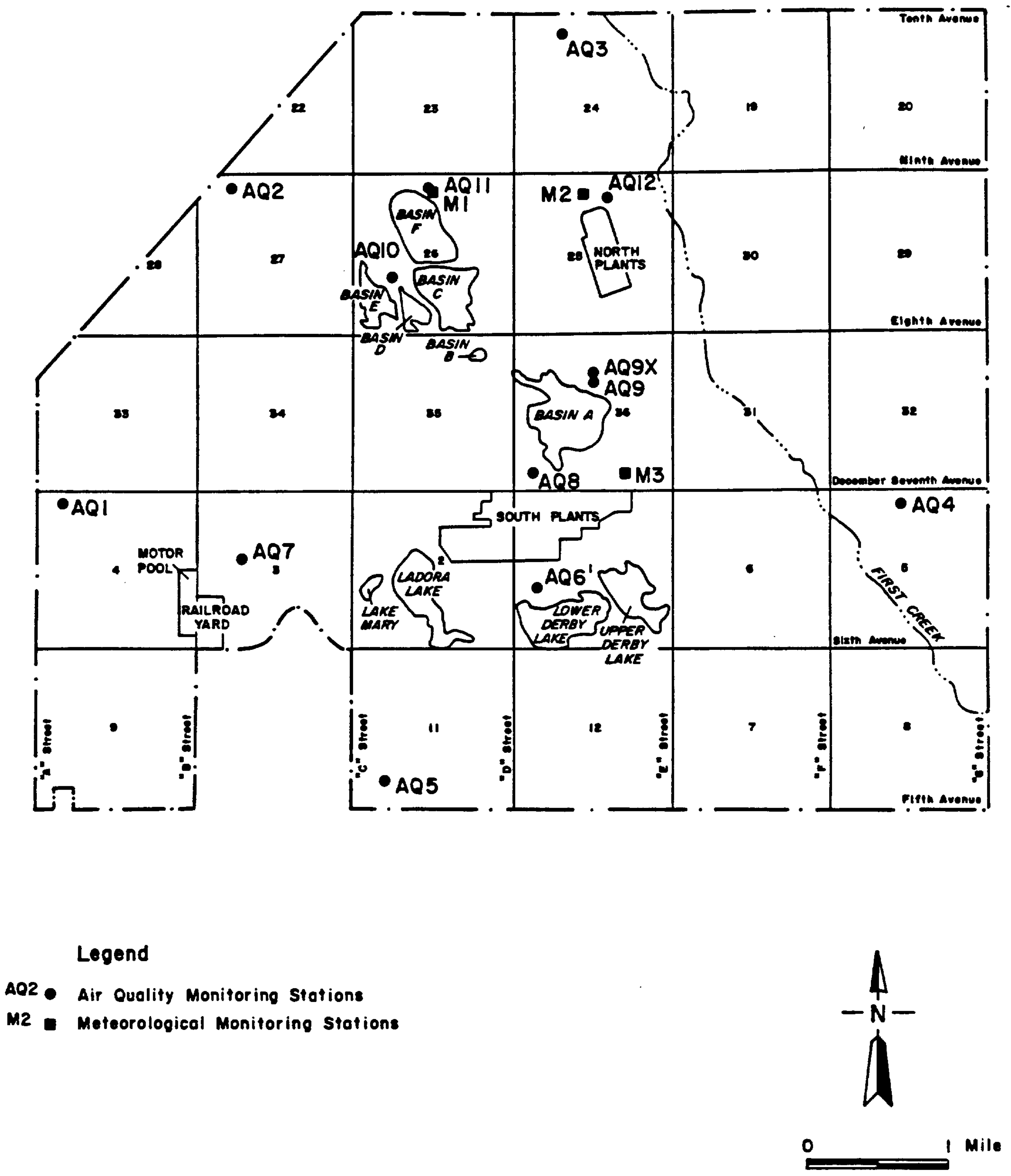
The air quality RI sampling program (ESE, 1988e/RIC 88263R01) was divided into two separate components: baseline air quality sampling and "event" sampling. Baseline air quality data were collected from 13 permanent sampling locations at RMA from June 1986 to June 1987. These sites were located both near the RMA boundary and downwind of key on-post sources. The sampled downwind areas are north to northeast of the key sources on post. These sampling locations (AQ1-AQ12, AQ9x) are shown in Figure RISR A2.4-1. Total suspended particulates (TSPs) and respirable particulates (called PM-10) were monitored for 24-hour sampling periods every sixth day in compliance with the Colorado Department of Health (CDH) schedule. Total suspended particulates were monitored at all AQ sites, and respirable particulates were monitored at AQ2, AQ5, and AQ9. Also, as part of the baseline effort, asbestos was monitored every 2 weeks for 8-hour periods at AQ1, AQ6, AQ8, and AQ12. Sampler AQ9x was located alongside station AQ9 from late October 1986 through June 1987 for quality control purposes; these two samplers gave consistent results during the

Table RISR A2.3-4. Target Analytes, Analytical Methods, and CRLs for Task 2 Structures Dust Sampling.
Page 1 of 1.

Analyte Groups/Analytes	Analytical Method	CRL (ug/g) DataChem	CRL (ug/g) CAL
Semivolatile Organic Compounds			
Dichlorodiphenylethane	GC/MS	0.6	0.3
Dichlorodiphenyltrichloroethane	GC/MS	0.5	0.6
Aldrin	GC/MS	0.3	0.3
Atrazine	GC/MS	0.3	0.3
Chlordane	GC/MS	2	0.6
Chlorophenylmethyl sulfone	GC/MS	0.3	0.6
Chlorophenylmethyl sulfoxide	GC/MS	0.3	7
Dibromochlorpropane	GC/MS	0.3	0.3
Dicyclopentadiene	GC/MS	1	0.4
Dieldrin	GC/MS	0.3	0.3
Endrin	GC/MS	0.5	0.3
Hexachlorocyclopentadiene	GC/MS	0.6	0.3
Isodrin	GC/MS	0.3	0.3
Parathion	GC/MS	0.9	0.4
Supona	GC/MS	0.6	0.3
Vapona	GC/MS	3	0.3
ICP Metals			
Cadmium	ICP	0.74	0.66
Chromium	ICP	6.5	5.2
Copper	ICP	4.7	4.9
Lead	ICP	8.4	13
Zinc	ICP	8.7	9.5
Arsenic	GFAA	2.5	5.0
Mercury	CVAA	0.050	0.060

Analytical Methods:
GC/MS = Gas chromatography/mass spectrometry
ICP = Inductively coupled argon plasma spectroscopy
GFAA = Graphite furnace atomic absorption
CVAA = Cold vapor atomic absorption

Laboratories:
DataChem = Formerly UBTL, Salt Lake City, UT
CAL = California Analytical Laboratory, W. Sacramento, CA



Source: ESE, 1988

Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A2.4-1
Meteorological and Air Quality
Monitoring Stations at
Rocky Mountain Arsenal

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

time they were both in operation. Because of poor equipment performance, sampling at sites AQ4 and AQ10 was discontinued during the RI program.

The second program component, event sampling, consisted of sampling for selected groups of target analytes, called air toxics, during predicted high-impact episodes when meteorological conditions favored emissions into the atmosphere. The effort was focused primarily on sampling near Basins F and A, particularly downwind of these sources. VOCs, SVOCs, and metals were analyzed in air samples collected on 7, 5, and 16 separate event days, respectively. Event sampling was conducted during the period of November 1986 to September 1987 on dry, warm days, primarily during the summer. The analytical techniques were based on EPA-recommended methods and were certified by PMRMA. The target analytes for air samples and their respective CRLs are shown in Table RISR A2.4-1.

Air samples were passed through a series of two tubes containing specialized absorbent material, and the sorbed material was analyzed for VOCs by GC/MS. The mass of each target compound on the medium and the volumes of air represented by the sample were used to determine ambient air concentrations. SVOCs, including pesticides, were collected on a polyurethane foam cartridge and were also analyzed by GC/MS. In addition, a separate, more sensitive analysis was provided for pesticides (aldrin, dieldrin, endrin, isodrin, dichlorodiphenyltrichloroethane [DDT], and dichlorodiphenylethane [DDE]) by gas chromatography/electron capture detector (GC/ECD).

Airborne metals including arsenic, cadmium, chromium, copper, lead, and zinc were collected along with airborne particulates on a fiberglass filter that was inserted into a high volume sampler. Analyses for all metals, except arsenic and mercury, were conducted by ICP spectroscopy. Arsenic was analyzed by graphite furnace atomic absorption (GFAA) spectroscopy. Mercury was collected on Hopcalite charcoal and analyzed by cold vapor atomic absorption (CVAA) spectroscopy.

Table RISR A2.4-1. Target Analytes and Lower CRLs for Air Samples.

Analyte Groups/Analytes	CRL (ug/m^3)**
<u>Volatile Organic Compounds</u>	
Bicycloheptadiene	19
Benzene	26
Carbon tetrachloride	12
Chlorobenzene	29
Chloroform	13
Dibromochloropropane*	40
1,1-Dichloroethane	27
1,2-Dichloroethane	26
trans-1,2-Dichloroethylene	27
Dicyclopentadiene*	19
Dimethyldisulfide	19
Ethylbenzene	20
Methylene chloride	11
Methylisobutyl ketone	8
Tetrachloroethylene	18
Toluene	7
1,1,1-Trichloroethane	22
1,1,2-Trichloroethane	6
Trichloroethylene	19
o- and p-Xylene	31
m-Xylene	19
<u>Semivolatile Organic Compounds</u>	
Aldrin	0.023
Atrazine	0.023
Chlordane	0.20
Chlorophenylmethyl sulfide	0.023
Chlorophenylmethyl sulfoxide	0.023
Chlorophenylmethyl sulfone	0.011
Dibromochloropropane*	0.023
Dicyclopentadiene*	0.023
Dichlorodiphenylethane	0.011
Dichlorodiphenyltrichloroethane	0.022
Dieldrin	0.018
Diisopropylmethyl phosphonate	0.023
Dithiane	0.023
Dimethylmethyl phosphonate	0.023
Endrin	0.015
Hexachlorocyclopentadiene	0.023
Isodrin	0.023
Malathion	0.18
1,4-Oxathiane	0.023
Parathion	0.046
Supona	0.040
Vapona	0.023

Analyte Groups/Analytes	CRL (ug/m^3)**
Inorganic Compounds	
Cadmium	0.0020
Chromium	0.0026
Copper	0.016
Lead	0.0077
Zinc	0.0097
Arsenic	0.0031
Mercury	0.063

*Compounds analyzed for under both volatile and semivolatile analyte groups.
**Lower CRL is based on analytical CRLs and target volumes for air samples.

TICs were identified by matching the spectra of unknown compounds to a library of spectra for known compounds. TICs and possible explanations for their presence are discussed in the Air RI Report (ESE, 1988e/RIC 88263R01). A summary list of TICs in air samples is presented in Table RISR A2.4-2.

Meteorological data were collected at three sites during the RI program. These locations are designated "M" in Figure RISR A2.4-1. Monitored parameters included wind speed, wind direction, temperature, precipitation, and barometric pressure. Atmospheric stability was determined from the standard deviation of recorded wind directions. All data except precipitation were collected atop a 33-ft (10-meter) tower at each site. Precipitation data were collected using a tipping-bucket precipitation gauge located adjacent to the tower. Data were recorded electronically and downloaded into a central on-site computer.

Additional air sampling is being conducted as part of the CMP. While CMP data is not a subject of the RISR, the data developed by the CMP will be incorporated into the overall RMA database and utilized in the decision-making process.

A2.5 BIOTA

Historical biota investigations and the RI studies of soils and water media were used to provide guidance regarding the locations and contaminants of major concern for the biota RI. Historical biota studies at RMA are presented in the Biota Assessment Technical Plan (ESE, 1988c/RIC 88243R05) and tabulated in the Biota RI Report (ESE, 1989b/RIC 89173R02) and discussed in the CMP Biota Monitoring Technical Plan (RLSA, 1988/RIC 88340R02). The early studies document the persistence and transport of some contaminants present in the ecosystem at RMA.

The general objectives of the biota RI were to (1) evaluate current and historical data on the sources, types, distribution, and concentrations of RMA contaminants in biota; (2) provide specific information on the migration and accumulation of contaminants through regional food

Table RISR A2.4-2. Summary of Tentatively Identified Compounds in Air Samples. Page 1 of 1.

Compound	Comments
1,2,3,4,5,7,7-Heptachlorobicyclo [2,2,1]hept-2-ene	------
1,2,3,4,7,7-Hexachlorobicyclo [2,2,1]hepta-2,5-diene	Also called Hexachloronorbornadiene.
1,2,3,4,10,10-Hexachloro-4,4a,5,8,8a-hexahydro-1,4,5,8-dimethanonaphthalene	------
2,6,10,15-Tetramethylheptadecane	------
3-Phenyl-2-propanoic acid, ethyl ester	------
4-(2,2,3,3-Tetramethylbutyl)phenol	------
6,10,14-Trimethyl-2-pentadecanone	------
Acetophenone	Decomposition product of Ciodrin.
Aliphatic hydrocarbon	------
Benzoic acid	------
Benzothiazole	A heterocyclic aromatic compound, prevalent in the manufacture of pesticides.
Butylbenzylphthalate	------
$C_{23}H_{48}$	------
Chlorophenylmethyl sulfone isomer	------
Dioctyl adipate	Plasticizer.
Docosane	------
Dodecanoic acid	------
Heptachloronorbornene	------
Isodrin isomer	------
Methyldodecanoate	------
Methylhexadecanoate	------
Methyltetradecanoate	------
Nonadecane	------
Nonanoic acid	------
Oil (C_{16} to C_{28} hydrocarbon)	------
Oil (C_{18} to C_{20} hydrocarbon)	------
Phenanthrene	A polynucleated aromatic hydrocarbon compound.
Tetrachlorobenzene	------
Tetramethylbutylphenol	------
Tetramethylheptadecane ($C_{21}H_{44}$)	------
Tetramethylhexadecane	------
Trimethylpentadecanone	------

webs in relation to important species and to overall ecosystem effects; and (3) assess the environmental effects of RMA contamination.

The biota RI proceeded in two phases. Phase I was primarily a reconnaissance level investigation, while Phase II involved collection of new information from field work at RMA. Data were obtained on the current distribution and concentration of contamination in RMA biota, and were evaluated in relation to chemical contamination in the abiotic environment and to control sites outside the defined RMA study area. Pathway analysis was used to examine relationships between the abiotic and biotic environment and among components of the biota medium. Additional studies of contaminant effects were conducted in conjunction with contaminant distribution studies in order to determine the relationships between observed adverse effects and RMA contamination.

A2.5.1 Phase I

Phase I biota investigations focused on the acquisition and review of available data from the literature, and evaluation of pertinent information from all sources. Brief field surveys were conducted to verify acquired information. A database was developed from these investigations that included historical and current information on species presence and abundance at RMA, biota contamination, and specific biological effects of contamination. In addition, information was collected on pathways for contaminant movement in the biosphere and the potential ecological and human health hazards.

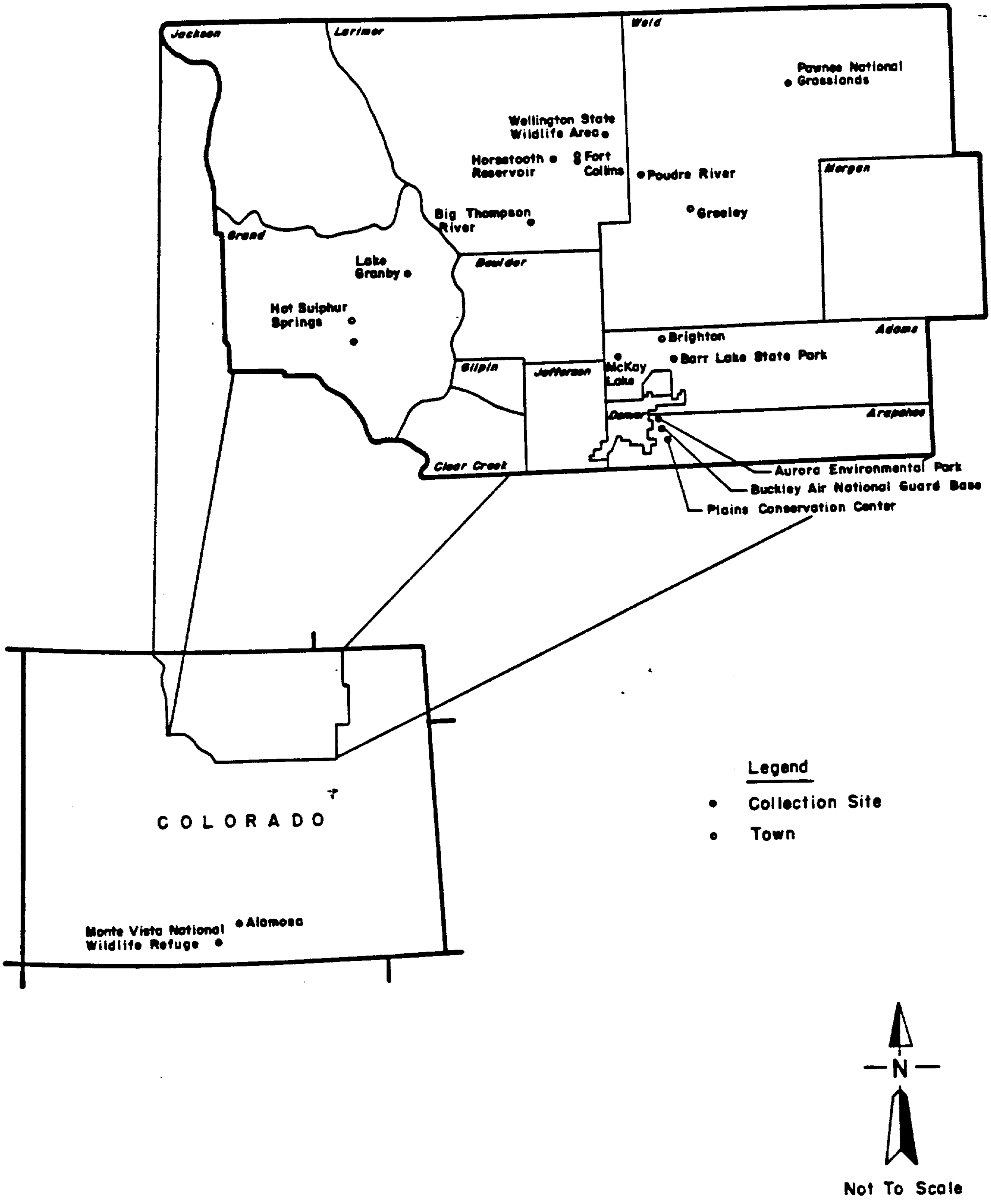
The Phase I investigations provided a preliminary determination of biota contamination, and allowed development of plans for obtaining additional relevant information. A work plan addressing data gaps that required additional efforts in order to provide an adequate basis for assessing various aspects of biota contamination at RMA was the primary product of Phase I. This work plan (ESE, 1988c/RIC 88243R05) served as the guiding document for investigation of biota contamination during the second phase of study. Supplemental studies continued concurrently to further document the biotic communities at RMA.

A2.5.2 Phase II

Phase II of the biota assessment was designed to augment and update past studies, to characterize regional and study area biota, and to provide a current comprehensive assessment of biota contaminant levels and effects in conformance with regulatory requirements. Scoping and design of the investigation were partially determined by the types and concentrations of contaminants still present in abiotic components of the biosphere. The project scope was discussed and modified by the Biota Assessment Working Group (formerly the Biota Assessment Subcommittee) of the RMA Committee that met periodically throughout the study. The committee was composed of representatives of the federal government (U.S. Army and their contractors, and the U.S. Fish and Wildlife Service), the State of Colorado (Colorado Division of Wildlife), and Shell Oil Company (Shell and their contractors). The resulting program studied selected populations and addressed the contaminants of concern to biota, potential adverse effects of contaminants on biota, and the pathways of contaminant movement to and through biological systems.

To focus the Phase II investigations, important wildlife species were first identified on the basis of their state or federal population status, their potential consumption by humans, and their ecological value. Population studies, acetylcholinesterase inhibition measurements, and contaminant analyses were conducted on these species.

Population studies were conducted of three invertebrate groups (earthworms, grasshoppers, and snails), three bird species (mallard, ring-necked pheasant, and American kestrel), and black-tailed prairie dogs to address the effects of RMA contaminants on biotic systems. These studies also included specific surveys for black-footed ferrets and investigation of the breeding habits, habitat use, and prey of bald eagles wintering at RMA. Populations were counted at various on- and off-post control locations, including Barr Lake State Park, Wellington State Wildlife Area, Fort Collins Lee Martinez Park, and Aurora Environmental Park (Figure RISR A2.5-1). Specific details regarding the survey methods and locations are provided in the Biota RI Report. All of the species on which population studies were



Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared August 1991

FIGURE RISR A2.5-1
Off-Post Control Sampling Locations for RMA Biota Remedial Investigation

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

conducted, with the exception of snails, were also sampled for chemical analysis. Snails were not present in sufficient numbers.

Two endangered species were of interest at RMA: the black-footed ferret, because of its potential presence; and the bald eagle, because it had begun using RMA as a winter roost. Current USFWS guidelines were followed in the unsuccessful effort to discover ferrets at RMA. The bald eagle studies, which included midday censuses, roost counts, casting analyses, and feeding observations, are summarized in a Bald Eagle Study Report (ESE, 1988g/RIC 88293R09).

Acetylcholinesterase inhibition studies were conducted on black-tailed prairie dogs from an off-post control location, an on-post control location, RMA Section 36, and the toxic storage yard in Section 31. Similar studies of cottontails were completed on samples from an on-post control location, an off-post control location near Horsetooth Reservoir (Figure RISR A2.5-1), and Section 36, as well as several species found dead at RMA. Acetylcholinesterase inhibition in brain tissue is indicative of organophosphorus and carbamate pesticide presence and may result in disruption of nerve function and death.

Contaminant analyses were performed to determine the presence and quantity of target analytes in taxonomically and geographically variable samples collected from key biota species at RMA and at on- and off-post control areas. The species, tissues, and contaminants selected for study, and the analytical methods used were discussed in detail at meetings of the Biota Assessment Working Group, comprised of representatives from the Army and the organizations and state. Species were selected for sampling on the basis of five criteria:

- Significance as identified threatened, endangered, or candidate species
- Potential consumption by humans
- Ecologic value as expressed by contribution to the range of trophic levels
- Representation of higher trophic levels
- Importance in regional ecosystems.

In addition to the selected species, animals found dead at RMA and specimens collected by the USFWS were also used for chemical analysis.

Samples for chemical analysis were collected from a variety of areas associated with known or potential abiotic contamination at RMA. Control sites for less mobile species were located on post, and control sites for more mobile species were located off post at Barr Lake State Park, Wellington State Wildlife Area, Pawnee National Grasslands, Aurora Environmental Park, McKay Lake, Lake Granby, Big Thompson River, Monte Vista National Wildlife Refuge, Poudre River, and near Hot Sulphur Springs (Figure RISR A2.5-1). Species were variously distributed among the contaminated and control areas of collection. Tissues selected from each species for chemical analysis were based on the probable fate of the organism within a food web. The tissues chosen were those most likely to be consumed by the organisms feeding on the sampled species.

The selection criteria developed during Phase I were used in the selection of target analytes in Phase II for biota tissues. Compounds were selected as target analytes if they were present in the RMA environment above ambient concentrations, rated at least moderately toxic, and present in the environment in sufficient quantity and/or over a sufficient time period to pose a hazard to biota. Thirty-nine contaminants of concern emerged from this selection process. They were evaluated as to whether they were found in elevated levels in biota based on past studies, found in the abiotic environment based on current studies, present in high volumes and/or in an areal extent of greater than 5 acres, and known to cause adverse effects in tissues. From this process, seven major contaminants of concern were selected: aldrin, arsenic, DBCP, dieldrin, endrin, isodrin, and mercury. Of these contaminants, DBCP does not bioaccumulate significantly, and isodrin is converted to endrin by metabolic processes. Therefore, these two compounds were not designated as target analytes. The five remaining major contaminants of concern, together with DDE and DDT, which were added because of their environmental persistence and toxicity, became the seven target analytes for which all tissue samples were analyzed.

Contaminant levels were measured in organisms from sites of known or suspected contamination, and from on- and off-post control sites. Analytical methods used for biota samples were GC/ECD for OCPs, CVAA spectroscopy for mercury, and GFAA spectroscopy for arsenic. The samples were analyzed by the ESE laboratory. CRLs are presented in Table RISR A2.5-1.

A2.5.3 Supplemental Studies

Supplemental studies were conducted on the biotic components of the aquatic ecosystem and the vegetation and wildlife components of the terrestrial ecosystem. These studies were focused toward characterizing these components according to populations and community structure.

Aquatic studies investigated the water quality and biotic communities of lakes in the southern portion of RMA (except Upper Derby Lake) and an off-post control lake, McKay Lake. During five periods between April and November 1987, water samples were collected for analysis from the inlet and outlet of each lake. For each inlet and outlet location, water samples were collected from various depths and then composited. At the same time, measurements of dissolved oxygen, temperature, pH, specific conductance, and water transparency were recorded. The two resulting water samples for each lake were analyzed for standard water quality parameters, and for the composition and biomass of phytoplankton and zooplankton. Macrozooplankton and benthic invertebrates were sampled for taxonomic identification. The fish community was sampled from the inlet and outlet of each lake to determine the species and size ranges present. Fish eggs and larvae were identified to the lowest practicable level. The condition of bluegills and largemouth bass was evaluated based on weight relative to length. Aquatic macrophytes were sampled only during August to determine areal extent and community constituents.

Vegetation studies included both quantitative and qualitative methods applied to sites at RMA and at off-post control areas at Buckley Air Field, Plains Conservation Center, and Aurora Environmental Park (Figure RISR A2.5-1). Standard quantitative methods were employed at

Table RISR A2.5-1 Certified Reporting Limits for Biota Analytical Methods.

Matrix Type	Analyte	Lower CRL (µg/g)	Upper CRL (µg/g)
Animals and Plants	Arsenic	0.25	5.0
Animals and Plants	Mercury	0.050	0.40
Plants	Aldrin	0.022	0.30
	Dieldrin	0.044	0.30
	Endrin	0.040	0.60
Animals	Aldrin	0.020	0.30
	Dieldrin	0.031	0.30
	Endrin	0.40	0.60
Animals	DDE	0.094	1.88
	DDT	0.289	3.75

Source: ESE, 1989b/RIC 89173R02

sample locations in each of the vegetation types. Data were collected on cover, height, frequency, and woody plant density. A sampling design was constructed to compare on-post to off-post vegetation and to determine whether plant communities near the most contaminated sites differed from comparable communities growing in other portions of RMA. Qualitative methods included floristic surveys, phenological studies, and an evaluation of successional status. A detailed vegetation map of RMA is presented in Figure RISR A1.6-1 in Appendix A1 of this report.

Studies of wildlife employed detailed quantitative analyses, semiquantitative indices, and qualitative observations to provide information on the occurrence, distribution, and relative abundance of selected vertebrate groups at RMA and in control locations at Buckley Air Field and Plains Conservation Center (Figure RISR A2.5-1). Studies involved a combination of road transects, fecal pellet transects, and opportunistic sightings for deer and rabbits; scent station surveys for coyotes, foxes, and other carnivores; live-trapping in different habitat types for small mammals; age class composition counts for prairie dogs; road transects and incidental observations for birds of prey; and road transects of vocalizations for ring-necked pheasants and mourning doves. Also obtained were sex ratio data on pheasants; occurrence and abundance of waterfowl, shorebirds, and wading birds at RMA from systematic observational surveys; and numbers and distribution of songbirds from linear winter transects and surveys of breeding plots at RMA and off-post control areas.

The CMP has continued data collection for biota at RMA. These additional data will be incorporated into the overall decision-making process. As previously noted, CMP data are not a subject of the RISR. The interested reader is encouraged to explore the CMP results as presented in various CMP documents.

Appendix A3

Nature and Extent of Contamination
Text and Tables

Remedial Investigation Summary Report

A3 NATURE AND EXTENT OF CONTAMINATION

Chemicals routinely manufactured, handled, and stored at RMA over its 40-year history have been detected on post in the soils/sewers, water, air, structures, and biota environmental media. The nature and extent of contamination must be viewed within an appropriate context for each environmental medium. Comparisons regarding the environmental quality of these media on post are made to comparable off-post media, or to on-post samples that are believed to be uncontaminated. Thus, contaminant concentrations are viewed in a relative sense in order to assess how RMA activities have impacted the environmental media.

Generally, the highest detected concentrations of contaminants were measured in samples collected from soils, surface water, and groundwater in the central sections of RMA. Most of the structures classified as contaminated are also located in the central part of RMA. The most concentrated portions of contaminant plumes in alluvial groundwater also occur below contaminant sources in soils in the central, and to a lesser extent, western parts of RMA. Contaminant concentrations generally decrease as the plumes migrate towards RMA boundaries. Contaminant detections in air are limited within the RMA interior, and are actually elevated near the boundaries. Elevated contaminant concentrations detected in air, surface water, and groundwater at the southern and western RMA boundaries indicate that off-post sources have impacted these media on the southern and western sides of RMA. The distribution of target analytes in biota is sporadic, and subject to variable habits for mobile species; however, a pattern of bioaccumulation, with increased concentrations at the upper end of the food-chain, is apparent for dieldrin and, to some extent, arsenic. In the sections that follow, contamination in soils and sewers, surface water, groundwater, structures, air, and biota is discussed for RMA as a whole. Information presented in previous RI reports, including the CARs, Phase II Data Addenda, media RI reports, other task reports, and the SARs, were used to develop this comprehensive summary.

For soil and water, data tables and histograms are used to summarize voluminous data and allow comparisons between various soil site types or unconfined groundwater plume groups.

For most media, the extensive RI data sets were synthesized into summary data tables that include CRLs, ratio of detections to analyses, ranges of detected concentrations, and for the detections, the mean and standard deviation values for each analyte, and the geometric mean and geometric standard deviation values (standard deviation of the log-transformed data). Adjusted geometric means (AGMs) were used to convey mean values for soil, water, and biota data sets with less than 100 percent detections. The AGM is calculated by multiplying the geometric mean of all detected values by the ratio of detections to total sample analyses conducted (Romberg et al., 1984) as follows:

$$AGM = (N/S)\,(a_1 \cdot a_2 \cdot a_3 \cdot \ldots\ldots \cdot a_N)^{(1/N)}$$

N = number of detections
S = number of sample analyses conducted
a_N = concentration of the Nth detection

Thus, samples with values below the CRL are taken into consideration by "adjusting" the geometric mean by the ratio of detectable values to samples analyzed. These statistical values are presented for general comparative and informational purposes only; unwarranted significance should not be attached to the statistical values, nor is it appropriate to interpret these values as representing "averages" for the purpose of assessing exposures or evaluating remedial alternatives.

For the soils/sewer medium total concentrations for organics, inorganics, or by analyte group are calculated by summing the concentrations of individual analytes within the group for each sample. For the water medium, total AGM concentrations are calculated by summing the AGMs for individual analytes. AGMs are generally a reliable measure of water quality where similar transporting and attenuating processes are active. However, care should be taken when using AGMs to characterize water quality data that result from sporadic, irregular, or episodic hydrologic processes. While it is recognized that the AGM generally does not compute a representative mean value for sample populations with less than about 25 percent detections, summed total AGMs better reflect the actual sampled conditions in the water medium than do other methods, which either artificially assign values to samples with no detections, or overweight the significance of sporadic or anomalous detections. For soil, water, and biota it should be noted that as the percentage of analyses below the CRL increases, the AGM becomes a less reliable measure of a mean concentration for the data set.

Histograms were generated for each soil site type and unconfined groundwater plume group to graphically display the nature of contamination within these media. These histograms are discussed in Sections A3.1.1 and A3.2.3 below. For each site type or plume group, the percentage of the total detections for all analytes corresponding to each of the 16 analyte groups is calculated, and is represented on the histogram by the relative height of the corresponding "bar" for that analyte group. The relative significance of each analyte group in contributing to the contamination for a site type or plume group is thus readily apparent. Additional detail is also available in these figures.

For relative purposes only, total summed concentration ranges used in these discussions will be referred to as low (CRL to 100 µg/g), moderate (greater than 100 to 1,000 µg/g), high (greater than 1,000 to 10,000 µg/g), and very high (greater than 10,000 µg/g).

A3.1 SOILS/SEWERS

The presence of multiple sources of soil contamination reflects the history of RMA waste disposal and accidental releases over its 40-year history. Contaminant distribution and concentrations have been modified by various transporting and attenuation mechanisms that have produced the currently observed pattern of contamination. As discussed in Section 1.2 of this report, the designation of specific sites has evolved during the RI program as historical and field studies have progressed. Each site incorporates an area with similar physical characteristics, historical use, and contaminant patterns. All areas where soil contamination was detected have been included in the boundaries of a site.

The RI has identified 178 sites of contamination on RMA. To facilitate discussion of the nature of soil contamination, these 178 sites have been grouped into the following nine site types, based on common use and contamination pattern:

- Basins and Lagoons
- Ditches, Lakes, and Ponds
- Ordnance Testing and Disposal Areas
- Solid Waste Burial Sites
- Buildings, Equipment, and Storage Sites
- Spill Sites
- Sewer Sites
- Surficial Soil and Other Predominantly Near-Surface Contamination
- Isolated Contamination.

The distribution of these site types throughout RMA is shown in Figure RISR A3.1-1. In addition to the nine site types, additional analytical data were collected for nonsource areas. The spatial relationship of soil borings sampled during the RI to the site types is indicated in Figure RISR A3.1-2. Detailed descriptions of the site types and the dominant migration processes that affect them are presented in Appendix E.

As a group, basins and lagoons are among the most contaminated sites at RMA. A wide diversity of contaminants with considerable lateral and vertical extent in soils have been detected. Contaminant detections extending to the water table, and the association of high concentrations of the same or similar contaminants in groundwater beneath the basins and lagoons indicate that they are important sources of groundwater contamination. Basins and lagoons exhibit the highest percentage of detections and greatest number of detected analytes of all the site types.

Other important sources of contaminant releases are solid waste burial sites and buildings, equipment, and storage sites. The solid waste burial sites generally exhibit limited areal extent but significant vertical contamination. The buildings, equipment, and storage sites are widespread relative to many other types of sites. The most significant contamination for this site type occurs in the North Plants GB manufacturing area and the South Plants processing area. A diversity of analyte groups was detected at both the solid waste burial sites and the buildings, equipment, and storage sites.

Ditches, lakes, and ponds exhibit a high number of detections and analyte groups in their shallow sediments. With increasing depth at these sites, the overall number of analyte groups, and their concentrations, decrease.

A high percentage of all detections for ordnance testing and disposal areas comprised the ICP metals, arsenic, and mercury. Few organic analytes were detected. Analytes detected at ordnance testing and disposal areas exhibit low mobility and are generally confined to shallow soils.

Spill sites and sewer sites tend to behave as point sources of contamination that may extend to depth through the soil column. The extent of contamination attributed to a spill or to sewer leakage is strongly affected by the nature of the local soils and the proximity of groundwater. The resulting vertical extent of contamination is generally greater where sandy soils are present or where large volumes of material were spilled. The ten analyte groups detected at spill sites represent a variety of accidental chemical releases at RMA. Leakage from the chemical sewer has impacted soil at various locations between the manufacturing plants and Basins A and F. Contamination associated with these sites is similar to that observed in the basins and lagoons, but is generally greater at depths.

Surficial soil and other predominantly near-surface contamination sites reflect secondary transport of wastewater aerosols or of contaminated surficial soils from poorly vegetated source areas. This contamination is characterized by low concentrations and widespread, shallow distribution. Isolated contamination sites are represented by single detections or do not exhibit lateral or vertical extent. They are not considered major sources of contamination.

The distribution of contaminants in soils are discussed by site type and overall lateral and vertical extent in the two subsections that follow. The final subsection briefly discusses analytical results of sediment samples collected from within sanitary sewer and process water lines.

A3.1.1 Contaminant Distribution by Site Type

Soil data tables and histograms incorporating Phase I and Phase II data are presented to convey the nature of contamination at each site type (Tables RISR A3.1-1 through RISR A3.1-10 and Figures RISR A3.1-3 through RISR A3.1-12). As described above, these histograms present the results of the soils analytical program, and are normalized for all detections within a site type by analyte group. The data are also sorted by depth interval, as represented by vertical segments of the histogram bars corresponding to the 0- to 2-ft, 2- to 5-ft, 5- to 20-ft, and greater than 20 ft depth intervals, for each analyte group where detections occurred. The relative proportion of the total bar height represented by a vertical segment corresponding to a given depth interval, indicates the percentage of all detections of analytes in the analyte group that were within that depth interval. Similarly, each depth interval segment is subdivided horizontally into color-coded portions corresponding to the percentage of all detections within that depth interval, for that analyte group in that site type, that fall into the concentration ranges indicated by the colors shown on the figure explanations. In other words, for each site type the histograms represent the analytical data collected by the RI, normalized by site type for analyte groups, by analyte group for depth intervals, and by depth interval for concentration ranges. The total number of analyses and detections of analytes composing each analyte group are shown for each site type on their respective histograms.

Because of the limitations inherent in graphically summarizing results of over 260,000 analyses, detections representing a very small percentage of the normalized data are not depicted at this scale on the histograms. These data typically account for less than 0.04 percent for all analyte groups, and less than 1.0 percent of normalized data for concentration ranges within a depth interval for any group.

For the polynuclear aromatic hydrocarbons (PAHs), all analytes comprising the group are significant TICs. As a result, the number of detections for this group always sum to 100 percent of the number of analyses shown on the histograms, since the significant TICs were not specifically analyzed for by USATHAMA-certified methods, and are only reported if a tentative identification is made. For arsenic, mercury, and the ICP metals both the total number of detections and the detections above IR are presented. Gray areas correspond to the detections within the IR. These occurrences are considered indicative of natural soil concentrations. As indicated on the histograms for the nine site types, a considerable percentage of the arsenic and ICP metal detections are within the IRs and are usually attributed to natural occurrences. Discussions of prevalent contaminants in each of the site types emphasize occurrences of arsenic, mercury, and the ICP metals at concentrations above the IR.

A3.1.1.1 Basins and Lagoons

Fourteen basin and lagoon sites have been documented at RMA. Basins in Sections 26, 35, and 36 of the North Central Study Area (NCSA) were constructed to receive industrial aqueous wastes from the processing facilities in North Plants and South Plants. Intermittently, liquids were conveyed along open ditches, overflow channels, and sewers to Basins A, B, C, D, E, and F. Evidence suggests that solid wastes were also disposed in the southeastern corner of Basin F. Other smaller basins and lagoons located primarily within or near the South Plants complex were used for flood control, separation, evaporation, and disposal of liquid wastes. Periodically, the basins contained fluids with relatively high concentrations of contaminants that varied as a function of waste disposal practices, water storage, and seasonal and annual variances in precipitation and evaporation. Soil contamination associated with the basins and lagoons commonly occurs in shallow basin sediments and throughout infiltration routes in the unsaturated zone.

Contaminant migration by surface water flow, groundwater flow, and wind dispersion resulting from waste disposal in basins and lagoons has produced the primary environmental impacts at RMA. The RI has determined that these sites in conjunction with solid waste burial sites and areas of storage sites, buildings, and equipment are the source of most organic and inorganic contamination. For example, contaminant concentrations and distribution associated with the basins exceed those attributed to other RMA site types. OCPs, OPHGBs, arsenic, mercury, and ICP metals exhibit the highest percentages of detections in basins and lagoons (Figure RISR A3.1-3). OCPs are the most frequently detected analytes suspected to have resulted from RMA activities. The greatest frequency of detections, discounting metals below indicator levels, was for fluoroacetic acid (FC2A on the histograms), OPHGBs, OCPs, arsenic, and mercury (Table RISR A3.1-1)[1].

Although the percentage of ICP metal detections is high, the majority of these detections are within the IR and are, therefore, generally attributed to natural occurrences. For organics and inorganics, respectively; volatile hydrocarbons (VHCs) and volatile aromatic organics (VAOs), and arsenic and mercury exhibit the highest concentrations, in excess of 10,000 µg/g. These elevated concentrations occur in the 0- to 2-ft through 5- to 20-ft intervals. Generally, a greater percentage of detections occurs in the deeper 5- to 20-ft depth interval for the more mobile compounds, such as volatile halogenated organics (VHOs) and VAOs. In contrast, the shallower 0- to 2-ft and 2- to 5-ft depth intervals exhibit a greater number of detections for

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[1] Prior reports including the Basin A CAR (ESE, 1987b/RIC 87203R07) have erroneously reported that mustard was detected in Basin A during a study done by the Office of the Surgeon General (Cogley, 1976/RIC 81226R09). That study did not report the detection of mustard in Basin A.

Table RISR A3.1-1 Summary of Analytical Results for Soils in Basins and Lagoons.

Total Bores Sampled: 506
Total Samples Collected: 1,489

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g)					Adjusted Geometric Mean
				Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	
Volatile Halogenated Organics (VHOs)									
1,1-Dichloroethane	0/538	---	0.13-170	---	---	---	---	---	---
1,2-Dichloroethane	1/538	1.0	0.08-56	NC	NC	NC	NC	NC	NC
1,1-Dichloroethylene	0/59	---	0.12	---	---	---	---	---	---
trans-1,2-Dichloroethylene	0/451	---	0.15-170	---	---	---	---	---	---
1,1,2,2-Tetrachloroethane*†	15/29	NC-20	0.3-0.65	NC	NC	NC	NC	NC	NC
1,1,1-Trichloroethane	2/538	0.40-0.55	0.12-43	NC	NC	NC	NC	NC	NC
1,1,2-Trichloroethane	0/539	---	0.12-39	---	---	---	---	---	---
Carbon tetrachloride	0/538	---	0.12-25	---	---	---	---	---	---
Chlorobenzene	9/508	0.34-5.0	0.18-150	1.7	2.2	1.7	1.6	0.90	0.029
Chloroform	22/538	0.12-70	0.10-29	1.8	5.2	15	1.5	1.4	0.060
Methylene chloride	58/422	0.27-6.7	0.15-150	1.0	1.6	1.4	1.1	0.83	0.16
Tetrachloroethylene	19/537	0.20-40	0.12-25	2.8	7.2	10	2.8	1.5	0.099
Trichloroethylene	4/538	0.14-1.0	0.090-54	0.51	0.55	0.46	0.39	1.0	0.0029
Trichloropropene*	1/1	NC	0.3	NC	NC	NC	NC	NC	NC
Volatile Hydrocarbons (VHCs)									
2-Butoxyethanol*	NI	---	---	---	---	---	---	---	---
4-Hydroxy-4-methyl-2-pentanone*	NI	---	---	---	---	---	---	---	---
1-Methyl-1,3-cyclopentadiene*	NI	---	---	---	---	---	---	---	---
2,2-Oxybisethanol*	36/36	0.6-8	0.3	2	2.7	2	2	0.68	2
2-Pentanone*	9/9	1-20	0.3	10	11	7.5	7.6	1.2	7.6
Bicycloheptadiene	16/541	0.95-5,100	0.25-5.1	9.7	430	1300	20	2.6	0.59
Dicyclopentadiene	58/1,079	0.35-22,000	0.26-500	24	1400	4000	32	3.2	1.7
Methylcyclohexane*	1/1	30	0.3	NC	NC	NC	NC	NC	NC
Methylisobutyl ketone	2/543	0.40-1.0	0.30-73	NC	NC	NC	NC	NC	NC

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‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
† Typically TIC; but target compound of some special investigations.
** Reported as total xylenes
NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.
NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

Table RISR A3.1-1 Summary of Analytical Results for Soils in Basins and Lagoons.

Total Bores Sampled: 506
Total Samples Collected: 1,489

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g)					Adjusted Geometric Mean
				Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	
Volatile Aromatic Organics (VAOs)									
Benzene	17/552	0.24-6.0	0.081-25	1.2	1.7	1.7	1.1	1.1	0.033
Ethylbenzene	11/552	0.14-9.3	0.043-38	1.6	2.8	3.4	1.1	1.6	0.022
m-Xylene	15/552	0.14-12	0.053-74	1.0	2.9	3.7	1.1	1.6	0.030
o- and p-Xylene**	9/553	0.15-12	0.086-490	2.0	3.4	4.5	1.3	1.6	0.021
Toluene	18/550	0.13-1,000	0.096-25	0.95	160	310	5.1	3.2	0.17
Organosulfur Compounds, Mustard-Agent Related (OSCMs)									
1,4-Oxathiane	1/1,069	0.52	0.25-6,000	NC	NC	NC	NC	NC	NC
Chloroacetic acid	23/242	43-7,900	18-36	140	1100	2300	240	1.7	22
Dithiane	8/1,065	0.47-370	0.25-6,500	0.70	48	130	1.8	2.3	0.014
Thiodiglycol	11/242	6.0-120	2.6-4.2	25	47	42	30	1.1	1.4
Organosulfur Compounds, Herbicide Related (OSCHs)									
Benzothiazole	0/281	---	1.1-11	---	---	---	---	---	---
Chlorophenylmethyl sulfide	18/1,070	0.50-700	0.25-6,500	5.4	85	180	8.9	2.3	0.15
Chlorophenylmethyl sulfone	83/1,070	0.34-300	0.25-1,900	2.5	12	35	2.8	1.6	0.22
Chlorophenylmethyl sulfoxide	25/1,067	0.58-70	0.25-4,200	2.6	6.0	14	2.7	1.1	0.062
Dimethyldisulfide	3/760	2.0-70	0.25-2,000	10	NC	NC	NC	NC	NC

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‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
† Typically TIC; but target compound of some special investigations.
** Reported as total xylenes
NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.
NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

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Total Bores Sampled: 506
Total Samples Collected: 1,489

		Concentration		Detections (µg/g)					
Analytical Groups and Analytes Detected	Frequency of Detections	Range (µg/g)	CRL Range‡ (µg/g)	Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	Adjusted Geometric Mean
Organophosphorous Compounds, GB-Agent Related (OPHGBs)									
Diisopropylmethyl phosphonate	119/968	0.12-10	0.11-1,800	1.3	2.0	2.0	1.2	1.2	0.14
Dimethylmethyl phosphonate	9/767	3.0-70	0.13-3,000	6.0	14	21	8.3	0.97	0.098
Isopropylmethyl phosphonic acid	34/234	4.6-3,700	2.1-4.7	39	170	630	37	1.5	5.4
Methylphosphonic acid	24/122	3.1-400	2.0-4.0	16	65	110	22	1.5	4.3
Phosphoric acid, tributyl ester*	NI	---	---	---	---	---	---	---	---
Phosphoric acid, triphenyl ester*	33/33	1-20	0.3	10	8.2	5	6	0.79	6
Organophosphorous Compounds, Pesticide Related (OPHPs)									
Atrazine	0/789	---	0.25-1,900	---	---	---	---	---	---
Malathion	0/786	---	0.30-1,500	---	---	---	---	---	---
Parathion	0/787	---	0.40-3,000	---	---	---	---	---	---
Supona	0/788	---	0.30-2,900	---	---	---	---	---	---
Vapona	0/789	---	0.25-6,500	---	---	---	---	---	---
Dibromochloropropane (DBCP)	14/1,099	0.0061-20	0.0050-6,500	0.019	2.2	5.6	0.072	2.8	0.00090
Organonitrogen Compounds (ONCs)									
Caprolactam*	NI	---	---	---	---	---	---	---	---
Hydrazine	NA	---	---	---	---	---	---	---	---
Methylhydrazine	NA	---	---	---	---	---	---	---	---
n-Nitrosodimethylamine	0/85	---	1.8-9,000	---	---	---	---	---	---
n-Nitrosodi-n-propylamine	NA	---	---	---	---	---	---	---	---
Unsymmetrical dimethylhydrazine	NA	---	---	---	---	---	---	---	---

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‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.

Δ Standard deviation of log values (base e) of detections

* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.

† Typically TIC; but target compound of some special investigations.

** Reported as total xylenes

NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.

NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

Total Bores Sampled: 506
Total Samples Collected: 1,489

		Concentration		Detections (µg/g)					
Analytical Groups and Analytes Detected	Frequency of Detections	Range (µg/g)	CRL Range‡ (µg/g)	Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	Adjusted Geometric Mean
Fluoroacetic Acid	25/124	3.4-200	2.0	8.5	19	39	9.9	0.90	2.0
Polynuclear Aromatic Hydrocarbons (PAHs)									
Fluoranthene*	4/4	4-8	0.3	5	5.5	2	5	0.29	5
Methyl naphthalene*	1/1	9	0.3	NC	NC	NC	NC	NC	NC
Phenanthrene*	NI	---	---	---	---	---	---	---	---
Pyrene*	3/3	1-100	0.3	4	NC	NC	NC	NC	NC
Semivolatile Halogenated Organics (SHOs)									
Hexachlorobenzene*	NI	---	0.3	---	---	---	---	---	---
Hexachlorobutadiene*	NI	---	0.3	---	---	---	---	---	---
Hexachlorocyclopentadiene	24/1,121	0.0040-2,600	0.0011-7,000	0.018	120	530	0.10	3.8	0.0022
Pentachlorobenzene*	NI	---	0.3	---	---	---	---	---	---
Tetrachlorobenzene*	1/1	NC	0.3	NC	NC	NC	NC	NC	NC
Trichlorobenzene*	NI	---	0.3	---	---	---	---	---	---
Organochlorine Pesticides (OCPs)									
Aldrin	169/1,249	0.0024-18,000	0.0018-1,300	2.0	250	1,500	2.0	3.8	0.27
Chlordane	56/1,125	0.072-660	0.023-12,000	0.44	24	89	1.8	2.4	0.088
Dichlorodiphenylethane (DDE)	79/1,256	0.0014-28	0.0010-1,300	0.038	1.4	4.3	0.075	2.7	0.0047
Dichlorodiphenyltrichloroethane (DDT)	56/1,251	0.0028-60	0.0020-2,300	0.030	2.1	8.4	0.087	2.5	0.0039
Dieldrin	401/1,247	0.0014-2,100	0.0012-1,300	0.60	31	170	0.42	3.3	0.13
Endrin	217/1,246	0.0011-1,100	0.0010-3,700	0.085	2	120	0.17	3.5	0.030
Isodrin	108/1,251	0.0014-11,000	0.0011-1,300	1.5	210	1,200	0.92	3.9	0.081

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‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
† Typically TIC; but target compound of some special investigations.
** Reported as total xylenes
NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.
NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

Table RISR A3.1-1 Summary of Analytical Results for Soils in Basins and Lagoons.

Total Bores Sampled: 506
Total Samples Collected: 1,489

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g)					Adjusted Geometric Mean
				Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	
Arsenic	531/1,253	2.4-110,000	2.0-19	12	1300	9100	3.8	1.7	1.6
Mercury	313/1,099	0.050-35,000	0.037-0.10	0.27	360	2900	0.52	2.5	0.15
ICP Metals									
Cadmium	163/1,047	0.63-3,900	0.31-1.7	1.3	26	310	1.7	0.93	0.26
Chromium	768/1,047	6.9-110	2.5-12	14	15	6.6	2.5	0.34	1.8
Copper	919/1,047	4.8-2,300	3.4-4.9	12	27	110	2.2	0.75	1.9
Lead	305/1,039	10-1,100	8.4-17	25	42	93	10	0.63	3.0
Zinc	969/1,047	11-910	8.7-28	44	50	43	2.1	0.46	1.9

---

‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
† Typically TIC; but target compound of some special investigations.
** Reported as total xylenes
NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.
NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

the less mobile analytes such as semivolatile halogenated organics (SHOs), OCPs, and the inorganic suite.

A3.1.1.2 Ditches, Lakes, and Ponds

Thirty-six ditch, lake, and pond sites containing contaminated soil or sediment were identified by the RI. Only the contaminated soil and sediment of these sites are included in the soils medium. Related surface waters are discussed in Section A3.2. Ditches were constructed to drain surface water adjacent to roads, railroads, and sites; convey liquid waste to and between the basins; and accommodate return flow to the process water system. Most of the ditches are associated with the South Plants and the distribution network to the basins in Sections 26, 35, and 36. The majority of the lakes and intermittent ponds on RMA are shallow, closed depressions and low lying areas that were impounded by earthen embankments primarily to collect surface runoff and groundwater seepage. The three major lakes on RMA, Upper and Lower Derby Lakes and Lake Ladora, were used as reservoirs for the South Plants process water system.

As shown in Figure RISR A3.1-4 and Table RISR A3.1-2, OCPs, mercury, and the ICP metals exhibit the highest percentage of detections for the ditches, lakes, and ponds. Discounting detections within the IR, fluoroacetic acid, OCPs, arsenic, and mercury exhibit the greatest frequencies of detections. OCPs, VHOs, and DBCP comprise the majority of detected organic contaminants. More than 10 percent of OCP analyses were hits. For the majority of the analyte groups, observed concentrations are limited to the lowest concentration range. The highest organic concentrations detected for this site type, 1,000 to 10,000 μg/g for SHOs, occurred in one sample in the shallowest depth interval.

The highest inorganic concentrations are associated with the ICP metals and occur in the 0- to 2-ft and 2- to 5-ft intervals. These occurrences represent limited migration due in part to the tendency of SHOs and metals to sorb to fine-grained sediments. As sample depth increases,

Table RISR A3.1-2 Summary of Analytical Results for Soils in Ditches, Lakes and Ponds.

Total Bores Sampled: 459
Total Samples Collected: 1,148

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g) Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	Adjusted Geometric Mean
Volatile Halogenated Organics (VHOs)									
1,1-Dichloroethane	0/327	---	0.074-2.0	---	---	---	---	---	---
1,2-Dichloroethane	0/327	---	0.085-0.60	---	---	---	---	---	---
1,1-Dichloroethylene	0/31	---	0.24	---	---	---	---	---	---
trans-1,2-Dichloroethylene	0/326	---	0.25-2.0	---	---	---	---	---	---
1,1,2,2-Tetrachloroethane*	26/26	NC-2	0.3	NC	NC	NC	NC	NC	NC
1,1,1-Trichloroethane	2/327	0.37-0.60	0.088-0.50	NC	NC	NC	NC	NC	NC
1,1,2-Trichloroethane	0/327	---	0.25-0.60	---	---	---	---	---	---
Carbon tetrachloride	2/327	0.39-0.73	0.12-0.50	NC	NC	NC	NC	NC	NC
Chlorobenzene	0/322	---	0.20-1.50	---	---	---	---	---	---
Chloroform	0/327	---	0.068-0.70	---	---	---	---	---	---
Methylene chloride	16/321	0.64-170	0.25-100	1.7	13	42	2.3	1.4	0.12
Tetrachloroethylene	6/327	0.30-1.0	0.25-0.50	0.40	0.57	0.34	0.49	0.56	0.0091
Trichloroethylene	1/327	2.0	0.14-0.60	NC	NC	NC	NC	NC	NC
Trichloropropene*	NI	---	---	---	---	---	---	---	---
Volatile Hydrocarbons (VHCs)									
2-Butoxyethanol*	NI	---	---	---	---	---	---	---	---
4-Hydroxy-4-methyl-2-pentanone*	1/1	4	0.3	NC	NC	NC	NC	NC	NC
1-Methyl-1,3-cyclopentadiene*	NI	---	---	---	---	---	---	---	---
2,2-Oxybisethanol*	2/2	0.5-1	0.3	NC	NC	NC	NC	NC	NC
2-Pentanone*	NI	---	---	---	---	---	---	---	---
Bicycloheptadiene	0/305	---	0.25-1.1	---	---	---	---	---	---
Dicyclopentadiene	0/898	---	0.26-10	---	---	---	---	---	---
Methylcyclohexane*	NI	---	---	---	---	---	---	---	---
Methylisobutyl ketone	1/305	1.0	0.30-0.73	NC	NC	NC	NC	NC	NC

---

‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.

Δ Standard Deviation of log values (base e) of detections

* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.

† Typically TIC; but target compound of some special investigations.

** Reported as total xylenes

NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.

NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

RIFS 5/RISR Soil Tables/Table A 3.1-2. 8/12/91 1:24 PM - dm

Total Bores Sampled: 459
Total Samples Collected: 1,148

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g)					Adjusted Geometric Mean
				Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	
Volatile Aromatic Organics (VAOs)									
Benzene	2/322	0.15-0.56	0.085-1.0	NC	NC	NC	NC	NC	NC
Ethylbenzene	0/322	---	0.16-0.50	---	---	---	---	---	---
m-Xylene	0/322	---	0.25-0.80	---	---	---	---	---	---
o- and p-Xylene**	0/322	---	0.30-5.0	---	---	---	---	---	---
Toluene	4/322	0.30-4.0	0.19-0.50	0.70	1.4	1.7	0.83	1.2	0.010
Organosulfur Compounds, Mustard-Agent Related (OSCMs)									
1,4-Oxathiane	0/626	---	0.25-100	---	---	---	---	---	---
Chloroacetic acid	0/52	---	18-36	---	---	---	---	---	---
Dithiane	0/625	---	0.25-100	---	---	---	---	---	---
Thiodiglycol	0/52	---	2.6-4.2	---	---	---	---	---	---
Organosulfur Compounds, Herbicide Related (OSCHs)									
Benzothiazole	0/16	---	1.1	---	---	---	---	---	---
Chlorophenylmethyl sulfide	0/626	---	0.25-80	---	---	---	---	---	---
Chlorophenylmethyl sulfone	1/626	0.40	0.25-10	NC	NC	NC	NC	NC	NC
Chlorophenylmethyl sulfoxide	0/626	---	0.25-100	---	---	---	---	---	---
Dimethyldisulfide	0/312	---	0.25-20	---	---	---	---	---	---

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‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard Deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
† Typically TIC; but target compound of some special investigations.
** Reported as total xylenes
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Table RISR A3.1-2 Summary of Analytical Results for Soils in Ditches, Lakes and Ponds.

Total Bores Sampled: 459
Total Samples Collected: 1,148

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g)						Adjusted Geometric Mean
				Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.		
Organophosphorous Compounds, GB-Agent Related (OPHGBs)										
Diisopropylmethyl phosphonate	23/687	0.19-5.0	0.050-10	3.2	2.9	1.6	2.1	0.96		0.072
Dimethylmethyl phosphonate	0/195	---	0.050-5.9	---	---	---	---	---		---
Isopropylmethyl phosphonic acid	1/60	5.6	2.1-4.7	NC	NC	NC	NC	NC		NC
Methylphosphonic acid	2/32	4.9-42	2.0	NC	NC	NC	NC	NC		NC
Phosphoric acid, tributyl ester*	NI	---	---	---	---	---	---	---		---
Phosphoric acid, triphenyl ester*	NI	---	---	---	---	---	---	---		---
Organophosphorous Compounds, Pesticide Related (OPHPs)										
Atrazine	0/610	---	0.25-6.0	---	---	---	---	---		---
Malathion	0/610	---	0.30-7.0	---	---	---	---	---		---
Parathion	0/610	---	0.40-9.0	---	---	---	---	---		---
Supona	0/610	---	0.30-6.0	---	---	---	---	---		---
Vapona	0/609	---	0.25-30	---	---	---	---	---		---
Dibromochloropropane (DBCP)	31/1,236	0.0068-0.65	0.0050-13	0.036	0.07	0.12	0.033	1.2		0.00082
Organonitrogen Compounds (ONCs)										
Caprolactam*	NI	---	---	---	---	---	---	---		---
Hydrazine	0/2	---	50	---	---	---	---	---		---
Methylhydrazine	0/2	---	200	---	---	---	---	---		---
n-Nitrosodimethylamine	0/27	---	0.26-18	---	---	---	---	---		---
n-Nitrosodi-n-propylamine	0/2	---	0.10	---	---	---	---	---		---
Unsymmetrical dimethylhydrazine	0/2	---	200	---	---	---	---	---		---

‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard Deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
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NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.
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Table RISR A3.1-2 Summary of Analytical Results for Soils in Ditches, Lakes and Ponds.

Total Bores Sampled: 459
Total Samples Collected: 1,148

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g)					Adjusted Geometric Mean
				Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	
Fluoroacetic Acid	4/32	2.6-9.1	2.0	3.4	4.6	3.0	4.1	0.56	0.51
Polynuclear Aromatic Hydrocarbons (PAHs)									
Fluoranthene*	1/1	2	0.3	NC	NC	NC	NC	NC	NC
Methylnaphthalene*	3/3	3-4	0.3	4	NC	NC	NC	NC	NC
Phenanthrene*	NI	---	---	---	---	---	---	---	---
Pyrene*	NI	---	---	---	---	---	---	---	---
Semivolatile Halogenated Organics (SHOs)									
Hexachlorobenzene*	NI	---	---	---	---	---	---	---	---
Hexachlorobutadiene*	NI	---	---	---	---	---	---	---	---
Hexachlorocyclopentadiene	26/918	0.0043-3,000	0.0018-14	0.023	120	590	0.037	2.6	0.0010
Pentachlorobenzene*	NI	---	---	---	---	---	---	---	---
Tetrachlorobenzene*	NI	---	---	---	---	---	---	---	---
Trichlorobenzene*	NI	---	---	---	---	---	---	---	---
Organochlorine Pesticides (OCPs)									
Aldrin	164/1,041	0.0022-1,100	0.0018-6.0	0.14	30	130	0.26	3.4	0.040
Chlordane	48/995	0.026-800	0.023-24	0.13	19	120	0.32	2.1	0.015
Dichlorodiphenylethane (DDE)	95/1,041	0.0012-6.6	0.0010-6.0	0.014	0.32	0.95	0.029	2.0	0.0027
Dichlorodiphenyltrichloroethane (DDT)	67/1,041	0.0025-10.0	0.0020-10	0.041	0.56	1.8	0.055	2.0	0.0036
Dieldrin	263/1,041	0.0015-3,000	0.0012-6.0	0.19	18	190	0.23	2.9	0.059
Endrin	96/1,041	0.0020-20	0.0010-7.4	0.040	0.53	2.2	0.063	1.8	0.0058
Isodrin	68/1,041	0.0013-500	0.0011-6.0	0.024	8.4	61	0.057	2.7	0.0037

‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard Deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
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RIFS 5/RISR Soil Tables/Table A 3.1-2. 8/12/91 1:24 PM - dm

Table RISR A3.1-2 Summary of Analytical Results for Soils in Ditches, Lakes and Ponds.

Total Bores Sampled: 459
Total Samples Collected: 1,148

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g) Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	Adjusted Geometric Mean
Arsenic	139/601	2.5-190	2.0-5.2	7.5	14	21	8.8	0.85	2.0
Mercury	187/833	0.052-18	0.037-0.10	0.16	0.43	1.5	0.19	0.99	0.042
ICP Metals									
Cadmium	60/663	0.74-30	0.51-1.7	1.3	2.5	4.0	1.7	0.71	0.15
Chromium	415/663	6.1-490	5.2-12	13	18	33	5.5	0.51	3.5
Copper	526/663	5.3-220	4.7-5.0	11	16	16	3.9	0.59	3.1
Lead	250/663	10-2,000	8.4-17	25	92	250	17	1.1	6.4
Zinc	649/663	11-2,300	8.7-28	39	57	110	3.0	0.62	2.9

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‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.

Δ Standard Deviation of log values (base e) of detections

* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.

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overall concentrations of the analyte groups and the number of analyte groups detected decreases.

A3.1.1.3 Ordnance Testing and Disposal Areas

Twelve ordnance testing and disposal area sites have been documented by the RI on RMA. They include surface sites, shallow pits, and trenches that were used to test, burn, or dispose of incendiary devices and munitions. Incinerators in Section 36 that were used to destroy munitions and reduce the volume of solid waste are also included in this site type. Other ordnance testing and disposal areas are located in the eastern portions of RMA and in Sections 25 and 36. Some of the ordnance testing and disposal areas may contain unexploded ordnance that may pose a physical hazard if disturbed.

In the ordnance testing and disposal areas, the number of analyte groups present is very limited, as shown in Figure RISR A3.1-5 and Table RISR A3.1-3. The highest percentage of detections is associated with ICP metals and fluoroacetic acid. The volatile organics exhibit a higher percentage of detections than other organic analytes, but the number of detections is relatively low. Highest concentrations, over 10,000 µg/g, are associated with the ICP metals in the 0- to 2-ft and 5- to 20-ft depth intervals. In contrast, concentrations of other analyte groups are typically in the lowest concentration range for all depth intervals.

A3.1.1.4. Solid Waste Burial Sites

Three general categories of sites, including contaminated waste burial sites, buried lake sediments, and sanitary landfills, are included in this site type. Eighteen sites of this type are documented by the RI. The contaminated waste burial sites include shallow trenches where solid and liquid waste materials were formerly disposed from manufacturing and demilitarization processes. These sites are characterized by extreme spatial variability of the wastes and include high concentrations of contaminants. Three contaminated waste burial sites --CSA-1a, CSA-1b, and CSA-1c --each including multiple trenches, are located within Section 36, and one burial site (SPSA-1e) is within the South Plants area. The buried lake sediment sites in

Table RISR A3.1-3 Summary of Analytical Results for Soils in Ordnance Testing and Disposal Areas.

Total Bores Sampled: 158
Total Samples Collected: 436

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g) Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	Adjusted Geometric Mean
Volatile Halogenated Organics (VHOs)									
1,1-Dichloroethane	0/71	---	0.074-1.7	---	---	---	---	---	---
1,2-Dichloroethane	0/71	---	0.085-0.56	---	---	---	---	---	---
1,1-Dichloroethylene	0/14	---	0.24	---	---	---	---	---	---
trans-1,2-Dichloroethylene	0/71	---	0.25-1.7	---	---	---	---	---	---
1,1,2,2-Tetrachloroethane*	NI	---	---	---	---	---	---	---	---
1,1,1-Trichloroethane	0/71	---	0.088-0.50	---	---	---	---	---	---
1,1,2-Trichloroethane	0/71	---	0.25-0.60	---	---	---	---	---	---
Carbon tetrachloride	0/71	---	0.12-0.40	---	---	---	---	---	---
Chlorobenzene	0/68	---	0.20-1.5	---	---	---	---	---	---
Chloroform	1/71	0.44	0.068-0.70	NC	NC	NC	NC	NC	NC
Methylene chloride	2/46	0.31-0.76	0.25-3.7	NC	NC	NC	NC	NC	NC
Tetrachloroethylene	1/71	0.35	0.25-0.50	NC	NC	NC	NC	NC	NC
Trichloroethylene	0/71	---	0.14-0.60	---	---	---	---	---	---
Trichloropropene*	NI	---	---	---	---	---	---	---	---
Volatile Hydrocarbons (VHCs)									
2-Butoxyethanol*	NI	---	---	---	---	---	---	---	---
4-Hydroxy-4-methyl-2-pentanone*	NI	---	---	---	---	---	---	---	---
1-Methyl-1,3-cyclopentadiene*	NI	---	---	---	---	---	---	---	---
2,2-Oxybisethanol*	12/12	0.6-2	0.3	0.9	0.92	0.4	0.9	0.36	0.9
2-Pentanone*	NI	---	---	---	---	---	---	---	---
Bicycloheptadiene	0/57	---	0.25-0.80	---	---	---	---	---	---
Dicyclopentadiene	0/336	---	0.26-6.0	---	---	---	---	---	---
Methylcyclohexane*	NI	---	---	---	---	---	---	---	---
Methylisobutyl ketone	0/57	---	0.30-0.73	---	---	---	---	---	---

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‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard Deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
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				Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	
Volatile Aromatic Organics (VAOs)									
Benzene	4/74	0.31-0.47	0.085-1.0	0.35	0.37	0.76	0.36	0.20	0.020
Ethylbenzene	0/74	---	0.16-0.40	---	---	---	---	---	---
m-Xylene	0/74	---	0.25-0.74	---	---	---	---	---	---
o- and p-Xylene**	0/74	---	0.30-4.9	---	---	---	---	---	---
Toluene	0/74	---	0.19-0.30	---	---	---	---	---	---
Organosulfur Compound Mustard-Agent Related (OSCMs)									
1,4-Oxathiane	0/320	---	0.25-60	---	---	---	---	---	---
Chloroacetic acid	0/42	---	18-36	---	---	---	---	---	---
Dithiane	0/321	---	0.25-70	---	---	---	---	---	---
Thiodiglycol	0/42	---	2.6-4.2	---	---	---	---	---	---
Organosulfur Compounds, Herbicide Related (OSCHs)									
Benzothiazole	0/10	---	1.1	---	---	---	---	---	---
Chlorophenylmethyl sulfide	0/321	---	0.25-40	---	---	---	---	---	---
Chlorophenylmethyl sulfone	0/321	---	0.25-6.0	---	---	---	---	---	---
Chlorophenylmethyl sulfoxide	0/321	---	0.25-70	---	---	---	---	---	---
Dimethyldisulfide	0/67	---	0.25-20	---	---	---	---	---	---

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RIFS 5/RISR Soil Tables/Table A 3.1-3. 8/12/91 1:26 PM - dm

Table RISR A3.1-3 Summary of Analytical Results for Soils in Ordnance Testing and Disposal Areas.

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Total Samples Collected: 436

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g) Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	Adjusted Geometric Mean
Organophosphorous Compounds, GB-Agent Related (OPHGBs)									
Diisopropylmethyl phosphonate	0/321	---	0.11-3.0	---	---	---	---	---	---
Dimethylmethyl phosphonate	0/279	---	0.13-3.0	---	---	---	---	---	---
Isopropylmethyl phosphonic acid	0/45	---	2.1-4.7	---	---	---	---	---	---
Methylphosphonic acid	0/27	---	2.0-10	---	---	---	---	---	---
Phosphoric acid, tributyl ester*	NI	---	---	---	---	---	---	---	---
Phosphoric acid, triphenyl ester*	NI	---	---	---	---	---	---	---	---
Organophosphorous Compounds, Pesticide Related (OPHPs)									
Atrazine	0/347	---	0.25-3.0	---	---	---	---	---	---
Malathion	0/347	---	0.25-3.0	---	---	---	---	---	---
Parathion	0/347	---	0.25-4.0	---	---	---	---	---	---
Supona	0/347	---	0.25-3.9	---	---	---	---	---	---
Vapona	0/347	---	0.25-3.0	---	---	---	---	---	---
Dibromochloropropane (DBCP)	0/275	---	0.0050-3.00	---	---	---	---	---	---
Organonitrogen Compounds (ONCs)									
Caprolactam*	NI	---	---	---	---	---	---	---	---
Hydrazine	NA	---	---	---	---	---	---	---	---
Methylhydrazine	NA	---	---	---	---	---	---	---	---
n-Nitrosodimethylamine	NA	---	---	---	---	---	---	---	---
n-Nitrosodi-n-propylamine	NA	---	—	---	---	---	---	---	---
Unsymmetrical dimethylhydrazine	NA	---	---	---	---	---	---	---	---

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* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
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				Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	
Fluoroacetic Acid	2/27	2.6-18	2.0	NC	NC	NC	NC	NC	NC
Polynuclear Aromatic Hydrocarbons (PAHs)									
Fluoranthene*	NI	---	---	---	---	---	---	---	---
Methyl naphthalene*	4/4	0.5-1	0.3	0.6	0.68	0.2	0.7	0.30	0.7
Phenanthrene*	1/1	1	0.3	NC	NC	NC	NC	NC	NC
Pyrene*	NI	---	---	---	---	---	---	---	---
Semivolatile Halogenated Organics (SHOs)									
Hexachlorobenzene*	NI	---	---	---	---	---	---	---	---
Hexachlorobutadiene*	NI	---	---	---	---	---	---	---	---
Hexachlorocyclopentadiene	0/296	---	0.0026-3.0	---	---	---	---	---	---
Pentachlorobenzene*	NI	---	---	---	---	---	---	---	---
Tetrachlorobenzene*	NI	---	---	---	---	---	---	---	---
Trichlorobenzene*	NI	---	---	---	---	---	---	---	---
Organochlorine Pesticides (OCPs)									
Aldrin	0/315	---	0.0018-3.0	---	---	---	---	---	---
Chlordane	0/296	---	0.11-6.0	---	---	---	---	---	---
Dichlorodiphenylethane (DDE)	0/315	---	0.0010-3.0	---	---	---	---	---	---
Dichlorodiphenyltrichloroethane (DDT)	0/315	---	0.0023-6.0	---	---	---	---	---	---
Dieldrin	3/315	0.0029-2.8	0.0012-3.0	0.35	NC	NC	NC	NC	NC
Endrin	0/315	---	0.0010-4.0	---	---	---	---	---	---
Isodrin	0/315	---	0.0011-3.0	---	---	---	---	---	---

‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
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* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
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Arsenic	56/303	2.8-32	2.0-5.2	5.8	6.5	4.7	5.7	0.47	1.1
Mercury	43/310	0.061-0.32	0.037-0.070	0.084	0.10	0.058	0.094	0.43	0.013
ICP Metals									
Cadmium	35/313	0.63-59	0.51-0.92	2.5	8.1	14	3.2	1.2	0.36
Chromium	261/313	7.8-56	6.5-7.4	17	19	8.2	15	0.40	13
Copper	306/314	5.0-340	4.7-4.9	17	26	36	10	0.65	9.9
Lead	89/313	11-3,400	8.4-17	28	170	530	40	1.2	11
Zinc	295/313	15-57,000	8.7-28	59	370	3500	11	0.80	10

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‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard Deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
† Typically TIC; but target compound of some special investigations.
** Reported as total xylenes
NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.
NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

Sections 11 and 12 contain contaminated sediments dredged from Lake Ladora and Upper and Lower Derby Lakes.

Dredged lake sediments were placed in shallow trenches, covered, and revegetated. Sanitary landfills were used for the disposal of trash, construction debris, and other material related to RMA activities, with the exclusion of chemical waste. The contents of the trenches of some sites were burned before being covered. Identified landfill contents include paper, lumber, rags, glass, and metal containers that possibly had contained petroleum products or pesticides. Sporadic, low-level concentrations of contaminants have been detected in samples from exploratory excavations. The largest landfill on RMA is located in Section 30. Smaller landfills, often called "trash pits," are found throughout the Arsenal with the exception of the northwest portion.

The solid waste burial sites contain a relatively wide range of contaminants at relatively high concentrations, as shown in Figure RISR A3.1-6 and Table RISR A3.1-4. OCPs, VHOs, VAOs, ICP metals, and mercury were the most frequently detected contaminant groups in the solid waste burial sites. Concentrations of organics are low in the shallow 0- to 2-ft and 2- to 5-ft intervals, but tend to increase in the 5- to 20-ft intervals. All analyte groups except OPHPs and organonitrogen compounds (ONCs) are present in soils from these sites. More mobile compounds have commonly migrated from these soils to the UFS.

A3.1.1.5. Buildings, Equipment, and Storage Sites

Twenty-five sites of this type were identified by the RI. Storage sites were used to store chemicals, munitions, and salvage debris. Buildings and equipment sites include areas surrounding tanks, pipelines, and buildings. Only the below-ground structures and soils at these sites are included in the soils medium. Although spills are inferred to have occurred at many of these sites, secondary airborne and surface water dispersion of contaminants may be largely responsible for current analyte distribution.

Table RISR A3.1-4 Summary of Analytical Results for Soils in Solid Waste Burial Sites.

Total Bores Sampled: 450
Total Samples Collected: 1,234

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g) Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	Adjusted Geometric Mean
Volatile Halogenated Organics (VHOs)									
1,1-Dichloroethane	0/510	---	0.074-13	---	---	---	---	---	---
1,2-Dichloroethane	1/510	0.42	0.080-8.0	NC	NC	NC	NC	NC	NC
1,1-Dichloroethylene	1/134	0.20	0.12-12	NC	NC	NC	NC	NC	NC
trans-1,2-Dichloroethylene	1/496	5.9	0.15-15	NC	NC	NC	NC	NC	NC
1,1,2,2-Tetrachloroethane*	2/2	0.6-2	0.3	NC	NC	NC	NC	NC	NC
1,1,1-Trichloroethane	8/510	0.50-3.0	0.088-12	0.79	1.1	0.81	0.91	0.56	0.014
1,1,2-Trichloroethane	2/510	0.18-0.43	0.12-12	NC	NC	NC	NC	NC	NC
Carbon tetrachloride	5/510	1.0-8.7	0.12-12	1.0	3.9	3.9	2.4	1.1	0.023
Chlorobenzene	1/510	1.0	0.18-18	NC	NC	NC	NC	NC	NC
Chloroform	20/510	0.15-8.8	0.068-10	1.1	2.4	2.8	1.1	1.4	0.045
Methylene chloride	55/496	0.17-760	0.15-15	0.80	16	100	0.98	1.2	0.11
Tetrachloroethylene	29/510	0.19-120	0.12-6.0	1.0	6.6	22	1.3	1.5	0.072
Trichloroethylene	11/510	0.11-25	0.090-9.0	1.0	3.2	7.3	1.0	1.4	0.022
Trichloropropene*	NI	---	---	---	---		---	---	---
Volatile Hydrocarbons (VHCs)									
2-Butoxyethanol*	NI	---	---	---	---	---	---	---	---
4-Hydroxy-4-methyl-2-pentanone*	1/1	0.80	0.3	NC	NC	NC	NC	NC	NC
1-Methyl-1,3-cyclopentadiene*	NI	---	---	---	---	---	---	---	---
2,2-Oxybisethanol*	NI	---	---	---	---	---	---	---	---
2-Pentanone*	NI	---	---	---	---	---	---	---	---
Bicycloheptadiene	6/450	0.91-56	0.25-51	5.9	16	22	5.6	1.7	0.074
Dicyclopentadiene	15/1,196	1.0-450	0.26-600	37	110	140	29	2.1	0.36
Methylcyclohexane*	4/4	5-100	0.3	40	46	40	30	1.3	30
Methylisobutyl ketone	3/459	8.8-20	0.30-52	14	NC	NC	NC	NC	NC

‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.

Δ Standard Deviation of log values (base e) of detections

* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.

† Typically TIC; but target compound of some special investigations.

** Reported as total xylenes

NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.

NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

Table RISR A3.1-4 Summary of Analytical Results for Soils in Solid Waste Burial Sites.

Total Bores Sampled: 450
Total Samples Collected: 1,234

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g) Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	Adjusted Geometric Mean
Volatile Aromatic Organics (VAOs)									
Benzene	25/437	0.12-26	0.081-8.1	0.74	3.6	7.2	0.95	1.6	0.054
Ethylbenzene	11/437	0.43-9.9	0.043-4.3	0.98	2.7	3.5	1.5	1.1	0.038
m-Xylene	14/437	0.18-13	0.053-5.3	2.2	3.3	4.1	1.9	1.1	0.061
o- and p-Xylene**	13/437	0.16-14	0.086-8.6	3.2	4.9	4.1	3.1	1.2	0.093
Toluene	24/437	0.12-370	0.096-9.6	3.9	44	97	4.4	2.3	0.24
Organosulfur Compounds, Mustard-Agent Related (OSCMs)									
1,4-Oxathiane	1/899	0.46	0.25-86	NC	NC	NC	NC	NC	NC
Chloroacetic acid	1/113	310	18-36	NC	NC	NC	NC	NC	NC
Dithiane	9/898	0.46-12	0.25-200	3.2	5.2	4.4	3.2	1.2	0.033
Thiodiglycol	0/113	---	2.6-4.2	---	---	---	---	---	---
Organosulfur Compounds, Herbicide Related (OSCHs)									
Benzothiazole	3/125	1.9-130	1.1-110	60	NC	NC	NC	NC	NC
Chlorophenylmethyl sulfide	10/899	0.50-100	0.25-110	2.7	15	31	3.9	1.6	0.043
Chlorophenylmethyl sulfone	8/899	0.68-20	0.25-240	1.3	3.6	6.7	1.6	1.1	0.014
Chlorophenylmethyl sulfoxide	6/899	1.0-4.2	0.25-230	3.6	3.0	1.2	2.7	0.56	0.018
Dimethyldisulfide	8/501	0.39-100	0.25-20	13	22	33	6.9	1.9	0.11

---

‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.

Δ Standard Deviation of log values (base e) of detections

* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.

† Typically TIC; but target compound of some special investigations.

** Reported as total xylenes

NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.

NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

Total Bores Sampled: 450
Total Samples Collected: 1,234

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g) Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	Adjusted Geometric Mean
Organophosphorous Compounds, GB-Agent Related (OPHGBs)									
Diisopropylmethyl phosphonate	38/889	0.16-36	0.11-300	1.7	4.2	7.0	1.9	1.3	0.080
Dimethylmethyl phosphonate	5/569	0.19-0.65	0.13-300	0.24	0.31	0.19	0.28	0.49	0.0024
Isopropylmethyl phosphonic acid	3/61	3.7-17	2.1	8.3	NC	NC	NC	NC	NC
Methylphosphonic acid	5/61	2.8-220	2.0	3.9	47	97	8.8	1.8	0.72
Phosphoric acid, tributyl ester*	NI	---	---	---	---	---	---	---	---
Phosphoric acid, triphenyl ester*	NI	---	---	---	---	---	---	---	---
Organophosphorous Compounds, Pesticide Related (OPHPs)									
Atrazine	0/789	---	0.25-50	---	---	---	---	---	---
Malathion	0/789	---	0.25-200	---	---	---	---	---	---
Parathion	0/789	---	0.25-200	---	---	---	---	---	---
Supona	0/789	---	0.25-90	---	---	---	---	---	---
Vapona	0/790	---	0.25-30	---	---	---	---	---	---
Dibromochloropropane (DBCP)	51/1,344	0.0076-670	0.0050-50	0.15	17	94	0.21	2.7	0.0080
Organonitrogen Compounds (ONCs)									
Caprolactam*	NI	---	---	---	---	---	---	---	---
Hydrazine	NA	---	---	---	---	---	---	---	---
Methylhydrazine	NA	---	---	---	---	---	---	---	---
n-Nitrosodimethylamine	0/3	---	1.8	---	---	---	---	---	---
n-Nitrosodi-n-propylamine	NA	---	---	---	---	---	---	---	---
Unsymmetrical dimethylhydrazine	NA	---	---	---	---	---	---	---	---

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‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard Deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
† Typically TIC; but target compound of some special investigations.
** Reported as total xylenes
NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.
NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

Table RISR A3.1-4 Summary of Analytical Results for Soils in Solid Waste Burial Sites.

Total Bores Sampled: 450
Total Samples Collected: 1,234

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g)					
				Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	Adjusted Geometric Mean
Fluoroacetic Acid	14/58	2.7-27	2.0	7.5	9.6	7.6	7.0	0.84	1.7
Polynuclear Aromatic Hydrocarbons (PAHs)									
Fluoranthene*	NI	---	---	---	---	---	---	---	---
Methyl naphthalene*	NI	---	---	---	---	---	---	---	---
Phenanthrene*	1/1	3	0.3	NC	NC	NC	NC	NC	NC
Pyrene*	4/4	0.7-10	0.3	2	3.7	4	2	1.1	2
Semivolatile Halogenated Organics (SHOs)									
Hexachlorobenzene*	1/1	NC	0.3	NC	NC	NC	NC	NC	NC
Hexachlorobutadiene*	NI	---	---	---	---	---	---	---	---
Hexachlorocyclopentadiene	33/871	0.0037-53,000	0.0018-100	1.1	2600	9,500	1.7	5.1	0.063
Pentachlorobenzene*	NI	---	---	---	---	---	---	---	---
Tetrachlorobenzene*	NI	---	---	---	---	---	---	---	---
Trichlorobenzene*	NI	---	---	---	---	---	---	---	---
Organochlorine Pesticides (OCPs)									
Aldrin	109/978	0.0033-670	0.0018-73	0.95	34	110	0.66	3.4	0.74
Chlordane	46/861	0.18-100	0.023-4,400	2.0	8.5	20	1.4	1.8	0.077
Dichlorodiphenylethane (DDE)	32/979	0.0026-1.9	0.0010-50	0.015	0.17	0.44	0.021	1.8	0.00069
Dichlorodiphenyltrichloroethane (DDT)	29/979	0.0033-26	0.0020-200	0.022	0.97	4.8	0.030	1.9	0.00089
Dieldrin	212/978	0.0021-360	0.0012-60	0.83	12	42	0.74	2.7	0.16
Endrin	98/968	0.0018-370	0.0010-400	0.38	18	65	0.34	3.0	0.034
Isodrin	62/979	0.0026-870	0.0011-60	0.11	55	160	0.35	3.7	0.022

‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard Deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
† Typically TIC; but target compound of some special investigations.
** Reported as total xylenes
NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.
NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

Total Bores Sampled: 450
Total Samples Collected: 1,234

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g)					Adjusted Geometric Mean
				Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	
Arsenic	184/823	2.3-1,200	2.0-5.2	7.2	32	130	10	1.1	2.3
Mercury	219/980	0.053-40	0.037-0.10	0.17	0.77	3.4	0.23	1.2	0.052
ICP Metals									
Cadmium	75/830	0.64-1,100	0.51-0.92	1.6	33	180	2.6	1.4	0.24
Chromium	590/829	5.9-4,900	5.2-52	13	29	220	3.3	0.56	2.4
Copper	699/829	4.8-27,000	4.7-19	11	80	1,100	2.8	0.82	2.3
Lead	224/829	10-7,100	8.4-17	20	120	560	24	1.1	6.4
Zinc	798/829	11-12,000	9.5-55	41	81	460	2.4	0.67	2.3

---

‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.

Δ Standard Deviation of log values (base e) of detections

* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.

† Typically TIC; but target compound of some special investigations.

** Reported as total xylenes

NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.

NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

Analytes of all but two of the analyte groups were detected from the buildings, equipment, and storage sites. OCPs and ICP metals exhibit the greatest percentage of detections as shown in Figure RISR A3.1-7 and Table RISR A3.1-5. Volatiles and semivolatiles comprise the bulk of the remaining organics detected. With the exception of the organosulfur compounds, OPHGBs, and OCPs, the number of detections tends to increase with depth for the organic contaminants. For most of the analyte groups detected in this site type, the highest percentage of detections occur in the two lowest concentration ranges. However, DBCP and arsenic occur at concentrations over 10,000 µg/g in the 0- to 2-ft depth interval, and OCPs were detected at over 10,000 µg/g in the 0- to 2-, 2- to 5-, and 5- to 20-ft depth intervals. The percentage of detections above 10 µg/g tends to increase from the 0- to 2-ft interval to the 5- to 20-ft interval for most analyte groups, except VHCs, herbicide-related organosulfur compounds (OSCHs), OPHGBs, mercury, and the ICP metals. For these analyte groups, concentrations tend to stabilize or decrease with depth.

A3.1.1.6. Spill Sites

Spills have been reported throughout the period of operation of RMA in many areas where chemicals were routinely handled. Fourteen spill sites have been located by the RI. Spills have been documented or reported to have taken place predominantly at railyard transfer facilities, sumps, and tanks. A wide range of contaminants have been detected. Infiltration of liquids and incomplete recovery of spilled solids have resulted in soil and groundwater contamination at these sites. Contaminant distribution at spill sites varies in response to individual contaminant behavior. Relatively soluble compounds may migrate through the unsaturated zone; volatile compounds tend to rapidly attenuate at the surface, and less mobile compounds are concentrated in shallow soil. For example, DBCP spilled in the rail classification/maintenance yard of the Western Study Area (WSA) migrated through relatively sandy soils, creating a well defined plume in the UFS (EBASCO, 1989a/RIC 89166R03). Elsewhere, less mobile metals and PAH compounds have concentrated in shallow soils at spill sites. Although difficult to determine, secondary dispersion may also have contributed to

Table RISR A3.1-5 Summary of Analytical Results for Soils in Buildings, Equipment, and Storage Sites.

Total Bores Sampled: 555
Total Samples Collected: 1,826

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g)					Adjusted Geometric Mean
				Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	
Volatile Halogenated Organics (VHOs)									
1,1-Dichloroethane	0/643	---	0.074-3,600	---	---	---	---	---	---
1,2-Dichloroethane	3/644	1.6-2.0	0.085-1,200	0.23	NC	NC	NC	NC	NC
1,1-Dichloroethylene	0/90	---	0.24-0.25	---	---	---	---	---	---
trans-1,2-Dichloroethylene	0/643	---	0.26-1,200	---	---	---	---	---	---
1,1,2,2-Tetrachloroethane*†	41/46	NC-23	0.3-0.65	NC	NC	NC	NC	NC	NC
1,1,1-Trichloroethane	7/643	0.17-6.5	0.088-1,200	0.62	1.7	2.2	0.91	1.2	0.0099
1,1,2-Trichloroethane	0/643	---	0.26-1,200	---	---	---	---	---	---
Carbon tetrachloride	5/643	3.4-240	0.12-1,200	25	65	100	25	1.6	0.19
Chlorobenzene	6/642	2.4-40	0.20-1,200	4.0	10	15	5.9	1.1	0.055
Chloroform	28/646	0.44-40,000	0.068-1.3	5.0	1500	7,600	8.0	2.3	0.35
Methylene chloride	29/644	0.90-200	0.70-2,800	10	23	39	9.3	1.4	0.42
Tetrachloroethylene	31/644	0.30-52	0.25-1,200	0.89	5.3	11	1.5	1.5	0.074
Trichloroethylene	2/642	0.33-0.84	0.14-1,200	NC	NC	NC	NC	NC	NC
Trichloropropene*	NI	---	---	---	---	---	---	---	---
Volatile Hydrocarbons (VHCs)									
2-Butoxyethanol*	7/7	NC	0.3	NC	NC	NC	NC	NC	NC
4-Hydroxy-4-methyl-2-pentanone*	NI	---	---	---	---	---	---	---	---
1-Methyl-1,3-cyclopentadiene*	18/18	NC-40	0.3	NC	NC	NC	NC	NC	NC
2,2-Oxybisethanol*	NI	---	---	---	---	---	---	---	---
2-Pentanone*	2/2	NC	0.3	NC	NC	NC	NC	NC	NC
Bicycloheptadiene	6/579	0.30-25	0.30-1,200	1.5	5.2	9.7	1.7	1.5	0.018
Dicyclopentadiene	65/1,710	0.50-3,000	0.26-2,500	26	180	420	29	2.2	1.1
Methylcyclohexane*	6/6	NC-2	0.3	NC	NC	NC	NC	NC	NC
Methylisobutyl ketone	13/580	0.40-89	0.30-1,200	10	20	26	5.7	1.9	0.13

---

‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.

Δ Standard Deviation of log values (base e) of detections

* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.

† Typically TIC; but target compound of some special investigations.

** Reported as total xylenes

NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.

NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

Table RISR A3.1-5 Summary of Analytical Results for Soils in Buildings, Equipment, and Storage Sites.

Total Bores Sampled: 555
Total Samples Collected: 1,826

				Detections (µg/g)					
Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	Adjusted Geometric Mean
Volatile Aromatic Organics (VAOs)									
Benzene	24/569	0.29-84	0.081-1,200	0.90	7.6	18	1.8	1.6	0.074
Ethylbenzene	10/568	0.40-30	0.043-1,200	2.2	5.8	9.1	1.8	1.7	0.032
m-Xylene	12/570	0.80-80	0.053-2,800	2.8	12	22	3.6	1.6	0.076
o- and p-Xylene**	10/569	0.40-40	0.086-1,200	5.0	13	13	7.0	1.3	0.12
Toluene	27/572	0.40-250	0.096-1,200	5.0	22	48	6.0	1.7	0.28
Organosulfur Compounds, Mustard-Agent Related (OSCMs)									
1,4-Oxathiane	2/1,216	2.1-9.8	0.25-3,000	NC	NC	NC	NC	NC	NC
Chloroacetic acid	6/280	57-340	3.6-36	130	160	100	140	0.61	3.0
Dithiane	10/1,218	1.0-330	0.25-3,300	19	60	99	22	1.6	0.18
Thiodiglycol	4/405	5.9-31	2.6-4.2	19	19	11	16	0.73	0.16
Organosulfur Compounds, Herbicide Related (OSCHs)									
Benzothiazole	0/66	---	1.1-2.0	---	---	---	---	---	---
Chlorophenylmethyl sulfide	11/1,214	1.1-1,100	0.25-3,300	3.0	120	330	9.0	2.3	0.081
Chlorophenylmethyl sulfone	29/1,216	0.30-80	0.25-930	2.9	9.4	20	2.7	1.5	0.065
Chlorophenylmethyl sulfoxide	11/1,218	0.38-43	0.20-3,000	2.9	9.7	14	3.5	1.6	0.032
Dimethyldisulfide	1/622	5.0	0.30-3,200	NC	NC	NC	NC	NC	NC

---

‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.

Δ Standard Deviation of log values (base e) of detections

* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.

† Typically TIC; but target compound of some special investigations.

** Reported as total xylenes

NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.

NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

Table RISR A3.1-5 Summary of Analytical Results for Soils in Buildings, Equipment, and Storage Sites.

Total Bores Sampled: 555
Total Samples Collected: 1,826

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g)					
				Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	Adjusted Geometric Mean
Organophosphorous Compounds, GB-Agent Related (OPHGBs)									
Diisopropylmethyl phosphonate	7/1,256	0.059-0.40	0.050-880	0.068	0.12	0.12	0.092	0.69	0.00051
Dimethylmethyl phosphonate	1/262	6.5	0.050-1,500	NC	NC	NC	NC	NC	NC
Isopropylmethyl phosphonic acid	0/167	---	2.1-4.7	---	---	---	---	---	---
Methylphosphonic acid	0/11	---	2.0-20	---	---	---	---	---	---
Phosphoric acid, tributyl ester*	NI	---	---	---	---	---	---	---	---
Phosphoric acid, triphenyl ester*	NI	---	---	---	---	---	---	---	---
Organophosphorous Compounds, Pesticide Related (OPHPs)									
Atrazine	8/1,150	0.30-10	0.25-950	0.75	2.0	3.3	0.99	1.1	0.0069
Malathion	1/1,152	0.30	0.30-750	NC	NC	NC	NC	NC	NC
Parathion	0/1,150	---	0.30-1,500	---	---	---	---	---	---
Supona	4/1,152	2.0-49	0.30-1,500	25	25	19	16	1.4	0.055
Vapona	0/1,150	---	0.25-3,300	---	---	---	---	---	---
Dibromochloropropane (DBCP)	45/2,044	0.0056-11,000	0.0050-3,300	2.0	580	2100	1.6	4.3	0.036
Organonitrogen Compounds (ONCs)									
Caprolactam*	NI	---	---	---	---	---	---	---	---
Hydrazine	0/53	---	50	---	---	---	---	---	---
Methylhydrazine	0/53	---	200	---	---	---	---	---	---
n-Nitrosodimethylamine	0/198	---	0.26-1,800	---	---	---	---	---	---
n-Nitrosodi-n-propylamine	0/109	---	0.10	---	---	---	---	---	---
Unsymmetrical dimethylhydrazine	0/53	---	200	---	---	---	---	---	---

‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard Deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
† Typically TIC; but target compound of some special investigations.
** Reported as total xylenes
NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.
NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

Table RISR A3.1-5 Summary of Analytical Results for Soils in Buildings, Equipment, and Storage Sites.

Total Bores Sampled: 555
Total Samples Collected: 1,826

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (μg/g)	CRL Range‡ (μg/g)	Detections (μg/g) Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	Adjusted Geometric Mean
Fluoroacetic Acid	0/11	---	2.0	---	---	---	---	---	---
Polynuclear Aromatic Hydrocarbons (PAHs)									
Fluoranthene*	2/2	0.4-9	0.3	NC	NC	NC	NC	NC	NC
Methyl naphthalene*	3/3	10-20	0.3	20	NC	NC	NC	NC	NC
Phenanthrene*	NI	---	---	---	---	---	---	---	---
Pyrene*	3/3	1-8	0.3	1	NC	NC	NC	NC	NC
Semivolatile Halogenated Organics (SHOs)									
Hexachlorobenzene*	4/4	NC-60	0.3	NC	NC	NC	NC	NC	NC
Hexachlorobutadiene*	17/17	NC-90	0.3	NC	NC	NC	NC	NC	NC
Hexachlorocyclopentadiene	36/1,234	0.0029-7,000	0.0018-3,500	2.0	380	1,300	2.1	4.1	0.061
Pentachlorobenzene*	1/1	NC-0.8	0.3	NC	NC	NC	NC	NC	NC
Tetrachlorobenzene*	12/12	NC-50	0.3	NC	NC	NC	NC	NC	NC
Trichlorobenzene*	2/2	NC-1	0.3	NC	NC	NC	NC	NC	NC
Organochlorine Pesticides (OCPs)									
Aldrin	167/1,304	0.0024-25,000	0.0018-250	3.7	960	3,300	6.4	3.8	0.82
Chlordane	27/1,281	0.030-1,000	0.023-2,400	2.9	88	230	3.1	3.0	0.065
Dichlorodiphenylethane (DDE)	43/1,294	0.0017-100	0.0010-630	0.19	4.8	16	0.22	2.8	0.0074
Dichlorodiphenyltrichloroethane (DDT)	52/1,297	0.0029-400	0.0020-1,200	0.50	27	78	0.77	3.5	0.031
Dieldrin	261/1,300	0.0016-7,200	0.0012-630	2.0	97	570	2.7	2.8	0.55
Endrin	60/1,295	0.0036-4,700	0.0010-1,900	0.70	140	680	0.82	3.4	0.038
Isodrin	89/1,302	0.0016-890	0.0011-630	4.6	59	140	2.3	3.8	0.16

‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard Deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 μg/g, typically corresponding to 10 percent of the internal standard, was used.
† Typically TIC; but target compound of some special investigations.
** Reported as total xylenes
NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.
NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

Table RISR A3.1-5 Summary of Analytical Results for Soils in Buildings, Equipment, and Storage Sites.

Total Bores Sampled: 555
Total Samples Collected: 1,826

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g) Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	Adjusted Geometric Mean
Arsenic	282/1,032	2.5-21,000	2.0-26	6.4	180	1,400	12	1.7	3.3
Mercury	188/1,100	0.050-17,000	0.037-0.50	0.40	93	1,200	0.49	1.7	0.083
ICP Metals									
Cadmium	75/1,051	0.56-760	0.31-0.92	1.5	14	88	2.4	1.2	0.17
Chromium	736/1,051	1.4-280	5.2-7.4	14	17	18	2.6	0.51	1.8
Copper	902/1,037	5.4-880	3.4-4.9	14	22	38	2.2	0.68	1.9
Lead	482/1,051	1.4-11,000	13-84	20	85	550	4.4	0.92	2.0
Zinc	1,046/1,051	9.5-3,300	8.7-16	54	72	140	2.0	0.61	2.0

---

‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.

Δ Standard Deviation of log values (base e) of detections

* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.

† Typically TIC; but target compound of some special investigations.

** Reported as total xylenes

NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.

NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

transport of low-mobility analytes in surficial soils in areas exposed to winds or high traffic areas.

OPHGBs, VHOs, VAOs, mercury, and ICP metals represent the highest percentage of detections at spill sites (Figure RISR A3.1-8 and Table RISR A3.1-6). The majority of concentrations for all organic analytes at all depth intervals are less than 10 µg/g. Only arsenic and ICP metals showed concentrations above this level. Except for VHOs and OPHGBs, the majority of detections for all analyte groups are limited to depths of less than 5 ft.

A3.1.1.7. Sewer Sites

The ten sites collectively comprising the sewer site type include portions of the chemical sewer, sanitary sewer, and process water systems. The chemical sewer was used to collect and transfer industrial aqueous waste from the processing facilities in the North and South Plants to the disposal basins. A short segment also connected Basin F to the deep disposal well in Section 26. The sanitary sewer delivers domestic sewage from various facilities throughout RMA to the wastewater treatment plant in Section 24. The process water system consists of a series of pipelines and ditches used to transport cooling water between the southern lakes and South Plants complex. The majority of contamination associated with these systems is limited to the NCSA and South Plants Study Area (SPSA).

Evidence of leakage was documented during partial excavation of the chemical sewer system and investigation of joints and manholes in the sanitary sewer lines. The sewers were typically installed at depths greater than 5 ft, which is generally the upper limit of soil contamination associated with these systems. While the sanitary sewer and process water systems exhibited minor contamination or were implicated in historically documented contaminant releases, the vast majority of contaminant detections are associated with the chemical sewers; consequently, the following discussion focuses on the chemical sewer system.

Table RISR A3.1-6 Summary of Analytical Results for Soils in Spill Sites. Page 1 of 5

Total Bores Sampled: 38
Total Samples Collected: 152

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g) Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	Adjusted Geometric Mean
Volatile Halogenated Organics (VHOs)									
1,1-Dichloroethane	0/63	---	0.074-2.0	---	---	---	---	---	---
1,2-Dichloroethane	0/62	---	0.085-0.60	---	---	---	---	---	---
1,1-Dichloroethylene	0/6	---	0.24	---	---	---	---	---	---
trans-1,2-Dichloroethylene	0/62	---	0.26-2.0	---	---	---	---	---	---
1,1,2,2-Tetrachloroethane*	NI	---	---	---	---	---	---	---	---
1,1,1-Trichloroethane	0/62	---	0.088-0.43	---	---	---	---	---	---
1,1,2-Trichloroethane	0/62	---	0.26-0.40	---	---	---	---	---	---
Carbon tetrachloride	1/62	0.30	0.12-0.30	NC	NC	NC	NC	NC	NC
Chlorobenzene	0/62	---	0.20-1.5	---	---	---	---	---	---
Chloroform	0/62	---	0.068-0.30	---	---	---	---	---	---
Methylene chloride	7/62	1.0-5.0	0.70-3.7	2.0	2.4	1.5	2.1	0.62	0.23
Tetrachloroethylene	1/62	0.40	0.25-0.30	NC	NC	NC	NC	NC	NC
Trichloroethylene	0/62	---	0.14-0.54	---	---	---	---	---	---
Trichloropropene*	NI	---	---	---	---	---	---	---	---
Volatile Hydrocarbons (VHCs)									
2-Butoxyethanol*	1/1	2	0.3	NC	NC	NC	NC	NC	NC
4-Hydroxy-4-methyl-2-pentanone*	NI	---	---	---	---	---	---	---	---
1-Methyl-1,3-cyclopentadiene*	NI	---	---	---	---	---	---	---	---
2,2-Oxybisethanol*	NI	---	---	---	---	---	---	---	---
2-Pentanone*	NI	---	---	---	---	---	---	---	---
Bicycloheptadiene	0/56	---	0.30-0.40	---	---	---	---	---	---
Dicyclopentadiene	0/158	---	0.30-10	---	---	---	---	---	---
Methylcyclohexane*	NI	---	---	---	---	---	---	---	---
Methylisobutyl ketone	0/56	---	0.30-0.73	---	---	---	---	---	---

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‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard Deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
† Typically TIC; but target compound of some special investigations.
** Reported as total xylenes
NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.
NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

Total Bores Sampled: 38
Total Samples Collected: 152

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g) Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	Adjusted Geometric Mean
Volatile Aromatic Organics (VAOs)									
Benzene	7/75	0.35-1.0	0.085-0.30	0.60	0.61	0.22	0.58	0.34	0.054
Ethylbenzene	0/75	---	0.16-0.40	---	---	---	---	---	---
m-Xylene	0/75	---	0.26-0.80	---	---	---	---	---	---
o- and p-Xylene**	0/75	---	0.30-5.0	---	---	---	---	---	---
Toluene	0/75	---	0.19-0.30	---	---	---	---	---	---
Organosulfur Compounds, Mustard-Agent Related (OSCMs)									
1,4-Oxathiane	0/102	---	0.25-6.0	---	---	---	---	---	---
Chloroacetic acid	0/59	---	36	---	---	---	---	---	---
Dithiane	0/102	---	0.36-7.0	---	---	---	---	---	---
Thiodiglycol	0/59	---	4.2	---	---	---	---	---	---
Organosulfur Compounds, Herbicide Related (OSCHs)									
Benzothiazole	NA	---	---	---	---	---	---	---	---
Chlorophenylmethyl sulfide	0/102	---	0.90	---	---	---	---	---	---
Chlorophenylmethyl sulfone	0/102	---	0.25-3.0	---	---	---	---	---	---
Chlorophenylmethyl sulfoxide	0/102	---	0.25-7.0	---	---	---	---	---	---
Dimethyldisulfide	0/56	---	0.80-20	---	---	---	---	---	---

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‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard Deviation of log values (base e) of detections.
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
† Typically TIC; but target compound of some special investigations.
** Reported as total xylenes
NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.
NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

Total Bores Sampled: 38
Total Samples Collected: 152

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g)					
				Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	Adjusted Geometric Mean
Organophosphorous Compounds, GB-Agent Related (OPHGBs)									
Diisopropylmethyl phosphonate	13/179	0.088-0.40	0.05-10	0.29	0.29	0.12	0.26	0.51	0.019
Dimethylmethyl phosphonate	0/77	---	0.050	---	---	---	---	---	---
Isopropylmethyl phosphonic acid	0/48	---	4.7	---	---	---	---	---	---
Methylphosphonic acid	NI	---	---	---	---	---	---	---	---
Phosphoric acid, tributyl ester*	NI	---	---	---	---	---	---	---	---
Phosphoric acid, triphenyl ester*	NI	---	---	---	---	---	---	---	---
Organophosphorous Compounds, Pesticide Related (OPHPs)									
Atrazine	0/102	---	0.25-3.0	---	---	---	---	---	---
Malathion	0/102	---	0.30-7.0	---	---	---	---	---	---
Parathion	0/102	---	0.40-9.0	---	---	---	---	---	---
Supona	0/102	---	0.30-6.0	---	---	---	---	---	---
Vapona	0/102	---	0.30-30	---	---	---	---	---	---
Dibromochloropropane (DBCP)	2/190	0.38-1.3	0.0050-3.0	NC	NC	NC	NC	NC	NC
Organonitrogen Compounds (ONCs)									
Caprolactam*	NI	---	---	---	---	---	---	---	---
Hydrazine	NA	---	---	---	---	---	---	---	---
Methylhydrazine	NA	---	---	---	---	---	---	---	---
n-Nitrosodimethylamine	NA	---	---	---	---	---	---	---	---
n-Nitrosodi-n-propylamine	NA	---	---	---	---	---	---	---	---
Unsymmetrical dimethylhydrazine	NA	---	---	---	---	---	---	---	---

‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.

Δ Standard Deviation of log values (base e) of detections

* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.

† Typically TIC; but target compound of some special investigations.

** Reported as total xylenes

NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.

NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

Total Bores Sampled: 38
Total Samples Collected: 152

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g) Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	Adjusted Geometric Mean
Fluoroacetic Acid	NA	---	---	---	---	---	---	---	---
Polynuclear Aromatic Hydrocarbons (PAHs)									
Fluoranthene*	3/3	NC-2	0.3	NC	NC	NC	NC	NC	NC
Methyl naphthalene*	NI	---	---	---	---	---	---	---	---
Phenanthrene*	NI	---	---	---	---	---	---	---	---
Pyrene*	2/2	NC-4	0.3	NC	NC	NC	NC	NC	NC
Semivolatile Halogenated Organics (SHOs)									
Hexachlorobenzene*	NI	---	---	---	---	---	---	---	---
Hexachlorobutadiene*	NI	---	---	---	---	---	---	---	---
Hexachlorocyclopentadiene	0/104	---	0.0018-6.0	---	---	---	---	---	---
Pentachlorobenzene*	NI	---	---	---	---	---	---	---	---
Tetrachlorobenzene*	NI	---	---	---	---	---	---	---	---
Trichlorobenzene*	NI	---	---	---	---	---	---	---	---
Organochlorine Pesticides (OCPs)									
Aldrin	1/104	0.033	0.0019-3.0	NC	NC	NC	NC	NC	NC
Chlordane	0/104	---	0.023-20	---	---	---	---	---	---
Dichlorodiphenylethane (DDE)	0/104	---	0.0024-6.0	---	---	---	---	---	---
Dichlorodiphenyltrichloroethane (DDT)	0/104	---	0.0020-5.0	---	---	---	---	---	---
Dieldrin	3/104	0.0083-2.8	0.0012-3.0	0.40	NC	NC	NC	NC	NC
Endrin	0/104	---	0.0058-5.0	---	---	---	---	---	---
Isodrin	0/104	---	0.0011-3.0	---	---	---	---	---	---

‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard Deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
† Typically TIC; but target compound of some special investigations.
** Reported as total xylenes
NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.
NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

Table RISR A3.1-6 Summary of Analytical Results for Soils in Spill Sites.

Total Bores Sampled: 38
Total Samples Collected: 152

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g)						Adjusted Geometric Mean
				Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.		
Arsenic	17/80	2.9-4,800	2.5-5.0	4.0	290	1,200	8.1	1.9		1.7
Mercury	17/91	0.060-2.9	0.050-0.070	0.41	0.58	0.71	0.33	1.1		0.062
ICP Metals										
Cadmium	7/75	0.97-4.5	0.66-0.74	1.3	1.7	1.3	1.4	0.52		0.13
Chromium	52/75	6.8-30	5.2-6.5	17	18	6.1	17	0.38		12
Copper	62/75	6.1-57	4.7-4.9	12	14	8.8	12	0.45		10
Lead	32/75	11-110	8.4-18	17	25	21	21	0.59		8.8
Zinc	74/75	13-190	8.7	42	50	30	43	0.55		42

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‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard Deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
† Typically TIC; but target compound of some special investigations.
** Reported as total xylenes
NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.
NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

Although all contaminant groups except ONCs and fluoroacetic acid were sporadically detected at sewers sites, detections of OCPs and ICP metals were most frequent (Figure RISR A3.1-9 and Table RISR A3.1-7). The majority of detections at all depth intervals for organics except DBCP are less than 100 µg/g. DBCP and OCPs exhibit the highest concentrations, with some occurrences at levels greater than 10,000 µg/g. The highest concentrations occur in the 5- to 20-ft interval for all analyte groups except ICP metals. Relatively few detections of volatiles, OPHGBs, DBCP, OCPs, and ICP metals are present at depths greater than 20 ft.

A3.1.1.8. Surficial Soil and Other Predominantly Near-Surface Contamination

This group of 11 designated sites and the surficial (0- to 2-inch depth) soils throughout RMA represent secondary sources of contamination resulting from a number of transport mechanisms. The bulk of the surficial soil and most of the designated sites, including areas adjacent to Basin A, Basin F, and sites within South Plants, are inferred to have been contaminated by windblown materials. Contaminants sorbed to soil particles were dispersed from sparsely vegetated areas during periods of high winds, or from wastewater aerosols. While all analyte groups except ONCs were detected in this site type, contamination conditions are characterized primarily by near-surface soil contamination of OCPs, ICP metals, and mercury (Figure RISR A3.1-10 and Table RISR A3.1-8). These analytes typically exhibit low mobility, tend to bind strongly to soil particles, and resist transport by solution or volatilization. VHOs, VHCs, and VAOs are most prevalent in the deeper intervals. The majority of detections for all analyte groups are less than 100 µg/g. Only organic analytes within the OPHGB (one hit) and OCP groups exhibit concentrations greater than 1,000 µg/g, and these occur only in the 0- to 2-ft and 2- to 5-ft depth intervals, respectively. ICP metals and very sporadic arsenic and mercury detections exceeded 1,000 µg/g, principally in the 2- to 5-ft depth interval.

While this site type is predominantly characterized by windblown contamination, other spatially related sources of contamination are included, which accounts for the contamination

Table RISR A3.1-7 Summary of Analytical Results for Soils in Sewer Sites.

Total Bores Sampled: 258
Total Samples Collected: 526

		Concentration		Detections (µg/g)					
Analytical Groups and Analytes Detected	Frequency of Detections	Range (µg/g)	CRL Range‡ (µg/g)	Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	Adjusted Geometric Mean
Volatile Halogenated Organics (VHOs)									
1,1-Dichloroethane	0/288	---	0.074-2.0	---	---	---	---	---	---
1,2-Dichloroethane	1/288	40	0.085-1.9	NC	NC	NC	NC	NC	NC
1,1-Dichloroethylene	0/21	---	0.24	---	---	---	---	---	---
trans-1,2-Dichloroethylene	0/287	---	0.25-2.2	---	---	---	---	---	---
1,1,2,2-Tetrachloroethane*†	1/5	0.5	0.3-0.65	NC	NC	NC	NC	NC	NC
1,1,1-Trichloroethane	2/290	0.46-2.0	0.088-1.1	NC	NC	NC	NC	NC	NC
1,1,2-Trichloroethane	1/289	0.81	0.25-39	NC	NC	NC	NC	NC	NC
Carbon tetrachloride	32/297	0.36-200	0.12-1.2	10	27	47	9.4	1.5	1.0
Chlorobenzene	9/288	2.0-21	0.20-3.0	5.3	8.4	6.8	6.2	0.85	0.19
Chloroform	45/301	0.84-350	0.068-1.3	5.0	20	53	6.6	1.3	0.99
Methylene chloride	27/266	1.0-34	0.25-3.7	2.0	4.7	7.1	2.8	0.90	0.28
Tetrachloroethylene	35/291	0.25-86	0.25-25	4.0	10	16	3.9	1.5	0.47
Trichloroethylene	1/288	0.60	0.14-54	NC	NC	NC	NC	NC	NC
Trichloropropene*	NI	---	---	---	---	---	---	---	---
Volatile Hydrocarbons (VHCs)									
2-Butoxyethanol*	NI	---	---	---	---	---	---	---	---
4-Hydroxy-4-methyl-2-pentanone*	NI	---	---	---	---	---	---	---	---
1-Methyl-1,3-cyclopentadiene*	NI	---	---	---	---	---	---	---	---
2,2-Oxybisethanol*	1/1	2	0.3	NC	NC	NC	NC	NC	NC
2-Pentanone*	NI	---	---	---	---	---	---	---	---
Bicycloheptadiene	27/276	0.71-72	0.25-5.1	10	13	16	6.9	1.2	0.68
Dicyclopentadiene	5/672	1.9-8.4	0.26-2,000	3.4	5.1	3.1	4.3	0.65	0.032
Methylcyclohexane*	NI	---	---	---	---	---	---	---	---
Methylisobutyl ketone	3/268	4.5-10	0.30-73	7.0	NC	NC	NC	NC	NC

‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard Deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
† Typically TIC; but target compound of some special investigations.
** Reported as total xylenes
NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.
NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

Table RISR A3.1-7 Summary of Analytical Results for Soils in Sewer Sites.

Total Bores Sampled: 258
Total Samples Collected: 526

				Detections (µg/g)					
Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	Adjusted Geometric Mean
Volatile Aromatic Organics (VAOs)									
Benzene	6/288	0.98-17	0.085-25	1.7	4.5	6.3	2.5	1.1	0.052
Ethylbenzene	2/287	2.5-20	0.16-1.6	NC	NC	NC	NC	NC	NC
m-Xylene	13/289	0.94-99	0.25-1.4	3.0	13	27	4.5	1.4	0.20
o- and p-Xylene**	4/288	8.9-50	0.30-5.0	31	30	18	25	0.77	0.35
Toluene	30/297	0.36-300	0.19-25	25	50	78	17	1.8	1.7
Organosulfur Compounds, Mustard-Agent Related (OSCMs)									
1,4-Oxathiane	0/442	---	0.25-30,000	---	---	---	---	---	---
Chloroacetic acid	1/199	232	18-36	NC	NC	NC	NC	NC	NC
Dithiane	0/442	---	0.25-40,000	---	---	---	---	---	---
Thiodiglycol	2/216	3.2-14	2.6-42	NC	NC	NC	NC	NC	NC
Organosulfur Compounds, Herbicide Related (OSCHs)									
Benzothiazole	0/1	---	1.1	---	---	---	---	---	---
Chlorophenylmethyl sulfide	0/443	---	0.25-20,000	---	---	---	---	---	---
Chlorophenylmethyl sulfone	4/442	0.30-0.90	0.25-3,000	0.65	0.63	0.25	0.58	0.47	0.0053
Chlorophenylmethyl sulfoxide	0/444	---	0.25-40,000	---	---	---	---	---	---
Dimethyldisulfide	1/268	20	0.25-20	NC	NC	NC	NC	NC	NC

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‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard Deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
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				Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	Adjusted Geometric Mean
Organophosphorous Compounds, GB-Agent Related (OPHGBs)									
Diisopropylmethyl phosphonate	10/465	0.50-3.0	0.05-2,000	0.74	1.1	0.81	0.89	0.53	0.019
Dimethylmethyl phosphonate	0/163	---	0.05-3.0	---	---	---	---	---	---
Isopropylmethyl phosphonic acid	0/83	---	2.1-4.7	---	---	---	---	---	---
Methylphosphonic acid	0/9	---	2.0	---	---	---	---	---	---
Phosphoric acid, tributyl ester*	NI	---	---	---	---	---	---	---	---
Phosphoric acid, triphenyl ester*	NI	---	---	---	---	---	---	---	---
Organophosphorous Compounds, Pesticide Related (OPHPs)									
Atrazine	1/433	4.0	0.25-2,000	NC	NC	NC	NC	NC	NC
Malathion	0/433	---	0.30-2,000	---	---	---	---	---	---
Parathion	3/435	20-25	0.40-2,000	25	NC	NC	NC	NC	NC
Supona	13/435	0.70-25	0.30-2,000	3.0	7.6	9.2	4.0	1.2	0.12
Vapona	0/435	---	0.25-2,000	---	---	---	---	---	---
Dibromochloropropane (DBCP)	74/765	0.0055-32,000	0.0050-200	77	1800	4,700	96	3.0	9.3
Organonitrogen Compounds (ONCs)									
Caprolactam*	NI	---	---	---	---	---	---	---	---
Hydrazine	NA	---	---	---	---	---	---	---	---
Methylhydrazine	NA	---	---	---	---	---	---	---	---
n-Nitrosodimethylamine	0/5	---	1.8	---	---	---	---	---	---
n-Nitrosodi-n-propylamine	NA	---	---	---	---	---	---	---	---
Unsymmetrical dimethylhydrazine	NA	---	---	---	---	---	---	---	---

‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard Deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
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Table RISR A3.1-7 Summary of Analytical Results for Soils in Sewer Sites.

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				Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	
Fluoroacetic Acid	0/9	---	2.0	---	---	---	---	---	---
Polynuclear Aromatic Hydrocarbons (PAHs)									
Fluoranthene*	NI	---	---	---	---	---	---	---	---
Methyl naphthalene*	NI	---	---	---	---	---	---	---	---
Phenanthrene*	NI	---	---	---	---	---	---	---	---
Pyrene*	1/1	0.9	0.3	NC	NC	NC	NC	NC	NC
Semivolatile Halogenated Organics (SHOs)									
Hexachlorobenzene*	NI	---	---	---	---	---	---	---	---
Hexachlorobutadiene*	NI	---	---	---	---	---	---	---	---
Hexachlorocyclopentadiene	21/504	0.70-4,000	0.0018-2,000	25	490	1100	46	2.4	1.9
Pentachlorobenzene*	3/3	4-30	0.3	9	NC	NC	NC	NC	NC
Tetrachlorobenzene*	2/2	1-2	0.3	NC	NC	NC	NC	NC	NC
Trichlorobenzene*	NI	---	---	---	---	---	---	---	---
Organochlorine Pesticides (OCPs)									
Aldrin	91/529	0.0030-40,000	0.0018-30	7.0	1300	5,500	7.4	3.9	1.3
Chlordane	1/497	0.11	0.023-3,000	NC	NC	NC	NC	NC	NC
Dichlorodiphenylethane (DDE)	17/510	0.0021-7.0	0.0010-2,000	0.012	1.2	1.9	0.065	3.1	0.0022
Dichlorodiphenyltrichloroethane (DDT)	29/515	0.0027-500	0.0023-3,000	9.6	31	92	1.7	3.8	0.093
Dieldrin	104/518	0.0014-200	0.0012-2,000	1.1	10	28	0.89	2.6	0.18
Endrin	45/521	0.0013-9.0	0.0010-2,000	0.58	1.6	2.5	0.19	2.9	0.017
Isodrin	57/525	0.0049-1,000	0.0011-2,000	7.0	51	150	3.4	3.0	0.37

‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard Deviation of log values (base e) of detections
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** Reported as total xylenes
NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.
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Table RISR A3.1-7 Summary of Analytical Results for Soils in Sewer Sites.

Total Bores Sampled: 258
Total Samples Collected: 526

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g)					Adjusted Geometric Mean
				Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	
Arsenic	99/377	2.9-740	2.5-26	5.1	31	89	8.4	1.3	2.2
Mercury	78/429	0.053-10	0.037-0.51	0.17	0.81	1.9	0.24	1.4	0.044
ICP Metals									
Cadmium	23/454	1.1-34	0.51-1.7	3.1	5.2	6.7	3.5	0.81	0.18
Chromium	348/452	6.3-120	5.2-12	14	16	9.1	7.7	0.38	5.9
Copper	424/454	5.3-1,500	4.7-37	15	26	77	5.3	0.68	5.0
Lead	120/452	8.4-640	8.4-17	20	38	82	24	0.71	6.3
Zinc	436/452	12-1,000	8.7-28	53	69	76	5.1	0.51	4.9

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Table RISR A3.1-8 Summary of Analytical Results for Soils in Surficial Soil and Other Predominantly Near-Surface Contamination Sites.

Total Bores Sampled: 350
Total Samples Collected: 892

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g)					Adjusted Geometric Mean
				Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	
Volatile Halogenated Organics (VHOs)									
1,1-Dichloroethane	0/354	---	0.074-4.8	---	---	---	---	---	---
1,2-Dichloroethane	0/354	---	0.080-5.7	---	---	---	---	---	---
1,1-Dichloroethylene	0/24	---	0.12-0.24	---	---	---	---	---	---
trans-1,2-Dichloroethylene	0/354	---	0.15-6.6	---	---	---	---	---	---
1,1,2,2-Tetrachloroethane*†	5/51	NC-1.0	0.3-0.65	NC	NC	NC	NC	NC	NC
1,1,1-Trichloroethane	3/354	0.47-4.0	0.088-3.3	0.50	NC	NC	NC	NC	NC
1,1,2-Trichloroethane	0/354	---	0.12-3.6	---	---	---	---	---	---
Carbon tetrachloride	0/354	---	0.25-3.6	---	---	---	---	---	---
Chlorobenzene	0/351	---	0.18-3.9	---	---	---	---	---	---
Chloroform	2/354	1.0-2.1	0.068-3.9	NC	NC	NC	NC	NC	NC
Methylene chloride	43/346	0.42-19	0.15-39	2.4	3.5	3.6	2.5	0.85	0.31
Tetrachloroethylene	7/354	0.25-1.0	0.12-3.6	0.60	0.56	.27	0.51	0.50	0.010
Trichloroethylene	1/354	0.45	0.090-3.0	NC	NC	NC	NC	NC	NC
Trichloropropene*	1/1	NC	0.3	NC	NC	NC	NC	NC	NC
Volatile Hydrocarbons (VHCs)									
2-Butoxyethanol*	NI	---	---	---	---	---	---	---	---
4-Hydroxy-4-methyl-2-pentanone*	6/6	NC-1.0	0.3	NC	NC	NC	NC	NC	NC
1-Methyl-1,3-cyclopentadiene*	2/2	NC	0.3	NC	NC	NC	NC	NC	NC
2,2-Oxybisethanol*	1/1	0.70	0.3	NC	NC	NC	NC	NC	NC
2-Pentanone*	1/1	NC	0.3	NC	NC	NC	NC	NC	NC
Bicycloheptadiene	4/417	1.0-20	0.25-5.1	2.0	6.3	9.2	2.8	1.4	0.027
Dicyclopentadiene	8/1126	2.0-20	0.26-2,000	7.3	9.3	7.0	7.1	0.82	0.051
Methylcyclohexane*	NI	---	---	---	---	---	---	---	---
Methylisobutyl ketone	4/417	0.90-30	0.30-7.2	5.7	11	14	4.4	1.7	0.042

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Δ Standard Deviation of log values (base e) of detections
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Volatile Aromatic Organics (VAOs)									
Benzene	8/377	0.89-20	0.081-4.2	3.6	7.3	8.2	3.9	1.3	0.082
Ethylbenzene	1/377	0.90	0.043-4.8	NC	NC	NC	NC	NC	NC
m-Xylene	1/377	0.90	0.053-6.0	NC	NC	NC	NC	NC	NC
o- and p-Xylene**	1/377	0.40	0.086-7.8	NC	NC	NC	NC	NC	NC
Toluene	4/377	0.60-30	0.096-6.0	1.3	8.3	14	2.1	1.8	0.023
Organosulfur Compounds, Mustard-Agent Related (OSCMs)									
1,4-Oxathiane	0/867	---	0.25-2,400	---	---	---	---	---	---
Chloroacetic acid	2/78	80-210	18-36	NC	NC	NC	NC	NC	NC
Dithiane	0/867	---	0.25-2,600	---	---	---	---	---	---
Thiodiglycol	2/78	5.6-14	2.6-4.2	NC	NC	NC	NC	NC	NC
Organosulfur Compounds, Herbicide Related (OSCHs)									
Benzothiazole	0/95	---	1.1-11	---	---	---	---	---	---
Chlorophenylmethyl sulfide	0/867	---	0.25-2,600	---	---	---	---	---	---
Chlorophenylmethyl sulfone	8/867	0.28-10	0.25-740	3.7	4.0	3.6	2.2	1.4	0.024
Chlorophenylmethyl sulfoxide	2/867	2.4-5.9	0.25-1,700	NC	NC	NC	NC	NC	NC
Dimethyldisulfide	0/426	---	0.25-20	---	---	---	---	---	---

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				Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	
Organophosphorous Compounds, GB-Agent Related (OPHGBs)									
Diisopropylmethyl phosphonate	3/893	0.13-2.4	0.050-700	1.9	NC	NC	NC	NC	NC
Dimethylmethyl phosphonate	0/383	---	0.050-1,200	---	---	---	---	---	---
Isopropylmethyl phosphonic acid	7/74	27-1,100	2.1-4.7	130	270	380	130	1.3	12
Methylphosphonic acid	1/25	5.0	2.0	NC	NC	NC	NC	NC	NC
Phosphoric acid, tributyl ester*	NI	--	---	--	---	---	--	---	--
Phosphoric acid, triphenyl ester*	NI	--	---	--	---	---	--	---	--
Organophosphorous Compounds, Pesticide Related (OPHPs)									
Atrazine	0/772	---	0.25-760	---	---	---	---	---	---
Malathion	0/772	---	0.30-600	---	---	---	---	---	---
Parathion	0/772	---	0.30-1,200	---	---	---	---	---	---
Supona	1/772	20.00	0.30-1,200	NC	NC	NC	NC	NC	NC
Vapona	0/772	---	0.25-2,600	---	---	---	---	---	---
Dibromochloropropane (DBCP)	6/1261	0.0086-0.072	0.0050-2,600	0.030	0.03	0.023	0.026	0.78	0.00014
Organonitrogen Compounds (ONCs)									
Caprolactam*	NI	--	---	---	---	---	---	---	---
Hydrazine	0/6	---	50	---	---	---	---	---	---
Methylhydrazine	0/6	---	200	---	---	---	---	---	---
n-Nitrosodimethylamine	0/99	---	0.26-3,600	---	---	---	---	---	---
n-Nitrosodi-n-propylamine	0/6	---	0.10	---	---	---	---	---	---
Unsymmetrical dimethylhydrazine	0/6	---	200	---	---	---	---	---	---

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‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.

Δ Standard Deviation of log values (base e) of detections

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Total Bores Sampled: 350
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Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g) Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	Adjusted Geometric Mean
Fluoroacetic Acid									
	7/25	2.3-6.9	2.0	2.97	3.6	1.6	3.4	0.38	0.94
Polynuclear Aromatic Hydrocarbons (PAHs)									
Fluoranthene*	5/5	NC	0.3	NC	NC	NC	NC	NC	NC
Methyl naphthalene*	2/2	NC-0.9	0.3	NC	NC	NC	NC	NC	NC
Phenanthrene*	2/2	NC-0.7	0.3	NC	NC	NC	NC	NC	NC
Pyrene*	9/9	NC-3	0.3	NC	NC	NC	NC	NC	NC
Semivolatile Halogenated Organics (SHOs)									
Hexachlorobenzene*	NI	---	0.3	---	---	---	---	---	---
Hexachlorobutadiene*	NI	---	0.3	---	---	---	---	---	---
Hexachlorocyclopentadiene	22/1151	0.0018-40	0.0014-2,800	0.0057	2.3	8.51	0.028	3.0	0.0005
Pentachlorobenzene*	NI	---	0.3	---	---	---	---	---	---
Tetrachlorobenzene*	NI	---	0.3	---	---	---	---	---	---
Trichlorobenzene*	NI	---	0.3	---	---	---	---	---	---
Organochlorine Pesticides (OCPs)									
Aldrin	290/1239	0.0024-13,000	0.0018-3.0	0.015	85	870	0.043	2.8	0.010
Chlordane	63/1190	0.021-33	0.014-4,700	0.11	2.1	5.8	0.19	2.0	0.0099
Dichlorodiphenylethane (DDE)	56/1239	0.0026-1.0	0.0010-500	0.013	0.08	0.18	0.021	1.5	0.0010
Dichlorodiphenyltrichloroethane (DDT)	132/1239	0.0024-55	0.0020-920	0.0098	0.51	4.8	0.015	1.6	0.0016
Dieldrin	465/1239	0.0014-2,300	0.0012-500	0.11	16	150	0.14	2.5	0.0053
Endrin	234/1235	0.0014-80	0.0010-1,500	0.020	0.96	7.1	0.031	1.9	0.0059
Isodrin	98/1239	0.0017-56	0.0011-500	0.0061	1.0	5.9	0.017	2.4	0.0014

---

‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard Deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
† Typically TIC; but target compound of some special investigations.
** Reported as total xylenes
NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.
NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

Table RISR A3.1-8 Summary of Analytical Results for Soils in Surficial Soil and Other Predominantly Near-Surface Contamination Sites.

Total Bores Sampled: 350
Total Samples Collected: 892

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g)					Adjusted Geometric Mean
				Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	
Arsenic	164/679	1.3-49,000	0.91-5.2	4.0	430	4200	4.7	1.2	1.1
Mercury	143/735	0.028-6,100	0.027-1.6	0.12	47	510	0.17	1.6	0.034
ICP Metals									
Cadmium	23/651	0.72-1,900	0.31-74	2.5	85	400	3.1	1.6	0.11
Chromium	435/651	5.9-3,500	5.2-36	12	23	170	5.1	0.50	3.4
Copper	563/650	5.2-2,100	3.4-4.9	12	25	100	3.5	0.75	3.1
Lead	225/649	9.0-5,400	8.4-84	19	85	510	23	0.87	7.9
Zinc	635/651	13-1,600	8.7-28	44	59	110	3.1	0.56	3.0

---

‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.

Δ Standard Deviation of log values (base e) of detections

* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.

† Typically TIC; but target compound of some special investigations.

** Reported as total xylenes

NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.

NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

observed at depth. Deeper contamination at these sites is generally not attributed to eolian transport. These contaminants are believed to have migrated vertically or laterally through the soil column or underlying aquifer by a wide variety of surface water infiltration, groundwater, or vapor phase transport mechanisms. Some migration of OCPs by infiltration of rainwater, snowmelt, or other surface moisture may account for the limited detections at depths greater than 0- to 2-ft. In addition, a special study of surficial (0-2 inch depth) soils conducted after completion of the SARs found widespread low-level OCP contamination. Results of that study are incorporated into Figure RISR A3.1-10 and Table RISR A3.1-8, and are summarized in Appendix D of this report. The findings of the surficial soil study have been previously presented in the Final Surficial Soil Data Summary (EBASCO, 1991/RIC 91121R01).

A3.1.1.9 Isolated Contamination

The RI identified 38 isolated areas of contamination that are not associated with known activity on RMA. These isolated occurrences are not associated with source areas and are generally attributed to naturally occurring constituents, or to sampling or analytical artifacts. Occurrences of OPHGBs, DBCP, fluoroacetic acid, PAHs, and OCPs at low concentrations that do not appear to have resulted from the phenomena mentioned above are presumably residual concentrations from small, localized spills, anthropogenic transport, or wind dispersion.

The ICP metals, OPHGBs, and OCPs exhibit the highest percentage of detections at areas of isolated contamination (Figure RISR A3.1-11 and Table RISR A3.1-9). The majority of the detections occur in the 0- to 2-ft and 2- to 5-ft depth intervals. For all depth intervals, most of the analyte concentrations are within the lowest concentration range. The ICP metals exhibited the highest concentrations for this site type; between 100 and 1,000 µg/g for the sum of the five ICP metals. Only the VHO and ICP metals analyte groups are present within this site type at depths greater than 20-ft.

Table RISR A3.1-9 Summary of Analytical Results for Soils in Areas of Isolated Contamination.

Total Bores Sampled: 84
Total Samples Collected: 224

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g)					Adjusted Geometric Mean
				Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	
Volatile Halogenated Organics (VHOs)									
1,1-Dichloroethane	0/64	---	0.074-2.0	---	---	---	---	---	---
1,2-Dichloroethane	0/64	---	0.085-0.60	---	---	---	---	---	---
1,1-Dichloroethylene	0/15	---	0.24	---	---	---	---	---	---
trans-1,2-Dichloroethylene	0/64	---	0.25-2.0	---	---	---	---	---	---
1,1,2,2-Tetrachloroethane*	NI	---	---	---	---	---	---	---	---
1,1,1-Trichloroethane	0/64	---	0.088-0.50	---	---	---	---	---	---
1,1,2-Trichloroethane	0/64	---	0.25-0.60	---	---	---	---	---	---
Carbon tetrachloride	0/64	---	0.12-0.40	---	---	---	---	---	---
Chlorobenzene	0/64	---	0.20-1.5	---	---	---	---	---	---
Chloroform	0/64	---	0.068-0.70	---	---	---	---	---	---
Methylene chloride	8/63	1.0-5.0	0.25-3.7	2.0	2.4	1.3	2.1	0.55	0.27
Tetrachloroethylene	0/64	---	0.25-0.50	---	---	---	---	---	---
Trichloroethylene	0/64	---	0.14-0.60	---	---	---	---	---	---
Trichloropropene*	NI	---	---	---	---	---	---	---	---
Volatile Hydrocarbons (VHCs)									
2-Butoxyethanol*	NI	---	---	---	---	---	---	---	---
4-Hydroxy-4-methyl-2-pentanone*	NI	---	---	---	---	---	---	---	---
1-Methyl-1,3-cyclopentadiene*	NI	---	---	---	---	---	---	---	---
2,2-Oxybisethanol*	5/5	0.2-0.9	0.3	0.5	0.48	0.3	0.4	0.57	0.4
2-Pentanone*	1/1	3.0	0.3	NC	NC	NC	NC	NC	NC
Bicycloheptadiene	0/49	---	0.25-0.80	---	---	---	---	---	---
Dicyclopentadiene	0/161	---	0.26-6.0	---	---	---	---	---	---
Methylcyclohexane*	2/2	NC	0.3	NC	NC	NC	NC	NC	NC
Methylisobutyl ketone	1/58	1.00	0.30-0.73	NC	NC	NC	NC	NC	NC

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‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.

Δ Standard Deviation of log values (base e) of detections

* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.

† Typically TIC; but target compound of some special investigations.

** Reported as total xylenes

NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.

NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

Table RISR A3.1-9 Summary of Analytical Results for Soils in Areas of Isolated Contamination.

Total Bores Sampled: 84
Total Samples Collected: 224

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g)					Adjusted Geometric Mean
				Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	
Volatile Aromatic Organics (VAOs)									
Benzene	0/49	---	0.25-1.0	---	---	---	---	---	---
Ethylbenzene	0/49	---	0.25-0.40	---	---	---	---	---	---
m-Xylene	0/49	---	0.25-0.80	---	---	---	---	---	---
o- and p-Xylene**	0/49	---	0.30-5.0	---	---	---	---	---	---
Toluene	0/49	---	0.25-0.30	---	---	---	---	---	---
Organosulfur Compounds, Mustard-Agent Related (OSCMs)									
1,4-Oxathiane	0/115	---	0.26-6.0	---	---	---	---	---	---
Chloroacetic acid	0/12	---	18-36	---	---	---	---	---	---
Dithiane	0/115	---	0.25-7.0	---	---	---	---	---	---
Thiodiglycol	0/12	---	2.6-4.2	---	---	---	---	---	---
Organosulfur Compounds, Herbicide Related (OSCHs)									
Benzothiazole	NA	---	---	---	---	---	---	---	---
Chlorophenylmethyl sulfide	0/115	---	0.25-4.0	---	---	---	---	---	---
Chlorophenylmethyl sulfone	0/115	---	0.29-0.60	---	---	---	---	---	---
Chlorophenylmethyl sulfoxide	0/115	---	0.30-7.0	---	---	---	---	---	---
Dimethyldisulfide	0/49	---	0.25-20	---	---	---	---	---	---

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‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard Deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
† Typically TIC; but target compound of some special investigations.
** Reported as total xylenes
NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.
NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

Total Bores Sampled: 84
Total Samples Collected: 224

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g) Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	Adjusted Geometric Mean
Organophosphorous Compounds, GB-Agent Related (OPHGBs)									
Diisopropylmethyl phosphonate	8/135	0.14-0.86	0.05-3.00	0.40	0.46	0.26	0.39	0.63	0.023
Dimethylmethyl phosphonate	0/58	---	0.05-3.00	---	---	---	---	---	---
Isopropylmethyl phosphonic acid	0/12	---	2.1-4.70	---	---	---	---	---	---
Methylphosphonic acid	0/4	---	2.0	---	---	---	---	---	---
Phosphoric acid, tributyl ester*	4/4	NC	0.3	NC	NC	NC	NC	NC	NC
Phosphoric acid, triphenyl ester*	NI	---	---	---	---	---	---	---	---
Organophosphorous Compounds, Pesticide Related (OPHPs)									
Atrazine	0/115	---	0.30-0.73	---	---	---	---	---	---
Malathion	0/115	---	0.30-2.0	---	---	---	---	---	---
Parathion	0/115	---	0.40-2.0	---	---	---	---	---	---
Supona	0/115	---	0.30-0.90	---	---	---	---	---	---
Vapona	0/115	---	0.25-3.0	---	---	---	---	---	---
Dibromochloropropane (DBCP)	1/191	0.050	0.0050-2.4	NC	NC	NC	NC	NC	NC
Organonitrogen Compounds (ONCs)									
Caprolactam*	NI	---	---	---	---	---	---	---	---
Hydrazine	NA	---	---	---	---	---	---	---	---
Methylhydrazine	NA	---	---	---	---	---	---	---	---
n-Nitrosodimethylamine	NA	---	---	---	---	---	---	---	---
n-Nitrosodi-n-propylamine	NA	---	---	---	---	---	---	---	---
Unsymmetrical dimethylhydrazine	NA	---	---	---	---	---	---	---	---

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‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.

Δ Standard Deviation of log values (base e) of detections

* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.

† Typically TIC; but target compound of some special investigations.

** Reported as total xylenes

NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.

NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

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Table RISR A3.1-9 Summary of Analytical Results for Soils in Areas of Isolated Contamination.

Total Bores Sampled: 84
Total Samples Collected: 224

				Detections (µg/g)					
Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	Adjusted Geometric Mean
Fluoroacetic Acid	2/4	3.7-8.3	2.0	NC	NC	NC	NC	NC	NC
Polynuclear Aromatic Hydrocarbons (PAHs)									
Fluoranthene*	NI	---	---	---	---	---	---	---	---
Methyl naphthalene*	1/1	0.7	0.3	NC	NC	NC	NC	NC	NC
Phenanthrene*	NI	---	---	---	---	---	---	---	---
Pyrene*	NI	---	---	---	---	---	---	---	---
Semivolatile Halogenated Organics (SHOs)									
Hexachlorobenzene*	NI	---	---	---	---	---	---	---	---
Hexachlorobutadiene*	NI	---	---	---	---	---	---	---	---
Hexachlorocyclopentadiene	1/99	0.80	0.0018-1.1	NC	NC	NC	NC	NC	NC
Pentachlorobenzene*	NI	---	---	---	---	---	---	---	---
Tetrachlorobenzene*	NI	---	---	---	---	---	---	---	---
Trichlorobenzene*	NI	---	---	---	---	---	---	---	---
Organochlorine Pesticides (OCPs)									
Aldrin	2/117	0.016-1.9	0.0019-0.94	NC	NC	NC	NC	NC	NC
Chlordane	1/99	0.094	0.023-6.0	NC	NC	NC	NC	NC	NC
Dichlorodiphenylethane (DDE)	1/117	0.012	0.0024-0.60	NC	NC	NC	NC	NC	NC
Dichlorodiphenyltrichloroethane (DDT)	1/117	0.031	0.0020-2.0	NC	NC	NC	NC	NC	NC
Dieldrin	4/117	0.46-7.4	0.0033-0.60	0.82	2.4	3.4	1.2	1.3	0.040
Endrin	1/117	0.058	0.0058-4.0	NC	NC	NC	NC	NC	NC
Isodrin	0/117	---	0.0011-0.60	---	---	---	---	---	---

‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard Deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
† Typically TIC; but target compound of some special investigations.
** Reported as total xylenes
NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.
NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

Table RISR A3.1-9 Summary of Analytical Results for Soils in Areas of Isolated Contamination.

Total Bores Sampled: 84
Total Samples Collected: 224

				Detections (µg/g)					
Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	Adjusted Geometric Mean
Arsenic	18/122	3.1-44	2.0-5.2	5.8	8.8	9.3	6.9	0.61	1.0
Mercury	8/115	0.052-0.20	0.050-0.070	0.094	0.11	0.056	0.099	0.51	0.0069
ICP Metals									
Cadmium	10/123	0.96-6.5	0.51-0.92	2.8	2.8	1.8	2.2	0.70	0.18
Chromium	77/123	6.2-57	5.2-7.4	13	14	7.5	13	0.41	8.3
Copper	96/123	5.8-81	4.7-4.9	11	15	13	12	0.59	9.7
Lead	50/123	12-120	8.4-17	20	24	17	21	0.45	8.5
Zinc	121/123	11-350	28	40	45	36	38	0.58	37

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‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard Deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
† Typically TIC; but target compound of some special investigations.
** Reported as total xylenes
NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.
NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

A3.1.1.10 Balance of Areas Investigated

In addition to the nine site types discussed above, a number of analyte detections exist that do not indicate the presence of RMA contamination. These detections consist almost entirely of ICP metals, as shown in Figure RISR A3.1-12 and Table RISR A3.1-10. VHOs and VHCs are the only organic analyte groups detected. The primary VHO is methylene chloride, which generally has been verified as a laboratory artifact by its parallel occurrence in laboratory blanks. The VHCs consist of oxybisethanol, an antifreeze that was accidentally introduced to sampled soils during the cold weather sampling. The ICP metals detections are considered naturally occurring background concentrations that are locally elevated in soil or bedrock. Sporadic arsenic and mercury detections above IR may also be locally elevated natural occurrences.

A3.1.2 Contaminant Distribution by Depth

Contaminant distribution maps for five depth intervals are presented in order to describe the extent of contamination at depth. Variations with depth are primarily due to individual contaminant mobilities, available transport and attenuation mechanisms, and volumes or concentrations of contaminants released to the environment. Analytical results of sediment collected from within the sewer and process water lines are shown on a distribution map at the end of the section. The limited data for sewers contents did not warrant compilation of summary tables or histograms.

The distribution of organic and inorganic contaminants in soil at RMA occurs at highest concentrations within the central sections of RMA, where manufacturing and disposal activities have been focused throughout RMA history. Surficial disposal and eolian redistribution have resulted in widespread, generally low concentration occurrences of OCPs and inorganic analytes in shallow or surficial soils. These analytes typically exhibit relatively low environmental mobility, as described in Appendix E. The past disposal of various materials and wastes in open trenches has contributed to organic and inorganic soil

Table RISR A3.1-10 Summary of Analytical Results for Soils in the Balance of Areas Investigated.

Total Bores Sampled: 1,196
Total Samples Collected: 1,765

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g)					Adjusted Geometric Mean
				Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	
Volatile Halogenated Organics (VHOs)									
1,1-Dichloroethane	0/305	---	0.074-8.0	---	---	---	---	---	---
1,2-Dichloroethane	0/305	---	0.085-9.5	---	---	---	---	---	---
1,1-Dichloroethylene	0/16	---	0.24	---	---	---	---	---	---
trans-1,2-Dichloroethylene	0/301	---	0.25-11	---	---	---	---	---	---
1,1,2,2-Tetrachloroethane*†	5/25	NC-2	0.3-0.65	NC	NC	NC	NC	NC	NC
1,1,1-Trichloroethane	0/305	---	0.088-5.5	---	---	---	---	---	---
1,1,2-Trichloroethane	0/305	---	0.25-6.0	---	---	---	---	---	---
Carbon tetrachloride	0/306	---	0.12-6.0	---	---	---	---	---	---
Chlorobenzene	0/305	---	0.20-6.5	---	---	---	---	---	---
Chloroform	0/305	---	0.068-6.5	---	---	---	---	---	---
Methylene chloride	3/283	2.0-5.1	0.25-13	3.0	NC	NC	NC	NC	NC
Tetrachloroethylene	0/305	---	0.25-6.0	---	---	---	---	---	---
Trichloroethylene	0/305	---	0.14-5.0	---	---	---	---	---	---
Trichloropropene*	NI	---	---	---	---	---	---	---	---
Volatile Hydrocarbons (VHCs)									
2-Butoxyethanol*	NI	---	---	---	---	---	---	---	---
4-Hydroxy-4-methyl-2-pentanone*	NI	---	---	---	---	---	---	---	---
1-Methyl-1,3-cyclopentadiene*	NI	---	---	---	---	---	---	---	---
2,2-Oxybisethanol*	23/23	0.3-4	0.3	0.6	1.0	0.9	0.7	0.75	0.7
2-Pentanone*	NI	---	---	---	---	---	---	---	---
Bicycloheptadiene	0/290	---	0.25-7.0	---	---	---	---	---	---
Dicyclopentadiene	0/1,746	---	0.26-6.0	---	---	---	---	---	---
Methylcyclohexane*	NI	---	---	---	---	---	---	---	---
Methylisobutyl ketone	0/291	---	0.30-12	---	---	---	---	---	---

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‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard Deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
† Typically TIC; but target compound of some special investigations.
** Reported as total xylenes
NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.
NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

Total Bores Sampled: 1,196
Total Samples Collected: 1,765

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g) Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	Adjusted Geometric Mean
Volatile Aromatic Organics (VAOs)									
Benzene	0/314	---	0.081-7.0	---	---	---	---	---	---
Ethylbenzene	0/313	---	0.043-8.0	---	---	---	---	---	---
m-Xylene	0/314	---	0.053-7.0	---	---	---	---	---	---
o- and p-Xylene**	0/315	---	0.086-13	---	---	---	---	---	---
Toluene	0/314	---	0.096-5.5	---	---	---	---	---	---
Organosulfur Compounds, Mustard-Agent Related (OSCMs)									
1,4-Oxathiane	0/1,530	---	0.25-6.0	---	---	---	---	---	---
Chloroacetic acid	0/90	---	18-35	---	---	---	---	---	---
Dithiane	0/1,530	---	0.25-7.0	---	---	---	---	---	---
Thiodiglycol	0/109	---	2.6-4.2	---	---	---	---	---	---
Organosulfur Compounds, Herbicide Related (OSCHs)									
Benzothiazole	0/1	---	1.1	---	---	---	---	---	---
Chlorophenylmethyl sulfide	0/1,533	---	0.25-4.0	---	---	---	---	---	---
Chlorophenylmethyl sulfone	0/1,531	---	0.25-2.4	---	---	---	---	---	---
Chlorophenylmethyl sulfoxide	0/1,530	---	0.25-70	---	---	---	---	---	---
Dimethyldisulfide	0/290	---	0.25-20	---	---	---	---	---	---

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‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard Deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
† Typically TIC; but target compound of some special investigations.
** Reported as total xylenes
NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.
NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

Table RISR A3.1-10 Summary of Analytical Results for Soils in the Balance of Areas Investigated.

Total Bores Sampled: 1,196
Total Samples Collected: 1,765

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/g)	CRL Range‡ (µg/g)	Detections (µg/g)					Adjusted Geometric Mean
				Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	
Organophosphorous Compounds, GB-Agent Related (OPHGBs)									
Diisopropylmethyl phosphonate	0/1,628	---	0.050 -3.0	---	---	---	---	---	---
Dimethylmethyl phosphonate	0/881	---	0.050-3.0	---	---	---	---	---	---
Isopropylmethyl phosphonic acid	0/94	---	2.1-4.7	---	---	---	---	---	---
Methylphosphonic acid	0/19	---	2.0-20	---	---	---	---	---	---
Phosphoric acid, tributyl ester*	NI	---	---	---	---	---	---	---	---
Phosphoric acid, triphenyl ester*	NI	---	---	---	---	---	---	---	---
Organophosphorous Compounds, Pesticide Related (OPHPs)									
Atrazine	0/1,522	---	0.25-3.0	---	---	---	---	---	---
Malathion	0/1,522	---	0.30-2.0	---	---	---	---	---	---
Parathion	0/1,523	---	0.40-2.0	---	---	---	---	---	---
Supona	0/1,523	---	0.30-1.0	---	---	---	---	---	---
Vapona	0/1,522	---	0.25-6.0	---	---	---	---	---	---
Dibromochloropropane (DBCP)	0/2,139	---	0.0050-2.4	---	---	---	---	---	---
Organonitrogen Compounds (ONCs)									
Caprolactam*	NI	---	---	---	---	---	---	---	---
Hydrazine	NA	---	---	---	---	---	---	---	---
Methylhydrazine	NA	---	---	---	---	---	---	---	---
n-Nitrosodimethylamine	0/33	---	1.8	---	---	---	---	---	---
n-Nitrosodi-n-propylamine	NA	---	---	---	---	---	---	---	---
Unsymmetrical dimethylhydrazine	NA	---	---	---	---	---	---	---	---

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‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard Deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
† Typically TIC; but target compound of some special investigations.
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				Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	
Fluoroacetic Acid	0/19	---	2.0	---	---	---	---	---	---
Polynuclear Aromatic Hydrocarbons (PAHs)									
Fluoranthene*	NI	---	---	---	---	---	---	---	---
Methyl naphthalene*	NI	---	---	---	---	---	---	---	---
Phenanthrene*	NI	---	---	---	---	---	---	---	---
Pyrene*	NI	---	---	---	---	---	---	---	---
Semivolatile Halogenated Organics (SHOs)									
Hexachlorobenzene*	NI	---	---	---	---	---	---	---	---
Hexachlorobutadiene*	NI	---	---	---	---	---	---	---	---
Hexachlorocyclopentadiene	0/1,143	---	0.0018-1.4	---	---	---	---	---	---
Pentachlorobenzene*	NI	---	---	---	---	---	---	---	---
Tetrachlorobenzene*	NI	---	---	---	---	---	---	---	---
Trichlorobenzene*	NI	---	---	---	---	---	---	---	---
Organochlorine Pesticides (OCPs)									
Aldrin	0/1,541	---	.0018-0.94	---	---	---	---	---	---
Chlordane	0/1,135	---	0.023-6.0	---	---	---	---	---	---
Dichlorodiphenylethane (DDE)	0/1,533	---	0.0010-1.0	---	---	---	---	---	---
Dichlorodiphenyltrichloroethane (DDT)	0/1,533	---	0.0020-2.0	---	---	---	---	---	---
Dieldrin	0/1,541	---	0.0012-0.80	---	---	---	---	---	---
Endrin	0/1,541	---	0.0010-4.0	---	---	---	---	---	---
Isodrin	0/1,542	---	0.0011-0.60	---	---	---	---	---	---

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‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard Deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
† Typically TIC; but target compound of some special investigations.
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				Median	Mean	Standard Deviation	Geometric Mean	Geometric Δ Std. Dev.	
Arsenic	180/1,561	2.3-50	2.0-110	5.2	5.5	4.0	4.9	0.43	0.56
Mercury	31/1,547	0.054-0.27	0.037-0.11	0.070	0.09	0.047	0.081	0.40	0.0016
ICP Metals									
Cadmium	41/1,540	0.73-6.6	0.31-1.7	1.5	2.0	1.2	1.7	0.55	0.046
Chromium	1,173/1,541	5.7-69	5.2-52	14	14	5.0	1.8	0.32	1.4
Copper	1,294/1,541	4.7-110	3.4-4.9	12	13	6.8	1.7	0.41	1.5
Lead	475/1,540	10-69	8.4-17	17	19	7.5	4.5	0.34	1.4
Zinc	1,444/1,542	11-470	8.7-28	42	44	20	1.6	0.40	1.5

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‡ Both lower and upper CRL range values may reflect sample dilution prior to analysis.
Δ Standard Deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target analyte status in the SARs; there is no CRL for TICs. For the purpose of this report, a CRL of 0.3 µg/g, typically corresponding to 10 percent of the internal standard, was used.
† Typically TIC; but target compound of some special investigations.
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NA - Not analyzed NI - Not identified NC - Not calculated, as sample population is too small, or TICs not sufficiently quantified to permit statistical manipulation.
NOTE: Two significant figures reported for target analytes; one significant figure reported for TICs.

contamination at intermediate depths. Infiltration of contaminated water, manufacturing products, and liquid wastes from sewers, basins, ditches, and spills is primarily responsible for contamination of soils at depth, including those in excess of 20 ft. For some of these analytes, such as VHOs, VHCs, VAOs, mustard-related organosulfur compounds (OSCMs), and some OSCHs and OPHGBs, transport is enhanced by their relatively high environmental mobility, which is described in Appendix E. Contaminant distributions in soils reflect the disposal history, contaminant behavior, and environmental conditions at RMA. All of these factors have been influential in controlling contaminant fate and transport, and thus the current nature and extent of contamination at RMA.

A series of maps depicting analyte occurrences at varying depths has been constructed to summarize the overall spatial distribution and relative concentration of soil contamination as discussed above. These maps were derived from data collected under Phases I and II of the RI program. The distribution of soil borings for the primary RI program is shown in Figure RISR A3.1-13. Maps of total organic and inorganic contaminant distribution were prepared for the depth intervals 0 to 2 ft, 2 to 5 ft, 5 to 20 ft, and greater than 20 ft using data generated during the RI, reported in the CARs and Phase II Data Addenda, and subsequently presented in the SARs (EBASCO, 1989a-c, e-h/RIC 89166R01 through 89166R07). For the majority of soil boring locations, the 0- to 2-ft depth interval is represented by a 0- to 1-ft sample, and the 2- to 5-ft depth interval is represented by a 4- to 5-ft sample. The 5- to 20-ft depth interval may include 9- to 10-ft, 14- to 15-ft, and 19- to 20-ft samples. At depths greater than 20 ft, samples were taken every 10 ft. These depth intervals are consistent with those presented in the SARs, and correspond to the depths used for the site type histograms discussed earlier in this section. Thus, these depth interval maps, the contaminant site type map (Figure RISR A3.1-1), and the histograms (Figures RISR A3.1-3 through A3.1.12) may be used in combination to examine the nature and lateral and vertical extent of contamination associated with a given site type.

On the depth maps discussed below, concentrations of organic and inorganic analytes were separately summed for each sample collected at each boring. It should be noted that typical concentrations encountered for many of the summed analytes may vary by one or more order of magnitude. Therefore, these total values should be viewed merely as general indications of contamination. The resulting sums were assigned to concentration ranges and are plotted in the accompanying maps. Where more than one sample was collected from within a depth interval, the sample with the highest total organic or inorganic concentration was plotted. The specific concentrations for each sample are presented in the CARs and the Phase II Data Addenda. In addition to the depth interval maps, supplementary maps indicating detections of arsenic, mercury, or ICP metals above their IRs have also been generated. These IRs range maps present data from all depths sampled within each boring, rather than considering a series of depth intervals. Each analyte-specific IR includes concentrations considered representative of naturally occurring conditions. For the ICP metals, the sampling location was plotted if the occurrence of any one of the metals was above its respective IR.

A3.1.2.1 Zero- to 2-ft Depth Interval

The distribution of total organic analytes in soils from 0 to 2 ft is shown in Figure RISR A3.1-14. Detectable organics at this depth occur primarily in the central portion of RMA within basins, lakes, ditches, solid waste disposal areas, and the North and South Plants manufacturing complexes. Shallow detections within the lakes are predominantly OCPs that have been transported by surface water to these areas. A greater number of detections in Lower Derby Lake, Upper Derby Lake, and the eastern part of Upper Derby Lake in Section 6 is probably a result of inflow from the South Plants process water system at the upstream end. High and very high total organics concentrations occur in Basin A, former Basin F, the lime settling basins, and the South Plants complex. Several samples exhibiting high concentrations were collected in the former Basin F area, the primary repository for North and South Plants aqueous wastes. A recent IRA designed as an interim remediation of Basin F has altered this site such that it is no longer a basin (Appendix C). The contaminant distribution that is displayed on maps within this report has been significantly altered as a result of that action. Basin F contamination in the near surface soils has been greatly reduced or eliminated. The radial pattern of detections around Basin F reflects sampling of shallow soils along prominent wind vectors. OCPs detected in this area are generally associated with wind-transported material. Detections of total organics outside of the central RMA area are generally at concentrations less than 10 µg/g, and include surface burn sites in Sections 19, 20, 29, and 30; toxic storage areas in Sections 5, 6, and 31; buried lake sediments in Section 12; the motor pool area and a sanitary landfill in Section 4; and well borings along the NBCS.

Total inorganic analyte in the 0- to 2-ft depth interval are widely distributed as shown in Figure RISR A3.1-15. However, on this and the other total inorganic analyte maps, the majority of the detectable concentrations are associated with sums of individual inorganic concentrations that are within or below their respective IRs and do not suggest contamination. Therefore, inorganic concentrations less than 200 µg/g may still be attributed to natural occurrences. High and very high concentrations of total inorganics occur in the central portion of RMA in Basin D and former Basin F, a solid waste disposal area east of Basin A; the North and South Plants manufacturing complexes; and intermittently along the Sand Creek Lateral. Other elevated total inorganic concentrations occur in burn pits in Section 32, a sanitary landfill and the motor pool area in Section 4, and adjacent to the sewage treatment pond.

A3.1.2.2 Two- to 5-ft Depth Interval

The distribution of total organic analytes in the 2- to 5-ft depth interval, shown in Figure RISR A3.1-16, is very similar to the shallower 0- to 2-ft interval. Detections of total organics in Lower Derby Lake and Upper Derby Lake are dominantly OCPs which tend to bind to fine-grained lake sediments. A few areas exhibit a decrease in total organics concentrations when compared to the shallower interval. This phenomena is displayed along the Sand Creek Lateral, in the eastern part of Upper Derby Lake in Section 6, and in a sanitary landfill and along a southern drainage ditch in South Plants. An increase in total organics concentrations in the 2- to 5-ft interval is evident in the processing area, tank farm, and open storage area of South Plants; the pesticide pits southeast of Basin A; buried lake sediments in Section 12; Section 30 sanitary landfill; and buried burn sites in Basin A. At many of these sites, a relatively clean layer of soil overlies buried wastes or other subsurface sources.

The distribution of total inorganic analytes in the 2- to 5-ft interval, shown in Figure RISR A3.1-17, is similar to the distribution in the 0- to 2-ft interval. However, most of the areas with high to moderate arsenic, mercury, and ICP metals concentrations in the 0- to 2-ft interval display decreased concentrations in the 2- to 5-ft interval. These areas include the disposal basins, the chemical sewer east of former Basin F, portions of the North and South Plants manufacturing complexes, the Sand Creek Lateral, and burn pits in Section 32. Detections in the 2- to 5-ft interval are absent in portions of the lakes that exhibit low total inorganic concentrations at 0- to 2-ft depth. High to very high total concentrations of inorganics occur in the 2- to 5-ft interval in a sanitary landfill and the motor pool area in Section 4, a burn site in Basin A, and in disposal pits and a former tank storage area in South Plants. As described above, these types of sites are generally buried potential source areas that are not expected to release contaminants to surface soils. Contaminant distribution at this level is a result of subsurface disposal, liquid infiltration, or leaching of contaminants from surficial horizons. The distribution is further influenced by the environmental mobility of each analyte under conditions described above.

A3.1.2.3 Five- to 20-ft Depth Interval

Considerably fewer total organic analyte detections are present in the 5- to 20-ft interval (Figure RISR A3.1-18) as compared to the shallower intervals. Moderate to very high concentrations are confined to a limited area in the central portion of RMA. This area includes burial trenches east and southeast of Basin A, a storage yard in Section 5, and the processing area, disposal pits, and a former tank and open storage area in South Plants. The highest total organics concentrations occur in the processing area in South Plants and in the pesticide disposal trenches southeast of Basin A. Where samples exhibit higher total organic concentrations in the 5- to 20-ft interval than in the shallower intervals, these higher concentrations at depth are attributed to disposal in open trenches or basins where contaminant transport has been aided by infiltration of liquid wastes or contaminated water.

Increases in the total inorganic analyte concentrations relative to the 2- to 5-ft interval are evident on the 5- to 20-ft depth interval map (Figure RISR A3.1-19). These areas, which are predominantly burial sites, include a solid waste disposal site along the eastern edge of Basin A, burn pits in Section 32, a sanitary landfill in the northern portion of Section 4, and the processing area in South Plants. A shallow burial pit in South Plants, which exhibits very high total inorganic concentrations in both of the shallower intervals, exhibits moderate concentrations in the 5- to 20-ft interval. A decrease in total inorganic concentrations with depth is evident in a few sites characterized by surface activities. These include the motor pool area in Section 4 and a toxic storage yard in Section 31. In addition to the elevated inorganics associated with trenches east of Basin A, inorganics are elevated along a shallow bedrock feature which trends northwest/southeast across Section 36. This occurrence, like other elevated inorganics in bedrock samples, probably reflects the natural bedrock geochemistry.

A3.1.2.4 Greater Than 20-ft Depth Interval

The distribution of total organic analytes in the greater than 20 ft depth interval, shown in Figure RISR A3.1-20, is limited. Moderate and high total organics concentrations occur in Basins A and F, the processing area in South Plants, and a sanitary landfill in Section 4, where contaminant migration has resulted from infiltrating liquids. Low concentrations are present in various areas that also exhibited low concentrations in shallower intervals.

Figure RISR A3.1-21, the total inorganic analytes map for the deepest interval, exhibits a limited distribution with low and moderate concentrations. Moderate concentrations occur in some of the same areas that exhibit moderate to very high concentrations for shallower intervals. Several of these occurrences are probably associated with natural concentrations in bedrock. Other areas are associated with basins, ditches, or sewers where contaminant migration has been enhanced by infiltrating waters.

A3.1.2.5 Inorganic Concentrations Above Indicator Range (All Depth Intervals)

The distribution of arsenic, mercury, and ICP metal concentrations above the upper limit of the IR is more clearly displayed in Figures RISR A3.1-22, A3.1-23, and A3.1-24. Symbols on these maps indicate the occurrence of an inorganic analyte detection above the upper limit of the IR at any depth, and detections of inorganic analytes that are considered naturally occurring. All three maps display a similar distribution, with the majority of elevated detections located in the central portion of RMA. For summary purposes, the relationship of arsenic, mercury, and ICP metals above IR for each depth interval are not depicted on maps in this report. Therefore, these relationships are discussed briefly below and in greater detail in the SARs.

Arsenic contamination in shallow soils is confined to the manufacturing plants and waste disposal basins. Solid waste burial sites account for a few limited occurrences of elevated arsenic in the western part of the WSA and Eastern Study Area (ESA). This pattern is also reflected in arsenic at the 2- to 5-ft and 5- to 20-ft depth intervals. Arsenic above IR at depths greater than 20 ft is confined to a total of three occurrences in Basins C and D.

In shallow soils, mercury above IR shows a wider distribution than arsenic. In addition to occurrences at the manufacturing plants and basins, elevated mercury is present in ditches and lakes, solid waste burial sites, and in areas of suspected windblown contamination near Basins A and F. At 2- to 5-ft depths, it is more confined to basins, manufacturing areas, lakes, buried lake sediments, and solid waste burial sites. Elevated occurrences decrease with depth and appear to include shallow bedrock in Section 36 and the ESA.

Elevated ICP metals in shallow soils are coincident with mercury and arsenic at many of the sites described above. In addition, notable occurrences in nonsource areas suggest that some natural occurrences may exceed IRs. This pattern is reflected at all depth intervals, and may actually be used to identify areas of shallow bedrock in Section 36 and the ESA. This ICP metals distribution is consistent with the phenomena of natural bedrock concentrations exceeding those in overlying soils.

A3.1.3 Sewers and Process Water Systems

Samples of sewer sediments were collected at six locations in the sanitary sewer system. Total organic analyte concentrations were low, as shown in Figure RISR A3.1-25. Total inorganic analyte concentrations were moderate, as shown in Figure RISR A3.1-26. Samples were not collected from the chemical sewers or the process water lines; however, soil samples collected adjacent to or beneath all three systems were considered in characterizing contaminant conditions.

The contaminants detected within the sanitary sewer system are predominantly OSCMs (chloroacetic acid), DBCP, arsenic, mercury, and ICP metals. A sample collected from the sanitary sewer downgradient of the North Plants contained DBCP, mercury, and ICP metals. DBCP was not manufactured at North Plants, so the source of this detection could not be identified. Sewer sediment data were generally consistent with data for samples collected beneath the system, indicating that leakage from the sewers was a local source of contaminant releases to surrounding soils and possibly groundwater.

A3.2 WATER

The water media RI included both surface water and groundwater. Although off-post sources of contamination appear to have impacted streams flowing onto RMA, only two isolated bodies of surface water on post appear to have suffered significantly from RMA activities. The alluvial aquifer, however, has received a wide variety of contaminants from a variety of sources on post and off post. On-post activities have resulted in two spatially distinct, multi-analyte plumes that flow north and northwest below RMA. Downward migration from the alluvial aquifer is responsible for isolated occurrences of analytes in the deeper water-bearing zones of the confined Denver Formation. The nature and extent of contamination in surface water, in alluvial groundwater in the UFS, and in Denver Formation groundwater in the CFS are summarized in the three subsections that follow. Greater detail may be found in the WRIR (EBASCO, 1989d/RIC 89186R01).

As noted in Section A3, total AGM contaminant concentrations have been plotted to generate surface water quality maps and groundwater quality maps. Surface water data from 1985 through 1989 were considered and used to characterize contamination. For the groundwater presentation, the focus was on data from the most comprehensive sampling programs conducted during the time period of the RI, the third quarter FY87 (April, May, June 1987) and the CMP (November 1987 through February 1989). Trends in the nature and extent of contamination, as indicated by the complete set of RI data, are also considered in this discussion.

A3.2.1 Surface Water

Surface water at RMA currently shows little impact from former contaminant releases, due largely to the reduction or elimination of water from most ditches and disposal basins. RMA-related contaminants are introduced to the on-post surface-water system at points of groundwater discharge or where surface runoff from contaminated soils collects. Points where organic and inorganic contaminants have been introduced to surface water in detectable concentrations include Basin A and the South Plants sedimentation pond. Water flowing into First Creek from the sewage treatment plant also shows moderately elevated levels of inorganic analytes.

When they contain water, both Basin A and the South Plants sedimentation pond exhibit elevated levels of contaminants, while other surface-water bodies show little or none. During the RI the South Plants sedimentation pond, which receives runoff from contaminated soils in the South Plants area, typically exhibited concentrations an order of magnitude lower than those detected in Basin A. The concentrations and number of detections that occurred in samples from Basin A and the South Plants sedimentation pond are not characteristic of surface water flowing out of RMA. First Creek is the only continuous surface water drainage through RMA'. Although sporadic detections occurred at all stations along First Creek, an overall downstream decline in water quality was not apparent. The lakes generally did not exhibit elevated organic contaminant levels indicative of RMA influences, although inorganic analytes were detected. However, inorganic concentrations may reflect the combined influence of natural and anthropogenic effects.

There are two temporary, lined liquid waste holding ponds constructed as part of the Basin F IRA to hold liquid wastes from former Basin F (Appendix C). These ponds are isolated from their environment by a system of liners, sump collection systems, and covers. These holding ponds were not studied in the RI program.

A low frequency of contaminant detections is typical of most surface water locations at RMA. This suggests that contaminants are introduced to surface water during unusual precipitation and runoff events. During periods of intense or prolonged rainfall or during periods of rapid snowmelt, contaminated soils may act as sources of contamination in surface runoff. Historical water quality data have been collected at regular intervals rather than synchronized to irregular and episodic periods of high discharge; consequently, little information is available to characterize water quality during high stream flow. A major objective of the ongoing CMP surface water monitoring program is characterizing high-flow periods.

Surface water sampling locations (stations) are shown in Figure RISR A3.2-1. For the purposes of this discussion, the stations have been grouped by locations used to monitor on-post water quality, including changes in water quality in First Creek as it flows across RMA, water quality in the lakes, and the quality of intermittent surface water occurrences. Analytical results are summarized in Table RISR A3.2-1. The geometric mean of detections has been calculated for each analyte group; the means of individual analytes are not considered separately in this calculation. However, the summed AGM concentration of

Table RISR A3.2-1. Summary of Detections in Surface Water.

Site ID/ Description	Analyte Group	Frequency of Detections (detections/analyses)	Range of Detections (ug/l)	Geometric Mean of Detections (ug/l)	Summed AGM Concentrations of Individual Analytes ** (ug/l)	Total AGM Plotted in Figures RISR A3.2-2 and A3.2-3
SOUTH BOUNDARY						
SW07002-	Organics					0.08
Uvalda Ditch B	OPHGB	1/8	0.64	0.64	0.08	
	Inorganics					10
	Arsenic	1/7	2.6	2.6	0.38	
	ICP Metals	2/12	18-41	27	9.9	
SW08001-	Organics					0.04
South First Creek Boundary	OCP	1/4	0.16	0.16	0.04	
	Inorganics					1.3
	Arsenic	1/2	2.6	2.6	1.3	
SW08002-	Inorganics					51
Highline Lateral South Boundary	ICP Metals	2/6	75-77	76	51	
SW11001-	Organics					5.8
Peoria Interceptor	VHO	4/40	1.3-2.9	1.7	0.35	
	VAO	1/21	1.5	1.5	0.070	
	OSCH	4/9	3.7-34	11.7	5.2	
	OPHP	1/10	1.0	1	0.10	
	PAH*	3/3	10-70	25	NC	
	SHO	2/19	0.71-1.8	1.10	0.12	
	OCP	1/19	0.25	0.25	0.013	
	Inorganics					28
	Arsenic	3/15	4.6-5.9	5	1.0	
	ICP Metals	7/14	22-170	54	27	

AGM - Adjusted Geometric Mean

NC - Not calculated; TICS not sufficiently quantified to permit statistical manipulation.

* Significant former nontarget compound; not included in calculation of AGM.

** AGMs for all analytes were calculated for summary purposes; however, for analytes with less than 25 percent detections, this number has limited significance.

Site ID/ Description	Analyte Group	Frequency of Detections (detections/analyses)	Range of Detections (ug/l)	Geometric Mean of Detections (ug/l)	Summed AGM Concentrations of Individual Analytes ** (ug/l)	Total AGM Plotted in Figures RISR A3.2-2 and A3.2-3
SW11002- Havana Interceptor	Organics					1.1
	VHC*	1/1	19	19	NC	
	OSCH	2/11	3.0-9.3	5.3	0.96	
	OPHGB	1/16	0.43	0.43	0.027	
	SHO	2/16	0.26-3.3	0.93	0.12	
	Inorganics					61
	Arsenic	1/15	4.2	4.2	0.28	
	ICP Metals	11/54	11-190	46.	61	
SW12004- Storm Drainage	Organics					5.3
	OSCH	1/9	36	36	4.0	
	OPHP	2/8	0.70-4.3	1.7	1.3	
	Inorganics					27
	Arsenic	1/6	3.8	3.8	0.63	
	ICP Metals	6/14	13-87	30	27	
SW12005- South Uvalda	Organics					1.1
	VHO	2/26	2.7-7.5	4.5	0.79	
	VAO	1/13	3.0	3.0	0.23	
	SHO	1/12	0.83	0.83	0.069	
	Inorganics					13
	Arsenic	1/12	2.4	2.4	0.20	
	Mercury	2/10	0.23-0.26	0.24	0.049	
	ICP Metals	3/9	27-64	39	13	

FIRST CREEK

SW08001- South First Creek Boundary (see listing under South Boundary)

AGM - Adjusted Geometric Mean
NC - Not calculated; TICS not sufficiently quantified to permit statistical manipulation.
* Significant former nontarget compound; not included in calculation of AGM.
** AGMs for all analytes were calculated for summary purposes; however, for analytes with less than 25 percent detections, this number has limited significance.

Site ID/ Description	Analyte Group	Frequency of Detections (detections/analyses)	Range of Detections (ug/l)	Geometric Mean of Detections (ug/l)	Summed AGM Concentrations of Individual Analytes ** (ug/l)	Total AGM Plotted in Figures RISR A3.2-2 and A3.2-3
SW05001-	Inorganics					0.95
South First Creek	Arsenic	1/4	3.8	3.8	0.95	
SW31002-	Organics					0.44
First Creek Toxic Yard B	VHO	1/8	3.5	3.5	0.44	
	Inorganics					2.8
	Arsenic	5/8	3.6-7.3	4.32	2.7	
	Mercury	2/8	0.18-0.22	0.20	0.050	
SW30002-	Inorganics					0.63
First Creek North Plants	Arsenic	1/5	3.1	3.1	0.63	
SW24001-	Organics					1.3
North First Creek	VHO	2/13	4.9-9.7	6.9	1.1	
Sewage Treatment Plant	OPHGB	1/12	0.51	0.51	0.043	
	DBCP	1/13	0.15	0.15	0.012	
	OCP	7/23	0.10-0.94	0.27	0.17	
	Inorganics					46
	Arsenic	7/7	26-39	29	29	
	ICP Metals	2/8	31-150	68	17	
SW24004-	Organics					8.9
North First Creek	VHO	1/4	36	36	8.9	
	Inorganics					2.3
	Arsenic	2/4	4.0-4.7	4.3	2.2	
	Mercury	1/4	0.31	0.31	0.078	

AGM - Adjusted Geometric Mean

NC - Not calculated; TICS not sufficiently quantified to permit statistical manipulation.

* Significant former nontarget compound; not included in calculation of AGM.

** AGMs for all analytes were calculated for summary purposes; however, for analytes with less than 25 percent detections, this number has limited significance.

Site ID/ Description	Analyte Group	Frequency of Detections (detections/analyses)	Range of Detections (ug/l)	Geometric Mean of Detections (ug/l)	Summed AGM Concentrations of Individual Analytes ** (ug/l)	Total AGM Plotted in Figures RISR A3.2-2 and A3.2-3
SW24003-	Inorganics					41
North Bog	Arsenic	1/5	2.6	2.6	0.51	
	ICP Metals	1/4	160	160	41	
LAKES						
SW01004	Organics					0.033
Upper Derby Lake	OCP	2/6	0.050-0.050	0.05	0.033	
	Inorganics					1.2
	Arsenic	2/4	2.4-2.6	2.5	1.2	
SW01005-	Inorganics					10
Lower Derby Lake	ICP Metals	2/5	23-28	25	10	
SW02001-	None Detected					
Lower Derby Lake						
SW02003-	Inorganics					0.075
Lake Ladora	Mercury	2/5	0.16-0.22	0.19	0.075	
SW02004-	Organics					0.020
Lake Mary	OCP	1/5	0.10	0.10	0.020	
	Inorganics					13
	Arsenic	4/7	3.2-3.8	3.5	2.0	
	Mercury	1/7	0.26	0.26	0.037	
	ICP Metals	1/7	79	79	11	

AGM - Adjusted Geometric Mean
NC - Not calculated; TICS not sufficiently quantified to permit statistical manipulation.
* Significant former nontarget compound; not included in calculation of AGM.
** AGMs for all analytes were calculated for summary purposes; however, for analytes with less than 25 percent detections, this number has limited significance.

Table RISR A3.2-1. Summary of Detections in Surface Water.

Site ID/ Description	Analyte Group	Frequency of Detections (detections/analyses)	Range of Detections (ug/l)	Geometric Mean of Detections (ug/l)	Summed AGM Concentrations of Individual Analytes ** (ug/l)	Total AGM Plotted in Figures RISR A3.2-2 and A3.2-3
SW11003-	<u>Organics</u>					14
Havana Pond	OSCH	3/24	2.1->100	>19.2	>14	
	SHO	1/8	0.090	0.090	0.020	
	OCP	5/27	0.060-0.49	0.11	0.092	
	<u>Inorganics</u>					18
	ICP Metals	1/7	130	130	18	
<u>MISCELLANEOUS LOCATIONS</u>						
SW36001-	<u>Organics</u>					2300
Basin A	VHO	73/106	0.97-7500	44	1100	
	VHC	20/25	8.8-3700	75	360	
	VAO	38/55	1.7-690	58	280	
	OSCM	1/11	1.6	1.6	0.14	
	OSCH	24/38	1.8-1600	63	370	
	OPHGB	6/22	0.50-17	5.1	3.0	
	OPHP	11/20	1.9->500	>22	>140	
	DBCP	8/10	>2.2-170	>36	>29	
	SHO	3/9	0.67-2.6	1.2	0.40	
	OCP	22/69	0.46-64	2.8	5.0	
	<u>Inorganics</u>					240
	Arsenic	9/9	120-440	240	240	
	ICP Metals	1/9	33	33	3.6	
SW01002-	<u>Organics</u>					200
South Plants	VHO	6/21	1.2-7.1	11	6.7	
Sedimentation Pond	VHC	4/7	16-97	38.5	22	
	VAO	5/21	1.5-8.4	3.2	2.4	
	OSCH	14/22	2.2-750	52	170	
	OPHGB	1/8	0.74	0.74	0.093	
	DBCP	4/7	0.34-38	2.5	1.4	

AGM - Adjusted Geometric Mean

NC - Not calculated; TICS not sufficiently quantified to permit statistical manipulation.

* Significant former nontarget compound; not included in calculation of AGM.

** AGMs for all analytes were calculated for summary purposes; however, for analytes with less than 25 percent detections, this number has limited significance.

Table RISR A3.2-1. Summary of Detections in Surface Water.

Site ID/ Description	Analyte Group	Frequency of Detections (detections/analyses)	Range of Detections (ug/l)	Geometric Mean of Detections (ug/l)	Summed AGM Concentrations of Individual Analytes ** (ug/l)	Total AGM Plotted in Figures RISR A3.2-2 and A3.2-3
SW01002-	SHO	1/6	0.31	0.31	0.052	32
South Plants	OCP	9/31	0.14-4.8	1.5	2.9	
Sedimentation Pond	<u>Inorganics</u>					
(continued)	Arsenic	4/4	7.4-19	13	13	
	Mercury	3/4	0.16-0.23	0.20	0.15	
	ICP Metals	2/4	35-40	37	19	
SW01001-	<u>Organics</u>					0.10
North Uvalda Interceptor	OPHGB	1/10	1.0	1.0	0.10	
	<u>Inorganics</u>					0.37
	Arsenic	1/7	2.6	2.6	0.37	

AGM - Adjusted Geometric Mean

NC - Not calculated; TICS not sufficiently quantified to permit statistical manipulation.

* Significant former nontarget compound; not included in calculation of AGM.

** AGMs for all analytes were calculated for summary purposes; however, for analytes with less than 25 percent detections, this number has limited significance.

individual analytes comprising the groups are presented on this table as are the total summed AGMs for organics and inorganics, calculated from the AGM concentrations of individual analytes for each surface water sampling station. In this method, sampling dates and analytes are combined in order to summarize contaminant concentrations detected at each station; however, it is important to evaluate individual analyte data, including range of concentrations and frequency of detection when considering specifics for the highly variable surface water medium. As discussed in Section A3, as the percentage of analyses below the CRL increases, the AGM becomes a less reliable measure of a mean concentration for the data set. Total AGM contaminant concentrations have been plotted to generate surface water quality maps using data obtained from 1985 through 1989.

A3.2.1.1 South RMA Boundary

Water flowing on post at the south boundary in First Creek, the Highline Lateral, Uvalda Interceptor, Peoria Interceptor, and Havana Interceptor shows low total organic an concentrations (less than 10 µg/l), as shown in Figure RISR A3.2-2. Individual analytes do not occur repeatedly in water entering RMA. In general, neither contaminant concentration nor frequency of detection increases in water as it flows across RMA. Detections of organic analytes were generally sporadic at the south boundary, occurring in less than half of the samples collected from any one location. A wide variety of compounds were detected in single samples. However, only the analytes of VHO, OCP, and OSCM groups were detected in more than one sample at a location. Inorganic detections in water entering RMA, primarily arsenic and zinc, tended to occur more frequently.

The organic analytes detected in surface water entering RMA include VHOs, VAOs, OSCHs, OPHGBs, SHOs, OPHPs, and OCPs (Table RISR A3.2-1). PAHs were tentatively identified in a single sample from Peoria Interceptor. Another TIC, 2-butoxyethanol (a VHC), was detected in a sample from Havana Interceptor. Total AGM concentrations of organic analytes ranged from 0.040 µg/l at the South First Creek Boundary to 5.8 µg/l at Peoria Interceptor.

The total AGM concentration of inorganic analytes did not exceed 30 µg/l (Figure RISR A3.2-3).

A3.2.1.2 First Creek

First Creek is an intermittent stream that flows across RMA from south to north. It receives inflow from surface runoff and groundwater discharge. Sporadic contaminant detections have been observed here; however, water quality does not appear to be seriously impacted by transit across RMA. OCPs, VHOs, and arsenic were observed along a drainage to First Creek near the sewage treatment plant, but water quality did not appear to be altered at downgradient stations along First Creek. Groundwater inflow to First Creek occurs at the north end of RMA. This inflow generally is a small portion of the total stream flow and, on average, does not substantially increase the concentrations or occurrence of the target organic or inorganic analytes. The organic analytes detected at stations along First Creek include VHOs, OPHGBs, DBCP, and OCPs (Table RISR A3.2-1 and Figure RISR A3.2-2). Single detections of organics at stations along First Creek included OCPs at the south boundary, and VHOs at the Toxic Storage Yard B and North First Creek gaging stations. Although all were single occurrences, concentrations of individual organic analytes ranged from 0.16 µg/l to 36 µg/l for these samples. OCPs were detected in seven discharge samples from the sewage treatment plant, and chloroform, a VHO, was detected in two samples. DBCP and dimethylmethyl phosphonate (an OPHGB) were each detected in one sample. Organics were not detected at the remaining stations.

Arsenic, mercury, and ICP metals were detected at stations along First Creek. Total AGM concentrations for inorganic analytes ranged from 0.63 µg/l near North Plants to 46 µg/l at the sewage treatment plant. Concentrations were low (<10 µg/l) at all sites except the sewage treatment plant and the North Bog. In one sample from the North Bog, zinc was detected at 160 µg/l in the third quarter of 1987, but was below CRLs in later samples. Arsenic was detected in all samples collected from below the sewage treatment plant, and zinc was detected in two of eight samples. There were multiple detections of arsenic and mercury at the Toxic Yard B gaging station on First Creek. Arsenic was detected in two samples at the RMA north boundary (SW24004). All other detections at stations along First Creek were unverifiable single occurrences.

A3.2.1.3 RMA Lakes

The surface water sampling stations at the RMA lakes include Lake Ladora, Lower Derby and Upper Derby Lakes, Lake Mary, and Havana Pond. The highest total AGM concentration for organic analytes detected at RMA in surface water, other than the temporary standing waters of Basin A or the South Plants sedimentation pond, was detected at Havana Pond (Figure RISR A3.2-2). The total AGM concentration at Havana Pond was 14 µg/l. Havana Pond primarily receives off-post water, which is likely to be the source of these organic analytes. Single detections of individual organics included OSCHs and SHOs, and OCPs were detected in two samples. One OSCH, chlorophenylmethyl sulfone, was detected once in ten samples at a concentration greater than 100 µg/l. Concentrations of individual SHOs and OCPs ranged from 0.060 µg/l to 0.49 µg/l. OCPs were detected at 0.10 µg/l in one of five samples from Lake Mary. The OCPs dieldrin and endrin were each detected in one of three samples at 0.050 µg/l at Upper Derby Lake. Organic analytes were not detected in the other lake and pond samples.

Inorganic analytes were detected in samples from five of six sampling locations. Total AGM concentrations ranged from 0.075 µg/l at Lake Ladora to 18 µg/l at Havana Pond. The high value for Havana Pond resulted from a single high concentration of the ICP metal zinc (130 µg/l.) However, zinc was below the CRL in a duplicate sample. Zinc also was detected at Lower Derby Lake; arsenic, mercury, and zinc were detected at Lake Mary; zinc was detected at Lower Derby Lake and Havana Pond; arsenic was detected at Upper Derby Lake; and mercury was detected at Lake Ladora. Detections were repeatable in duplicate samples for zinc at Lower Derby Lake, mercury at Lake Ladora, and arsenic at Lake Mary and Upper Derby Lake.

A3.2.1.4 Basin A and the South Plants Sedimentation Pond

The largest number of organic analytes detected, the highest concentrations, and the highest frequency of detections occur at Basin A. This sampling station receives surface runoff from contaminated soils in the South Plants area as well as water from storm sewer and groundwater discharge. Volatiles, both VHOs and VAOs, as well as atrazine (an OPHP) and arsenic are the principal contaminants, although many other organics have also been detected with high frequency. The total AGM concentration of organic analytes was 2,300 µg/l. Summed AGM concentrations for multiple detections of individual organics ranged from 0.40 µg/l for SHOs to 1,100 µg/l for VHOs in Basin A. Individual concentrations reached 7,500 µg/l for the VHO chlorobenzene. The total AGM concentration of inorganic analytes was 240 µg/l at this station.

The South Plants sedimentation pond also receives runoff from contaminated soils in the South Plants area and is a location of significant, though intermittent, surface water contamination. Concentrations were typically an order of magnitude lower than that detected in Basin A. Chlorophenylmethyl sulfone (an OSCH) and arsenic were detected in all samples from the sedimentation pond. Several other organics were detected in a majority of the samples from this location. The total AGM concentration of organic analytes was 200 µg/l, and the total AGM concentration of inorganic analytes was 32 µg/l at this station.

A3.2.2 Unsaturated Zone

The nature and extent of contaminated water in unsaturated zone soils is primarily a function of complex environmental parameters and analyte behavior. The relative concentration of an analyte in coexisting soil and water phases is described by the soil/water partition coefficient (K_d). Analytes with a high K_d are partitioned onto or have a higher affinity for the solid phase. A low K_d indicates the analyte will be more prevalent in the aqueous phase and is more likely to be found in unsaturated zone water than adsorbed to the soil. Solubility is also a major characteristic that determines a contaminant's potential environmental distribution. In the unsaturated zone, the more soluble analytes are less likely to adsorb to the soil and will dissolve in water that moves through the unsaturated zone. A more detailed discussion of factors influencing and controlling individual contaminant behavior is presented in Appendix E.

As discussed in Section A3.1, there is a notable mass of contaminants in the surficial soils and underlying alluvium of the unsaturated zone. Most of the contaminants were detected near production and associated support facilities, and below sewers, disposal basins, solid waste burial sites, and ditches. Knowledge of contaminant behavior and the concentration and extent of organic contaminants in the soil can be qualitatively related to the concentration and extent of contamination in soil water.

A3.2.3 Unconfined Flow System

Contaminants have migrated from a variety of source areas along both historical and present-day groundwater flow paths, resulting in large areas of groundwater contamination in the UFS. As discussed in Section A1.5.3 of Appendix A, the UFS includes saturated surficial deposits and subcropping parts of the Denver Formation where lithologic data indicate the presence of sandstone or relatively permeable material. In most areas, including areas where these deposits are unsaturated, groundwater in the uppermost subcropping stratum of the underlying Denver Formation is under unconfined flow conditions.

Regional contaminant distributions have not changed significantly since 1987. Therefore, the data used to describe the nature and extent of contamination in the UFS were collected primarily during the RI, from the spring of 1987 through the fall of 1989. These data are incorporated in the accompanying data tables, histograms, and inorganic distribution maps for the UFS. However, increased sampling density since 1987 and, less significantly, variations in organic analyte suites have resulted in changes in interpretations of organic plume configurations. Therefore, plume maps of the organics were constructed from subsets of these data (spring 1987, fall 1988, and winter 1989) and also from fall 1989, which was the most recent, comprehensive data set available. These subsets were chosen to depict the contaminant distribution representative of each year by using data collected and analyzed by comparable methods during a finite period of time. Additional data were considered in constructing and refining the plume maps. As with the soils data tables (Section 3.1), statistical information is presented on the groundwater data summary tables for general comparative and informational purposes only. Unwarranted significance should not be attached to the statistical values.

Wells screened in the UFS that were sampled from the spring of 1987 through the fall of 1989 are shown in Figure RISR A3.2-4. Data from these wells were considered while evaluating the nature and extent of contamination in the UFS. Maps of total organic contaminants constructed from spring 1987 and later data show that the largest areas of contaminated groundwater are in the north, central, and western parts of RMA and occur as two spatially distinct contaminant plumes. The plumes consist of one or more contaminants at varying concentrations that migrate together as a unit through the aquifer. In many cases, migration has resulted in merging of contaminant plumes from individual source areas and has reduced confidence in correlations between plumes and their origins. Consequently, names used in this report for contaminant plumes and plume groupings are based on proximity to well known physiographic or cultural features and may not indicate the specific source(s) of a particular plume. For the purpose of discussing the chemical composition of contaminated groundwater in the UFS, contaminant plumes have been placed into five groups. The South Plants group, the Basin A group, the Northwest Boundary group, and the North Boundary group collectively form the central groundwater plume at RMA. The Western group is located along the western tier of sections at RMA (Figure RISR A3.2-5). Other sporadic, scattered detections are not assigned to a plume group.

Analytes or analyte groups that constitute definable groundwater plumes in the UFS include VHOs, VAOs, VHCs, OSCs, OPHGBs, DBCP, OCPs, arsenic, mercury, fluoride, and chloride. The chemical composition and migration rate of contaminants within each plume group varies in response to local hydrogeologic conditions and the individual chemical nature of contaminants. A histogram is presented for each plume group showing the percentage of total detections for each analyte group that makes up the plume, and the percentage of detections within each analyte group that correspond to specific concentration ranges. These histograms define unique signatures for each plume group. Summary data tables for each plume group are also presented. These data tables list the frequency of detections, concentration ranges, CRL ranges, and the median, geometric mean and AGM of detected concentrations for individual analytes constituting the plumes in each plume group.

The histograms and data tables incorporate target analyte data as well as significant former nontarget analyte data. As discussed in Section A2, these nontarget compounds were tentatively identified by GC/MS on the basis of spectral character. Assessment of the nontarget data collected between 1987 and 1989 indicates the reported detections of one of the nontargets, caprolactam, are anomalous and likely not representative of aquifer concentrations. This interpretation is supported by the following observations:
(1) caprolactam was only detected in one sampling episode (in 1987) and by one laboratory, and (2) the spatial distribution and reported high concentrations of caprolactam do not indicate a relationship to historical activities or potential source areas. In addition, reported detections of one other tentatively identified nontarget, 1,1,2,2-tetrachloroethane, were not repeatable in groundwater samples collected between 1987 and 1989 and may also be anomalous. Because the significant nontargets were identified at varying levels of confidence, they are specifically identified on the data tables as tentatively identified compounds.

The Basin A plume group contains the greatest diversity and highest concentration of analytes. Plumes migrating toward the NBCS show slightly less diversity and lower concentrations of analytes. Plumes migrating towards the NWBCS contain a large variety of analytes, but concentrations tend to be lower than concentrations near the NBCS. Plumes in the vicinity of South Plants contain fewer analyte groups, and lower concentrations, than do the Northwest Boundary and North Boundary groups; however, these plumes result from a greater number of isolated contaminant sources than plumes in other areas of RMA. In addition, because South Plants is situated on a groundwater high where variable hydrogeologic conditions may exist, contaminated groundwater in the area follows a number of different flowpaths. This phenomenon is described in greater detail in the WRIR (EBASCO, 1989d/RIC 89186R01) and the South Plants Study Area Report (EBASCO, 1989e/RIC 89166R04). Plumes in the western part of RMA consist primarily of VHOs and DBCP, and tend to show the lowest analyte concentrations of the five plume groups.

Plume maps of the organic compounds are depicted separately for each of the major sampling periods: third quarter FY87, fall of 1988 through winter of 1988, and fall of 1989 (Figures RISR A3.2-6 through RISR A3.2-8). The results of first quarter FY90 sampling are included in Figure RISR 3.2-8. The organic plumes incorporate analytical data for target and significant nontarget organic analytes with the exception of caprolactam, which is plotted on a separate figure for the reasons discussed above (Figure RISR A3.2-9). The fall 1989 plume map of total organics is interpreted to be the most representative of organic contaminant distribution at RMA; it incorporates results from the highest number of wells, including wells newly installed in 1988 and 1989.

A broad area with summed organic concentrations greater than 100 µg/l is located in the vicinity of South Plants, Basin A, Basin A Neck, Basins C and F, and the NBCS (Figures RISR A3.2-6 through A3.2-8). Within this broad area, "hot spots" with concentrations greater than 100,000 µg/l are located along the south boundary of South Plants and beneath the southern part of Basin A. Concentrations greater than 10,000 µg/l extend beneath and north of former Basin F, and from South Plants north beneath Basin A and south towards Lower Derby Lake. Other locations with summed organic concentrations greater than 100 µg/l include North Plants, small areas southeast of the NWBCS, and in the western part of RMA.

Organic contamination has migrated to the north and northwest boundaries of RMA where contaminated water is being withdrawn from the UFS, treated, and returned to the flow system downgradient of the boundaries (ESE, 1989a/RIC 89103R01; ESE, 1986/RIC

86317R01). Summed organic concentrations in groundwater approaching the NBCS ranged from 0.1 µg/l to approximately 3,500 µg/l. Summed organic concentrations in groundwater approaching the NWBCS ranged from below CRL to over 100 µg/l.

Plume maps of the inorganics were constructed from AGMs of concentrations reported from the spring of 1987 through the winter of 1989. The extent of inorganic contaminants in water of the UFS is similar to the extent of organic contaminants, with the exception of Sections 3, 4, 9, and 33 in the western part of RMA. Elevated levels of chloride and fluoride occur over wide areas of RMA (Figures RISR A3.2-10 and A3.2-11). Areas with fluoride concentrations greater than 5,000 µg/l are located beneath Basin A and along the groundwater flow path from the former Basin F towards the NBCS. The distribution of arsenic is more restricted than the distributions of chloride and fluoride, as shown in Figure RISR A3.2-12. Arsenic concentrations greater than 10 µg/l are located in the vicinities of Basins A, B, C, D, E, and former Basin F, and extend to the area north of former Basin F and northwest of Basin E. Mercury concentrations are greater than 10 µg/l beneath the southern part of Basin A, and less than or equal to 1.0 µg/l in other RMA areas (Figure RISR A3.2-13). The distribution of ICP metals is irregular and cannot be mapped as occurring in continuous plumes associated with RMA source areas. Zinc is the most frequently detected ICP metal, and its widespread occurrence suggests a natural origin for the detected concentrations in the groundwater (Figure RISR A3.2-14).

A3.2.3.1 South Plants Plume Group

The South Plants plume group consists of several plumes that originate from distinct source areas. The South Plants SAR provides detailed descriptions of each plume. In addition, more detailed discussions are included in the WRIR. In general, the chemical composition and range of concentrations within each plume are unique and reflect numerous variables, including the chemical and physical nature of contaminated soils in associated source areas. Because of local hydrogeologic conditions, groundwater moves radially away from South Plants. As a result, individual contaminant plumes migrate in different directions within this area. In areas south and west of South Plants, migration occurs partly through unconfined strata of the Denver Formation. In areas north and northeast of South Plants, migration occur primarily through alluvium and eolian sediments.

Histograms of contaminant occurrence for the South Plants plume group indicate that a wide variety of analytes are present in this area (Figure RISR A3.2-15). Most analyte groups have been identified within the South Plants plume group. Analytes or analyte groups occurring more frequently and with the highest concentrations include VHOs, VHCs, VAOs, OSCHs, OPHPs, DBCP, and ICP metals. Other analyte groups were detected at relatively low concentrations or with lower frequency (Table RISR A3.2-2). The list of contaminants present in an individual South Plants plume, however, is more limited. For example, the South Tank Farm plume, migrating south toward Lake Ladora, consists primarily of VHCs and VAOs. Concentrations of contaminants in this plume are among the highest observed at RMA.

A3.2.3.2 Basin A Plume Group

The Basin A plume group is of diverse chemical composition. It shows a great variety of contaminant groups, and overall higher concentrations than the South Plants plume. The contaminant diversity and increased concentrations are due to two major factors. The northern lobe of the South Plants plume group flows beneath Basin A and merges with the Basin A plume. In addition, the Basin A plume received South Plants runoff, wastewater, and chemical sewer leakage, which contributed contaminants to groundwater below Basin A. Contributions from solid waste burial sites within or adjacent to Basin A have further contributed to the wide diversity of contaminants at levels greater than 10,000 µg/l in this plume.

Nearly all organic analyte groups have been detected in water of the UFS beneath Basin A (Figure RISR A3.2-16; Table RISR A3.2-3). Arsenic, mercury, fluoride, chloride, and ICP metals are also present. Concentrations of several analyte groups, including VHOs, VAOs,

Table RISR A3.2-2 Summary of Analytical Results for the Unconfined Flow System in the South Plants Plume Group.

Total Wells Sampled: 44 (Apr 87)
Total Samples Collected: 70

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/l)	CRL Range^{+} (µg/l)	Detections (µg/l)					Adjusted Geometric Mean
				Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev.$^{\Delta}$	
Volatile Halogenated Organics (VHOs)									
1,1-Dichloroethane	16/65	1.4-69	0.73-240,000	6.6	12	18	6.4	1.1	1.6
1,2-Dichloroethane	4/65	2.3-9.2	0.61-150,000	3.7	4.7	3.1	4.1	0.58	0.25
1,1-Dichloroethylene	2/40	5.2-5.8	1.0-8.5	NC	NC	NC	NC	NC	NC
trans-1,2-Dichloroethylene	11/65	1.2-17	0.76-96,000	3.7	6.9	6.1	4.6	0.96	0.78
1,1,2,2-Tetrachloroethane*†	3/29	7.4-11	1.5-76,000	7.8	NC	NC	NC	NC	NC
1,1,1-Trichloroethane	1/65	2.5	0.76-140,000	NC	NC	NC	NC	NC	NC
1,1,2-Trichloroethane	1/65	18	0.78-140,000	NC	NC	NC	NC	NC	NC
Carbon tetrachloride	7/65	1.4-820	0.99-130,000	2.0	120	310	5.1	2.3	0.55
Chlorobenzene	10/65	0.97-1,100	0.58-100,000	51	230	360	67	2.0	10
Chloroform	39/64	0.58-10,000	0.50-30,000	4.3	340	1,700	8.6	2.0	5.3
Methylene chloride	1/65	11,000	1.0-54,000	NC	NC	NC	NC	NC	NC
Tetrachloroethylene	15/65	0.98-27	0.75-190,000	1.6	7.0	10	2.8	1.3	0.66
Trichloroethylene	16/65	0.63-9.8	0.56-100,000	3.6	3.5	2.6	2.7	0.81	0.66
Trichloropropene*	NI	---	---	---	---	---	---	---	---
Volatile Hydrocarbons (VHCs)									
2-Butoxyethanol*	NI	---	---	---	---	---	---	---	---
4-Hydroxy-4-methyl-2-pentanone*	NI	---	---	---	---	---	---	---	---
1-Methyl-1,3-cyclopentadiene*	NI	---	---	---	---	---	---	---	---
2,2-Oxybisethanol*	NI	---	---	---	---	---	---	---	---
2-Pentanone*	NI	---	---	---	---	---	---	---	---
Bicycloheptadiene‡	10/56	7.1-17,000	1.3-26,000	740	3400	5,800	640	2.3	110
Dicyclopentadiene	18/63	8.7-10,000	5.0-310	170	1200	2,400	220	2.0	63
Methylcyclohexane*	NI	---	---	---	---	---	---	---	---
Methylisobutyl ketone	1/64	17	1.4-160,000	NC	NC	NC	NC	NC	NC

\+ Includes maximum CRL values for diluted samples

Δ Standard deviation of log values (base e) of detections

* Tentatively identified compounds (TICs) elevated to target status in the SARs; there is no CRL for TICs. For the purpose of this report a CRL of 5 µg/l, typically corresponding to 10 percent of the internal standard, was used.

† Nontarget analyte for which concentrations reported as part of a USATHAMA-certified analytical method.

‡ Target analytes under CMP or Task 11

** Reported as total xylenes

NA - Not analyzed NC - Not calculated, as sample population is too small for comparison purposes NI - Not identified

Table RISR A3.2-2 Summary of Analytical Results for the Unconfined Flow System in the South Plants Plume Group.

Total Wells Sampled: 44 (Apr 87)
Total Samples Collected: 70

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/l)	CRL Range$^+$ (µg/l)	Detections (µg/l) Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev.$^\Delta$	Adjusted Geometric Mean
Volatile Aromatic Organics (VAOs)									
Benzene	29/61	0.85-1,100,000	1.1-670	8,300	300,000	430,000	6,600	4.6	3,200
Ethylbenzene	1/61	5,000	1.0-220,000	NC	NC	NC	NC	NC	NC
m-Xylene	1/61	7,900	1.0-280,000	NC	NC	NC	NC	NC	NC
o- and p-Xylene**	1/61	5,700	1.4-380,000	NC	NC	NC	NC	NC	NC
Toluene	3/61	60-10,000	1.0-160,000	8,200	NC	NC	NC	NC	NC
Organosulfur Compounds, Mustard-Agent Related (OSCMs)									
1,4-Oxathiane	2/62	5.5-16	1.4-130	NC	NC	NC	NC	NC	NC
Chloroacetic acid*	NI	---	---	---	---	---	---	---	---
Dithiane	1/62	3.9	1.3-210	NC	NC	NC	NC	NC	NC
Thiodiglycol‡	NI	---	---	---	---	---	---	---	---
Organosulfur Compounds, Herbicide Related (OSCHs)									
Benzothiazole	1/37	44	1.1-5.0	NC	NC	NC	NC	NC	NC
Chlorophenylmethyl sulfide	3/62	8.4-84	1.1-170	9.8	NC	NC	NC	NC	NC
Chlorophenylmethyl sulfone	11/62	3.9-200	2.2-130	20	51	71	24	1.3	4.2
Chlorophenylmethyl sulfoxide	3/62	18-140	2.0-290	66	NC	NC	NC	NC	NC
Dimethyldisulfide	0/62	---	0.55-220,000	---	---	---	---	---	---

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+ Includes maximum CRL values for diluted samples
Δ Standard deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target status in the SARs; there is no CRL for TICs. For the purpose of this report a CRL of 5 µg/l, typically corresponding to 10 percent of the internal standard, was used.
† Nontarget analyte for which concentrations reported as part of a USATHAMA-certified analytical method.
‡ Target analytes under CMP or Task 11
** Reported as total xylenes
NA - Not analyzed NC - Not calculated, as sample population is too small for comparison purposes NI - Not identified

Total Wells Sampled: 44 (Apr 87)
Total Samples Collected: 70

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/l)	CRL Range$^+$ (µg/l)	Detections (µg/l) Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev.$^{\Delta}$	Adjusted Geometric Mean
Organophosphorous Compounds, GB-Agent Related (OPHGBs)									
Diisopropylmethyl phosphonate	6/62	0.46-16	0.39-250	0.70	3.3	6.4	1.1	1.3	0.11
Dimethylmethyl phosphonate	5/59	0.25-2.0	0.19-380	1.0	0.92	0.71	0.68	0.92	0.058
Isopropylmethyl phosphonic acid	NA	---	---	---	---	---	---	---	---
Methylphosphonic acid	NA	---	---	---	---	---	---	---	---
Phosphoric acid, tributyl ester*	NI	---	---	---	---	---	---	---	---
Phosphoric acid, triphenyl ester*	NI	---	---	---	---	---	---	---	---
Organophosphorous Compounds, Pesticide Related (OPHPs)									
Atrazine‡	3/38	4.6-220	2.6-130	6.3	NC	NC	NC	NC	NC
Malathion‡	0/38	---	0.37-140	---	---	---	---	---	---
Parathion‡	2/38	4.1-4.4	0.65-190	NC	NC	NC	NC	NC	NC
Supona‡	5/35	0.99-1.6	0.79-200	1.1	1.2	0.25	1.2	0.19	0.16
Vapona‡	0/38	---	0.38-170	---	---	---	---	---	---
Dibromochloropropane (DBCP)	6/60	0.27-280	0.13-190	1.0	48	110	2.4	2.6	0.23

\+ Includes maximum CRL values for diluted samples

Δ Standard deviation of log values (base e) of detections

* Tentatively identified compounds (TICs) elevated to target status in the SARs; there is no CRL for TICs. For the purpose of this report a CRL of 5 µg/l, typically corresponding to 10 percent of the internal standard, was used.

† Nontarget analyte for which concentrations reported as part of a USATHAMA-certified analytical method.

‡ Target analytes under CMP or Task 11

** Reported as total xylenes

NA - Not analyzed NC - Not calculated, as sample population is too small for comparison purposes NI - Not identified

Table RISR A3.2-2 Summary of Analytical Results for the Unconfined Flow System in the South Plants Plume Group.

Total Wells Sampled: 44 (Apr 87)
Total Samples Collected: 70

		Concentration		Detections (µg/l)					
Analytical Groups and Analytes Detected	Frequency of Detections	Range (µg/l)	CRL Range+ (µg/l)	Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev.Δ	Adjusted Geometric Mean
Organonitrogen Compounds (ONCs)									
Caprolactam*	1/1	200	5	NC	NC	NC	NC	NC	NC
Hydrazine	NA	---	---	---	---	---	---	---	---
Methylhydrazine	NA	---	---	---	---	---	---	---	---
n-Nitrosodimethylamine	0/10	---	2.6-130	---	---	---	---	---	---
n-Nitrosodi-n-propylamine	NA	---	---	---	---	---	---	---	---
Unsymmetrical dimethylhydrazine	NA	---	---	---	---	---	---	---	---
Polynuclear Aromatic Hydrocarbons (PAHs)									
Fluoranthene*	NI	---	---	---	---	---	---	---	---
Methyl naphthalene*	NI	---	---	---	---	---	---	---	---
Phenanthrene*	NI	---	---	---	---	---	---	---	---
Pyrene*	NI	---	---	---	---	---	---	---	---
Semivolatile Halogenated Organics (SHOs)									
Hexachlorobenzene*	2/2	100-200	5	NC	NC	NC	NC	NC	NC
Hexachlorobutadiene*	NI	---	---	---	---	---	---	---	---
Hexachlorocyclopentadiene	0/61	---	0.048-210	---	---	---	---	---	---
Pentachlorobenzene*	NI	---	---	---	---	---	---	---	---
Tetrachlorobenzene*	NI	---	---	---	---	---	---	---	---
Trichlorobenzene*	NI	---	---	---	---	---	---	---	---

+ Includes maximum CRL values for diluted samples
Δ Standard deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target status in the SARs; there is no CRL for TICs. For the purpose of this report a CRL of 5 µg/l, typically corresponding to 10 percent of the internal standard, was used.
† Nontarget analyte for which concentrations reported as part of a USATHAMA-certified analytical method.
‡ Target analytes under CMP or Task 11
** Reported as total xylenes
NA - Not analyzed NC - Not calculated, as sample population is too small for comparison purposes NI - Not identified

Table RISR A3.2-2 Summary of Analytical Results for the Unconfined Flow System in the South Plants Plume Group.

Total Wells Sampled: 44 (Apr 87)
Total Samples Collected: 70

		Concentration		Detections (µg/l)					
Analytical Groups and Analytes Detected	Frequency of Detections	Range (µg/l)	CRL Range+ (µg/l)	Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev.Δ	Adjusted Geometric Mean
Organochlorine Pesticides (OCPs)									
Aldrin	4/62	0.11-0.68	0.050-280	0.17	0.28	0.27	0.21	0.86	0.014
Chlordane	3/62	0.66-2.1	0.095-950	1.1	NC	NC	NC	NC	NC
Dichlorodiphenylethane (DDE)	6/62	0.059-0.32	0.046-130	0.077	0.12	0.10	0.10	0.63	0.0097
Dichlorodiphenyltrichloroethane (DDT)	3/62	0.054-0.14	0.049-130	0.11	NC	NC	NC	NC	NC
Dieldrin	20/62	0.047-5.3	0.050-130	0.090	0.55	1.2	0.16	1.4	0.052
Endrin	6/62	0.041-0.10	0.050-300	0.049	0.06	0.020	0.060	0.34	0.0054
Isodrin	5/62	0.062-2.1	0.051-240	0.24	0.56	0.86	0.26	1.3	0.021
Arsenic	0/37	---	2.3-2.5	---	---	---	---	---	---
Mercury	11/38	0.11-0.27	0.10-0.50	0.13	0.15	0.05	0.14	0.31	0.041
ICP Metals									
Cadmium	0/38	---	5.2-8.4	---	---	---	---	---	---
Chromium	2/38	11-31	6.0-24	NC	NC	NC	NC	NC	NC
Copper	5/38	23-314	7.9-26	46	93	120	56	1.0	7.4
Lead	3/38	21-287	19-74	24	NC	NC	NC	NC	NC
Zinc	16/38	22-137	20-22	43	51	33	44	0.56	18

\+ Includes maximum CRL values for diluted samples
Δ Standard deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target status in the SARs; there is no CRL for TICs. For the purpose of this report a CRL of 5 µg/l, typically corresponding to 10 percent of the internal standard, was used.
† Nontarget analyte for which concentrations reported as part of a USATHAMA-certified analytical method.
‡ Target analytes under CMP or Task 11
** Reported as total xylenes
NA - Not analyzed   NC - Not calculated, as sample population is too small for comparison purposes   NI - Not identified

Table RISR A3.2-3 Summary of Analytical Results for the Unconfined Flow System in the Basin A Plume Group.

Total Wells Sampled : 70 (Apr 87 - Feb 89)
Total Samples Collected: 158

		Concentration		Detections (µg/l)					
Analytical Groups and Analytes Detected	Frequency of Detections	Range (µg/l)	CRL Range+ (µg/l)	Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev. Δ	Adjusted Geometric Mean
Volatile Halogenated Organics (VHOs)									
1,1-Dichloroethane	20/154	0.84-74	0.73-40,000	4.5	8.8	16	4.3	1.1	0.56
1,2-Dichloroethane	45/153	0.73-600	0.61-24,000	24	72	120	29	1.3	8.6
1,1-Dichloroethylene	18/133	1.5-1,900	1.0-10,000	7.0	130	440	13	1.8	1.7
trans-1,2-Dichloroethylene	33/153	0.83-990	0.76-50,000	36	110	210	26	1.9	5.7
1,1,2,2-Tetrachloroethane*†	3/23	6-10	1.5-15,000	6.4	NC	NC	NC	NC	NC
1,1,1-Trichloroethane	13/153	1.1-2,200	0.76-22,000	14	230	610	17	2.4	1.5
1,1,2-Trichloroethane	27/154	1.6-150	0.78-23,000	25	46	51	19	1.5	3.4
Carbon tetrachloride	46/154	1.2-3,500	0.99-21,000	47	270	630	51	2.0	15
Chlorobenzene	79/154	0.91-70,000	0.58-17,000	52	8800	18,000	130	3.7	66
Chloroform	128/148	0.64-3,900,000	0.50-750	40	71000	440,000	110	3.7	92
Methylene chloride	30/150	6.4-33,000	1.0-10,000	860	4400	7,200	760	2.4	150
Tetrachloroethylene	81/154	0.88-2,900	0.75-31,000	20	200	520	25	2.0	13
Trichloroethylene	112/154	0.62-7,600	0.56-17,000	15	530	1,500	27	2.6	19
Trichloropropene*	NI	---	---	---	---	---	---	---	---
Volatile Hydrocarbons (VHCs)									
2-Butoxyethanol*	NI	---	---	---	---	---	---	---	---
4-Hydroxy-4-methyl-2-pentanone*	NI	---	---	---	---	---	---	---	---
1-Methyl-1,3-cyclopentadiene*	NI	---	---	---	---	---	---	---	---
2,2-Oxybisethanol*	NI	---	---	---	---	---	---	---	---
2-Pentanone*	NI	---	---	---	---	---	---	---	---
Bicycloheptadiene‡	12/115	2.7-16,000	1.0-4,300	210	3100	5,700	230	2.8	24
Dicyclopentadiene	42/193	13-600	1.1-750	75	130	140	80	1.1	17
Methylcyclohexane*	NI	---	---	---	---	---	---	---	---
Methylisobutyl ketone	21/150	16-110,000	1.0-26,000	1,900	12000	29,000	1,200	2.5	170

\+ Includes maximum CRL values for diluted samples
Δ Standard deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target status in the SARs; there is no CRL for TICs. For the purpose of this report a CRL of 5 µg/l, typically corresponding to 10 percent of the internal standard, was used.
† Nontarget analyte for which concentrations reported as part of a USATHAMA-certified analytical method.
‡ Target analytes under CMP or Task 11
** Reported as total xylenes
NA - Not analyzed NC - Not calculated, as sample population is too small for comparison purposes NI - Not identified

Table RISR A3.2-3 Summary of Analytical Results for the Unconfined Flow System in the Basin A Plume Group.

Total Wells Sampled : 70 (Apr 87 - Feb 89)
Total Samples Collected: 158

		Concentration		Detections (µg/l)					
Analytical Groups and Analytes Detected	Frequency of Detections	Range (µg/l)	CRL Range+ (µg/l)	Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev. Δ	Adjusted Geometric Mean
Volatile Aromatic Organics (VAOs)									
Benzene	66/145	1.4-97,000	1.0-20,000	250	7600	19,000	260	3.4	120
Ethylbenzene	23/147	1.7-640	0.56-36,000	8.9	100	160	19	2.0	3.0
m-Xylene	17/147	1.5-510	1.0-46,000	23	110	160	21	2.2	2.4
o- and p-Xylene**	25/147	1.8-1,100	1.4-63,000	24	210	310	41	2.2	7.0
Toluene	34/147	2.2-92,000	1.0-26,000	78	3500	16,000	94	2.7	22
Organosulfur Compounds, Mustard-Agent Related (OSCMs)									
1,4-Oxathiane	66/179	3.1-1,500	1.4-27	45	140	290	46	1.5	17
Chloroacetic acid*	NI	---	---	---	---	---	---	---	---
Dithiane	77/178	2.0-7,900	1.3-67	150	600	1,200	140	1.9	60
Thiodiglycol‡	NA	---	---	---	---	---	---	---	---
Organosulfur Compounds, Herbicide Related (OSCHs)									
Benzothiazole	23/117	1.2-820	1.1-5.0	13	99	200	21	1.7	4.1
Chlorophenylmethyl sulfide	59/180	2.5-1,700	1.1-26	19	84.	270	24	1.3	7.8
Chlorophenylmethyl sulfone	61/178	6.7-7,700	2.2-26	53	360	1,100	70	1.6	24
Chlorophenylmethyl sulfoxide	19/180	3.7-440	2.0-42	40	92	130	42	1.3	4.4
Dimethyldisulfide	24/138	0.64-5,800	0.55-36,000	11	670	1,800	18	2.5	3.1

\+ Includes maximum CRL values for diluted samples

Δ Standard deviation of log values (base e) of detections

* Tentatively identified compounds (TICs) elevated to target status in the SARs; there is no CRL for TICs. For the purpose of this report a CRL of 5 µg/l, typically corresponding to 10 percent of the internal standard, was used.

† Nontarget analyte for which concentrations reported as part of a USATHAMA-certified analytical method.

‡ Target analytes under CMP or Task 11

** Reported as total xylenes

NA - Not analyzed NC - Not calculated, as sample population is too small for comparison purposes NI - Not identified

Table RISR A3.2-3 Summary of Analytical Results for the Unconfined Flow System in the Basin A Plume Group.

Total Wells Sampled : 70 (Apr 87 - Feb 89)
Total Samples Collected: 158

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/l)	CRL Range+ (µg/l)	Detections (µg/l)					Adjusted Geometric Mean
				Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev. Δ	
Organophosphorous Compounds, GB-Agent Related (OPHGBs)									
Diisopropylmethyl phosphonate	77/175	0.69-34,000	0.39-190	170	2000	5,700	95	3.0	42
Dimethylmethyl phosphonate	32/173	0.36-870	0.19-2,900	24	76	160	18	1.9	3.4
Isopropylmethyl phosphonic acid	NA	---	---	---	---	---	---	---	---
Methylphosphonic acid	NA	---	---	---	---	---	---	---	---
Phosphoric acid, tributyl ester*	NI	---	---	---	---	---	---	---	---
Phosphoric acid, triphenyl ester*	NI	---	---	---	---	---	---	---	---
Organophosphorous Compounds, Pesticide Related (OPHPs)									
Atrazine‡	24/103	4.6-180	2.6-4,000	33	59	59	34	1.2	7.8
Malathion‡	17/103	0.59-500	0.37-26	5.4	56	130	7.1	2.0	1.2
Parathion‡	11/103	0.87-24	0.65-37	5.8	7.6	7.0	4.8	1.1	0.51
Supona‡	16/103	0.97-130	0.79-39	3.0	20	35	5.7	1.6	0.88
Vapona‡	5/103	0.86-190	0.38-26	17	49	80	12	2.1	0.60
Dibromochloropropane (DBCP)	59/194	0.19-57,000	0.13-1,500	18	1100	7,400	16	2.9	4.8

\+ Includes maximum CRL values for diluted samples

Δ Standard deviation of log values (base e) of detections

* Tentatively identified compounds (TICs) elevated to target status in the SARs; there is no CRL for TICs. For the purpose of this report a CRL of 5 µg/l, typically corresponding to 10 percent of the internal standard, was used.

† Nontarget analyte for which concentrations reported as part of a USATHAMA-certified analytical method.

‡ Target analytes under CMP or Task 11

** Reported as total xylenes

NA - Not analyzed NC - Not calculated, as sample population is too small for comparison purposes NI - Not identified

Total Wells Sampled : 70 (Apr 87 - Feb 89)
Total Samples Collected: 158

		Concentration		Detections (µg/l)					
Analytical Groups and Analytes Detected	Frequency of Detections	Range (µg/l)	CRL Range+ (µg/l)	Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev. Δ	Adjusted Geometric Mean
Organonitrogen Compounds (ONCs)									
Caprolactam*	8/8	10-1,000	5	100	330	400	100	1.5	100
Hydrazine	0/8	---	31	---	---	---	---	---	---
Methylhydrazine	0/8	---	3,000	---	---	---	---	---	---
n-Nitrosodimethylamine	0/7	---	2.6-26	---	---	---	---	---	---
n-Nitrosodi-n-propylamine	NA	---	---	---	---	---	---	---	---
Unsymmetrical dimethylhydrazine	0/8	---	23	---	---	---	---	---	---
Polynuclear Aromatic Hydrocarbons (PAHs)									
Fluoranthene*	NI	---	---	---	---	---	---	---	---
Methyl naphthalene*	NI	---	---	---	---	---	---	---	---
Phenanthrene*	NI	---	---	---	---	---	---	---	---
Pyrene*	NI	---	---	---	---	---	---	---	---
Semivolatile Halogenated Organics (SHOs)									
Hexachlorobenzene*	24/24	10-200,000	5	100	9200	30,000	300	2.5	300
Hexachlorobutadiene*	NI	---	---	---	---	---	---	---	---
Hexachlorocyclopentadiene	21/159	0.062-460	0.048-4,800	0.22	48	130	0.86	2.8	0.11
Pentachlorobenzene*	NI	---	---	---	---	---	---	---	---
Tetrachlorobenzene*	1/1	10	5	NC	NC	NC	NC	NC	NC
Trichlorobenzene*	8/8	10-200	5	30	75	83	40	1.1	40

+ Includes maximum CRL values for diluted samples
Δ Standard deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target status in the SARs; there is no CRL for TICs. For the purpose of this report a CRL of 5 µg/l, typically corresponding to 10 percent of the internal standard, was used.
† Nontarget analyte for which concentrations reported as part of a USATHAMA-certified analytical method.
‡ Target analytes under CMP or Task 11
** Reported as total xylenes
NA - Not analyzed NC - Not calculated, as sample population is too small for comparison purposes NI - Not identified

Total Wells Sampled : 70 (Apr 87 - Feb 89)
Total Samples Collected: 158

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/l)	CRL Range+ (µg/l)	Detections (µg/l) Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev. Δ	Adjusted Geometric Mean
Organochlorine Pesticides (OCPs)									
Aldrin	28/184	0.066-300	0.050-55	0.79	18	58	1.5	2.2	0.22
Chlordane	18/184	0.21-460	0.10-190	5.1	36	110	5.4	1.8	0.53
Dichlorodiphenylethane (DDE)	17/185	0.074-3.6	0.046-26	0.28	0.65	0.96	0.32	1.2	0.029
Dichlorodiphenyltrichloroethane (DDT)	24/185	0.066-6.5	0.049-26	0.27	0.81	1.4	0.37	1.2	0.048
Dieldrin	50/185	0.046-80	0.050-26	0.38	4.0	14	0.51	1.7	0.14
Endrin	39/185	0.046-20	0.050-59	0.25	2.7	4.5	0.58	1.9	0.12
Isodrin	25/184	0.074-3.2	0.051-47	0.44	0.88	0.95	0.50	1.1	0.068
Arsenic	55/117	2.5-310	2.4-2.5	42	47	50	28	1.2	13
Mercury	27/115	0.11-12	0.10-0.50	0.22	1.3	3.0	0.40	1.3	0.094
ICP Metals									
Cadmium	5/122	10-38	5.2-8.4	16	21	12	19	0.55	0.77
Chromium	18/122	6.0-190	6.0-24	52	57	51	38	1.0	5.6
Copper	32/122	9.5-130	7.9-26	45	52	35	40	0.76	11
Lead	1/122	24	19-74	NC	NC	NC	NC	NC	NC
Zinc	68/122	21-1900	20-100	40	94	230	52	0.84	29

+ Includes maximum CRL values for diluted samples
Δ Standard deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target status in the SARs; there is no CRL for TICs. For the purpose of this report a CRL of 5 µg/l, typically corresponding to 10 percent of the internal standard, was used.
† Nontarget analyte for which concentrations reported as part of a USATHAMA-certified analytical method.
‡ Target analytes under CMP or Task 11
** Reported as total xylenes
NA - Not analyzed NC - Not calculated, as sample population is too small for comparison purposes NI - Not identified

OSCMs, DBCP, and OCPs, are particularly high in the southern part of Section 36 near the western South Plants drainage ditch.

Significant hydrogeologic characteristics of the Basin A plume group include relatively low hydraulic conductivity within the UFS and local interchange of groundwater and surface water. The relatively low hydraulic conductivity has decreased the rate of contaminant migration in the UFS through the Basin A Neck and partly contained contamination within the vicinity of Basin A. In addition, the groundwater interception and treatment system IRA in the Basin A Neck area (Appendix C) is having major impacts on both groundwater flow and contaminant concentrations downgradient of the Basin A neck. Local interchange of groundwater and surface water has resulted in locations where contaminated groundwater is at or near land surface. The two locations where interchange of contaminated surface water and groundwater is most likely are near the Basin A and South Plants sedimentation pond surface water sampling stations.

A3.2.3.3 Northwest Boundary Plume Group

The Northwest Boundary plume group consists of contaminated groundwater that is migrating toward the northwest boundary. In general, plumes in the Northwest Boundary plume group represent downgradient extensions of plumes that originated near the disposal basins. Recharge from Basins C, D, and E is suspected to have formerly entered the UFS in this area. The chemical composition of this plume group reflects changes in historical wastes and waste disposal practices at RMA. Consequently the chemical composition is a mixture of numerous analytes. Most organic analyte groups present at RMA have been detected in the Northwest Boundary plume group. Organic analyte concentrations generally are lower than organic concentrations found in other plume groups (Figure RISR A3.2-17; Table RISR A3.2-4). The highest concentrations of organic analytes detected in the plume group (greater than 1,000 µg/l) are associated with OPHGBs. Some detections of VHOs, OSCMs, OSCHs, and ONCs are greater than 100 µg/l. Among inorganics, chloride, fluoride, arsenic, and ICP metals are present at elevated concentrations.

Table RISR A3.2-4 Summary of Analytical Results for the Unconfined Flow System in the Northwest Boundary Plume Group.

Total Wells Sampled: 82 (Apr 87 - Feb 89)
Total Samples Collected: 282

		Concentration		Detections (µg/l)					
Analytical Groups and Analytes Detected	Frequency of Detections	Range (µg/l)	CRL Range$^+$ (µg/l)	Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev. Δ	Adjusted Geometric Mean
Volatile Halogenated Organics (VHOs)NC									
1,1-Dichloroethane	0/288	---	0.73-5.8	---	---	---	---	---	---
1,2-Dichloroethane	17/288	0.70-24	0.61-6.2	3.2	5.4	5.5	3.8	0.84	0.22
1,1-Dichloroethylene	1/280	2.0	1.0-5.6	NC	NC	NC	NC	NC	NC
trans-1,2-Dichloroethylene	0/288	---	0.76-5.2	---	---	---	---	---	---
1,1,2,2-Tetrachloroethane*†	6/15	8.6-67	1.5	19	27	23	21	0.79	8.3
1,1,1-Trichloroethane	0/288	---	0.76-3.27	---	---	---	---	---	---
1,1,2-Trichloroethane	0/288	---	0.78-4.9	---	---	---	---	---	---
Carbon tetrachloride	0/288	---	0.99-5.1	---	---	---	---	---	---
Chlorobenzene	29/288	1.6-70	0.58-4.1	7.7	16	18	8.3	1.2	0.84
Chloroform	226/286	0.55-460	0.50-1.9	20	23	33	14	1.1	11
Methylene chloride	1/284	4.7	1.0-7.4	NC	NC	NC	NC	NC	NC
Tetrachloroethylene	12/288	0.91-6.9	0.75-8.3	2.6	2.9	1.9	2.4	0.68	0.10
Trichloroethylene	75/288	0.67-11	0.56-3.9	1.7	2.3	1.8	1.9	0.60	0.50
Trichloropropene*	NI	---	---	---	---	---	---	---	---
Volatile Hydrocarbons (VHCs)									
2-Butoxyethanol*	NI	---	---	---	---	---	---	---	---
4-Hydroxy-4-methyl-2-pentanone*	NI	---	---	---	---	---	---	---	---
1-Methyl-1,3-cyclopentadiene*	NI	---	---	---	---	---	---	---	---
2,2-Oxybisethanol*	NI	---	---	---	---	---	---	---	---
2-Pentanone*	NI	---	---	---	---	---	---	---	---
Bicycloheptadiene‡	0/111	---	1.0-5.9	---	---	---	---	---	---
Dicyclopentadiene	9/314	1.2-33	1.1-9.3	11	12	9.8	8.6	1.0	0.25
Methylcyclohexane*	NI	---	---	---	---	---	---	---	---
Methylisobutyl ketone	0/262	---	1.0-13	---	---	---	---	---	---

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\+ Includes maximum CRL values for diluted samples
Δ Standard deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target status in the SARs; there is no CRL for TICs. For the purpose of this report a CRL of 5 µg/l, typically corresponding to 10 percent of the internal standard, was used.
† Nontarget analyte for which concentrations reported as part of a USATHAMA-certified analytical method.
‡ Target analytes under CMP or Task 11
** Reported as total xylenes
NA - Not analyzed NC - Not calculated, as sample population is too small for comparison purposes NI - Not identified

Table RISR A3.2-4 Summary of Analytical Results for the Unconfined Flow System in the Northwest Boundary Plume Group.

Total Wells Sampled: 82 (Apr 87 - Feb 89)
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Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/l)	CRL Range+ (µg/l)	Detections (µg/l) Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev. Δ	Adjusted Geometric Mean
Volatile Aromatic Organics (VAOs)									
Benzene	14/282	1.2-8.7	1.0-1.9	2.1	3.1	2.3	2.5	0.65	0.13
Ethylbenzene	0/283	---	0.56-1.4	---	---	---	---	---	---
m-Xylene	2/283	2.0-2.4	1.0-2.0	NC	NC	NC	NC	NC	NC
o- and p-Xylene**	0/283	---	1.3-3.2	---	---	---	---	---	---
Toluene	2/282	1.8-4.3	1.0-2.8	NC	NC	NC	NC	NC	NC
Organosulfur Compounds, Mustard-Agent Related (OSCMs)									
1,4-Oxathiane	16/220	1.8-73	1.4-27	7.9	21	26	9.7	1.3	0.70
Chloroacetic acid*	NI	---	---	---	---	---	---	---	---
Dithiane	10/221	2.2-840	1.1-170	55	170	260	51	1.8	2.3
Thiodiglycol‡	NA	---	---	---	---	---	---	---	---
Organosulfur Compounds, Herbicide Related (OSCHs)									
Benzothiazole	5/152	1.4-45	1.1-5.0	23	23.	21	11	1.6	0.37
Chlorophenylmethyl sulfide	4/221	1.8-12	1.1-17	6.4	6.6	4.1	5.5	0.78	0.10
Chlorophenylmethyl sulfone	10/221	2.7-850	2.2-12	8.5	160	320	18	2.0	0.81
Chlorophenylmethyl sulfoxide	11/220	2.2-21	0.12-29	3.9	6.6	6.1	4.9	0.77	0.24
Dimethyldisulfide	0/168	---	0.55-16	---	---	---	---	---	---

+ Includes maximum CRL values for diluted samples
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Table RISR A3.2-4 Summary of Analytical Results for the Unconfined Flow System in the Northwest Boundary Plume Group.

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		Concentration		Detections (µg/l)					
Analytical Groups and Analytes Detected	Frequency of Detections	Range (µg/l)	CRL Range+ (µg/l)	Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev. Δ	Adjusted Geometric Mean
Organophosphorous Compounds, GB-Agent Related (OPHGBs)									
Diisopropylmethyl phosphonate	120/328	0.47-5,200	0.39-21	16	250	820	20	2.0	7.4
Dimethylmethyl phosphonate	14/323	0.68-67	0.19-1,500	1.3	6.5	18	1.8	1.2	0.079
Isopropylmethyl phosphonic acid	NA	---	---	---	---	---	---	---	---
Methylphosphonic acid	NA	---	---	---	---	---	---	---	---
Phosphoric acid, tributyl ester*	NI	---	---	---	---	---	---	---	---
Phosphoric acid, triphenyl ester*	NI	---	---	---	---	---	---	---	---
Organophosphorous Compounds, Pesticide Related (OPHPs)									
Atrazine‡	17/115	4.9-77	4.0-5.9	9.9	20	21	13	0.83	2.0
Malathion‡	10/115	0.57-7.2	0.37-21	2.3	2.9	2.1	2.3	0.73	0.20
Parathion‡	3/115	1.0-4.6	0.65-37	1.0	NC	NC	NC	NC	NC
Supona‡	14/112	1.0-5.3	0.79-19	1.5	2.0	1.3	1.8	0.49	0.22
Vapona‡	5/115	0.88-32	0.38-17	1.6	7.6	14	2.5	1.47	0.11
Dibromochloropropane (DBCP)	55/343	0.15-0.44	0.04-19	0.24	0.25	0.08	0.24	0.30	0.038

\+ Includes maximum CRL values for diluted samples

Δ Standard deviation of log values (base e) of detections

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Analytical Groups and Analytes Detected	Frequency of Detections	Range (µg/l)	CRL Range+ (µg/l)	Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev. Δ	Adjusted Geometric Mean
Organonitrogen Compounds (ONCs)									
Caprolactam*	4/4	30-500	5	200	210	200	100	1.4	100
Hydrazine	NI	---	---	---	---	---	---	---	---
Methylhydrazine	NI	---	---	---	---	---	---	---	---
n-Nitrosodimethylamine	NI	---	---	---	---	---	---	---	---
n-Nitrosodi-n-propylamine	NI	---	---	---	---	---	---	---	---
Unsymmetrical dimethylhydrazine	NI	---	---	---	---	---	---	---	---
Polynuclear Aromatic Hydrocarbons (PAHs)									
Fluoranthene*	NI	---	---	---	---	---	---	---	---
Methyl naphthalene*	NI	---	---	---	---	---	---	---	---
Phenanthrene*	NI	---	---	---	---	---	---	---	---
Pyrene*	NI	---	---	---	---	---	---	---	---
Semivolatile Halogenated Organics (SHOs)									
Hexachlorobenzene*	NI	---	---	---	---	---	---	---	---
Hexachlorobutadiene*	NI	---	---	---	---	---	---	---	---
Hexachlorocyclopentadiene	12/308	0.067-0.26	0.048-54	0.10	0.12	0.06	0.11	0.42	0.0042
Pentachlorobenzene*	NI	---	---	---	---	---	---	---	---
Tetrachlorobenzene*	NI	---	---	---	---	---	---	---	---
Trichlorobenzene*	NI	---	---	---	---	---	---	---	---

\+ Includes maximum CRL values for diluted samples

Δ Standard deviation of log values (base e) of detections

* Tentatively identified compounds (TICs) elevated to target status in the SARs; there is no CRL for TICs. For the purpose of this report a CRL of 5 µg/l, typically corresponding to 10 percent of the internal standard, was used.

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NA - Not analyzed NC - Not calculated, as sample population is too small for comparison purposes NI - Not identified

Table RISR A3.2-4 Summary of Analytical Results for the Unconfined Flow System in the Northwest Boundary Plume Group.

Total Wells Sampled: 82 (Apr 87 - Feb 89)
Total Samples Collected: 282

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/l)	CRL Range$^+$ (µg/l)	Detections (µg/l) Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev. Δ	Adjusted Geometric Mean
Organochlorine Pesticides (OCPs)									
Aldrin	39/335	0.061-6.1	0.050-13	0.20	0.55	1.1	0.26	1.1	0.030
Chlordane	12/331	0.12-12	0.095-37	0.56	2.2	4.1	0.66	1.5	0.024
Dichlorodiphenylethane (DDE)	20/335	0.049-0.57	0.046-14	0.12	0.17	0.14	0.13	0.73	0.0078
Dichlorodiphenyltrichloroethane (DDT)	24/335	0.059-0.77	0.049-18	0.13	0.17	0.15	0.14	0.61	0.010
Dieldrin	201/334	0.051-86	0.050-26	0.29	1.02	6.1	0.32	1.1	0.19
Endrin	59/331	0.055-0.87	0.050-18	0.17	0.20	0.15	0.16	0.65	0.029
Isodrin	23/335	0.063-5.2	0.051-7.8	0.20	0.48	1.1	0.22	1.0	0.015
Arsenic	110/268	2.6-44	2.4-2.5	8.0	9.5	7.1	7.9	0.57	3.3
Mercury	28/125	0.11-0.46	0.10-0.50	0.17	0.19	0.09	0.18	0.41	0.040
ICP Metals									
Cadmium	3/129	7.1-13	5.2-8.4	8.9	NC	NC	NC	NC	NC
Chromium	12/128	9.2-650	6.0-24	17	83	180	26	1.3	2.4
Copper	6/129	9.3-590	7.9-26	44	150	230	52	1.6	2.4
Lead	4/129	24-120	19-74	50	61	46	48	0.80	1.5
Zinc	46/129	22-2,200	20-100	36	120	340	50	0.91	18

+ Includes maximum CRL values for diluted samples
Δ Standard deviation of log values (base e) of detections
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† Nontarget analyte for which concentrations reported as part of a USATHAMA-certified analytical method.
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As groundwater flows toward the northwest boundary, under the Basin A Neck, Basin C, and former Basin F, it moves from an area of relatively thin alluvium with moderate to low hydraulic conductivity into an area of thick saturated alluvium with higher hydraulic conductivity. The result of these hydrogeologic changes is an increase in advective transport. The increased advective transport, combined with mixing of relatively uncontaminated water as the plumes approach the northwest boundary, may contribute to the lower levels of contamination in the Northwest Boundary plume group relative to others.

A3.2.3.4 North Boundary Plume Group

The North Boundary plume group consists of contaminated groundwater migrating toward the NBCS. It includes plumes originating beneath North Plants and plumes migrating northward under the vicinity of Basin C and former Basin F. The North Boundary plume group may have received leakage from the former Basin F disposal Basin and the chemical sewer systems. Along with the Basin A and South Plants plume groups, the North Boundary plume group contains some of the highest summed AGM concentrations in groundwater at RMA. All organic analyte groups investigated are present (Figure RISR A3.2-18; Table RISR A3.2-5). Concentrations of VHOs and OPHGBs exceed 10,000 µg/l at some locations along the groundwater flow path from former Basin F to the north boundary (Figure RISR A3.2-18). Other analytes or analyte groups with concentrations greater than or equal to 1,000 µg/l include VHCs, OPHPs, and ONCs. Concentrations of OCPs frequently exceed CRLs.

Elevated levels of chloride, fluoride, and arsenic are common in the North Boundary plume group. Areas with chloride concentration greater than 1,000,000 µg/l and fluoride concentration greater than 5,000 µg/l are located immediately north of former Basin F (Figures RISR A3.2-10 and A3.2-11). Elevated levels of ICP metals occur in an irregular pattern along the groundwater flow path under former Basin F toward the north boundary.

Table RISR A3.2-5 Summary of Analytical Results for the Unconfined Flow System in the North Boundary Plume Group.

Total Wells Sampled: 153 (Apr 87 - Feb 89)
Total Samples Collected: 621

		Concentration		Detections (µg/l)					
Analytical Groups and Analytes Detected	Frequency of Detections	Range (µg/l)	CRL Range+ (µg/l)	Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev. Δ	Adjusted Geometric Mean
Volatile Halogenated Organics (VHOs)									
1,1-Dichloroethane	38/599	0.84-7.7	0.73-1,000	1.6	2.3	1.7	1.9	0.63	0.12
1,2-Dichloroethane	128/601	1.2-950	0.61-1,000	9.7	61	160	14	1.5	3.0
1,1-Dichloroethylene	11/575	1.2-230	1.0-1,000	4.6	25.	68	5.9	1.4	0.11
trans-1,2-Dichloroethylene	10/601	0.90-14	0.76-5,000	2.5	4.7	5.0	2.8	1.1	0.047
1,1,2,2-Tetrachloroethane*†	5/20	10-26	1.5-1,500	17	18	6.3	17	0.37	4.2
1,1,1-Trichloroethane	32/601	0.83-120	0.76-1,000	1.5	7.4	22	2.2	1.1	0.12
1,1,2-Trichloroethane	2/601	4.3-6.0	0.78-1,000	NC	NC	NC	NC	NC	NC
Carbon tetrachloride	65/601	1.1-65	0.99-1,000	5.2	9.8	14	5.6	0.94	0.61
Chlorobenzene	89/600	0.96-180	0.58-1,000	4.3	16	31	5.7	1.3	0.85
Chloroform	325/601	0.56-86,000	0.50-28	20	4400	13,000	8.9	3.3	4.8
Methylene chloride	40/557	1.5-1,300	1.0-1,000	70	200	310	63	1.6	4.5
Tetrachloroethylene	240/601	0.88-1,100	0.75-1,000	25	67	160	19	1.6	7.7
Trichloroethylene	212/601	0.64-230	0.56-1,000	6.0	11	22	5.7	1.1	2.0
Trichloropropene*	NI	---	---	---	---	---	---	---	---
Volatile Hydrocarbons (VHCs)									
2-Butoxyethanol*	NI	---	---	---	---	---	---	---	---
4-Hydroxy-4-methyl-2-pentanone*	NI	---	---	---	---	---	---	---	---
1-Methyl-1,3-cyclopentadiene*	NI	---	---	---	---	---	---	---	---
2,2-Oxybisethanol*	NI	---	---	---	---	---	---	---	---
2-Pentanone*	NI	---	---	---	---	---	---	---	---
Bicycloheptadiene‡	48/203	1.4-1,100	1.0-6.0	45	180	300	59	1.6	14
Dicyclopentadiene	222/712	2.1-3,600	1.1-360	170	370	530	24	1.5	7.6
Methylcyclohexane*	NI	---	---	---	---	---	---	---	---
Methylisobutyl ketone	19/614	12-350	1.0-1,400	98	110	110	61	1.3	1.9

+ Includes maximum CRL values for diluted samples
Δ Standard deviation of log values (base e) of detections
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Volatile Aromatic Organics (VAOs)									
Benzene	110/595	1.3-520	1.3-1,000	7.1	39	110	8.9	1.4	1.7
Ethylbenzene	26/594	0.69-13	0.56-1,000	1.7	3.1	3.1	2.1	0.83	0.093
m-Xylene	9/595	1.8-13	1.0-1,000	2.2	5.1	4.3	3.8	0.79	0.057
o- and p-Xylene**	24/594	1.5-75	1.3-2,000	2.9	11	18	4.6	1.2	0.18
Toluene	54/594	1.5-340	1.0-1,000	8.7	46	77	14	1.6	1.3
Organosulfur Compounds, Mustard-Agent Related (OSCMs)									
1,4-Oxathiane	216/671	1.4-190	1.4-400	6.3	10	17	6.6	0.87	2.1
Chloroacetic acid*	NI	---	---	---	---	---	---	---	---
Dithiane	229/673	1.6-570	1.1-1,100	26.0	37	50	22	1.1	7.3
Thiodiglycol‡	0/5	---	66	---	---	---	---	---	---
Organosulfur Compounds, Herbicide Related (OSCHs)									
Benzothiazole	57/558	1.24-270	1.1-39	6.6	14	36	6.0	1.1	0.62
Chlorophenylmethyl sulfide	179/672	1.2-790	1.1-850	17	61	130	18	1.5	4.9
Chlorophenylmethyl sulfone	336/673	2.9-1,700	2.2-360	29	150	240	8.3	1.7	4.1
Chlorophenylmethyl sulfoxide	204/672	2.3-400	2.0-1,500	37	54	71	31	1.1	9.3
Dimethyldisulfide	32/586	0.93-29.0	0.55-675	6.0	7.0	6.7	5.0	0.85	0.27

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Organophosphorous Compounds, GB-Agent Related (OPHGBs)									
Diisopropylmethyl phosphonate	556/685	0.69-5,000	0.39-7000	220	580	800	3.6	1.6	2.9
Dimethylmethyl phosphonate	50/681	0.35-20,000	0.19-1,700	26	1500	31	4,200	3.1	2.3
Isopropylmethyl phosphonic acid	NA	---	---	---	---	---	---	---	---
Methylphosphonic acid	NA	---	---	---	---	---	---	---	---
Phosphoric acid, tributyl ester*	NI	---	---	---	---	---	---	---	---
Phosphoric acid, triphenyl ester*	NI	---	---	---	---	---	---	---	---
Organophosphorous Compounds, Pesticide Related (OPHPs)									
Atrazine‡	40/207	4.1-1,000	4.0-280	27	57	160	24	1.1	4.7
Malathion‡	23/207	0.65-7.4	0.37-700	2.5	2.5	1.6	2.1	0.66	0.23
Parathion‡	23/207	0.91-15	0.65-950	4.4	5.3	4.1	4.0	0.80	0.44
Supona‡	18/201	0.98-27	0.79-470	1.4	4.5	7.4	2.2	1.0	0.20
Vapona‡	11/207	0.58-9.8	0.38-850	0.71	1.9	2.7	1.2	0.90	0.064
Dibromochloropropane (DBCP)	189/724	0.15-190	0.13-950	1.4	4.4	15	1.4	1.4	0.37

+ Includes maximum CRL values for diluted samples
Δ Standard deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target status in the SARs; there is no CRL for TICs. For the purpose of this report a CRL of 5 µg/l, typically corresponding to 10 percent of the internal standard, was used.
† Nontarget analyte for which concentrations reported as part of a USATHAMA-certified analytical method.
‡ Target analytes under CMP or Task 11
** Reported as total xylenes
NA - Not analyzed NC - Not calculated, as sample population is too small for comparison purposes NI - Not identified

Table RISR A3.2-5 Summary of Analytical Results for the Unconfined Flow System in the North Boundary Plume Group.

Total Wells Sampled: 153 (Apr 87 - Feb 89)
Total Samples Collected: 621

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/l)	CRL Range$^+$ (µg/l)	Detections (µg/l) Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev. Δ	Adjusted Geometric Mean
Organonitrogen Compounds (ONCs)									
Caprolactam*	12/12	100-2,000	5	200	490	600	300	0.91	300
Hydrazine	NA	---	---	---	---	---	---	---	---
Methylhydrazine	NA	---	---	---	---	---	---	---	---
n-Nitrosodimethylamine	NA	---	---	---	---	---	---	---	---
n-Nitrosodi-n-propylamine	NA	---	---	---	---	---	---	---	---
Unsymmetrical dimethylhydrazine	NA	---	---	---	---	---	---	---	---
Polynuclear Aromatic Hydrocarbons (PAHs)									
Fluoranthene*	NI	---	---	---	---	---	---	---	---
Methyl naphthalene*	NI	---	---	---	---	---	---	---	---
Phenanthrene*	NI	---	---	---	---	---	---	---	---
Pyrene*	1/1	20	5	NC	NC	NC	NC	NC	NC
Semivolatile Halogenated Organics (SHOs)									
Hexachlorobenzene*	2/2	7-8	5	NC	NC	NC	NC	NC	NC
Hexachlorobutadiene*	NI	---	---	---	---	---	---	---	---
Hexachlorocyclopentadiene	61/656	0.071-92	0.048-1,100	1.0	5.8	15	1.3	1.7	0.12
Pentachlorobenzene*	NI	---	---	---	---	---	---	---	---
Tetrachlorobenzene*	4/4	8-30	5	8	13	10	10	0.66	10
Trichlorobenzene*	NI	---	---	---	---	---	---	---	---

+ Includes maximum CRL values for diluted samples
Δ Standard deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target status in the SARs; there is no CRL for TICs. For the purpose of this report a CRL of 5 µg/l, typically corresponding to 10 percent of the internal standard, was used.
† Nontarget analyte for which concentrations reported as part of a USATHAMA-certified analytical method.
‡ Target analytes under CMP or Task 11
** Reported as total xylenes
NA - Not analyzed NC - Not calculated, as sample population is too small for comparison purposes NI - Not identified

Table RISR A3.2-5 Summary of Analytical Results for the Unconfined Flow System in the North Boundary Plume Group.

Total Wells Sampled: 153 (Apr 87 - Feb 89)
Total Samples Collected: 621

		Concentration		Detections (µg/l)					
Analytical Groups and Analytes Detected	Frequency of Detections	Range (µg/l)	CRL Range[+] (µg/l)	Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev. [Δ]	Adjusted Geometric Mean
Organochlorine Pesticides (OCPs)									
Aldrin	66/679	0.058-10	0.050-380	0.31	0.92	1.9	0.38	1.2	0.037
Chlordane	36/675	0.15-120	0.10-470	2.2	14	27	3.1	1.7	0.16
Dichlorodiphenylethane (DDE)	54/689	0.048-6.8	0.046-300	0.30	0.67	1.0	0.34	1.2	0.027
Dichlorodiphenyltrichloroethane (DDT)	61/688	0.056-4.4	0.049-460	0.29	0.61	0.85	0.33	1.1	0.029
Dieldrin	370/684	0.045-150	0.050-240	0.44	1.3	7.8	0.46	1.2	0.25
Endrin	204/682	0.043-63	0.050-400	0.44	1.2	4.5	0.43	1.3	0.13
Isodrin	43/689	0.078-12	0.051-190	0.36	0.92	1.9	0.43	1.1	0.027
Arsenic	222/559	2.4-410	2.4-3.1	4.7	13	37	6.4	0.92	2.6
Mercury	52/238	0.10-2.0	0.10-0.50	0.21	0.27	0.27	0.22	0.53	0.048
ICP Metals									
Cadmium	7/242	5.5-35	5.2-8.4	9.5	14	10	11	0.63	0.33
Chromium	18/236	7.0-75	6.0-24	25	31	20	25	0.68	1.9
Copper	15/242	11-85	7.9-26	17	24	19	20	0.56	1.2
Lead	2/242	22-44	19-74	NC	NC	NC	NC	NC	NC
Zinc	90/239	22-210	20-22	42	56	37	47	0.56	18

[+] Includes maximum CRL values for diluted samples
[Δ] Standard deviation of log values (base e) of detections
[*] Tentatively identified compounds (TICs) elevated to target status in the SARs; there is no CRL for TICs. For the purpose of this report a CRL of 5 µg/l, typically corresponding to 10 percent of the internal standard, was used.
[†] Nontarget analyte for which concentrations reported as part of a USATHAMA-certified analytical method.
[‡] Target analytes under CMP or Task 11
[**] Reported as total xylenes
NA - Not analyzed NC - Not calculated, as sample population is too small for comparison purposes NI - Not identified

The occurrence of ICP metals is difficult to evaluate and probably indicates contributions from natural sources.

The distribution of contaminants in the North Boundary plume group area has been influenced by historical hydrogeologic conditions that differ substantially from present-day conditions. During periods when the disposal basins were filled with fluids, the groundwater table was closer to the land surface and rates of flow were more rapid than presently exist. Operation of the NBCS has also had an influence on water levels and the distribution of contaminants south of the containment system. In recent years, water levels in the UFS have declined to the point where the water table at many locations within the North Boundary plume group is near or within the Denver Formation. In these areas of low hydraulic conductivity, rates of contaminant migration have probably decreased significantly.

A3.2.3.5 Western Plume Group

The Western plume group is spatially and hydraulically separated from the large, complex plume system to the northeast. Concentrations are generally the lowest of any of the plume groups (Table RISR A3.2-6). The Western plume group consists of contaminants that originated near the RMA railyard, the motor pool, and off-post areas south of RMA. The chemical composition of the Western plume group is substantially different from the composition of other plume groups at RMA. The principal contaminants are volatiles and DBCP (Figure RISR A3.2-19). Concentrations of the ONCs (caprolactam) are the highest, ranging from 100 to greater than 1,000 µg/l; however, as discussed in Section A3.2.3, these concentrations are interpreted to be anomalous (Figure RISR A3.2-19). An isolated, narrow plume of DBCP originates in the railyard and is migrating toward the ICS. A plume of trichloroethylene extends at least from the motor pool to the ICS. Elevated levels of inorganic contaminants generally are limited to mercury and ICP metals.

The hydrogeology of the Western plume group is characterized by relatively thick saturated deposits of alluvium. Hydraulic conductivity is high. Consequently, rates of groundwater

Table RISR A3.2-6 Summary of Analytical Results for the Unconfined Flow System in the Western Plume Group. Page 1 of 5

Total Wells Sampled: 98 (Apr 87 - Feb 89)
Total Samples Collected: 219

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/l)	CRL Range+ (µg/l)	Detections (µg/l) Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev. Δ	Adjusted Geometric Mean
Volatile Halogenated Organics (VHOs)									
1,1-Dichloroethane	10/185	0.98-2.2	0.73-2.4	1.3	1.4	0.45	1.4	0.30	0.074
1,2-Dichloroethane	1/185	0.76	0.61-1.1	NC	NC	NC	NC	NC	NC
1,1-Dichloroethylene	45/183	1.8-58	1.0-1.7	8.4	13	13	8.7	0.88	2.2
trans-1,2-Dichloroethylene	36/185	0.94-8.5	0.76-5.0	1.9	2.8	2.2	2.1	0.69	0.42
1,1,2,2-Tetrachloroethane*†	2/8	6.4-16	1.5	NC	NC	NC	NC	NC	NC
1,1,1-Trichloroethane	56/185	0.88-130	0.76-1.7	14	24	28	13	1.3	3.9
1,1,2-Trichloroethane	8/185	0.95-3.4	0.78-1.0	1.2	1.4	0.80	1.3	0.41	0.056
Carbon tetrachloride	2/185	1.1-6.4	0.99-2.4	NC	NC	NC	NC	NC	NC
Chlorobenzene	19/184	0.54-93	0.58-1.1	8.0	21	25	6.8	1.8	0.70
Chloroform	51/184	0.57-29	0.50-1.4	1.3	4.1	6.8	1.9	1.1	0.52
Methylene chloride	0/185	---	1.0-7.4	---	---	---	---	---	---
Tetrachloroethylene	49/185	0.89-4.5	0.75-1.3	2.0	2.2	0.99	2.0	0.46	0.52
Trichloroethylene	123/185	0.63-140	0.56-1.4	7.0	19	26	8.8	1.2	5.9
Trichloropropene*	NI	---	---	---	---	---	---	---	---
Volatile Hydrocarbons (VHCs)									
2-Butoxyethanol*	NI	---	---	---	---	---	---	---	---
4-Hydroxy-4-methyl-2-pentanone*	NI	---	---	---	---	---	---	---	---
1-Methyl-1,3-cyclopentadiene*	NI	---	---	---	---	---	---	---	---
2,2-Oxybisethanol*	NI	---	---	---	---	---	---	---	---
2-Pentanone*	NI	---	---	---	---	---	---	---	---
Bicycloheptadiene‡	0/141	---	1.2-5.9	---	---	---	---	---	---
Dicyclopentadiene	9/194	3.2-54	4.7-9.3	12	17	14	13	0.73	0.60
Methylcyclohexane*	NI	---	---	---	---	---	---	---	---
Methylisobutyl ketone	1/175	8.3	1.0-13	NC	NC	NC	NC	NC	NC

\+ Includes maximum CRL values for diluted samples
Δ Standard deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target status in the SARs; there is no CRL for TICs. For the purpose of this report a CRL of 5 µg/l, typically corresponding to 10 percent of the internal standard, was used.
† Nontarget analyte for which concentrations reported as part of a USATHAMA-certified analytical method.
‡ Target analytes under CMP or Task 11
** Reported as total xylenes
NA - Not analyzed NC - Not calculated, as sample population is too small for comparison purposes NI - Not identified

Table RISR A3.2-6 Summary of Analytical Results for the Unconfined Flow System in the Western Plume Group.

Total Wells Sampled: 98 (Apr 87 - Feb 89)
Total Samples Collected: 219

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/l)	CRL Range+ (µg/l)	Detections (µg/l) Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev. Δ	Adjusted Geometric Mean
Volatile Aromatic Organics (VAOs)									
Benzene	19/176	1.3-46	1.0-1.7	8.1	13	13	8.0	1.0	0.86
Ethylbenzene	1/176	4.0	1.0-2.8	NC	NC	NC	NC	NC	NC
m-Xylene	2/176	1.7-2.4	1.0-4.0	NC	NC	NC	NC	NC	NC
o- and p-Xylene**	1/176	2.5	1.4-6.4	NC	NC	NC	NC	NC	NC
Toluene	1/176	2.2	1.0-5.6	NC	NC	NC	NC	NC	NC
Organosulfur Compounds, Mustard-Agent Related (OSCMs)									
1,4-Oxathiane	0/208	---	1.4-27	---	---	---	---	---	---
Chloroacetic acid*	NI	---	---	---	---	---	---	---	---
Dithiane	1/208	6.7	1.3-21	NC	NC	NC	NC	NC	NC
Thiodiglycol‡	0/1	---	6.7	---	---	---	---	---	---
Organosulfur Compounds, Herbicide Related (OSCHs)									
Benzothiazole	2/170	7.9-10	1.1-5.0	NC	NC	NC	NC	NC	NC
Chlorophenylmethyl sulfide	0/208	---	1.1-17	---	---	---	---	---	---
Chlorophenylmethyl sulfone	0/208	---	2.2-8.0	---	---	---	---	---	---
Chlorophenylmethyl sulfoxide	0/208	---	2.0-29	---	---	---	---	---	---
Dimethyldisulfide	0/172	---	0.55-14	---	---	---	---	---	---

+ Includes maximum CRL values for diluted samples
Δ Standard deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target status in the SARs; there is no CRL for TICs. For the purpose of this report a CRL of 5 µg/l, typically corresponding to 10 percent of the internal standard, was used.
† Nontarget analyte for which concentrations reported as part of a USATHAMA-certified analytical method.
‡ Target analytes under CMP or Task 11
** Reported as total xylenes
NA - Not analyzed NC - Not calculated, as sample population is too small for comparison purposes NI - Not identified

Table RISR A3.2-6 Summary of Analytical Results for the Unconfined Flow System in the Western Plume Group.

Total Wells Sampled: 98 (Apr 87 - Feb 89)
Total Samples Collected: 219

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/l)	CRL Range+ (µg/l)	Detections (µg/l)					Adjusted Geometric Mean
				Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev. Δ	
Organophosphorous Compounds, GB-Agent Related (OPHGBs)									
Diisopropylmethyl phosphonate	8/191	0.44-2.8	0.39-21	0.64	0.91	0.79	0.74	0.59	0.031
Dimethylmethyl phosphonate	2/188	0.26-0.35	0.19-130	NC	NC	NC	NC	NC	NC
Isopropylmethyl phosphonic acid	NA	---	---	---	---	---	---	---	---
Methylphosphonic acid	NA	---	---	---	---	---	---	---	---
Phosphoric acid, tributyl ester*	NI	---	---	---	---	---	---	---	---
Phosphoric acid, triphenyl ester*	NI	---	---	---	---	---	---	---	---
Organophosphorous Compounds, Pesticide Related (OPHPs)									
Atrazine‡	0/97	---	4.0-5.9	---	---	---	---	---	---
Malathion‡	2/97	0.59-0.68	0.37-21	NC	NC	NC	NC	NC	NC
Parathion‡	1/97	1.3	0.65-37	NC	NC	NC	NC	NC	NC
Supona‡	1/90	0.96	0.79-19	NC	NC	NC	NC	NC	NC
Vapona‡	1/97	1.5	0.38-17	NC	NC	NC	NC	NC	NC
Dibromochloropropane (DBCP)	65/252	0.051-61	0.040-19	1.5	7.9	15	1.5	2.0	0.38

+ Includes maximum CRL values for diluted samples
Δ Standard deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target status in the SARs; there is no CRL for TICs. For the purpose of this report a CRL of 5 µg/l, typically corresponding to 10 percent of the internal standard, was used.
† Nontarget analyte for which concentrations reported as part of a USATHAMA-certified analytical method.
‡ Target analytes under CMP or Task 11
** Reported as total xylenes
NA - Not analyzed NC - Not calculated, as sample population is too small for comparison purposes NI - Not identified

Table RISR A3.2-6 Summary of Analytical Results for the Unconfined Flow System in the Western Plume Group.

Total Wells Sampled: 98 (Apr 87 - Feb 89)
Total Samples Collected: 219

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/l)	CRL Range+ (µg/l)	Detections (µg/l)					Adjusted Geometric Mean
				Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev. Δ	
Organonitrogen Compounds (ONCs)									
Caprolactam*	5/5	700-2,000	5	900	1140	600	1,000	0.48	1,000
Hydrazine	NA	---	---	---	---	---	---	---	---
Methylhydrazine	NA	---	---	---	---	---	---	---	---
n-Nitrosodimethylamine	NA	---	---	---	---	---	---	---	---
n-Nitrosodi-n-propylamine	NA	---	---	---	---	---	---	---	---
Unsymmetrical dimethylhydrazine	NA	---	---	---	---	---	---	---	---
Polynuclear Aromatic Hydrocarbons (PAHs)									
Fluoranthene*	NI	---	---	---	---	---	---	---	---
Methyl naphthalene*	NI	---	---	---	---	---	---	---	---
Phenanthrene*	NI	---	---	---	---	---	---	---	---
Pyrene*	NI	---	---	---	---	---	---	---	---
Semivolatile Halogenated Organics (SHOs)									
Hexachlorobenzene*	2/2	20	5	NC	NC	NC	NC	NC	NC
Hexachlorobutadiene*	NI	---	---	---	---	---	---	---	---
Hexachlorocyclopentadiene	5/197	0.080-0.69	0.048-54	0.36	0.39	0.22	0.32	0.82	0.0081
Pentachlorobenzene*	NI	---	---	---	---	---	---	---	---
Tetrachlorobenzene*	NI	---	---	---	---	---	---	---	---
Trichlorobenzene*	NI	---	---	---	---	---	---	---	---

+ Includes maximum CRL values for diluted samples
Δ Standard deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target status in the SARs; there is no CRL for TICs. For the purpose of this report a CRL of 5 µg/l, typically corresponding to 10 percent of the internal standard, was used.
† Nontarget analyte for which concentrations reported as part of a USATHAMA-certified analytical method.
‡ Target analytes under CMP or Task 11
** Reported as total xylenes
NA - Not analyzed NC - Not calculated, as sample population is too small for comparison purposes NI - Not identified

Table RISR A3.2-6 Summary of Analytical Results for the Unconfined Flow System in the Western Plume Group.

Total Wells Sampled: 98 (Apr 87 - Feb 89)
Total Samples Collected: 219

		Concentration		Detections (µg/l)					
Analytical Groups and Analytes Detected	**Frequency of Detections**	**Range (µg/l)**	**CRL Range+ (µg/l)**	**Median**	**Mean**	**Standard Deviation**	**Geometric Mean**	**Geometric Std. Dev. Δ**	**Adjusted Geometric Mean**
Organochlorine Pesticides (OCPs)									
Aldrin	8/201	0.059-0.53	0.050-13	0.11	0.17	0.15	0.13	0.72	0.0052
Chlordane	0/201	---	0.10-37	---	---	---	---	---	---
Dichlorodiphenylethane (DDE)	1/201	0.76	0.046-14	NC	NC	NC	NC	NC	NC
Dichlorodiphenyltrichloroethane (DDT)	2/200	0.089-1.5	0.050-18	NC	NC	NC	NC	NC	NC
Dieldrin	0/201	---	0.050-26	---	---	---	---	---	---
Endrin	1/196	0.074	0.050-18	NC	NC	NC	NC	NC	NC
Isodrin	0/201	---	0.050-7.8	---	---	---	---	---	---
Arsenic	0/164	---	2.4-2.5	---	---	---	---	---	---
Mercury	45/170	0.10-0.68	0.10-0.50	0.19	0.20	0.10	0.19	0.38	0.050
ICP Metals									
Cadmium	0/166	---	5.2-8.4	---	---	---	---	---	---
Chromium	17/166	6.1-20	6.0-24	11	11	3.7	11	0.34	1.1
Copper	4/166	35-47	7.9-26	43	42	5.4	42	0.13	1.0
Lead	0/166	---	19-74	---	---	---	---	---	---
Zinc	53/165	22-184	20-40	37	50	33	43	0.52	14

\+ Includes maximum CRL values for diluted samples
Δ Standard deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target status in the SARs; there is no CRL for TICs. For the purpose of this report a CRL of 5 µg/l, typically corresponding to 10 percent of the internal standard, was used.
† Nontarget analyte for which concentrations reported as part of a USATHAMA-certified analytical method.
‡ Target analytes under CMP or Task 11
** Reported as total xylenes
NA - Not analyzed NC - Not calculated, as sample population is too small for comparison purposes NI - Not identified

flow and contaminant migration in this plume group are faster than rates of movement in other plume groups. Much of the contamination in the Western plume group originated in areas south of RMA, and in the process of migrating across RMA, has merged with plumes that originated within the RMA boundaries. Samples of contaminated groundwater originating off post to the south frequently contain elevated levels of VHOs and associated breakdown products. These analytes are detected less frequently in plumes that originated within the boundaries of RMA.

A3.2.3.6 Isolated Detections

Table RISR A3.2-7 is a data summary for groundwater samples from the UFS that have not been assigned to any plume group. These samples are generally isolated spatially or temporally. VHOs, OCPs, and ICP metals constitute most detections for this group. Some of the VHO detections are attributed to methylene chloride lab artifacts, as discussed in individual SARs and the WRIR. Sporadic high VHC and VAO concentrations were detected in areas adjacent to the South Plants plume group.

A3.2.4 Confined Flow System

Although the majority of contaminated groundwater at RMA occurs in the UFS, wells completed in the underlying Denver Formation have elevated levels of some contaminants. Much of the water in the Denver Formation is present under confined conditions. However, water in the upper portion of the Denver Formation is commonly under unconfined flow conditions, particularly where overlying alluvial deposits are unsaturated. The Denver Formation consists of fluvial and deltaic sediments that generally have low hydraulic conductivity. Wells in the Denver Formation are typically completed in sandstone units. Yields of these wells usually are low and the lateral extent and interconnectivity of individual sandstone bodies are extremely complex and not well characterized. In general, because the distribution of contaminants frequently appears to be irregular, occurrences in the Denver Formation groundwater cannot be depicted as continuous plumes. The irregular pattern of contamination is a reflection of the lenticular and discontinuous nature of the permeable

Table RISR A3.2-7 Summary of Analytical Results for Isolated Detections in the Unconfined Flow System.

Total Wells Sampled: 172 (Apr 87 - Feb 89)
Total Samples Collected: 632

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/l)	CRL Range+ (µg/l)	Detections (µg/l) Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev. Δ	Adjusted Geometric Mean
Volatile Halogenated Organics (VHOs)									
1,1-Dichloroethane	12/633	1.1-5.0	0.73-6,000	2.0	2.2	1.2	2.0	0.47	0.042
1,2-Dichloroethane	46/634	0.60-75	0.61-2,500	3.0	6.5	11	3.4	1.07	0.25
1,1-Dichloroethylene	1/626	2.7	1.0-2,500	NC	NC	NC	NC	NC	NC
trans-1,2-Dichloroethylene	4/634	1.1-2.9	0.76-12,000	1.9	2.0	0.9	1.8	0.49	0.011
1,1,2,2-Tetrachloroethane*†	1/30	14	1.5-3,800	NC	NC	NC	NC	NC	NC
1,1,1-Trichloroethane	27/634	0.82-29	0.76-2,500	3.2	6.4	8.3	3.4	1.1	0.14
1,1,2-Trichloroethane	1/634	1.5	0.78-2,500	NC	NC	NC	NC	NC	NC
Carbon tetrachloride	10/634	1.1-9.8	0.99-5,300	6.9	6.1	3.3	5.0	0.77	0.078
Chlorobenzene	124/629	0.62-120	0.58-2,800	4.5	9.0	15	4.5	1.1	0.89
Chloroform	192/631	0.57-1,500	0.50-2,800	9.3	51	200	9.0	1.6	2.7
Methylene chloride	5/632	2.7-32	1.0-10,000	8.9	12	12	8.7	0.89	0.069
Tetrachloroethylene	98/634	0.90-150	0.75-3,300	6.7	19	30	7.5	1.4	1.2
Trichloroethylene	71/634	0.65-9.1	0.56-3,500	2.6	3.2	2.1	2.6	0.66	0.29
Trichloropropene*	NI	---	---	---	---	---	---	---	---
Volatile Hydrocarbons (VHCs)									
2-Butoxyethanol*	NI	---	---	---	---	---	---	---	---
4-Hydroxy-4-methyl-2-pentanone*	NI	---	---	---	---	---	---	---	---
1-Methyl-1,3-cyclopentadiene*	NI	---	---	---	---	---	---	---	---
2,2-Oxybisethanol*	NI	---	---	---	---	---	---	---	---
2-Pentanone*	NI	---	---	---	---	---	---	---	---
Bicycloheptadiene‡	2/266	1,400	1.2-3,000	NC	NC	NC	NC	NC	NC
Dicyclopentadiene	48/660	9.3-12,000	1.5-3,800	28	420	1,700	57	1.6	4.1
Methylcyclohexane*	NI	---	---	---	---	---	---	---	---
Methylisobutyl ketone	2/620	19-23	1.0-3,500	NC	NC	NC	NC	NC	NC

+ Includes maximum CRL values for diluted samples
Δ Standard deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target status in the SARs; there is no CRL for TICs. For the purpose of this report a CRL of 5 µg/l, typically corresponding to 10 percent of the internal standard, was used.
† Nontarget analyte for which concentrations reported as part of a USATHAMA-certified analytical method.
‡ Target analytes under CMP or Task 11
** Reported as total xylenes
NA - Not analyzed NC - Not calculated, as sample population is too small for comparison purposes NI - Not identified

Table RISR A3.2-7 Summary of Analytical Results for Isolated Detections in the Unconfined Flow System.

Total Wells Sampled: 172 (Apr 87 - Feb 89)
Total Samples Collected: 632

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/l)	CRL Range+ (µg/l)	Detections (µg/l)					Adjusted Geometric Mean
				Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev. Δ	
Volatile Aromatic Organics (VAOs)									
Benzene	47/632	1.0-680,000	1.0-1.9	3.1	27,000	110,000	8.3	3.3	0.62
Ethylbenzene	2/632	5.2-400	0.62-70,000	NC	NC	NC	NC	NC	NC
m-Xylene	1/632	400	1.0-100,000	NC	NC	NC	NC	NC	NC
o- and p-Xylene**	4/632	2.0-400	1.3-160,000	2.6	100	200	8.5	2.6	0.054
Toluene	8/631	1.8-400	1.0-140,000	3.4	58	140	7.6	1.9	0.096
Organosulfur Compounds, Mustard-Agent Related (OSCMs)									
1,4-Oxathiane	15/655	1.4-62	1.4-400	4.9	16	21	7.2	1.4	0.16
Chloroacetic acid*	NI	---	---	---	---	---	---	---	---
Dithiane	27/656	1.8-530	1.1-1,100	8.3	67	150	12	1.7	0.48
Thiodiglycol‡	0/7	---	6.7	---	---	---	---	---	---
Organosulfur Compounds, Herbicide Related (OSCHs)									
Benzothiazole	5/560	1.2-310	1.1-5.0	7.1	66	140	8.4	2.3	0.075
Chlorophenylmethyl sulfide	16/656	1.2-42	1.1-850	3.8	8.1	10	4.9	0.98	0.12
Chlorophenylmethyl sulfone	43/656	2.7-670	2.2-360	8.6	73	160	14	1.6	0.89
Chlorophenylmethyl sulfoxide	53/656	2.1-140	2.0-1,500	35	45	43	23	1.4	1.8
Dimethyldisulfide	3/574	1.1-1.8	0.55-34,000	1.1	NC	NC	NC	NC	NC

\+ Includes maximum CRL values for diluted samples

Δ Standard deviation of log values (base e) of detections

* Tentatively identified compounds (TICs) elevated to target status in the SARs; there is no CRL for TICs. For the purpose of this report a CRL of 5 µg/l, typically corresponding to 10 percent of the internal standard, was used.

† Nontarget analyte for which concentrations reported as part of a USATHAMA-certified analytical method.

‡ Target analytes under CMP or Task 11

** Reported as total xylenes

NA - Not analyzed NC - Not calculated, as sample population is too small for comparison purposes NI - Not identified

Total Wells Sampled: 172 (Apr 87 - Feb 89)
Total Samples Collected: 632

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/l)	CRL Range+ (µg/l)	Detections (µg/l) Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev. Δ	Adjusted Geometric Mean
Organophosphorous Compounds, GB-Agent Related (OPHGBs)									
Diisopropylmethyl phosphonate	209/675	0.45-5500	0.39-700	53	360	740	30	2.3	9.2
Dimethylmethyl phosphonate	12/660	0.29-680	0.19-1,700	0.73	84	210	2.6	2.7	0.045
Isopropylmethyl phosphonic acid	NA	---	---	---	---	---	---	---	---
Methylphosphonic acid	NA	---	---	---	---	---	---	---	---
Phosphoric acid, tributyl ester*	NI	---	---	---	---	---	---	---	---
Phosphoric acid, triphenyl ester*	NI	---	---	---	---	---	---	---	---
Organophosphorous Compounds, Pesticide Related (OPHPs)									
Atrazine‡	19/214	4.2-51	4.0-280	13	17	14	13	0.81	1.1
Malathion‡	7/214	0.91-17	0.37-700	1.9	5.6	6.9	2.9	1.2	0.094
Parathion‡	6/214	0.84-5.0	0.65-950	2.1	2.5	1.6	2.1	0.68	0.058
Supona‡	7/203	0.92-35	0.79-470	1.3	7.2	12	2.7	1.4	0.095
Vapona‡	6/214	0.94-1.7	0.38-850	1.6	1.4	0.29	1.4	0.23	0.040
Dibromochloropropane (DBCP)	45/705	0.060-16	0.040-7,500	0.51	2.7	4.4	0.80	1.6	0.051

\+ Includes maximum CRL values for diluted samples
Δ Standard deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target status in the SARs; there is no CRL for TICs. For the purpose of this report a CRL of 5 µg/l, typically corresponding to 10 percent of the internal standard, was used.
† Nontarget analyte for which concentrations reported as part of a USATHAMA-certified analytical method.
‡ Target analytes under CMP or Task 11
** Reported as total xylenes
NA - Not analyzed NC - Not calculated, as sample population is too small for comparison purposes NI - Not identified

Total Wells Sampled: 172 (Apr 87 - Feb 89)
Total Samples Collected: 632

		Concentration		Detections (µg/l)					
Analytical Groups and Analytes Detected	Frequency of Detections	Range (µg/l)	CRL Range+ (µg/l)	Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev. Δ	Adjusted Geometric Mean
Organonitrogen Compounds (ONCs)									
Caprolactam*	4/4	10-400	5	200	220	200	100	1.5	100
Hydrazine	0/4	---	31	---	---	---	---	---	---
Methylhydrazine	0/4	---	3,000	---	---	---	---	---	---
n-Nitrosodimethylamine	NA	---	---	---	---	---	---	---	---
n-Nitrosodi-n-propylamine	NA	---	---	---	---	---	---	---	---
Unsymmetrical dimethylhydrazine	0/4	---	23	---	---	---	---	---	---
Polynuclear Aromatic Hydrocarbons (PAHs)									
Fluoranthene*	NI	---	---	---	---	---	---	---	---
Methyl naphthalene*	NI	---	---	---	---	---	---	---	---
Phenanthrene*	NI	---	---	---	---	---	---	---	---
Pyrene*	NI	---	---	---	---	---	---	---	---
Semivolatile Halogenated Organics (SHOs)									
Hexachlorobenzene*	5/5	6-300	5	20	140	200	50	1.8	50
Hexachlorobutadiene*	NI	---	---	---	---	---	---	---	---
Hexachlorocyclopentadiene	7/673	0.067-1.4	0.048-1,100	0.18	0.43	0.54	0.22	1.2	0.0023
Pentachlorobenzene*	NI	---	---	---	---	---	---	---	---
Tetrachlorobenzene*	NI	---	---	---	---	---	---	---	---
Trichlorobenzene*	NI	---	---	---	---	---	---	---	---

+ Includes maximum CRL values for diluted samples
Δ Standard deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target status in the SARs; there is no CRL for TICs. For the purpose of this report a CRL of 5 µg/l, typically corresponding to 10 percent of the internal standard, was used.
† Nontarget analyte for which concentrations reported as part of a USATHAMA-certified analytical method.
‡ Target analytes under CMP or Task 11
** Reported as total xylenes
NA - Not analyzed   NC - Not calculated, as sample population is too small for comparison purposes   NI - Not identified

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Table RISR A3.2-7 Summary of Analytical Results for Isolated Detections in the Unconfined Flow System.

Total Wells Sampled: 172 (Apr 87 - Feb 89)
Total Samples Collected: 632

Analytical Groups and Analytes Detected	Frequency of Detections	Concentration Range (µg/l)	CRL Range+ (µg/l)	Detections (µg/l)					
				Median	Mean	Standard Deviation	Geometric Mean	Geometric Std. Dev. Δ	Adjusted Geometric Mean
Organochlorine Pesticides (OCPs)									
Aldrin	26/687	0.063-0.46	0.050-380	0.17	0.18	0.11	0.15	0.62	0.0057
Chlordane	6/567	0.31-11	0.095-470	0.66	2.7	4.2	1.1	1.5	0.011
Dichlorodiphenylethane (DDE)	7/687	0.067-5.9	0.046-310	0.09	0.94	2.2	0.18	1.6	0.0019
Dichlorodiphenyltrichloroethane (DDT)	26/686	0.065-5.4	0.049-460	0.15	0.49	1.1	0.21	1.1	0.0080
Dieldrin	136/686	0.046-8.9	0.050-240	0.13	0.48	1.1	0.19	1.1	0.038
Endrin	47/674	0.042-4.2	0.050-400	0.17	0.37	0.69	0.17	1.1	0.012
Isodrin	9/687	0.11-6.2	0.051-190	0.33	1.1	2.0	0.47	1.3	0.0062
Arsenic	58/572	2.5-75	2.4-3.1	3.9	7.1	13	4.5	0.67	0.45
Mercury	96/468	0.10-0.51	0.10-0.50	0.21	0.22	0.09	0.21	0.38	0.043
ICP Metals									
Cadmium	22/470	5.3-41	5.2-8.4	5.9	9.1	7.7	7.8	0.50	0.36
Chromium	85/457	6.2-69	6.0-24	14	18	13	15	0.58	2.8
Copper	23/470	8.4-63	7.9-26	28	31	17	26	0.61	1.3
Lead	26/470	20-160	19-74	27	37	29	32	0.50	1.8
Zinc	171/470	21-368	20-100	41	57	50	46	0.59	17

+ Includes maximum CRL values for diluted samples
Δ Standard deviation of log values (base e) of detections
* Tentatively identified compounds (TICs) elevated to target status in the SARs; there is no CRL for TICs. For the purpose of this report a CRL of 5 µg/l, typically corresponding to 10 percent of the internal standard, was used.
† Nontarget analyte for which concentrations reported as part of a USATHAMA-certified analytical method.
‡ Target analytes under CMP or Task 11
** Reported as total xylenes
NA - Not analyzed NC - Not calculated, as sample population is too small for comparison purposes NI - Not identified

sandstones in this hydrogeologic unit, and the complex interaction of the stratigraphic, hydrologic, and chemical characteristics of the aquifer. In addition, artificial conduits caused by pre-RMA from wells and deteriorating or improperly constructed wells, generally installed prior to 1984, may also have contributed to the irregular pattern of contamination.

A3.2.4.1 Data Evaluation

An extensive evaluation of Denver Formation water quality was undertaken as part of the RISR. A complete description of the data evaluation and results of the evaluation are provided in Appendix B of this report. The primary effort was directed toward determining the vertical extent of contamination in the Denver Formation aquifer. A chronological well-by-well and analyte-by-analyte review of all available data collected from 1975 through September 1989 was conducted, and values representative of present-day contamination were determined. Where data were not conclusive, conservative values were selected. This tended to overestimate the extent of contamination. All sampled wells that were screened in the Denver Formation were used in this effort. No initial distinction was made between wells screened in the confined and unconfined parts of the Denver Formation; however, the resulting evaluation tended to focus on the CFS within the Denver Formation aquifer.

The evaluation included creation of a database of available water quality information that reliably lists the most recent representative contaminant concentration at wells. Previous attempts to characterize contamination in the Denver Formation aquifer were limited by the use of data from a single sampling period. Although the evaluation was conducted by the Army and its contractors, the organizations and state were consulted frequently, and they provided comments and guidance. The initial database was reviewed by the organizations and state and the Army, and refined accordingly. The resulting database represents the most comprehensive and reliable set of information available to characterize contamination in the Denver Formation aquifer at RMA.

For the purposes of this discussion, the distinction between the UFS and the CFS is important; consequently, the database was screened for those wells sampling Denver

Formation groundwater that is under confined flow conditions. The maps supporting this discussion present contaminant conditions for the CFS. Wells screened in the CFS that were sampled between 1975 and 1989 are shown in Figure RISR A3.2-20.

A3.2.4.2 Vertical Extent of Confined Flow System Contamination

Contaminant concentrations in the CFS are substantially less than in the overlying UFS. For example, concentration of total organic analytes in the UFS near Former Basin F exceeds 10,000 µg/l. Wells completed in the CFS near Basin F typically have summed organic concentrations less than 200 µg/l. The total organic concentration of the UFS in the vicinity of Basin A exceeds 10,000 µg/l over a large area (Figures RISR A3.2-6-A3.2-8), whereas concentrations in the CFS beneath this area typically are less than 700 µg/l (Figure RISR A3.2-21). Similar differences in concentration occur in other parts of RMA. Concentrations of chloride, fluoride, and metals in the CFS (Figures RISR A3.2-22, A3.2-23, and A3.2-24) also are substantially less than in the overlying UFS. High concentration values in the CFS typically occur only in the upper 20 ft of bedrock and in close proximity to highly contaminated portions of the UFS.

The number of contaminants measured in the CFS typically is less than the number measured in the overlying UFS. Contaminants that appear most frequently in the CFS are highly soluble with limited sorptive tendencies, such as many VHOs, VAOs, and OPHGBs. Unexpectedly, OCPs have been detected with a high frequency. These OCPs tend to readily sorb to fine-grained aquifer sediments and are not expected to migrate substantial distances in the Denver Formation. Cosolvency effects and utilization of flowpaths with minimal sorptive capacity may explain their widespread distribution. Elevated levels of inorganic analytes have also been detected in the CFS. As in the UFS, arsenic, fluoride, and chloride are the most widespread inorganic analytes. However, an understanding of the distribution of inorganic contaminants is complicated by naturally occurring concentrations of these substances in the Denver Formation aquifer.

Although the shallow bedrock of the Denver Formation aquifer appears to be effective in partially containing downward migration below the UFS, it is not a completely effective barrier. Hydrogeologic cross-sections (see Appendix B) indicate that concentrations of organic analytes vary with depth in an irregular manner. Although concentrations generally decrease with increasing depth, exceptions to this rule are found. The most notable exception occurs in the vicinity of the NBCS. Data from cluster wells in this area do not show a decreasing trend in concentration with increasing well depth. Reasons for the unordinary patterns of increasing concentration with depth may be the result of historical groundwater flow patterns that differed from present day patterns related to operation of the NBCS. The discontinuous nature of sandstone channels in the Denver Formation aquifer also may contribute to the irregular pattern of contamination.

Existing water quality data are sufficient to identify the total depth of contamination throughout most of RMA. In many areas, the deepest wells are not contaminated. In other areas, levels of contaminants in the deepest wells have decreased to near CRL, and a total depth of contamination can be estimated. Relatively low levels of several contaminants have been noted in many parts of RMA, at depths greater than 100 ft below the alluvium-bedrock contact. However, concentrations in wells deeper than 150 ft below the bedrock-alluvium contact are near or below CRLs. Areas where total depth of contamination can not be inferred because organics were detected in the deepest wells in these areas include Sections 22 and 26, the southeast corner of Section 35, Basin A, the NBCS, and North Plants.

A3.2.4.3 Distribution of Analyte Groups

Contamination in the CFS generally occurs in close proximity to contaminated areas in the UFS. Therefore, wells completed in the CFS have been classified into areas that correspond approximately with the plume groups discussed previously for the UFS. For ease of comparison, areas of the CFS will be denoted by the name of the corresponding unconfined plume group. These areas are the South Plants area, the Basin A area, the Northwest Boundary area, the North Boundary area, and the Western area. Wells not classified into one of these areas have been placed into the Miscellaneous area in order to assess the extent of contamination in the CFS where no unconfined plume is present.

Elevated levels of organic contaminants are present in virtually all wells of the CFS in the South Plants area (Figure RISR A3.2-21). The most frequently detected organic analyte groups are VHOs and VAOs. Other organic analytes occur less frequently and are not present at depths greater than 85 ft below the alluvium-bedrock contact. Concentrations of chloride, fluoride, and ICP metals (Figures RISR A3.2-22, A3.2-23, and A3.2-24) are similar to concentrations in the CFS in off-post areas.

The most frequently detected analyte group in the CFS near Basin A has been VHOs. This analyte group has been detected in wells completed to depths of 89 ft below the alluvium-bedrock contact. Concentrations in deeper wells have been below CRLs. Other organic analyte groups have been detected less frequently and generally in shallow wells. Elevated concentrations of fluoride, chloride, arsenic, mercury, and metals have been detected in this area.

VHOs, VHCs, and OPHGBs have been detected in 50 to 75 percent of wells sampled in the CFS in the Northwest Boundary area. However, concentrations recorded for most wells greater than 100 ft below the alluvium-bedrock contact are near the CRL. Other organic analytes occur infrequently. Concentrations of fluoride and chloride are similar to off-post levels. Metal concentrations were near background levels at the Northwest Boundary, but are higher in Section 35.

A number of organic analyte groups have been identified in wells of the CFS in the North Boundary area. Analyte groups identified in at least 50 percent of all sampled wells include VHOs, OCPs, and OPHGBs. Other analyte groups occurring in more than 30 percent of all sampled wells include VAOs, OSCs, and DBCP. Fluoride, chloride, and metal concentrations generally are similar to off-post levels.

VHOs have been detected in all the wells completed in the CFS within the Western area. OCPs have also been detected in five wells within the Western area. Fluoride, chloride, and metals were near background levels.

Water-quality data from wells included in the Miscellaneous area indicate that an irregular pattern of contamination in the CFS generally occurs only in areas where the UFS is contaminated. An important exception to this rule occurs in the area northwest of former Basin F, between the Northwest and North Boundary areas. Wells completed in these areas have been sampled infrequently but have contained slightly elevated levels of VHOs, VAOs, and OCPs. Because the sampling history at these wells is incomplete, analyte concentrations used in the assessment of contamination may be unreliable.

A3.3 STRUCTURES

The Structures RI was developed to examine the nature and extent of contamination associated with RMA buildings, foundations, tanks, and related piping. A variety of techniques were used to characterize these features, including structural use classification, liquid, dust, and asbestos sampling, and indoor air quality monitoring. The results of these programs are presented in the Structures Survey Report (EBASCO, 1988c/RIC 88306R02), and are summarized below.

A3.3.1 Building Classifications

Historical records of each structure were reviewed during the RI. Structures were classified on the basis of suspected contamination in conjunction with the limited sampling data available. Plate RISR A3.3-1 shows the locations of the three building category structures on RMA: suspected to be contaminated, suspected to be contaminated but cleanable, and suspected to be uncontaminated. The South Plants, North Plants, and Rail Classification/ Maintenance Yard are enlarged in windows on Plate RISR A3.3-1 for clarification. Historical records indicate that possible use or release of contaminants in warehouse, maintenance, utility, and laboratory structures were likely limited to discrete areas of those structures. There are 982 structures at RMA, including 219 electrical substations. Of the remaining 763 structures, 401 structures were classified as suspected to be contaminated, 254 were classified as suspected to be contaminated but cleanable, and 108 were classified as suspected to be uncontaminated. All 219 electrical substations contained transformers at the time of the RI, many of which were labeled as containing PCBs. The status of the electrical substations with respect to PCB-containing transformers is presented in Table 24.1-2 of the Structure Survey Report.

A3.3.2 Liquid Samples

Fifty-three liquid samples collected from fourteen structures were analyzed during the RI. VHOs, VHCs, and VAOs were most frequently detected, followed by OCPs, OPHGBs, and OSCHs. In addition, calcium, magnesium, potassium, sodium, ICP metals, arsenic, and mercury were also sporadically detected. Table RISR A3.3-1 summarizes the analytical results from the liquid sampling phase of the structures survey.

VHOs in liquid samples were detected in South Plants Buildings 243, 313A, 326, 412, 514, and 741 and in North Plants Buildings 1503B, 1703, and 1712. These buildings were used primarily for chlorine production, agent manufacture, demilitarization, storage, and Army laboratories. One sample containing VAOs was collected from South Plants Building 741, which is currently used as a laboratory. OCPs were detected in liquid from South Plants, Building 422, which was used for agent and pesticide manufacture and DBCP storage. One SHO occurrence was detected in liquid from the same building. OPHGBs were found in an air scrubber in Building 1503B, and in Building 1501 in the North Plants.

Chlorophenylmethyl sulfone, the only OSCH analyte detected, was found in the South Plants Building 365 sump and in Buildings 412 and 414. Arsenic was detected at the South Plants Building 313A sump and two manufacture and demilitarization locations in the North Plants (Buildings 1611 and 1703). Mercury was detected at the same North Plants and South Plants buildings as arsenic and also at South Plants Building 326. ICP metals were detected with mercury in the South Plants and at an explosive blending facility, Building 365. They were

Table RISR A3.3-1. Summary of Analytical Results for Structures Liquid Sampling.

		Concentration (µg/l)					
Constituent Detected	Number of Samples*	Range	Median**	Mean**	Standard Deviation**	DataChem Detection Limit	CAL Detection Limit
Volatiles (S=14)							
1,1-Dichloroethane	1	4	-	-	-	***	2
Bicycloheptadiene	1	7	-	-	-	***	1
Carbon tetrachloride	1	10	-	-	-	***	2
Chloroform	7	4-6000	70	1000	2000	***	1
Methylene chloride	4	7-2000	-	-	-	***	4
Tetrachloroethene	2	10-50	-	-	-	***	1
Toluene	1	1	-	-	-	***	1
Semivolatiles (S=14)							
Chlorophenylmethyl sulfone	3	10-40	-	-	-	7	***
Diisopropylmethyl phosphonate	2	50-200	-	-	-	20	***
Dieldrin	1	60	-	-	-	5	***
Organochlorine Pesticides (S=1)							
2,2-bis(Parachlorophenyl)-1,1-dichloroethane	1	0.32	-	-	-	0.054	***
Aldrin	1	10	-	-	-	0.050	***
Dieldrin	1	5.4	-	-	-	0.050	***
Hexachlorocyclopentadiene	1	1.0	-	-	-	0.048	***
Isodrin	1	0.74	-	-	-	0.51	***
Organophosphorous Compounds (S=6)							
Dimethylmethyl phosphonate	1	120	-	-	-	***	19

S - Number of samples analyzed
* - Number of samples in which constituent was detected; only these samples were used in statistical analyses
** - Median, mean, and standard deviation not calculated when constituent detected in fewer than five samples
*** - Laboratory not certified for analytical method and was not used for this analyte
**** - All sample results deemed invalid for litigation purposes since sample holding times were exceeded by laboratory
\+ - Samples analyzed by ESE with detection limits of 66 for thiodiglycol and 53 for thiodiglycolic acid

Table RISR A3.3-1. Summary of Analytical Results for Structures Liquid Sampling.

Constituent Detected	Number of Samples*	Concentration (µg/l) Range	Median**	Mean**	Standard Deviation**	DataChem Detection Limit	CAL Detection Limit
ICP Metals (S=4)							
Cadmium	0					8.4	***
Calcium	4	12,000-31,000	-	-	-	500	500
Chromium	1	67	-	-	-	24	***
Copper	2	36-390	-	-	-	26	***
Lead	2	360	-	-	-	74	***
Magnesium	4	1,200-61,000	-	-	-	500	500
Potassium	4	2,500-110,000	-	-	-	250	250
Sodium	4	21,000-230,000	-	-	-	940	940
Zinc	3	110-1,300	-	-	-	22	***
Arsenic (S=4)	3	4.0-220,000	-	-	-	***	2.5
Mercury (S=4)	4	0.35-1.1	-	-	-	0.10	***
Thiodiglycol (S=6)							
Thiodiglycol	2****	117-2,240	-	-	-	+	+
Thiodiglycolic Acid	2****	228-455	-	-	-	+	+

S	- Number of samples analyzed
*	- Number of samples in which constituent was detected; only these samples were used in statistical analyses
**	- Median, mean, and standard deviation not calculated when constituent detected in fewer than 5 samples
***	- Laboratory not certified for analytical method and was not used for this analyte
****	- All sample results deemed invalid for litigation purposes since sample holding times were exceeded by laboratory
+	- Samples analyzed by ESE with detection limits of 66 for thiodiglycol and 53 for thiodiglycolic acid

also detected at Building 1703, an agent manufacture and demilitarization building in the North Plants.

A3.3.3 Dust Samples

A 1978 study reported the presence of OCPs, copper, arsenic, and mercury in dust samples collected from Building 312, 313, 732, 741, 743, and 831 (USAEHA, 1978/RIC 81324R03). These samples were compared with the results of control samples taken from two households in Aurora, a nearby community. Dust samples from the RMA buildings showed significantly higher concentrations of some OCPs, while the concentrations for DDT isomers, copper, arsenic, and mercury were not significantly different between the two locations. Twenty-three analytes including OCPs, arsenic, mercury, and ICP metals were detected in dust samples from 80 buildings sampled in 1985. Analytical results from this program are presented in the Structures Survey Report (EBASCO, 1988c/RIC 88306R02) summarized in Table RISR A3.3-2. SVOCs were detected in 54 out of 80 building dust samples. Forty-seven out of 57 building dust samples analyzed for metals yielded arsenic, and ICP metals were detected in all 57 building dust samples. Dust samples from two buildings were analyzed for mercury, and both had detections.

A3.3.4 Asbestos Samples

During the Task 24 RI structures sampling investigation, asbestos was only detected in buildings from the South Plants. Analyses of 18 samples from 16 structures detected chrysotile asbestos in 11 samples and amosite asbestos in five samples. Neither crocidolite, actinolite/tremolite, nor anthophyllite asbestos were detected in any samples. Table RISR A3.3-3 summarizes analytical results from asbestos sampling. The Asbestos Removal IRA is currently addressing the need for additional assessment and removal of asbestos at RMA.

A3.3.5 Additional Air Monitoring in RMA Buildings

Beginning in 1986, PMRMA instituted an annual health and safety program of ambient air time-weighted average monitoring in selected buildings that had been used by the Army for

Table RISR A3.3-2 Summary of Analytical Results for Structures Dust Sampling. Page 1 of 2.

		Concentration (µg/g except asbestos, reported in %)					
Consituent Detected	Number of Samples*	Range	Median**	Mean**	Standard Deviation**	DataChem Detection Limit	CAL Detection Limit
Volatiles (S=O)							
Not analyzed							
Semivolatiles (S=79)							
Dichlorodiphenylethane	6	0.6-20	2	6	7	0.6	0.3
Dichlorodiphenyltrichloroethane	1	10	—	—	—	0.5	0.6
Aldrin	32	0.4-5,000	9	200	900	0.3	0.3
Atrazine	15	0.3-30,00	20	4,000	9,000	0.3	0.3
Chlordane	2	9-300	—	—	—	2	0.6
Chlorophenylmethyl sulfone	26	0.7-9,000	7	400	2,000	0.3	0.6
Chlorophenylmethyl sulfoxide	1	10	—	—	—	0.3	7
Dibromochloropropane	2	2-70	—	—	—	0.3	0.3
Dicyclopentadiene	1	200	—	—	—	1	0.4
Dieldrin	54	0.6-10,000	20	400	2,000	0.3	0.3
Endrin	5	9-100	50	50	30	0.5	0.3
Hexachlorocyclopentadiene	4	1-30	—	—	—	0.6	0.3
Isodrin	5	3-20	9	9	7	0.3	0.3
Parathion	1	3	—	—	—	0.9	0.4
Supona	3	3-30	—	—	—	0.6	0.3
Vapona	1	10	—	—	—	3	0.3
ICP Metals (S=57)							
Cadmium	55	1.0-100	14	22	24	0.74	0.66
Chromium	56	6.5-3,800	72	240	670	6.5	5.2
Copper	57	18-180,000	220	6,700	31,000	4.7	4.9
Lead	57	24-5,400	520	810	920	8.4	13
Zinc	57	58-22,000	1,300	2,100	3,300	8.7	9.5

Table RISR A3.3-2 Summary of Analytical Results for Structures Dust Sampling. Page 2 of 2.

Consituent Detected	Number of Samples*	Concentration (µg/g except asbestos, reported in %)					
		Range	Median**	Mean**	Standard Deviation**	DataChem Detection Limit	CAL Detection Limit
Arsenic (S-57)	47	6.4-130	17	24	21	2.5	5.0
Mercury (S=2)	2	10,000-67,000	—	—	—	0.050	0.060
Asbestos (S=56)							
Amosite	15	LT 1-20	—	—	—	****	***
Chrysotile	14	LT 1-50	—	—	—	***	***

LT- Less than
S- Number of samples analyzed
*- Number of samples in which constituent was detected; only these samples were used in statistical analyses
**- Median, mean, and standard deviation no calculated when constituent detected in fewer than five samples or for asbestos results, which are reported by the laboratories as ranges in some cases
***- Asbestos samples analyzed by visual inspection; if any asbestos fibers are observed, asbestos is reported as present

Table RISR A3.3-3. Results of Structures Asbestos Sampling.

Page 1 of 1.

Building Material	Floor Tile		Ceiling Tile		Interior Pipe Lagging	Interior Wall Board	Interior Wall Insulation	Fire Brick	Laboratory Bench
Building Sampled	T163	433	647A	731	511	867A	514	433	517
Air Samples	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Bulk Samples (%)									
Chrysotile Asbestos	ND	LT 1	ND	LT 1	60-65	ND	ND	ND	ND
Amosite Asbestos	ND	LT 1	ND	GT 1-2	ND	ND	GT 1-2	ND	ND
Crocidolite Asbestos	ND	ND	ND	ND	ND	ND	ND	ND	ND
Actinolite/Tremolite Asbestos	ND	ND	ND	ND	ND	ND	ND	ND	ND
Anthophyllite Asbestos	ND	ND	ND	ND	ND	ND	ND	ND	ND

Building Material	Laboratory Hood Counter	Exterior Pipe Lagging		Exterior Wall Board		Exterior Corrugated Siding		Exterior Coating	Tank Insulation
Building Sampled	525	332	517	317	412	514A	525A	351	732
Air Samples	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Bulk Samples (%)									
Chrysotile Asbestos	ND	45-50	10-20	Approx. 5	GT 1-2	GT 1-2	20-30	5-7	20-25
Amosite Asbestos	ND	LT 1	ND	ND	ND	ND	ND	ND	LT 1
Crocidolite Asbestos	ND	ND	ND	ND	ND	ND	ND	ND	ND
Actinolite/Tremolite Asbestos	ND	ND	ND	ND	ND	ND	ND	ND	ND
Anthophyllite Asbestos	ND	ND	ND	ND	ND	ND	ND	ND	ND

BDL – Below detection limit
GT – Greater than
LT – Less than
ND – None detected

Table RISRA3.3-3/RIFS5
8/15/91 mpf

agent operations. Buildings 536, 537, 538, and 742 in South Plants are monitored for mustard. Buildings 1501, 1506, 1601, 1606, and 1703 in North Plants are monitored for GB. Building 1611 in North Plants is monitored for mustard and GB. No agents have been detected to date.

A3.4 AIR

The RI air quality monitoring program at RMA consisted of routine monitoring for TSP, PM-10, and asbestos. It also included episodic monitoring for VOCs, SVOCs, and metals. Figure RISR A3.4-1 shows the locations of permanent air monitoring stations and the areas monitored during event sampling. Routine sampling included monitoring of TSP and PM-10 at 13 locations on RMA from June 1986 to June 1987. VOCs, SVOCs, and metals were monitored on an episodic basis when meteorological conditions favored elevated concentrations of these contaminants in air. The areas where portable air quality monitoring stations were deployed during event sampling are also shown in Figure RISR A3.4-1. It should be noted that the nature and extent of air contamination are not constant, but rather vary with weather conditions, and concentrations may change significantly over a very short time. Regulatory standards require that TSP be calculated as a geometric mean. Because TSP was detected in all RMA samples, the geometric mean is equivalent to the AGM. The PM-10 data approach a normal distribution and, therefore, are summarized as an arithmetic mean. The following discussions are based on these program results.

A3.4.1 Total Suspended Particulates

TSP measurements were collected at RMA from June 1986 through June 1987 at 12 air quality sampling stations, labeled AQ1 through AQ12 in Figure RISR A3.4-1. A thirteenth station, AQ9x, was located alongside station AQ9 from late October 1986 through June 1987. These two stations gave results consistent with one another during the time they were both in operation. TSP data are summarized in Table RISR A3.4-1 and in Figures RISR A3.4-2 and A3.4-3.

Table RISR A3.4-1. Total Suspended Particulates (TSP) Data Summary **Page 1 of 1.**

Month	Geometric Mean Monthly TSP Concentration ($\mu g/m^3$)*													
	AQ1	AQ2	AQ3	AQ4	AQ5	AQ6	AQ7	AQ8	AQ9	AQ9x	AQ10	AQ11	AQ12	All Stations
June 1986	62.8	79.3	48.9	39.3	36.2	36.9	-	43.6	39.0	-	50.2	45.1	46.1	46.6
July	47.2	64.3	42.4	46.8	-	33.1	41.2	41.4	46.0	-	46.0	46.6	42.9	44.7
August	57.7	61.4	41.8	-	-	-	42.7	48.5	55.3	-	45.5	46.6	40.4	48.4
September	52.4	53.0	36.7	-	-	-	40.6	40.6	40.5	-	-	38.9	35.3	41.8
October	47.3	37.1	21.4	-	41.6	44.6	27.9	26.4	20.7	44.4	-	22.9	20.9	30.7
November	46.1	45.4	24.5	-	29.7	27.9	28.7	36.3	20.8	25.6	-	26.3	24.2	29.6
December	102.2	78.3	50.9	-	77.6	60.9	68.1	68.9	57.7	58.6	-	62.1	53.0	65.8
January 1987	56.9	41.6	28.2	-	39.2	41.8	32.7	25.6	29.7	29.5	-	27.6	26.4	33.4
February	43.7	-	25.6	-	33.6	29.3	28.4	32.8	28.9	28.8	-	26.2	23.9	29.7
March	23.9	25.4	15.4	-	20.0	16.0	15.8	19.3	17.4	13.6	5.9	18.4	20.8	16.7
April	46.2	36.4	30.2	-	40.1	31.9	36.0	35.6	32.0	31.4	-	39.2	30.9	35.1
May	20.9	24.6	16.8	-	17.6	21.5	19.2	15.4	14.6	15.8	-	19.9	16.8	18.2
June	44.7	54.9	43.6	-	42.9	41.3	42.7	42.9	43.5	45.0	-	45.1	43.4	44.2
Annual Average	46.8	46.9	30.6	42.9	35.0	33.1	33.0	34.3	31.5	29.6	28.1	33.5	30.8	34.7
Range of Individual 24-hour samples	7.1-14.33	11.5-111.9	4.4-80.5	38.5-46.8	5.7-109.1	6.2-151.4	6.2-100.8	7.3-95.1	5.4-81.5	6.6-83.4	5.9-70.7	5.6-90.8	5.8-77.1	4.4-151.4
Percent Recovery of Data	98.3%	85.2%	98.3%	4.91%	6.23%	66.1%	98.1%	85.2%	88.5%	92.1%	16.4%	90.2%	95.1%	75.4%

* Federal/State TSP Standards - Annual Primary - 75 $\mu g/m^3$
Secondary - 60 $\mu g/m^3$

24-Hour Primary - 260 $\mu g/m^3$
Secondary - 150 $\mu g/m^3$

\- Data not available, station not operational

Figure RISR A3.4-1 shows that mean annual TSP levels were lowest at the stations in the interior of RMA and highest near the boundaries, especially at stations AQ1 and AQ2, those closest to population centers. These data suggest that elevated detections are from off-post sources. The annual geometric mean values for stations with at least 75 percent data recovery ranged from 32 µg/m^3 near Basin A (AQ9) to 47 µg/m^3 at the west and northwest boundaries (AQ1 and AQ2). These data show that air quality at RMA, with respect to TSP, is better than in the surrounding off-post area, and that RMA is not a significant source of airborne particulates.

Figure RISR A3.4-2 presents the primary and secondary EPA standards for mean annual TSP concentrations. While air in the Denver metropolitan area exceeds the EPA's primary annual standard on a regular basis, neither the primary nor the secondary annual standard was exceeded at any of the air quality stations on RMA during the monitoring period. EPA's TSP secondary 24-hour standard of 150 µg/m^3 was exceeded by only one 24-hour sample collected at AQ6 near the South Plants.

A3.4.2 Respirable Particulates (PM-10)

PM-10 data were collected at three stations during the monitoring period. The results are presented in Table RISR A3.4-2 and Figure RISR A3.4-4. Due to equipment problems, only 46 percent of all PM-10 data during this period were recovered. Because none of the three stations had a collection efficiency of greater than 75 percent, the data are of value only as qualitative indicators of ambient air quality. Like TSP, PM-10 levels were highest at the boundary stations and lowest in the interior of RMA, and appear to reflect similar off-post influences. Annual arithmetic mean values ranged from 18 µg/m^3 near Basin A to 35 µg/m^3 near the west boundary. Individual 24-hour values ranged from 5 to 94 µg/m^3. PM-10 concentrations are generally about two-thirds of TSP concentrations (ESE, 1988e/ RIC 88263R01). This pattern is reflected in the RMA data (Figure RISR A3.4-5). PM-10 monitoring at RMA continued after the RI as a part of the CMP. CMP data will be used to augment the RI data for purposes of the FS.

MONTH	Monthly PM-10 Arithmetic Mean Concentration by Station (µg/m^3)		
	AQ2	AQ5	AQ9
July, 1986	31.8	--	11.2
August	31.5	--	27.4
September	28.8	--	17.7
October	23.9	40.6	9.6
November	33.9	28.2	--
December	65.7	55.7	--
January, 1987	--	29.2	--
February	--	23.7	--
March	24.7	36.7	16.6
April	--	--	18.6
May	--	25.6	14.5
June	45.7	27.5	30.5
Annual (Arithmetic Mean)	35.4	34.1	17.6
Range of Individual 24-Hour Samples:	6.36-93.5	13.0-89.9	4.90-36.3
Percent Recovery of Data:	58.6%	39.6%	39.6%

-- Equipment failure.

A3.4.3 Asbestos

Asbestos was analyzed in ambient air samples collected at air quality stations AQ1, AQ6, AQ8, and AQ12. Asbestos was not detected in any of the samples during the monitoring period.

A3.4.4 Volatile Organic Compounds

VOCs, SVOCs, and metals were monitored on an episodic basis when meteorological conditions favored elevated concentrations of these contaminants in air. Figure RISR A3.4-1 shows areas where event sampling was conducted.

Former Basin F was a suspected source of VOCs. Sampling instruments were deployed around Basin F during several warm, low wind episodes. Samples collected from the north and south sides of Basin F contained detectable levels of methylene chloride, chloroform, and several TICs (Table RISR A3.4-3). Methylene chloride is a common laboratory solvent and some detections may be attributable to laboratory contamination. Chloroform is a common solvent but is generally not expected to occur as a laboratory contaminant. The TICs include naturally occurring compounds, industrial solvents, and possible laboratory contaminants. Siloxane, for example, is typically an artifact of the GC method. A more detailed presentation of data may be found in the Air RI Report (ESE, 1988e/RIC 88263R01).

A3.4.5 Semivolatile Organic Compounds

Basin A and former Basin F were suspected sources of SVOCs. Two target SVOCs, dieldrin (an OCP analyte) and chlorophenylmethyl sulfoxide (an OSCH analyte), were detected in samples from one of the three sampling events in the Basin A area (Table RISR A3.4-4). Six target SVOCs, all OCPs and OSCHs, were detected in samples collected from the northeast side of Basin F during one of the two sampling events at this location, and five were detected during the other. Tentatively identified SVOCs include phenanthrene and tetrachlorobenzene (significant TICs included in the PAH and SHO analyte groups, respectively), benzothiazole, and OSCH analyte, pesticide derivatives, gasoline-related compounds, and naturally occurring compounds.

Table RISR A3.4-3. Volatile Organic Compound (VOC) Sampling Events and Results.

Event	No. of Sites	Range of Results (µg/m³) Methylene Chloride	Range of Results (µg/m³) Chloroform	Nontarget Analytes Detected
11/28/86	3	33-2500	ND	Siloxane, limonene
06/10/87	6	ND-74	ND-30	Siloxane, 3-methylheptate, 1-pentane,trichlorofluoromethane acetamide, isodecene
06/22/87	6	ND	ND	Acetone, siloxane, limonene, 1-ethyl-2-heptylcyclopropane, n-butyl-1-1-butamine, 2-beta-pinene, 2,5,6-trimethyloctane, 2,6-bis-1,1-dimethylethyl-2,5-cyclohexadiene-1,4-dione
07/02/87	5	ND	ND	Siloxane, acetone
07/10/87	8	ND-38	ND	Siloxane, acetone, trichlorofluoromethane
07/24/89	8	ND	ND	Siloxane, 2-butanone, acetone
08/05/87	9	ND-70	ND	Siloxane, acetone, trichlorofluoromethane

ND - Not detected

Table RISR A3.4-4. Semivolatile Organic Compounds (SVOCs) Sampling Events and Observed Ranges of Target Analytes

			Range of Target Analytes (ug/m^3)					
			OCPs				OSCHs	
Sample Date	Location	No. of Samples	Dieldrin	Endrin	Aldrin	Isodrin	Chlorophenylmethyl sulfoxide	Chlorophenylmethyl sulfone
05/13/87	Basin A	3	ND-0.031	ND	ND	ND	ND	ND-0.024
05/15/87	Basin A	1	ND	ND	ND	ND	ND	ND
05/19/87	Basin A	4	ND	ND	ND	ND	ND	ND
06/12/87	Basin F	4	0.051-0.2	0.071-0.13	0.067-0.2	ND-0.038	0.047-0.065	0.34-0.37
06/18/87	Basin F	4	0.041-1.6	0.031-0.13	0.064-0.087	ND	0.026-0.039	0.56-1.7

ND = None detected.

A3.4.6. Metals

Samples for metals analysis were collected near the basins and near the RMA boundaries on 16 dry, windy days during the spring and summer of 1987. Samples were analyzed for arsenic, mercury, and the ICP metals; cadmium, chromium, copper, lead, and zinc. Table RISR A3.4-5 summarizes the results of the metals sampling effort. The most prevalent airborne metal was copper, with concentrations up to 0.9 $\mu g/m^3$ near the South Plants. Arsenic, cadmium, chromium, and copper detections were generally consistent with urban metals concentrations in air. All lead detections were in compliance with the minimum state requirement of 1.5 $\mu g/m^3$ as a 1-month average. Mercury was not detected in any of the samples analyzed.

A3.5 BIOTA

Biota present a unique sampling challenge because of the numerous species, their patchy distribution, and their mobility. An exposure pathway modeling approach was developed in the Biota RI in order to facilitate an understanding of the nature of contamination in biota (ESE, 1989b/RIC 89173R02). Contamination is addressed separately for terrestrial and aquatic ecosystems. OCPs, arsenic, and mercury were the target analytes selected for biota samples. Three factors are significant with respect to contaminants and biota. These are bioconcentration, the ratio of a contaminant concentrations in an aquatic organism to its environment; bioaccumulation, the tendency for an organism to take-up and retain contaminants within its tissues; and biomagnification, the tendency for the contaminant concentration to increase in the tissues of organisms of successively higher trophic levels. Only bioaccumulation and biomagnification are discussed in the context of the RI data in this report.

Terrestrial producers (plants), and to some degree carnivores, show elevated levels of OCPs in tissue samples that can be broadly associated with OCP concentrations in RMA soils. This relationship also tends to hold for mercury in carnivores. Based on data available at the time the Biota RI report was prepared, similar associations could not be made for OCPs, arsenic, or mercury in other trophic levels. In addition, a pattern of increasing biomagnification for

Table RISR A3.4-5. Summary of Air Sampling for Arsenic, Mercury, and ICP Metals.

Metals	Detection Limit (µg/m³)	Range of Values Above Detection Limits (µg/m³)	
		From TSP Filters*	From PM-10 Filters+
As	0.003	0.005-0.012 (2)	ND
Hg**	0.063	ND	ND
Cd	0.002	0.002-0.017 (21)	0.002-0.003 (4)
Cr	0.003	0.003-0.050 (19)	ND
Cu	0.016	0.026-0.912 (81)	0.019-0.029 (3)
Pb	0.008	0.010-0.062 (66)	0.009-0.037 (6)
Zn	0.010	0.128-10.2 (11)	ND

*	Total number of TSP filters analyzed - 87
+	Total number of PM-10 filters analyzed - 7
(2)	Number of hits above detection limits
ND	None detected
**	Hg collected on Hopcalite™ media

the OCP dieldrin was evident with progression up the food chain. In aquatic ecosystems, such spatial associations are not clear. Accumulations of arsenic, mercury, and OCPs were detected in species from various trophic levels in all of the lakes. However, a direct relationship between concentrations of these analytes in sediment or water and in biota is not evident.

A3.5.1 Terrestrial Ecosystems

The following discussion groups species investigated by trophic levels in order to discuss the nature and extent of biota contamination at RMA. These groupings and representative species are listed below.

• Primary Producers	Morning glory, sunflower
• Herbivores	Grasshopper, black-tailed prairie dog, cottontail, mule deer, mourning dove
• Omnivores	Ring-necked pheasant, mallard, blue-winged teal, redhead, American coot
• Carnivores	American kestrel, red-tailed hawk, ferruginous hawk, golden eagle, great horned owl, coyote, badger
• Detritivores	Earthworms

Terrestrial biota sampling locations at RMA are shown in Figure RISR A3.5-1 by trophic level. The distributions of terrestrial biota contaminant detections for OCPs, and for arsenic and mercury, are shown in Figures RISR A3.5-2 and A3.5-3, respectively. With the exception of the American kestrel, all other carnivores analyzed were opportunistic samples. These samples were considered important enough to include in the RI data set.

The distribution of OCP detections varied among trophic levels and study areas at RMA. A high frequency of OCP detections was generally associated with high organic analyte concentrations in soils around the disposal areas in the central portion of RMA. OCP detection frequencies for carnivores were lowest in the ESA and WSA, where organic analyte concentrations in soils tends to be lower than most other areas of soil contamination at RMA.

In general, detection frequencies for the OCP dieldrin at all trophic levels above primary producers were greater than or equal to arsenic and mercury detection frequencies in all study areas. Like OCPs, the extent of arsenic and mercury detections varied among trophic levels and study areas.

AGMs were determined for each analyte at each trophic level to facilitate comparisons of contaminant concentrations in biota with respect to trophic level and the associated biomagnification in RMA terrestrial species. All samples of a given trophic level were analyzed together, regardless of tissue type. On-post control areas were treated collectively because numbers of detections were variable and sample sizes were small. The results have been incorporated into a histogram presented in Figure RISR A3.5-4. Table RISR A3.5-1 allows some comparisons between six contaminants of concern for up to five trophic levels, using various mean values for data contained in previously published RMA studies. Given that sample populations for producers and detritivores range from approximately one-third to one-tenth the size of herbivores, omnivores, and carnivores, that not all trophic levels are represented for each contaminant, and that trophic levels may be represented by a single type or a variety of organisms, the following observations can be made based on these data:

- Dieldrin was detected in all trophic levels and showed a fairly clear biomagnification tendency from producers to carnivores. Detritivores also showed dieldrin detections.
- Aldrin was detected only in herbivores. Six of 94 samples showed detectable aldrin concentrations.
- Endrin was detected in herbivores and omnivores. In addition, a single sunflower sample from Basin C and an earthworm sample collected from Section 5 showed detectable endrin.
- DDE was found only in omnivores and carnivores. Mean concentrations in carnivores were higher than for omnivores.
- Arsenic did not appear to biomagnify trophically and was conspicuously absent in carnivores. Arsenic was detected most often in detritivores and producers.
- Mercury showed some tendency to bioaccumulate, and was most often detected in omnivores. Mercury was not detected in producers.

Table RISR A3.5-1 Statistical Comparisons of Terrestrial Trophic Level Contaminant Concentrations.

		Total # of Hits	Total # of Samples	Detection frequency (%)	Minimum Conc(ug/g)	Maximum Conc(ug/g)	ESE Mean*	Geometric Mean**	Adjusted Geometric Mean***	USFWS Geometric Mean****
Dieldrin										
Producers	(CRL = 0.044)	2	19	11	0.08	0.08	0.028	0.08	0.008	0.025
Herbivores	(CRL = 0.031)	39	94	41	0.03	56.3	1.2	0.45	0.19	0.063
Omnivores	(CRL = 0.031)	55	78	71	0.05	5.38	0.55	0.36	0.25	0.14
Carnivores	(CRL = 0.031)	43	73	59	0.05	27.7	2.3	1.3	0.75	0.21
Detritivores	(CRL = 0.031)	2	8	25	1.93	5.30	0.92	3.2	0.80	0.059
Aldrin	(CRL = 0.02)									
Herbivores		6	94	6	0.05	5.80	0.10	0.52	0.033	0.013
Endrin	(CRL = 0.04)									
Producers		1	20	5	0.19	0.19	0.029	0.19	0.01	0.022
Herbivores		5	94	5	0.14	3.74	0.12	0.96	0.051	0.025
Omnivores		2	73	3	0.07	0.14	0.022	0.099	0.003	0.021
Detritivores		1	9	11	0.91	0.91	0.12	0.91	0.101	0.031
DDE	(CRL = 0.094)									
Omnivores		10	71	14	0.10	0.92	0.09	0.28	0.039	0.06
Carnivores		10	72	14	0.22	5.5	0.59	1.7	0.24	0.078
Arsenic	(CRL = 0.025)									
Producers		5	20	25	0.42	4.5	0.46	0.96	0.24	0.21
Herbivores		7	94	7	0.48	6.6	0.31	1.7	0.12	0.15
Omnivores		3	59	5	0.49	1.82	0.17	0.93	0.047	0.14
Detritivores		8	9	89	0.62	1.53	0.93	0.98	0.88	0.78
Mercury	(CRL = 0.05)									
Herbivores		5	94	5	0.07	0.36	0.034	0.17	0.009	0.028
Omnivores		34	72	47	0.06	1.77	0.25	0.31	0.15	0.082
Carnivores		16	78	21	0.05	0.405	0.058	0.15	0.031	0.036
Detritivores		2	9	22	0.22	0.25	0.072	0.23	0.052	0.041

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* The ESE Mean is an arithmetic mean using the USFWS method of assigning one-half the CRL value to the non detections and calculating for the total number for samples.

** The geometric mean is based on the total number of detections. Descriptive statistics for fewer than three samples have limited value but are provided to facilitate comparisons.

*** The adjusted geometric mean = geometric mean x (number of detections/number of samples).

**** The USFWS geometric mean uses non-detections and assigns them a value equal to one half of the CRL. Normal application calculates a mean only when more than half of the samples have detections. Means for all groups are calculated here to facilitate comparisons.

- DDT was not found in any of the samples analyzed. Because DDT is known to bioaccumulate in carnivores, especially raptors, its absence in 72 carnivore samples is somewhat surprising. However, it is well known that DDT may degrade to DDE.

A3.5.2 Aquatic Ecosystems

Five aquatic trophic groups were developed for data analyses to summarize the aquatic ecosystem data from the Biota RI. The trophic level groupings and species within each aquatic tropic group are listed below.

- Primary Producers: Aquatic macrophytes (plant)
- Primary Consumers: Plankton
- Omnivores: Black bullhead
- Primary Carnivores: Bluegill
- Top Carnivores: Northern pike, largemouth bass

The results are presented in Table RISR A3.5-2 and Figure RISR A4.5-5. The biomagnification of chemical contaminants in biotic food chains is not generally evident for the RMA lakes. The following observations can be made based on these data:

- Dieldrin was detected in omnivores, primary carnivores, and top carnivores. AGM concentrations were slightly higher in top carnivores than primary carnivores. Omnivores showed higher AGM concentrations; however, the small number of samples make interpretations ambiguous.

- Aldrin and DDE were only detected in top carnivores, in about 20 percent to 30 percent of samples. DDE concentrations tended to be higher than aldrin.

- Arsenic was only detected in producers, in two of six samples.

- Mercury was detected in primary carnivores and top carnivores. The frequency of detections and the mean concentrations were higher in top carnivores.

- DDT was notably not detected.

In addition to these data for the RMA lakes, Rosenlund et al. (1986/RIC 86041R02) using 1984 data with lower detection limits than the CRLs but with greater uncertainty, reported dieldrin, aldrin, and mercury in aquatic plants; dieldrin, endrin, DDE, and mercury in

Table RISR A3.5-2 Statistical Comparisons of Aquatic Trophic Level Contaminant Concentrations.

		Total # of Hits	Total # of Samples	Detection frequency (%)	Minimum Conc(ug/g)	Maximum Conc(ug/g)	ESE Mean*	Geometric Mean**	Adjusted Geometric Mean***	USFWS Geometric Mean****
Dieldrin	(CRL = 0.031)									
Omnivores		3	3	100	0.0851	0.209	0.14	0.14	0.14	0.14
Top Carnivores		16	21	76	0.0376	0.161	0.082	0.094	0.071	0.061
Primary Carnivores		15	27	56	0.0319	0.86	0.15	0.17	0.092	0.058
Aldrin	(CRL = 0.020)									
Top Carnivores		5	27	19	0.0224	0.0527	0.015	0.037	0.007	0.013
DDE	(CRL = 0.094)									
Omnivores		1	3	33	0.098	0.098	0.064	0.098	0.033	0.06
Top Carnivores		9	27	33	0.101	0.839	0.20	0.41	0.14	0.10
Arsenic	(CRL = 0.025)									
Primary Consumers		1	9	11	0.432	0.432	0.16	0.43	0.048	0.14
Producers		2	6	33	0.465	0.782	0.29	0.60	0.20	0.21
Mercury	(CRL = 0.050)									
Omnivores		1	3	33	0.0516	0.0516	0.034	0.052	0.017	0.032
Primary Carnivores		11	21	52	0.0586	0.137	0.058	0.08	0.044	0.047
Top Carnivores		23	27	85	0.0627	0.55	0.22	0.22	0.18	0.16

---

* The ESE Mean is an arithmetic mean using the USFWS method of assigning one-half the CRL value to the non-detections and calculating for the total number for the samples.

** The geometric mean is based on the total number of detections. Descriptive statistics for fewer than three samples have limited value but are provided to facilitate comparisons.

*** The adjusted geometric mean = geometric mean x (number of detections/number of samples).

**** The USFWS geometric mean uses non-detections and assigns them a value equal to one-half of the CRL. Normal application calculates a mean only when more than half of the samples have detections. Means for all groups are calculated here to facilitate comparisons.

omnivores; dieldrin, aldrin, and mercury in primary carnivores; and dieldrin, aldrin, endrin, DDE, and mercury in top carnivores. Continued sedimentation and contaminant degradation since the Rosenlund study (conducted within approximately one year following cessation of manufacturing activities and associated lake water usage), as well as the differences in detection limits and CRLs, may account for the variations between the RI findings and Rosenlund's.

Contaminant levels in aquatic biota are not readily associated with observed sediment and water quality data collected during the RI. However, an analysis of variance test, ANOVA, was used to examine aquatic biota data from the lakes for statistical differences among lakes for the years 1984, 1986, and 1988. Statistically significant differences included:

- Aldrin concentrations in plankton, pike, and bass in Lower Derby Lake were higher than in Lake Ladora or Lake Mary in 1984.
- Dieldrin concentrations in plankton and bass in Lower Derby Lake were higher than in the other lakes in 1984.
- Dieldrin concentrations in bluegill were higher than in bass for the three lower lakes in 1986.
- Dieldrin concentrations in bass were higher than in bluegill in Lower Derby Lake in 1988.
- Mercury concentrations in bass were higher in Lake Ladora than in Lower Derby Lake, and concentrations in Lower Derby Lake were higher than in Lake Mary in 1984.
- Dieldrin, aldrin, and DDE concentrations in bass were higher in Lower Derby Lake than in the off-post control lake (McKay Lake) in 1988, although this was not the case for bluegill.

A3.5.3 Comparison of Off-Post and On-Post Biota Sampling Results

Specimens were collected at locations off post from RMA and analyzed for the same seven target analytes as on-post specimens. These off-post specimens were collected in areas presumed to represent background contaminant levels, and were used as baseline indicators. A comparison of pooled results for all terrestrial on-post and off-post samples is presented in

Figure RISR A3.5-6. It should be noted that highly mobile individuals may become contaminated on RMA and then move to an off-post control site, or vice versa. For example, one control raptor sample collected from just south of RMA could reasonably have become contaminated on the Arsenal. However in northern off-post control areas the closest contaminated samples were collected 56 miles away from RMA. While it is conceivable, given the home range extent of these species, that they may have become contaminated on RMA, it is equally likely that they did not.

The detection ratios between on-post and off-post samples show a pattern of on-post biota contamination by arsenic, mercury, and dieldrin not reflected in off-post controls. While these contaminants were also detected in off-post specimens, they were detected more often in on-post specimens. The opposite condition was true for DDE, and DDT was not detected on or off post. When the significance of on-post to off-post detection ratios was tested using both the chi-square test and the Fisher's Exact Test as suggested by Sokal and Rohlf (1981), the percentage of arsenic, mercury, and dieldrin detections for terrestrial species appeared significantly greater on post than off post. However, when the "true difference between percentages" test (ibid) was applied to establish whether the sample sizes were sufficient to determine if these differences were significant at the 80 percent confidence level with a 95 percent certainty, only the dieldrin data was from a sample population of sufficient size. Because these results are for pooled samples, diffemces between subsets of the sample populations, which may be significant, are masked. Consequently, these results should not be taken out of context.

A3.6 PHYSICAL HAZARDS

In addition to the chemical contaminants identified in the RI, assorted physical hazards have also been documented. Physical hazards pertain to aspects of the site that pose a significant risk of physical injury to persons present at RMA. These hazards result from the manufacturing and disposal activities that were conducted in the past, the age and deteriorated condition of many structures, ongoing activities related to site remediation or maintenance, and the remote nature of the large tracts of land. Although public access is carefully controlled, physical hazards may pose a threat to RMA site workers or visitors.

Manufacturing and disposal activities have resulted in a network of ditches constructed to supply process water and transport liquid wastes. These ditches and the associated open pits, ponds, and basins pose a danger to vehicles and pedestrians traversing the area. Tall grasses and other vegetation often obscure these features, resulting in potential injury to the unwary. Below ground storage tanks and pipelines traversing RMA, particularly within the manufacturing complexes, pose a similar hazard. In addition, they may contain residual amounts of hazardous materials or substances. Abandoned wells, some hand-excavated and dating to pre-RMA domestic and agricultural activities, may also be present, although the Abandoned Well Closure IRA (Appendix C) has removed some of these hazards. Obsolete stockpiles of munitions were demilitarized by controlled detonation or oven burning. Bomb debris and scrap metal remain as a result of these activities. Metal debris has also been observed in association with the sanitary landfills. In addition, various types of unexploded ordnance have been collected during site surveys prior to the RI in Section 36 and the eastern portion of RMA.

Many of the structures at RMA were constructed during the 1940s and early 1950s, and are currently in a deteriorated condition. Furthermore, electrical service to many buildings has been disconnected, resulting in poor visibility. Decontamination and salvage activities have resulted in removal of equipment from some facilities and left open gaps in floors and walls. Not all stairways and walkways are well maintained. Debris is common in some areas, and overhead construction materials or process equipment is in poor condition due to age and leaking roofs.

Ongoing activities related to site remediation or maintenance often require the use of heavy equipment or complex machinery. Physical hazards during such activities are varied and can be unexpected. Suitable protective equipment, as determined by the site supervisor, should be worn in all operational areas.

The remote nature of RMA and restricted public access results in several potential hazards that are uncommon in the surrounding urban areas. Wildlife abounds and is generally unaccustomed to human presence. Deer and other wildlife in the roads pose a hazard to vehicular traffic. Other animals may be present in abandoned buildings, and may be aggressive if disturbed. Finally, disease is a common occurrence, particularly in the prairie dog population, and direct contact with wildlife should be avoided.

Weather conditions can change unexpectedly, and severe thunderstorms are often accompanied by hail and lightning. Tornadoes have been reported and have caused damage to structures on RMA. Summer heat can cause stress to site workers, while winter weather can create hazardous driving conditions and the potential for extreme low-temperature exposures.

Appendix A4

References Cited

Remedial Investigation Summary Report

A4 REFERENCES CITED

RIC 81339R20
AMC (U.S. Army Materiel Command). 1973, August. Contamination Survey Rocky Mountain Arsenal.

RIC 84066R01
COE (U.S. Army Corps of Engineers). 1983, March. Evaluation of the Existing and Future Flood Potential on the Rocky Mountain Arsenal, Denver, CO.

RIC 81226R09
Cogley, D. 1976, October. Report on the Office of the Surgeon General (OTSG). Coring Data for Compounds at Rocky Mountain Arsenal.

RIC 87006R01
EBASCO (Ebasco Services Incorporated). 1985, August. South Plants Contamination Survey and Remedial Action Assessment Final Technical Plan. Revision 1, Task No. 2.

RIC 86239R03
EBASCO. 1986, April. Summary Report, Soil Gas Sampling Pilot Program at Rocky Mountain Arsenal.

RIC 87336R03
EBASCO. 1987, November. Final Technical Plan, Sewers and Process Water System Investigations. Version 3.1, Task No. 10.

RIC 88127R02
EBASCO. 1988a, April. Development and Evaluation of Analytical Methodologies Used in RMA Soil Investigations.

RIC 88357R01
EBASCO. 1988b, May. RMA Chemical Index, Volumes I, II, and III.

RIC 88306R02
EBASCO. 1988c, October. Final Summary of Results, Structures Survey Report. Task No. 24, Volumes I through III.

RIC 89166R03
EBASCO. 1989a, May. Final Remedial Investigation Report Volume XII, Western Study Area. Version 3.3, Volumes I through V.

RIC 89166R01
EBASCO. 1989b, June. Final Remedial Investigation Report Volume VI, Southern Study Area. Version 3.3, Volumes I through V.

RIC 89166R02
EBASCO. 1989c, June. Final Remedial Investigation Report Volume VII, Eastern Study Area. Version 3.3, Volumes I through IV.

RIC 89186R01
EBASCO. 1989d, July. Final Water Remedial Investigation Report. Version 3.3. Volumes I through V, Task No. 44.

RIC 89166R04
EBASCO. 1989e, July. Final Remedial Investigation Report Volume VIII, South Plants Study Area. Version 3.3, Volumes I through VI.

RIC 89166R05
EBASCO. 1989f, July. Final Remedial Investigation Report Volume IX, North Plants Study Area. Version 3.3, Volumes I through III.

RIC 89166R06
EBASCO. 1989g, July. Final Remedial Investigation Report Volume X, Central Study Area. Version 3.3, Volumes I through VIII.

RIC 89166R07
EBASCO. 1989h, July. Final Remedial Investigation Report Volume XI, North Central Study Area. Version 3.3, Volumes I through XIV.

RIC 91121R01
EBASCO. 1991. Final Surficial Soil Program Data Summary Version 3.1.

RIC 85127R07
ESE (Environmental Science and Engineering, Inc.). 1985, June. Section 36 Contamination Survey Technical Plan. Volumes I and II. Revision A, Task No. 1.

RIC 86317R01
ESE. 1986, October. Rocky Mountain Arsenal Water Quantity/Quality Survey, Initial Screening Program, Final Draft Report. Task No. 4.

RIC 88204R02
ESE. 1987a, April. Remedial Investigation Program Final Phase I Introduction to the Contamination Assessment Reports. Version 2.3, Task No. 1.

RIC 87203R07
ESE. 1987b, July. Final Phase 1 Contamination Assessment Report Site 36-1, Basin A. Version 3.2, Task No. 1 (Section 36).

RIC 87253R01
ESE. 1987c, August. Water Quantity/Quality Survey Final Initial Screening Program Report. Volumes I through III, Task No. 4.

RIC 88173R06
ESE. 1988a, May. Final Screening Program Third and Fourth Quarters, Final Report. Version 3.1, Volumes I through III, Task No. 4.

RIC 88203R05
ESE. 1988b, July. Overall Soil Assessment and Groundwater Integration Final Technical Plan. Version 3.2, Task No. 23, Volumes I and II.

RIC 88243R05
ESE. 1988c, July. Biota Assessment Phases I and II Final Technical Plan. Version 3.2, Task No. 9.

RIC 88244R02
ESE. 1988d, July. Composite Well Program Draft Final Report. Version 2.3, Task No. 44.

RIC 88263R01
ESE. 1988e, August. Air Remedial Investigation Final Report. Version 3.1, Task No. 18, Volumes I and II.

RIC 89173R01
ESE. 1988f, August. Off-Post Operable Unit Remedial Investigation and Chemical Specific Applicable or Relevant and Appropriate Requirements Draft Final Report, Version 3.1, Volumes 1 through 3, Task No. 39.

RIC 88293R09
ESE. 1988g, September. Biota Assessment Bald Eagle Study Winters 1986-1987, 1987-1988. Final Report. Version 3.1, Task No. 9.

RIC 88344R01
ESE. 1988h, September. Overall Soil Assessment and Ground Water Integration Determination of Partition Coefficients for the Primary Contaminant Sources of Section 36 Draft Final Report. Version 2.2, Task No. 23.

RIC 89024R02
ESE. 1988i, December. Boundary Control Systems Assessment Remedial Investigation Draft Final Report. Version 2.1, Volumes I through III, Task No. 25.

RIC 88344R02
ESE. 1988j. North Boundary System Component Response Action Assessment Draft Final Report. Version 2.2, Volumes I through III, Task No. 36.

RIC 89103R01
ESE. 1989a, February. North Boundary System Component Response Action Assessment Final Report. Volumes I through III. Task No. 36.

RIC 89173R02
ESE. 1989b, May. Biota Remedial Investigation Final Report. Version 3.2, Volumes I through IV, Task No. 9.

Green, J.L. 1983, May 23. Rocky Mountain Arsenal Buildings Reference List.

RIC 87047R01A-E
HB&A (Harland Bartholomew and Associates, Inc.). 1982a, October. Property Inventory and Condition Survey for the Group IV Utility Systems Property and Group II Chemical Plant Property within the Shell Oil Company Leasehold Area of U.S. Army Rocky Mountain Arsenal Commerce City, CO. Volumes I through III, September 27, 1982; Volumes IV and V, October 11, 1982.

RIC 87047R01F
HB&A. 1982b, December. Property Inventory and Survey Report for Selected Shell Constructed Buildings within the Shell Oil Company Leasehold Area at U.S. Army Rocky Mountain Arsenal Commerce City, CO. Volume VI, Shell Constructed Buildings.

RIC 87047R01G
HB&A. 1982c, December. Property Inventory and Survey Report for the Group I Chemical Plant Property within the Shell Oil Company Leasehold Area at U.S. Army Rocky Mountain Arsenal Commerce City, CO. Volume VIII, Group I Chemical Plant Property.

RIC 87188R01
HB&A. 1983. Real Property Inventory, Volumes I through IV.

J.P. Walsh and Associates. 1988. Soils Investigation and Inventory of Rocky Mountain Arsenal. Adams County, CO.

Lindvall, R.M. 1980a. Geological Map of the Commerce City Quadrangle. Adams and Denver Counties, CO. U.S. Geological Survey Map CQ-1541.

Lindvall, R.M. 1980b. Geological Map of the Sable Quadrangle. Adams and Denver Counties, CO. U.S. Geological Survey Map CQ-1542.

MKE (Morrison-Knudsen Engineers, Inc.). 1987. Preliminary Recharge Estimates for RMA Regional Flow Model, Final Version.

MKE. 1988. Geology of the Rocky Mountain Arsenal, Adams County, CO. Prepared for Holme, Roberts and Owen.

RIC 82096R01
RCI (Resource Consultants, Inc.). 1982, March. Surface-Water Hydrologic Analysis, Rocky Mountain Arsenal, Denver, CO.

RIC 88340R02
RLSA (R.L. Stollar and Associates). 1988, June. Comprehensive Biota Monitoring Program Final Technical Plan.

RLSA. 1990, June. Comprehensive Monitoring Program Final Surface Water Data Assessment Report for 1989. Version 2.0.

R.L. Stollar and Associates, Inc. (RLSA). 1991, August?. Applied Research: Contaminant Transport in Ground Water at RMA (planned to be released in mid-August).

RMA. 1966, June 30. AMC Installation and Activity Information Summary. Microfilm RMA102, Frame 1996FL.

RIC 83326R01
RMACCPMT (Rocky Mountain Arsenal Contamination Control Program Managers Team). 1983, September. Selection of a Contamination Control Strategy for RMA. Volumes I & II, Final Report.

RIC 84034R01
RMACCPMT. 1984, January. Decontamination Assessment of Land and Facilities at Rocky Mountain Arsenal. Draft Final Report.

Romberg, G.P., S.P. Pavlou, R.F. Shokes, W. Hom, E.A. Crecelius, P. Hamilton, J.T. Gonn, R.D. Muench, and J. Vinelli. 1984. Toxicant Pretreatment Planning Study Technical Report C.1: Presence, Distribution, and Fate of Toxicants in Puget Sound and Lake Washington, Appendix 13. Municipality of Metropolitan Seattle, Washington.

Romero, John C. 1976. Groundwater Resources of the Bedrock Aquifers of the Denver Basin, Colorado: Report prepared by Division of Water Resources, Department of Natural Resources. pp. 21, 22, 38.

RIC 86041R02

Rosenlund, B., D. Jennings, and B. Karey. 1986, January. Contaminants in Aquatic Systems at the Rocky Mountain Arsenal-1984. U.S. Fish and Wildlife Service. Microfilm No. RFA003, Frames 0659-0661.

RIC 81266R54
Sampson, J., T. Baber, and C. Prentice. 1974. Soil Survey of Adams County, CO. U.S. Soil Conservation Service, 77 p., maps.

Shelford, V.E. 1963. The Ecology of North America. University of Illinois Press, Urbana.

RIC 89216R01
Shell. 1989, July. Report of Hydrologic and Water Quality Investigations in the South Tank Farm Plume Section 2, RMA.

RIC 89264R01
Shell. 1989, August. Report of the Investigation of the LNAPL Plume Near Tank 464A, Section 1, RMA.

RIC 91002R01
Shell. 1990, December, Technical Work Plan, LNAPL Plume Soil Vapor Extraction (SVE) Process. Field Demonstration Treatability Study.

RIC 91002R06
Shell. 1990, December. Results of the Verification Monitoring Program South Tank Farm Plume, RMA.

RIC 90262R05
Shell. 1989, December. Results of Field Investigations Conducted August and September 1989, Shell Section 36 Trenches, Rocky Mountain Arsenal.

RIC 91002R04
Shell. 1990, December. Implementation Document for Other Contamination Sources Interim Response Action Shell Section 36 Trenches, RMA.

RIC 84324R02
Smith, R., P. Schneider, and L. Petri. 1963. Groundwater Resources of the South Platte River Basin in Western Adams and Southwestern Weld Counties, CO.

Sokal, R.R., and J.F. Rohlf. 1981. Biometry. The Principles and Practice of Statistics in Biological Research. 2nd ed. W.H. Freeman and Company, NY.

RIC 85133R04
Spaine, P., D. Thompson, and J. Dildine. 1984, September. Regional Ground Water Study of Rocky Mountain Arsenal, Denver, Colorado, Report 2, Contaminant Distribution.

RIC81324R03
USAEHA (U.S. Army Environmental Hygiene Agency). 1978. Investigation of Pesticide Levels in Various Buildings at Rocky Mountain Arsenal.

RIC 81266R68
USATHAMA (U.S. Army Toxic and Hazardous Materials Agency). 1977, March. Installation Assessment of Rocky Mountain Arsenal, Report No. 107.

Unauthored. Undated. AMC Facilities and Real Property Information Summary. Microfilm RMA102, Frames 1999F and 1981F.

RIC 88188R01
WWE (Wright Water Engineers, Inc.). 1988a, April. Hydrology Report for Planning of First Creek, Irondale Gulch, and DFA 0055 Outfall Systems.

RIC 89111R01
WWE. 1988b, December. Alternative Report for Planning of First Creek, Irondale Gulch, and DFA 0055 Outfall Systems.

RIC 90115R02
WWE. 1990a. Irondale Gulch and DFA Stormwater Outfall Systems Master Plan.

RIC 90115R01
WWE. 1990b, February. First Creek and DFA 0055 Outfall Systems Masterplan Preliminary Design Report.

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APPENDIX B
ORIGINAL

TECHNICAL SUPPORT FOR

ROCKY MOUNTAIN ARSENAL

FINAL
REMEDIAL INVESTIGATION SUMMARY REPORT
APPENDIX B
VERTICAL EXTENT OF GROUNDWATER CONTAMINATION IN THE DENVER AQUIFER
VERSION 3.2

January 1992

Contract Number DAAA15-88-D-0024

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THE INFORMATION AND CONCLUSIONS PRESENTED IN THIS REPORT REPRESENT THE OFFICIAL POSITION OF THE DEPARTMENT OF THE ARMY UNLESS EXPRESSLY MODIFIED BY A SUBSEQUENT DOCUMENT. THIS REPORT CONSTITUTES THE RELEVANT PORTION OF THE ADMINISTRATIVE RECORD FOR THIS CERCLA OPERABLE UNIT.

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TABLE OF CONTENTS

Section Page

TABLE OF CONTENTS
(continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Appendix B

Vertical Extent of Groundwater Contamination in the Denver Aquifer

Text and Tables

Remedial Investigation Summary Report

APPENDIX B - TABLE OF CONTENTS

APPENDIX B - TABLE OF CONTENTS
(continued)

APPENDIX B - LIST OF TABLES

APPENDIX B - LIST OF FIGURES

Note: All figures are presented directly following the complete text.

APPENDIX B - LIST OF FIGURES
(continued)

Note: All figures are presented directly following the complete text.

APPENDIX B - LIST OF FIGURES
(continued)

Note: All figures are presented directly following the complete text.

APPENDIX B - LIST OF PLATES

APPENDIX B - LIST OF ABBREVIATIONS

Analyte Groups and Selected Analytes

DBCP	Dibromochloropropane
DIMP	Diisopropylmethyl phosphonate
ICP metals	Metals analyzed for by inductively coupled argon plasma spectroscopy; includes cadmium, chromium, copper, lead, and zinc
OCP	Organochlorine pesticides
OPHGB	Organophosphorous compounds, GB-agent related
VAO	Volatile aromatic organics
VHC	Volatile hydrocarbons
VHO	Volatile halogenated organics

National Acts and Organizations

EPA	U.S. Environmental Protection Agency

Local Terminology

1A	Certification for gas chromatography/mass spectroscopy method
1B	Certification for low sample throughput - not a gas chromatography/mass spectroscopy method
C1	Certification for quantitative method
CMP	Comprehensive Monitoring Program
CRL	Certified reporting limit
FS	Feasibility Study
NBCS	North Boundary Containment System
NWBCS	Northwest Boundary Containment System
QA	Quality assurance
QA/QC	Quality assurance/quality control
RI	Remedial Investigation
RISR	Remedial Investigation Summary Report
RMA	Rocky Mountain Arsenal
VEC	Vertical Extent of Contamination
WA	water

LIST OF ABBREVIATIONS
(continued)

Companies

AL	Arthur D. Little
CH	Colorado Department of Health
CL	California Analytical Laboratories, Inc.
EBASCO	Ebasco Services Incorporated
ED	Environmental Science & Engineering, Inc. (Denver, CO)
EE	Envirodyne Engineers, Inc.
EN	Environmental Testing and Certification Corp. (Edison, NJ)
ES	Environmental Science & Engineering, Inc. (Gainesville, FL)
ME	MetaTrace, Inc. (St. Louis, MO)
MW	Midwest Research Institute
RL	Rocky Mountain Analytical Lab (Currently ENSECO-Denver, CO)
RLSA	R.L. Stollar and Associates, Inc. (Denver, CO)
RM	Rocky Mountain Arsenal
SC	Shell Chemical, Rocky Mountain Arsenal
UB	Datachem, Inc.

Measurements and Quantities

ft	Foot, feet
µg/l	Micrograms per liter

B.1 INTRODUCTION

Although a majority of the contaminated groundwater at Rocky Mountain Arsenal (RMA) occurs in the unconfined flow system, wells completed in the underlying confined portions of the Denver aquifer (collectively referred to as the confined flow system) exhibit the presence of some contaminants. Wells in the Denver aquifer typically are completed in sandstone strata. Yields of these wells usually are low, and the lateral extent and interconnectivity of individual sandstone strata are complex. Consequently, the distribution of contaminants in the Denver aquifer frequently appears to be irregular, and continuous plumes of contamination have not been mapped. The Denver aquifer consists of fluvial sediments that generally have low hydraulic conductivity. Estimates range from 10^{-4} ft per day (ft/day) for shale and claystone to 0.03 to 4 ft/day for sandstone, and are approximately two orders of magnitude less than those in the alluvium (Sections A1.5.3, A1.5.4).

While groundwater in the uppermost water-bearing zone of the Denver aquifer is locally unconfined, all wells screened in the Denver Formation were considered in this investigation. However, because the focus of this report is on the vertical extent of contamination, data for the confined flow system wells were emphasized. A more detailed discussion of the geology and hydrology of the Denver Formation is contained in Appendix A of this report. It is the position of the Army that the nature and extent of contamination in the Denver aquifer has been characterized by data developed in the RI to a level adequate to support the Feasibility Study (FS).

B.1.1 PURPOSE AND SCOPE

As part of the remedial investigation/feasibility study (RI/FS) at RMA, an extensive evaluation of contamination in the Denver aquifer has been undertaken. The purpose of the evaluation is to provide an improved description of the vertical extent of contamination in the Denver aquifer at RMA. The evaluation consists of two phases. Phase I has been conducted as part of the RI. If deemed necessary, Phase II will be designed and conducted to meet the needs of the FS. The Phase I evaluation stemmed from comments by the organizations and State on the Water RI Report.

During Phase I, existing water quality data were used to characterize the vertical extent of contamination and provide supporting documentation for the FS. Results of the Phase I investigation are presented in this appendix. Phase I included the creation of a database of water quality information that reliably depicts current contaminant concentrations at wells, the development of hydrogeologic cross-sections that characterize the vertical extent of contamination, and the description of contaminant concentrations in selected areas of RMA.

The FS will consider the information developed during Phase I, as well as other pertinent data and the information needs identified during the FS in order to select areas of RMA where additional characterization may be needed. In these areas, investigations will be conducted in support of the FS to characterize contaminant migration mechanisms.

B.1.2 ROLE OF THE WATER RI SUBCOMMITTEE

Although the Phase I evaluation was conducted by the Army and its contractors, the organizations and State were consulted frequently. Several water RI subcommittee meetings were held to ensure that the methods and procedures used in the data evaluation and the resulting database were understood by all parties. The meetings also provided the organizations and State with a forum for recommending changes to the methods of evaluation for the Phase I data. Topics discussed in these meetings included objectives of the Phase I evaluation, data evaluation criteria, procedures for identifying temporal trends in water quality at wells, procedures for selecting data for inclusion in the database, and data presentation. The methods of interpretation and the results presented in this appendix are largely a result of subcommittee discussions and recommendations.

Subcommittee meeting results were documented in minutes. The minutes were distributed to the organizations and State as part of an information package at subsequent RMA committee meetings. Table RISR B.1-1 provides a brief description of topics discussed at each subcommittee meeting.

B.2 EVALUATION OF WATER QUALITY DATA

The description of the extent of contamination in this report is based on a comprehensive well-by-well and analyte-by-analyte review of all on-post and off-post water quality data. Based on the chronological sequence of analyte concentration, values representative of present-day contamination were selected for use in characterizing the extent of contamination. Selected data were placed in a unique computerized database called the Vertical Extent of Contamination (VEC) database. This database is in dBase format and is included on the diskette in Attachment 2 of this appendix.

Previous hydrogeologic investigations of the Denver aquifer have emphasized water quality data obtained during a single sampling period. However, due to the generally low hydraulic conductivity and significant heterogeneity of the Denver aquifer, some data anomalies are likely to have occurred in any sampling period. Data interpretation based on a single sampling period may, therefore, produce misleading results by not comparing anomalous data to equivalent data from other sampling periods.

Data considered during the data review were downloaded from the RMA database in January 1990. The latest sample date for the data was September 27, 1989. Because quality assurance/quality control (QA/QC) procedures have been most rigorous since 1984, data obtained from 1984 to 1989 were weighted more heavily during the review. However, data collected between 1975 and 1984 were included in the VEC database if more recent data were not available at a well. The resulting database includes information that was obtained over a broad time period. Because rates of migration in the Denver aquifer are generally slow compared to rates of migration in the unconfined flow system, the VEC database is considered generally representative of the present-day extent of contamination.

Table RISR B.1-1 Summary of Water Remedial Investigation Subcommittee Meetings Related to the Vertical Extent of Groundwater Contamination

Meeting Date	Topics Discussed
June 28, 1989	Overall approach to the study. Specific approach to Phase I.
August 15, 1989	Results of preliminary evaluation by S. Coddington.
September 20, 1989	Well and sample selection criteria for preparing the vertical extent database.
November 16, 1989	Finalize well and sample selection criteria.
March 13, 1990	Database screening process. Database format -- presentation of database to organizations and State for review. Analyte groupings for presentation. Report Graphics.
April 10, 1990	Final selection of graphics. Finalize analyte groupings. Selection of areal plots and cross sections for presentation. State request for entire RMA groundwater database. Topic outline of Appendix B.
May 31, 1990	Clarification of items in previous correspondence from organizations and State. Finalize topic outline of Appendix B. Approach for selecting Phase II work.

B.2.1 REVIEW OF WATER SAMPLING AND ANALYSIS PROGRAMS

Procedures for well installation, sampling, and QA/QC, as well as changes in analytical methods can have a strong influence on the usefulness of data in assessing the extent of contamination in the Denver Formation. Detailed descriptions of applicable procedures and analytical methods are included in technical plans, reports, and related documents for specific tasks. Summaries of water-related tasks and sampling programs at RMA, including references to corresponding technical plans, are contained in Appendix F, Section 3.0 of the Water RI Report (EBASCO, 1989/RIC 89186R01). Some aspects of the water sampling and analytical programs that relate directly to development of the VEC database are described below.

Groundwater monitoring conducted as part of the RI and Comprehensive Monitoring Program (CMP) has provided litigation-quality data collected with documented sampling and analysis procedures. Data collection, analysis, and reporting have been conducted within the framework of written and approved quality assurance plans and data management plans. Generally these plans have been tailored to the unique objectives and requirements of specific programs or tasks, and they have been submitted to the organizations and State for review. Samples have been collected and tracked with the aid of established sampling and chain-of-custody forms. Decontamination of sampling equipment has followed detailed documented procedures. Quality assurance samples have routinely been included in data collection programs in order to detect potential problems with cross-contamination of wells, identify laboratory contamination of samples, and assess accuracy of data. Approximately 25 percent of all samples collected as part of recent programs have been obtained for QA purposes.

Although data prior to the beginning of the RI were obtained using the best available technology for sampling and analysis, supporting documentation generally did not meet current standards. Documentation of sampling procedures generally was limited to information written in field notebooks. Fewer QA samples were collected prior to 1984 than are presently recommended. Consequently, data collected prior to 1984 should be used primarily for qualitative description of contaminant extent. If needed for purposes of the FS, data collected prior to 1984 will be confirmed by more recent sampling results.

Improvements in drilling, sampling, and analytical technology were incorporated in monitoring programs as they became available. As a result, recently obtained data generally are more accurate and repeatable than historical data. Since 1984, wells drilled in the Denver Formation have been completed using telescoping casing and sealing of the annular space to prevent contaminant migration from shallow zones to deep zones. Prior to 1984, this technique was not routinely used. Equipment used for well development has evolved from use of bailers and bladder pumps to use of positive displacement pumps and in-line flow cells. This change has minimized the potential for contaminants to volatilize during sampling. Recent sampling programs have emphasized increasingly reliable field monitoring of water quality parameters as an aid in determining appropriate wellbore conditions for sampling.

Analytical methodologies were modified frequently when different laboratories were used, when analytical techniques changed, or when QA/QC requirements varied. As a result, certified reporting limits (CRLs) varied from program to program by up to three orders of magnitude (Attachment 1).

B.2.2 SELECTION OF WATER QUALITY DATA

Data included in the VEC database were selected manually by hydrogeologists who reviewed the entire chronological sequence of concentration values at individual on-post and off-post wells. To accomplish this, section-by-section printouts of the entire RMA water quality database were sorted by well identification number, water quality parameter, and sample date. Using these printouts, a concentration value was selected for each compound that represented the best estimate of present contamination. The concentration values were entered into the VEC database if they were above CRLs.

Values below CRLs were not entered into the VEC database. The programs conducted at RMA during the past decade included different CRLs, different suites of analytes, and changes in sampling and analytical techniques. Thus values below CRL could not be directly correlated between wells or through time. The database of excluded detections is contained in Attachment 2 (on diskette) so that the apparently anomalous detections can be reviewed. All wells that were considered in establishing the VEC database are shown on Plate RISR B.2-1. Some of these wells were later determined to be alluvial wells and were, therefore, eliminated from the data interpretations. Plate RISR B.2-2 shows the locations of all wells included in the VEC database. The distributions by depth below the bedrock contact of all the wells considered in establishing the VEC database are shown in Figures RISR B.2-1 through RISR B.2-4.

Although selection of representative values relied on the professional judgment of hydrogeologists reviewing the data, comparisons of values selected by several hydrogeologists showed that the differences were small. In cases where existing data could not be used to clearly identify consistent values of concentration, recent elevated detections were selected. The resulting VEC database tends to overestimate the extent of contamination in areas where data were not conclusive.

B.2.3 DATA EVALUATION CRITERIA

Criteria were established for all analytes in the RMA water quality database including anions and cations such as sodium, potassium, chloride, and fluoride that are generally considered nonhazardous. The following criteria were used in evaluating water quality for a particular well:

- The chronological sequence for sample data showed a detectable concentration for all sample dates for a particular compound. The most recent value of concentration was entered into the VEC database.
- The chronological sequence showed sporadic detections, but the most recent value was above the CRL. The most recent value of concentration was entered into the VEC database.

- A short chronological sequence and/or the most recent value was below the CRL (where the CRL was higher than CRLs for previous samples). The most recent value that was above the CRL was entered into the VEC database.
- The chronological sequence showed that all values were below the CRL. No value was entered into the VEC database.
- The chronological sequence showed anomalous detectable concentrations for a particular compound, but all subsequent values including the most recent sample were below the CRL. No value was entered into the VEC database. However, the anomalous value was placed in a separate file of excluded values and identified as a category A exclusion.
- Anomalous and/or marginal concentration values were identified in the chronological sequence or when compared to adjacent wells. No value was entered into the VEC database. However, the anomalous or marginal values were placed in a separate file of excluded values and identified as category B exclusions.
- No chronological sequence of detections was identified, but a single value above the CRL was anomalous when compared to other nearby wells. No value was entered into the VEC database. However, the anomalous value was placed in a separate file of excluded values and identified as a category C exclusion.

The database of excluded detections (HITSABC.DBF) includes 514 organic and inorganic detections. More than one half of the detections (354) were excluded as Category B. Concentrations of the organics and fluoride, chloride, and ICP metals in Category B range from 0.0461 to 4,950 µg/l and were reported in samples collected form 1977 to 1989. Category A, excluded detections (158), range from 0.0400 to 1,800µg/l, and were reported in samples collected from 1978 to 1989. In both Category A and B, the analyte with the highest number of detections was DBCP. Category C excluded detections is comprised of two detected analytes. These include zinc, detected at 22.6 µg/l in 1988, and DBCP, detected at 9.10 µg/l in 1989.

The initial database was prepared and distributed to the organizations and State for review. Based on this review and a parallel review by the Army, the database was refined. Data inadvertently excluded from the initial database were added. Duplicate data within the database were deleted. The resulting database represents the most comprehensive and reliable set of information currently available to characterize contamination in the Denver aquifer at RMA.

B.2.4 BACKGROUND WATER QUALITY

In order to characterize the extent of contamination in the Denver aquifer it is useful to identify contaminant concentrations in background areas. For the purpose of this report background areas are defined as areas that contain wells that are hydraulically upgradient of known source areas. The likely RMA source areas for contaminants in the Denver aquifer are the contaminant plumes of the overlying unconfined flow system. Areas of the Denver aquifer that are hydraulically upgradient of these plumes include Sections 5, 6, 7, 8, 11, 12, 19, 20, 29, 30, 31, and 32. Therefore, wells in these sections completed in the Denver aquifer generally represent background conditions.

In general, concentrations of many organics in areas that are hydraulically upgradient of plumes are near CRLs. A review of the VEC database has shown that slightly elevated concentrations of organics have been measured in a few wells designated as background wells. These wells (05001, 07004, 08005, 11004, 12003, 12004, 32002) have low concentrations of diisopropylmethyl phosphonate (DIMP), benzene, chloroform, tetrachloroethylene, chlorophenylmethyl sulfoxide, or organochlorine pesticides. All of these wells have been subsequently sampled by the CMP. Results indicate that organic concentrations in the VEC database for these wells are sporadic and likely artifacts of sampling or analytical techniques, and probably are not representative of background conditions. Additionally, some organic compounds occur naturally at detectable concentrations in association with coal, oil, carboniferous shale, or natural gas. Other organic compounds detected upgradient of RMA source areas may have originated from off-post sources.

Inorganics including fluoride, chloride, and inductively coupled plasma (ICP) metals (cadmium, chromium, copper, lead, and zinc) occur naturally at concentrations above CRLs; however, there are no values universally recognized by RMA investigators or regulators as representative of RMA background levels. In a hydrogeologic unit as lithologically and hydraulically variable as the Denver aquifer, background concentrations of naturally occurring inorganics are likely to vary spatially. Thus it is important to designate background concentrations for inorganics based on several wells completed in the Denver aquifer within or near RMA boundaries. Inorganic water quality data from upgradient wells in the VEC database were used to calculate background concentrations of chloride, fluoride, arsenic, mercury, and the ICP metals cadmium, chromium, copper, lead, and zinc in the Denver aquifer at RMA. Adjusted geometric means for chloride, fluoride, and total metals were calculated using the following equation:

$$\text{Adjusted Geometric Mean} = (n/s)(a_1 \cdot a_2 \cdot a_3 \cdot \ldots \cdot a_n)^{1/n}$$

Where n is the number of detections, s is the number of samples analyzed, and a_n is the concentration of the n_{th} detection.

The adjusted geometric mean concentrations provided in Table RISR B.2-1 are assumed to be representative of background conditions. These concentrations tend to correspond to those used in previous investigations (EBASCO, 1989/RIC 89186R01; RLSA, 1990/RIC 90231R01). However, previous investigation background concentrations were based on samples from relatively few wells, or else they included samples from wells located a substantial distance from RMA. The wide range of detected concentrations and high standard deviations of detections shown in Table B.2-1 show that background concentrations vary substantially from location to location. This extreme variability may be attributable either to naturally high spatial or temporal variation, or to the presence of more than one population subset. The latter possibility is suggested when the standard deviation is greater than the adjusted geometric mean.

Table RISR B.2-1 Background Concentrations of Inorganic Analytes in the Denver Aquifer

Analyte or Analyte Group	Frequency of Detections	Arithmetic Mean (µg/l)	Adjusted Geometric Mean Concentration (µg/l)	Maximum Concentration (µg/l)	Standard Deviation of Detections (µg/l)	Geometric Standard Deviation of Detections (log-base 10)
Chloride	38/38	105,000	65,400	689,000	121,000	0.461
Fluoride	36/38	1,820	1,520	4,670	960	0.221
Total Metals (As, Hg, Cd, Cr, Cu, Pb, and Zn)	11/18	12.6	5.95	99.3	29.6	0.774

As - Arsenic
Hg - Mercury
Cd - Cadmium
Cr - Chromium
Cu - Copper
Pb - Lead
Zn - Zinc
µg/l - micrograms per liter

B.3 AREAL DISTRIBUTION OF CONTAMINANTS

Denver aquifer contamination is generally associated with areas of contamination in the overlying unconfined flow system. A series of maps to illustrate this and to identify areas of contaminated Denver aquifer that are not directly associated with contamination in the unconfined aquifer were prepared. All maps are presented following the complete text. For these maps, analytes have been categorized into five groups. The five groups are total organic analytes; DIMP; the sum of arsenic, mercury and ICP metals (cadmium, chromium, copper, lead, zinc); fluoride; and chloride. Table RISR B.3-1 lists organic analytes summed for the total organics maps. DIMP is included on the total organics map and is also mapped separately.

Individual organic analytes are organized by analyte groups to facilitate discussion of their distribution. The groups each comprise several analytes with similar uses, chemical behavior, and histories of origin and disposal. On-post contamination is discussed and presented in this section and in Section B.4. Off-post contamination is summarized in Section B.5. Attachment 2 contains the plotted concentrations of each group on diskette.

The distribution and concentration of each analyte group is shown on maps corresponding to various depth intervals below the alluvium-bedrock contact. The depth intervals used for mapping are 0 to 50 ft, 50 to 100 ft, 100 to 150 ft, and greater than 150 ft below the alluvium-bedrock contact. Depths and corresponding depth intervals for each well were calculated from measurements of the alluvium-bedrock contact and the base of the well screen. Selection of the alluvium-bedrock contact as the datum for identifying depth intervals permits evaluation of the vertical extent of contamination. Other alternative methods, such as using elevations or depths below ground surface do not take into account the topography of the ground and/or bedrock surfaces and the vertical transport distance of the contaminant through the Denver Formation. The methodology used also eliminates the uncertainty in correlation of stratigraphic intervals or hydrostratigraphic units within the Denver Formation.

Table RISR B.3-1. Organic Analytes and Analyte Groups for Groundwater Samples. Page 1 of 3.

Analyte Groups/Analytes
Volatile Halogenated Organics (VHOs)
1,1-Dichloroethane
1,2-Dichloroethane
1,1-Dichloroethylene
trans-1,2-Dichloroethylene
1,1,2,2-Tetrachloroethane*
1,1,1-Trichloroethane
1,1,2-Trichloroethane
Carbon tetrachloride
Chlorobenzene
Chloroform
Methylene chloride
Tetrachloroethylene
Trichloroethylene
Trichloropropene*
Volatile Hydrocarbons (VHCs)
2-Butoxyethanol*
4-Hydroxy-4-methyl-2-pentanone*
1-Methyl-1,3-cyclopentadiene*
2,2-Oxybisethanol*
2-Pentanone*
Bicycloheptadiene
Dicyclopentadiene
Methylcyclohexane*
Methylisobutyl ketone
Volatile Aromatic Organics (VAOs)
Benzene
Ethylbenzene
m-Xylene
o- and p-Xylene
Toluene
Organosulfur Compounds, Mustard-Agent Related (OSCMs)
1,4-Oxathiane
Chloroacetic acid
Dithiane
Thiodiglycol

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* Significant former nontarget compound

Table RISR B.3-1. Organic Analytes and Analyte Groups for Groundwater Samples. Page 2 of 3.

Analyte Groups/Analytes
Organosulfur Compounds, Herbicide Related (OSCHs)
Benzothiazole
Chlorophenylmethyl sulfide
Chlorophenylmethyl sulfone
Chlorophenylmethyl sulfoxide
Dimethyldisulfide
Organophosphorous Compounds, GB-Agent Related (OPHGBs)
Diisopropylmethyl phosphonate
Dimethylmethyl phosphonate
Isopropylmethylphosphonic acid
Methylphosphonic acid
Phosphoric acid, tributyl ester*
Phosphoric acid, triphenyl ester*
Organophosphorous Compounds, Pesticide Related (OPHPs)
Atrazine
Malathion
Parathion
Supona
Vapona
Dibromochloropropane (DBCP)
Organonitrogen Compounds (ONCs)
Caprolactam*
Hydrazine
Methylhydrazine
n-Nitrosodimethylamine
n-Nitrosodi-n-propylamine
Unsymmetrial dimethylhydrazine
Fluoroacetic Acid
Polynuclear Aromatic Hydrocarbons (PAHs)
Fluoranthene*
Methyl naphthalene*
Phenanthrene*
Pyrene*

* Significant former nontarget compound

Table RISR B.3-1. Organic Analytes and Analyte Groups for Groundwater Samples.

Analyte Groups/Analytes

Semivolatile Halogenated Organics (SHOs)
- Hexachlorobenzene*
- Hexachlorobutadiene*
- Hexachlorocyclopentadiene
- Pentachlorobenzene*
- Tetrachlorobenzene*
- Trichlorobenzene*

Organochlorine Pesticides (OCPs)
- Aldrin
- Chlordane
- Dichlorodiphenylethane (DDE)
- Dichlorodiphenyltrichloroethane (DDT)
- Dieldrin
- Endrin
- Isodrin

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* Significant former nontarget compound

As a result, data are illustrated by depth interval and do not correspond directly with stratigraphic intervals or hydrostratigraphic units.

The maps of contaminant distribution show well locations where contaminants have been identified above CRLs. Wells where contaminants were not detected are not identified on the maps. Samples included in the VEC database have been obtained over an extended period of time. During this period, CRLs for most contaminants have changed and analytical suites have varied; consequently, a map showing wells without detectable concentrations of contaminants may be misleading. Plate RISR B.2-1 shows the location of wells that were sampled and, therefore, were considered in developing the VEC database. Coordinates for the wells and well completion and bedrock information are included in Attachment 2 (on diskette).

B.3.1 TOTAL ORGANIC ANALYTES

The total organic analyte concentration for each well is the sum of VEC database concentrations for one or more detected analytes. Most detections of total organic analytes exceeding 10,000 µg/l in the Denver aquifer occur in the South Plants and Basin A areas, and from Basin C to the North Boundary Containment System (NBCS) in Sections 23 and 26 (Figure RISR B.3-1). The highest concentrations typically occur in the 0- to 50-ft depth interval. A maximum concentration for total organics of 1,110,000 µg/l was detected in the South Plants area. Organics were detected in four wells at depths between 150 and 200 ft. Among these, the maximum total organic concentration of 33.7 µg/l occurred in Well 35084.

B.3.1.1 Areal Distribution

In the South Plants and Basin A areas, organic analytes were detected primarily in the 0- to 50-ft depth interval, with numerous samples having concentrations greater than 10,000 µg/l. In much of the South Plants area, the alluvium is unsaturated and many of the highest concentrations in the 0 to 50 ft depth interval are in the unconfined flow system. The maximum concentration of total organics was 1,110,000 µg/l, detected in Wells 01555 and

01565, which are screened to depths of 22 and 25 ft, respectively, below the alluvium-bedrock contact. These wells are screened in the unconfined flow system. Lower concentrations were detected below 50 ft (Figures RISR B.3-2 through B.3-4). At depths greater than 100 ft, total organic analyte concentrations in the South Plants area were less than 50 µg/l and concentrations in the Basin A area were less than 300 µg/l. The deepest detection of organic analytes was in the vicinity of South Plants and occurred 197 ft below the alluvium-bedrock contact in Well 01046. In this well, total organics were detected at a concentration of 3 µg/l. The only other detections in this area below 150 ft were southwest of Basin A in Wells 35072 and 35084.

In Section 26, concentrations of total organic analytes greater than 10,000 µg/l occurred in the vicinity of Basin C in the 0- to 50-ft depth interval. Concentrations between 1,000 and 10,000 µg/l were detected at depths between 0 and 100 ft around the perimeter of Basin C and in the 0- to 50-ft depth interval north of Basin F. Concentrations decreased with depth to less than 10 µg/l in the 100- to 150-ft depth interval.

The highest concentrations of total organics (greater than 10,000 µg/l) in Section 23 occurred in the 0- to 50-ft depth interval. The maximum detected concentration in the 50- to 100-ft depth interval was 807 µg/l, and 106 µg/l was the highest concentration detected in the 100- to 150-ft depth interval. Total organic analyte concentrations less than 50 µg/l were detected in Sections 22 and 24 in the 100- to 150-ft depth interval.

B.3.1.2 Relation to Alluvial Contamination

Organic analytes in both the Denver aquifer and the Unconfined Flow System were detected at the highest concentrations in the South Plants and Basin A areas and from Basin C to the NBCS. In the Western Tier and North Plants area, contamination is fairly common in the unconfined flow system, but less frequently detected in the Denver aquifer. Another area of dissimilar distribution between the unconfined flow system and the Denver aquifer includes Section 22.

In the North Plants area, a maximum concentration of 1,900 µg/l was detected in the Denver aquifer, but concentrations detected in the unconfined flow system were less than 500 µg/l. Concentration ranges in the Denver aquifer in the Western Tier were comparable to those in the unconfined flow system; however, the highest concentrations in the Denver aquifer did not consistently underlie the highest concentrations in the unconfined flow system.

In Section 22, north of the Northwest Boundary Containment System (NWBCS), organic compounds were detected to a depth of 106 ft below the alluvium-bedrock contact (Well 22002). No data for this well were collected after 1983; however, recent (1989) data for an upgradient well (22028) completed at a similar depth and in the same water-bearing zone indicated no detections of organic analytes. Contamination in these deeper zones may be indicative of earlier flow patterns and contamination distribution when the basins were full of liquid. In addition, the construction of Well 22002 may be of questionable quality; this well was recently abandoned.

B.3.2 DIISOPROPYLMETHYL PHOSPHONATE (DIMP)

The highest concentrations of DIMP were located in the Basin A area, south of Basin C north to the NBCS, and in North Plants (Figure RISR B.3-5). The highest concentrations were detected between depths of 0 and 100 ft, and the maximum concentration (25,600 µg/l) was detected below Basin C. DIMP was detected in one well in the 150- to 200-ft depth interval. A concentration of 0.900 µg/l was detected southwest of Basin A at a depth of 166 ft below the alluvium-bedrock contact.

B.3.2.1 Areal Distribution

In the Basin A area, concentrations were greater than 1,000 µg/l in the 0- to 100-ft depth range (Figures RISR B.3-5 and B.3-6). The maximum concentration of DIMP in this area, 14,600 µg/l, was detected 8 ft below the alluvium-bedrock contact. In the 100- to 150 ft depth interval, DIMP was detected at a maximum concentration of 11.1 µg/l (Figure RISR

B.3-7). The deepest and only detection of DIMP below 150 ft occurred southwest of Basin A at a concentration of 0.900 µg/l, 166 ft below the alluvium-bedrock contact in Well 35084.

Concentrations of DIMP greater than 1,000 µg/l were detected south of Basin C and north to the NBCS in the 0- to 50-ft depth interval. Below Basin C, DIMP was detected at a maximum concentration of 25,600 µg/l in Well 26053, at a depth of 16 ft below the alluvium-bedrock contact. This concentration was reported in 1979; no samples were collected after this date. In the 50- to 100-ft depth interval, the highest concentrations (up to 2,500 µg/l) were detected in the vicinity of Basin C. At the NBCS, the highest concentration in the 50-to 100-ft depth interval was 348 µg/l. Below this depth interval, DIMP was detected in one well at a concentration of 6.20 µg/l. To the northwest, in Section 22, DIMP was detected in the 100-to 150-ft depth interval at 21.0 and 33.0 µg/l near the NWBCS.

In North Plants, the highest concentrations of DIMP was detected in the 0- to 50-ft depth interval. Well 25051 contained DIMP at a concentration of 1,900 µg/l. No wells in the immediate area of North Plants are completed below this depth interval.

B.3.2.2 Relation to Alluvial Contamination

The areas of highest DIMP concentrations in the Denver aquifer correspond to areas with elevated concentrations in the unconfined flow system from Basin A northwest to Basin F and north to the NBCS (EBASCO, 1989/RIC 89186R01; RLSA, 1990/RIC 90231R01). In Section 22, DIMP concentrations of 21.0 and 33.0 µg/l were detected east and north of the NWBCS between 102 and 106 ft below the alluvium-bedrock contact. These concentrations were higher than those typically detected in the unconfined flow system in this area. Low concentrations of DIMP have been detected in a few wells near the south boundary of RMA. Data received after formation of the VEC database indicate that these detections do not tend to be repeatable. DIMP has not been detected near these wells in overlying alluvial material.

B.3.3 SUM OF ARSENIC, MERCURY, AND ICP METALS

Elevated levels of metals (100 to 1,000 µg/l) in the Denver aquifer were detected in areas of elevated organic compound concentrations near Basin A, Basins C and F, and the NBCS (Figure RISR B.3-8). Metals were also detected in Sections 3, 22, 23, and 27, and near Sand Creek Lateral in Sections 35 and 25. The highest concentrations were detected in the 0- to 100-ft depth range, and the maximum concentration (476 µg/l) was detected near Sand Creek Lateral in Section 35. In general, at all depth intervals, most concentrations were in the 10 to 100 µg/l concentration range. This is within the range of background detections from upgradient wells. However, the adjusted geometric mean of metals concentrations in the Denver aquifer is slightly greater than in background wells (Table RISR B.2-1). Metals were detected at a maximum depth of 177 ft below the alluvium-bedrock contact at a concentration of 41.9 µg/l (Well 08005).

B.3.3.1 Areal Distribution

In the Basin A area, metals concentrations in the Denver aquifer were greatest between depths of 0 and 100 ft (Figures RISR B.3-8 and B.3-9). A maximum concentration of 476 µg/l was detected in Well 35008, 19 ft below the alluvium-bedrock contact. Concentrations ranged from 22.5 to 48.6 µg/l in the 100- to 150-ft depth interval (Figure RISR B.3-10). Metals were not detected in the Basin A area below 150 ft.

In the Basin C and F area, concentrations ranged up to 186 µg/l to depths of 100 ft below the alluvium-bedrock contact. Metals were detected to a maximum depth of 95 ft in this area.

At the NBCS, the highest concentration of metals occurred in the 0- to 50-ft depth interval. A concentration of 128 µg/l was detected in Well 23204. Concentrations were less than 10 µg/l in the 50- to 100-ft depth interval. At the NBCS, the metals were not detected below the 50- to 100-ft depth interval. The detections of metals outside the areas discussed above generally were isolated and not persistent with depth. An exception occurs in Sections 22, 23, and 27 where concentrations greater than 100 µg/l were detected to a depth of 103 ft (Well 22031). The deepest detection of metals was in Section 8 at a depth of 177 ft below the alluvium-bedrock contact. A similar concentration was detected at approximately 77 ft below the bedrock contact in Well 08004.

B.3.3.2 Relation to Alluvial Contamination

The detections of metals in the Denver aquifer and unconfined flow system tend to occur in similar areas and appear to be only partially associated with areas of elevated organic analyte concentrations and related source areas on RMA. Concentrations of metals in the unconfined flow system not associated with areas of elevated organic analyte concentrations tended to be higher (approaching 1,000 µg/l) than concentrations of metals (less than 100 µg/l) in these areas in the Denver aquifer.

B.3.4 FLUORIDE

The calculated adjusted geometric mean background fluoride concentration of 1,520 µg/l (Table RISR B.2-1) generally corresponds to the highest fluoride CRL of 1,220 µg/l, which is used to define the lowest fluoride concentration range. Concentration of fluoride greater than 10,000 µg/l in the Denver aquifer occurred in the South Plants and Basin A areas, between Basin F and the NBCS, and in Section 22 north of the NWBCS (Figure RISR B.3-11). The highest concentrations were detected in the 0- to 100-ft depth range, and the maximum concentration (210,000 µg/l) was detected near Basin F, less than 3 ft below the alluvium-bedrock contact. Fluoride was detected in seven wells at depths between 150 ft and 200 ft at a maximum concentration of 4,400 µg/l. The maximum concentration detected in upgradient wells was 4,670 µg/l (Table RISR B.2-1). As points of comparison, the EPA drinking water limit for fluoride is 4,000 µg/l; the secondary drinking water standard is 2,000 µg/l.

B.3.4.1 Areal Distribution

In the South Plants area, the highest concentration of fluoride was 11,000 µg/l and occurred in the 50- to 100-ft depth interval (Figure RISR B.3-12). Fluoride concentrations in the 100- to 150-ft depth interval were generally less than 2,000 µg/l, although fluoride was detected in the depth interval at a concentration of 9,530 µg/l west of South Plants (Figure RISR B.3-13). At an approximate depth of 200 ft, fluoride was detected in two wells in the South Plants area at 1,950 and 2,370 µg/l (Figure RISR B.3-14).

In the Basin A area, the highest concentrations of fluoride were detected in the 0- to 50-ft depth interval. Fluoride was detected at a maximum concentration of 14,000 µg/l in the 0- to 50-ft depth interval, and at a maximum concentration of 10,000 µg/l in the 50- to 100-ft depth interval in this area. In the 100- to 150-ft depth interval, fluoride was not detected above a concentration of 2,330 µg/l. The deepest detections of fluoride in the Basin A area were between 165 and 168 ft below the alluvium-bedrock contact at concentrations of 1,670 and 2,800 µg/l.

Between Basin F and the NBCS, the highest concentrations of fluoride were detected in the 0- to 50-ft depth interval. The highest concentration was 210,000 µg/l, detected in Well 26041. Concentrations decreased with depth. Maximum concentrations of 5,100 and 4,600 µg/l were detected in the 50- to 100-ft and 100- to 150-ft depth intervals, respectively. Fluoride was detected in two wells below 150 ft, at concentrations less than 5,000 µg/l. Fluoride was not detected in this area below 196 ft.

In Section 22, fluoride was detected up to 35,000 µg/l in the 0- to 50-ft depth interval. Lower concentrations were detected below this depth interval, ranging from 400 to 3,200 µg/l below a depth of 50 ft below the alluvium-bedrock contact. In this section, fluoride was not detected below a depth of 106 ft.

B.3.4.2 Relation to Alluvial Contamination

Fluoride concentrations were elevated in the Basin A area and between Basin F and the NBCS in the Denver aquifer and the Unconfined Flow System. In both the Denver aquifer and unconfined flow system, detections approaching 10,000 µg/l occurred in Sections 3, 4, and 33, and concentrations up to 5,000 µg/l were detected in other areas of RMA.

In the northeast area of South Plants and northeast of Basin A, concentrations in the Denver aquifer were higher than those detected in the unconfined flow system. This also occurred in Sections 22 and 23 (north of the NWBCS), Section 3, Section 33, and in the western area of South Plants where the contrast in concentrations was greater. In the 0- to 50-ft depth interval of the Denver aquifer, fluoride was detected up to a concentration of 35,000 µg/l in Section 22. In Section 2, in the 50- to 100-ft depth interval, fluoride was detected at a concentration of 11,000 µg/l. In the 100- to 150-ft depth interval, fluoride was detected at 9,530 µg/l in Section 3. Fluoride concentrations in the unconfined flow system in these two areas were less than 4,000 µg/l. It should be noted that interference effects of chloride in ionchromatography analyses may cause artificially high reported fluoride values (G. Mohrman-PMRMA, oral communication with J.A. Bush - EBASCO, October 28, 1991).

B.3.5 CHLORIDE

Most chloride concentrations greater than or equal to 5,000,000 µg/l in the Denver aquifer were detected in the South Plants area, and in an area from Basin A northwest to Basin F and north toward the NBCS (Figure RISR B.3-15). The highest concentrations were detected between 0 and 100 ft, and the maximum concentration (14,000,000 µg/l) was detected near Basin F, less than 3 ft below the alluvium-bedrock contact. Chloride was detected in seven wells between 150 and 200 ft at a maximum concentration of 127,000 µg/l. This concentration is within the standard deviation of chloride detections (121,000 µg/l) in upgradient wells (Table RISR B.2-1). As a point of comparison the EPA has established a secondary drinking water standard of 250,000 µg/l for chloride.

B.3.5.1 Areal Distribution

In the South Plants area, the highest concentration of chloride was 5,500,000 µg/l and was detected in the 50- to 100-ft depth interval (Figure RISR B.3-16). Above this depth, chloride was detected at a maximum concentration of 1,200,000 µg/l. Concentrations of chloride were lower in the 100- to 150-ft depth interval, with a maximum detected concentration of 621,000 µg/l (Figure RISR B.3-17). Chloride was detected to a depth of 199 ft below the alluvium-bedrock contact in the South Platte area (Figure RISR B.3-18). Concentrations at this depth ranged from 20,000 to 40,000 µg/l.

In the area from Basin A northwest to Basin F and north to NBCS, there were several detections of chloride at concentrations greater than 1,000,000 µg/l in the 0- to 50-ft depth interval. A maximum concentration of 14,000,000 µg/l was detected near Basin F in Well 26041. In the 50- to 100-ft depth interval, the maximum detected concentration of chloride in this area was 1,200,000 µg/l and occurred southwest of Basin F. Concentrations were less than 650,000 µg/l in the 100- to 150-ft depth interval. Chloride was detected at 123,000 and 127,000 µg/l in two wells screened to depths of 172 and 194 ft, respectively, below the alluvium-bedrock contact. Chloride was not sampled below this depth.

B.3.5.2 Relation to Alluvial Contamination

The distribution of chloride in the 0- to 50-ft depth interval of the Denver aquifer is similar to the distribution in the unconfined flow system, with the highest concentrations extending from Basin A to Basins C and F and north to the NBCS. In both the unconfined flow system and Denver aquifer, concentrations of chloride, primarily ranging from CRL to 150,000 µg/l, were widespread. Differences in distribution were noted in the South Plants area, and near Basin D in Section 26.

In the 0- to 50-ft depth interval of the Denver aquifer, a concentration of 1,200,000 µg/l was detected in the western area of South Plants, and a concentration of 5,500,000 µg/l was detected in this area in the 50- to 100-ft depth interval. In the overlying unconfined flow system, chloride concentrations were typically not over 150,000 µg/l. In the Basin D area, a higher concentration of chloride was also detected in the Denver aquifer than in the overlying unconfined flow system. West of Basin D, chloride was detected below 700,000 µg/l in the unconfined flow system and at 1,200,000 µg/l in the 50- to 100-ft depth interval in the Denver aquifer.

B.4 VERTICAL EXTENT OF CONTAMINATION

Contaminant concentrations in the Denver aquifer are typically much lower than in the overlying unconfined flow system. For example, the concentration of total organic analytes in the unconfined flow system near Basin F exceeds 10,000 µg/l. Wells completed in the Denver aquifer near Basin F typically have total organic concentrations less than 200 µg/l. The total organic concentration of the unconfined flow system in the vicinity of Basin A exceeds 10,000 µg/l over a large area. In the Denver aquifer beneath this area the concentration typically is less than 7,000 µg/l. Similar differences in concentration occur in other parts of RMA. Higher concentration values in the Denver aquifer typically occur only in the top 20 ft of bedrock and are in close proximity to areas where the unconfined flow system is most contaminated.

The predominant processes affecting contaminant concentrations with depth at RMA and within the Denver aquifer are chemical and biological degradation, sorption, and dilution. A conceptual model of flow in the Denver has been developed in which water moves downward from the unconfined flow system through strata with relatively low hydraulic conductivity into predominantly sandstone and lignitic units of the Denver aquifer. This results in long travel times along flow paths in the Denver aquifer relative to flow paths in the alluvium, during which chemical and biological degradation can occur. The Denver aquifer with its clay-rich and lignitic strata also has a greater sorptive capacity for removing contaminants from groundwater than the overlying alluvium. Contaminants moving vertically downward in the Denver aquifer will be diluted by uncontaminated water moving horizontally along regional flow paths.

The number of contaminants measured in the Denver aquifer is also typically less than the number measured in the overlying unconfined flow system. The distribution of the individual organic contaminants has been presented in previous reports (EBASCO, 1989; RLSA, 1990). Contaminants that appear most frequently in the Denver aquifer are relatively nonsorbing compounds such as chloroform, trichloroethylene, benzene, and DIMP. Organochlorine pesticides (OCPs) have been detected with an unexpectedly high frequency, however. These compounds tend to adsorb readily and would not be expected to migrate substantial distances in the Denver aquifer. Cosolvency effects or utilization of flowpaths with minimal sorptive capacity may explain their widespread distribution.

Although the shallow bedrock of the Denver Formation appears to be effective in partly containing contamination within the unconfined flow system, it is not a completely effective barrier to migration. Hydrogeologic cross sections (Figures RISR B.4-1 through B.4-5 and Plates RISR B.4-2 through B.4-7) indicate that the concentrations of organic analytes vary with depth in an irregular manner. While concentrations typically decrease as depth increases, exceptions to this rule are common.

The most notable exception occurs in the vicinity of the NBCS (Figure RISR B.4-3). Data from cluster wells in this area show no general trend in concentration with increasing depth. For example, total organic concentration at Wells 23167 through 23169 varies from 11.1 µg/l to 375 µg/l to 50.7 µg/l with increasing depth. Reasons for the irregular pattern are not clear, but may be the result of historical groundwater flow patterns that are different from current patterns. The discontinuous nature of sandstone channels in the Denver aquifer may also contribute to the irregular pattern of contamination.

An inferred base of contamination, representing the CRLs for organic analytes, has been drawn on the detailed hydrogeologic cross sections (Figures RISR B.4-1 through B.4-5). The base was located using the following assumptions: 1) if organic contaminants were reported within a sandstone unit, the entire unit was assumed to be contaminated; 2) if no organics were detected in a sandstone unit, but were reported in the above unit, the base of the upper sandstone was interpreted as the base of contamination; and 3) if organics were present in the deepest screened sandstone unit, the concentration was assumed to decrease by an order of magnitude in each lower sandstone unit. This last assumption was inferred from a qualitative review of vertical contaminant distribution in the cluster wells.

B.4.1 ORGANIC ANALYTES

At depths more than 100 ft below the alluvium-bedrock contact, organic analytes were primarily detected in areas where elevated concentrations were detected in shallower zones of the Denver aquifer. Concentrations of organics ranging from 106 to 770 µg/l were detected in the 100- to 150-ft depth interval near Basin A, north of Basin F and in the Western Tier (Plates RISR B.4-2 and B.4-3). In the greater than 150-ft depth interval, organics were detected at a maximum concentration of 33.7 µg/l in Well 35084 southwest of Basin A (Plate RISR 3.4-6). There were three other detections in this depth interval, to a depth of 196 ft below the alluvium-bedrock contact. Concentrations of organics were near CRLs, ranging from 1.77 to 3.00 µg/l. The lowest detection was upgradient of known source areas on RMA, in Section 8 (Well 08005) (Plate RISR B.4-4). As discussed in Section B.2.4, additional data indicate that this detection likely occurred as a result of sampling or analytical techniques and may not be representative of actual conditions.

B.4.2 DIISOPROPYLMETHYL PHOSPHONATE (DIMP)

The deepest detections of DIMP primarily underlie areas where shallow zones of the Denver aquifer have high concentrations of DIMP. These areas include Basins A and F in Sections 35, 36, and 26. The deepest well in this area with a detectable concentration of DIMP was Well 35084 (Plate RISR B.4-6). In this well, DIMP was detected at a concentration of 0.900 µg/l, 166 ft below the alluvium-bedrock contact.

Other elevated concentrations of DIMP were detected in the 0- to 100-ft depth range between the NBCS and the NWBCS. In two of the deepest wells in this area, DIMP was detected at concentrations of 21.0 and 33.0 µg/l between 102 and 106 ft below the alluvium-bedrock contact (Plates RISR B.4-2 and B.4-5).

Near the central area of North Plants, DIMP was detected in the 0 to 50 ft depth interval in Well 25051 at a concentration an order of magnitude higher than the concentration in the overlying unconfined flow system. No deeper wells are present in this area.

B.4.3 ARSENIC, MERCURY, AND ICP METALS

The deepest detection of metals occurred in Section 8, upgradient of known source areas on RMA. In Well 08005, zinc was detected at a depth of 177 ft below the alluvium-bedrock contact at a concentration of 41.9 µg/l (Plate RISR B.4-4). Additional data for this well indicate that zinc is not present at a concentration above CRLs. In addition, the highest concentrations of the metals were not typically present in this area.

Metals were detected in several wells between 100 and 150 ft below the alluvium-bedrock contact. Most of these wells are located in the area from South Plants to the NBCS and the NWBCS. In the greater than 100-ft depth interval, concentrations ranged up to 114 µg/l. The highest concentration of metals (zinc) was detected in Well 22031, which is located in an area where elevated levels (up to 156 µg/l) were detected in shallow Denver aquifer zones (Plates RISR B.4-2 and B.4-5). In general, zinc was the primary metal detected in the groundwater in these wells. Arsenic, mercury, copper, and cadmium were detected infrequently at these depths.

B.4.4 FLUORIDE

The deepest detections of fluoride occurred in areas where high concentrations were detected in overlying zones, and in Sections 8 and 32 where fluoride was detected near background levels (1,520 µg/l; Table RISR B.2-1). In the greater than 150-ft depth interval, fluoride was detected above background southeast of South Plants, southwest of Basin A and near Basin F in Section 26. The highest concentration was 4,400 µg/l detected in Well 26137 near Basin F. The deepest well, screened to a depth of 198 ft below the alluvium-bedrock contact, contained fluoride at a concentration of 1,950 µg/l.

B.4.5 CHLORIDE

Chloride was detected to a depth of 198 ft below the alluvium-bedrock contact. Below 150 ft, concentrations were above background (approximately 65,400 µg/l; Table RISR B.2-1) for three wells located in Sections 26 (Well 26137), 23 (Well 23210), and 32 (Well 32003).

Chloride concentrations ranged from 103,000 to 127,000 µg/l in these wells. Wells 26137 and 23210, near Basin F and the NBCS, are located in areas of typically high fluoride concentrations. Well 32003 is located outside of these areas, indicating that background levels may vary depending on depth and stratigraphic unit. Several of the deepest wells at the NBCS (in Sections 19, 22 and 23) contained levels of chloride above background (Plate RISR B.4-2).

B.5 CONTAMINATED AREAS

Contamination in the Denver aquifer generally occurs near contaminated areas of the unconfined flow system. Therefore, wells completed in the Denver aquifer have been classified into areas of interest that correspond approximately with the plume groups discussed previously for the unconfined flow system in Section 4.0 of the Remedial Investigation Summary Report (RISR). For ease of comparison, areas of the Denver aquifer will be denoted by the name of the corresponding unconfined plume group. These areas are the South Plants area, the Basin A area, the Northwest Boundary area (which includes Basins D, E, and southwest Basin C), the North Boundary area (which includes North Plants, Basin F, and northeast Basin C), and the Western area. In addition, off-post contamination is presented in Figures B.5-1 through B.5-5 and discussed in Section B.5.6. Wells not classified into one of these areas have been placed into the Miscellaneous area in order to assess the extent of contamination in the Denver aquifer where no unconfined plume is present. Wells that have not been sampled in recent years, and wells with a limited number of samples and inconsistent data are listed by area in Table RISR B.5-1. This list is not all-inclusive; however, it contains wells in areas where the vertical extent of contamination is not well defined.

B.5.1 SOUTH PLANTS AREA

Volatile halogenated organics (VHOs) and volatile aromatic organics (VAOs) are present in virtually all wells of the Denver aquifer in the South Plants area. Other organic analytes

Table RISR B.5-1 Denver Wells with Inconclusive Sampling Chronologies

Area	Well Number	Latest Sample Date in VEC*	CMP Network
Basin A	35084	89142	Yes
	36151	84178	No
	36154	88040	Yes
	36171	89165	Yes
	36179	89165	Yes
Northwest Boundary	22012	80102	No
	22030	89145	Yes
	22031	89010	Yes
	26053	79031	No
	26135	82145	No
	27055	89136	Yes
North Boundary	23168	81044	No
	23169	81044	No
	24137	87343	No
	24172	89012	Yes
Western	04009	88027	Yes
Off-Post	37319	87322	Yes
Miscellaneous	22002	83335	No
	22027	89146	Yes
	22028	89145	Yes
	23184	88356	Yes
	25021	89023	No

CMP - Comprehensive Monitoring Program
VEC - Vertical Extent of Contamination
* - The date is given as a five-digit number where the first two digits indicate the year, and the last three indicate the number of days into the year the sample was taken (Julian date).

occur less frequently and at shallower depths. The concentrations of fluoride and chloride are similar to background levels calculated for the Denver aquifer (Table RISR B.2-1).

Although present in virtually all wells of the South Plants area, the concentration of VHOs and VAOs in deeper wells is relatively low. Consequently, for purposes of the FS the vertical extent of contamination has been approximately determined. Concentrations of a variety of contaminants are high in the upper part of the Denver aquifer, which is generally under unconfined flow conditions.

B.5.2 BASIN A AREA

The most frequently detected analyte group in the Denver aquifer near Basin A was VHOs. Other organic analyte groups were detected less frequently. The concentrations of fluoride and chloride are similar to or slightly above background levels in the Denver aquifer.

Although organic analyte concentrations in the Basin A area appear to decrease with increasing depth, concentrations in the deepest wells are usually above CRL, and the vertical extent of contamination has not been defined. Several deep wells in the area have a limited record of sampling; however, most of these wells have been and are included currently in the CMP network. One of these deep wells, Well 36151, has not been sampled since improved QA procedures have been implemented in recent years.

B.5.3 NORTHWEST BOUNDARY AREA

VHOs, volatile hydrocarbons (VHCs), and organophosphorous, GB agent-related compounds (OPHGBs) have been detected in 50 to 75 percent of Denver aquifer wells sampled in the Northwest Boundary area. The concentration recorded for most wells more than 100 ft below the alluvium-bedrock contact is near the CRL. Other organic analytes occur infrequently. Chloride concentrations were typically above background levels. Fluoride concentrations are similar to background levels in the Denver aquifer. The ICP metals have been detected in approximately 75 percent of Denver aquifer wells. Concentrations typically are slightly above background conditions.

With the exception of samples from Wells 27054 and 27055, contaminant concentrations of the Northwest Boundary Containment System area are relatively low, and concentrations in deeper wells are near the CRL. The concentration of chloroform in Wells 27054 and 27055 does not appear to decrease with increasing depth. These wells are part of the existing CMP well network. With the exception of the area of these wells, the approximate vertical extent of contamination has been established on the basis of data used to establish the VEC database.

In the vicinity of the Basins, the vertical extent of contamination is poorly defined. Few wells are screened deeper than 100 ft below the alluvium bedrock contact. However, in these wells, organic concentrations were near CRLs or not detected. Total organics were detected above 100 µg/l in the 50 to 100 ft depth interval at several locations. There are no wells at these locations screened at greater depths.

B.5.4 NORTH BOUNDARY AREA

A number of organic analyte groups have been identified in wells of the Denver aquifer in the North Boundary area. Analyte groups identified in at least 50 percent of all sampled wells include VHOs, OCPs, and OPHGBs. Other analyte groups occurring in more than 30 percent of all sampled wells include VAOs, organosulfur compounds, and dibromochloropropane (DBCP). The ICP metals have been detected in more than 50 percent of sampled wells. Concentrations in these wells are above background levels. Fluoride and chloride concentrations are generally near background levels.

The vertical extent of contamination is poorly defined in the North Boundary area. This is most clearly shown in Figures RISR B.4-3 and B.4-4. Concentrations of contaminants in wells along these cross sections vary in a highly irregular manner. Concentrations in the deeper wells often are several orders of magnitude above CRLs for relatively nonsorbing compounds such as DIMP. The localized hydraulic influences of the extraction and injection wells, recharge trenches, the north bog, and the slurry wall and geologic heterogeneities within the Denver Formation contribute to the variability in vertical contaminant distribution. These variables complicate characterization of mechanisms of contaminant migration in this area.

B.5.5 WESTERN AREA

Seven wells have been completed in the Denver aquifer within the Western area. VHOs have been detected in all these wells. OCPs also have been detected in five wells within the Western area. Fluoride and ICP metals have been detected at concentrations above background levels. Chloride is generally near background levels.

Concentrations in Denver aquifer wells of the Western area generally are low. With the exception of Well 04009, the vertical extent of contamination in the Western area has been approximated from existing data. Well 04009 is located adjacent to the RMA boundary and the source of contamination in this well is unknown.

B.5.6 OFF-POST AREA

Organics were detected in 14 of 16 off-post Denver Formation wells sampled (Figure B.5-1). All of these wells are located north and northwest of the NBCS. The primary organics detected were VHOs, DIMP, and an organophosphorous pesticide-related (OPHP) compound, atrazine (Figure B.5-2). Concentrations of fluoride were typically above background levels (Figure B.5-4, Table RISR B.2-1). Chloride concentrations were below background levels in a majority of the wells (Figure B.5-5). Metals were detected infrequently (Figure B.5-3).

Although organics have been detected in almost all Denver Formation wells north of the RMA boundary, all but one well (37319) are screened within 70 ft of the alluvium-bedrock contact. Detections in the deepest well indicate that concentrations decrease with increasing depth, however, no data were available for depths more than 124 ft below the alluvium-bedrock contact. Only VHOs were detected in the deepest well, indicating the vertical extent of the other organic contaminants in this off-post area is approximately defined. The latest analytical data that were available for this well (37319) are from 1987. Well 37319 is currently included in the CMP and was sampled in February 1991.

B.5.7 MISCELLANEOUS AREAS

Water quality data from wells included in the Miscellaneous area indicate that contamination in the Denver aquifer generally occurs only in areas where the unconfined flow system is contaminated. An important exception to this rule is the area northwest of the former Basin F, located between the Northwest and North Boundary areas. Wells completed in this area were sampled infrequently and contained low concentrations of VHOs, VAOs, OPHGBs, OCPs, and DBCP. Because the chronology of sampling at wells is incomplete, analyte concentrations used in the assessment of contamination in this area may be unreliable. Current data are being collected from several wells in this area under the CMP; however, one well containing DIMP (Well 22002) has not been sampled since 1983.

Six wells located in areas that are hydraulically upgradient of known RMA sources of contamination show slightly elevated concentrations of several organic compounds. The wells are 05001, 07004, 08005, 11004, 12003, and 12004. A review of temporal trends in concentrations at these wells and QA/QC data indicated that detections may have resulted from lowering of CRLs or insufficient decontamination of sampling equipment. Additional data, received after formation of the VEC database, indicate that these detections are sporadic and likely not representative of current concentrations in these wells.

B.6 SUMMARY

An extensive evaluation of contamination in the Denver aquifer has been undertaken as part of the RI/FS at RMA. This evaluation provides an enhanced description of the vertical extent of contamination. During Phase I, existing water quality data were used to characterize the vertical extent of contamination and to provide supporting documentation for the FS. The Army believes that this evaluation is adequate and sufficient to proceed with evaluation of remedial alternatives. The FS will use the information developed during Phase I and the information needs identified during the FS to select any areas of RMA where additional characterization may be needed. If necessary the characterization will be completed in support of the FS.

The report's description of contaminant extent is based on a comprehensive review of water quality data using the complete period of available data. This included a chronological well-by-well and compound-by-compound review of all data. Based on the chronological sequence of compound concentration, values most representative of current contamination were selected for use in characterizing the extent of contamination. Selected data were placed in a unique computerized database.

Although selection of representative data relied on the professional judgement of the hydrogeologist reviewing the data, comparisons of values selected by several hydrogeologists proved that differences were small. In cases where existing data could not be used to clearly identify reliable values of concentration, conservative values were selected. In other words, the resulting database tended to overestimate the extent of contamination in areas where data were not conclusive.

Contamination in the Denver aquifer is generally associated with areas of contamination in the overlying unconfined flow system. However, concentrations of contaminants in the Denver aquifer are substantially less than in the unconfined flow system. The number of contaminants measured in the Denver aquifer is also typically less than the number measured in the unconfined flow system. Contaminants that appear most frequently are relatively nonsorbing compounds such as chloroform, trichloroethylene, benzene, and DIMP.

The shallow bedrock of the Denver Formation appears to be effective in partly containing contamination within the unconfined flow system, but it is not a completely effective barrier to migration. Hydrogeologic cross sections indicate that the concentrations of organic analytes vary with depth in an irregular manner. While concentrations generally decrease with increasing depth, exceptions to this rule are common.

Existing water quality data are sufficient to identify the total depth of contamination throughout most of RMA. In some areas the deepest wells are not contaminated. In other areas, levels of contaminants in the deepest wells have decreased to near CRL and a total depth of contamination can be estimated. Relatively low levels of several contaminants have been noted in many parts of RMA at depths more than 100 ft below the alluvium-bedrock contact. However, concentrations in wells deeper than 150 ft below the bedrock-alluvium contact are not reportable or are near CRLs. On-post areas where total depth of contamination cannot be inferred include Sections 22 and 26, the southeast corner of Section 35, Basin A, the NBCS, and North Plants.

The Phase I evaluation of contamination in the Denver aquifer has identified several areas of RMA where the absolute vertical extent of contamination has not been defined. These areas include:

- North Boundary Containment System Area
- Between the North and Northwest Boundary Containment Systems Areas
- Basin A Area
- Northwest Boundary Containment System Area
- Western Area
- Southeast portion of Section 35
- South Tank Farm Plume
- North Plants
- Section 26 Basins area
- Wells with inconclusive sampling results

Final decisions regarding additional investigations will be made after appropriate consultation with the organizations and State in a subcommittee forum similar to the Water RI subcommittee. The subcommittee will include representatives from the Water RI subcommittee and the FS.

B.7 REFERENCES CITED

RIC 89186R01
Ebasco Services Incorporated (EBASCO). 1989, July. Final Water Remedial Investigation Report. Version 3.3, Volumes I through V, Task No. 44.

RIC 90231R01
R L. Stollar and Associates (RLSA). 1990, June. Comprehensive Monitoring Program, Annual Groundwater Report for 1989, Final Report, Volumes I and II.

Mohrman, G. - PMRMA. 1991, October 28. Oral communication with J.A. Bush - EBASCO.

APPENDIX B
Attachment 1 - Certified Reporting Limits for Groundwater

Analyte[1]	Method[2]	First Use	Last Use	Lab[3]	CRL	Unit[4]	Media[5]	Certification[6]
111TCE	2J	12/7/84	12/7/84	EE	--	UGL	--	NC
111TCE	J8	9/18/86	5/12/88	CL	1.00	UGL	WA	1A
111TCE	M8	4/3/86	10/8/87	ES	1.00	UGL	WA	1A
111TCE	N8	5/16/86	3/23/90	UB	0.76	UGL	WA	C1
111TCE	RM8A	2/25/88	5/13/88	RL	6.80	UGL	WA	1A
111TCE	TT8	2/24/87	1/10/90	ED	1.09	UGL	WA	C1
111TCE	UM21	11/7/88	3/12/90	UB	1.00	UGL	WA	1A
111TCE	UU8	4/20/89	4/21/89	ED	2.40	UGL	WA	1A
111TCE	Y8	12/9/85	4/8/88	ES	1.70	UGL	WA	C1
112TCE	J8	9/18/86	5/12/88	CL	1.00	UGL	WA	1A
112TCE	M8	4/3/86	10/8/87	ES	1.00	UGL	WA	1A
112TCE	N8	5/16/86	3/23/90	UB	0.78	UGL	WA	C1
112TCE	RM8A	2/25/88	5/13/88	RL	7.10	UGL	WA	1A
112TCE	TT8	1/19/87	1/10/90	ED	1.63	UGL	WA	C1
112TCE	UM21	11/7/88	3/12/90	UB	1.00	UGL	WA	1A
112TCE	UU8	4/20/89	4/21/89	ED	1.60	UGL	WA	1A
112TCE	Y8	12/9/85	4/8/88	ES	1.00	UGL	WA	C1
11DCE	7D	12/21/84	2/1/85	ES	--	UGL	--	NC
11DCE	N8	5/16/86	3/23/90	UB	1.70	UGL	WA	C1
11DCE	TT8	9/21/86	1/10/90	ED	1.85	UGL	WA	C1
11DCE	UM21	11/7/88	3/12/90	UB	1.00	UGL	WA	1A
11DCE	Y8	12/9/85	4/8/88	ES	1.10	UGL	WA	C1
11DCLE	J8	9/18/86	5/12/88	CL	2.40	UGL	WA	1A
11DCLE	M8	4/3/86	10/8/87	ES	2.00	UGL	WA	1A
11DCLE	N8	5/16/86	3/23/90	UB	0.73	UGL	WA	C1
11DCLE	RM8A	2/25/88	5/13/88	RL	12.00	UGL	WA	1A
11DCLE	TT8	10/26/86	1/10/90	ED	1.93	UGL	WA	C1
11DCLE	UM21	11/7/88	3/12/90	UB	1.00	UGL	WA	1A
11DCLE	UU8	4/20/89	4/21/89	ED	1.40	UGL	WA	1A
11DCLE	Y8	12/9/85	4/8/88	ES	1.20	UGL	WA	C1
12DCE	7D	12/21/84	11/4/88	ES	--	UGL	--	NC
12DCE	J8	9/18/86	5/12/88	CL	1.20	UGL	WA	1A
12DCE	M8	4/3/86	10/8/87	ES	1.20	UGL	WA	1A
12DCE	N8	5/16/86	3/23/90	UB	0.76	UGL	WA	C1
12DCE	RM8A	2/25/85	5/13/88	RL	4.80	UGL	WA	1A
12DCE	TT8	9/16/86	1/10/90	ED	1.75	UGL	WA	C1
12DCE	UM21	11/7/88	3/12/90	UB	5.00	UGL	WA	1A
12DCE	UU8	4/20/89	4/21/89	ED	3.20	UGL	WA	1A
12DCE	Y8	11/11/85	4/8/88	ES	1.20	UGL	WA	C1
12DCLE	J8	9/18/86	5/12/88	CL	1.00	UGL	WA	1A
12DCLE	M8	4/3/86	10/8/87	ES	1.00	UGL	WA	1A
12DCLE	N8	5/16/86	3/23/90	UB	1.10	UGL	WA	C1
12DCLE	RM8A	2/25/88	5/13/88	RL	7.40	UGL	WA	1A
12DCLE	TT8	2/24/87	1/10/90	ED	2.07	UGL	WA	C1
12DCLE	UM21	11/7/88	3/12/90	UB	1.00	UGL	WA	1A
12DCLE	UU8	4/20/89	4/21/89	ED	0.72	UGL	WA	1A
12DCLE	Y8	12/9/85	4/8/88	ES	0.61	UGL	WA	C1
12DCLP*	UM21	11/7/88	3/12/90	UB	1.00	UGL	WA	1A
13DCLB*	UM21	11/7/88	3/12/90	UB	1.00	UGL	WA	1A
13DCP*	UM21	11/7/88	3/12/90	UB	4.80	UGL	WA	1A
13DMB	7K	12/21/84	2/1/85	ES	--	UGL	--	NC
13DMB	AV8	5/11/88	2/6/90	UB	1.32	UGL	WA	C1
13DMB	C8	5/15/86	3/2/88	CL	2.00	UGL	WA	C1

Note: Explanations of footnotes begin on Page 16 of this Attachment

Analyte[1]	Method[2]	First Use	Last Use	Lab[3]	CRL	Unit[4]	Media[5]	Certification[6]
13DMB	J8	9/18/86	5/12/88	CL	1.30	UGL	WA	1A
13DMB	M8	4/3/86	10/8/87	ES	1.00	UGL	WA	1A
13DMB	RM8A	2/25/88	5/13/88	RL	14.00	UGL	WA	1A
13DMB	SS8	9/24/86	1/10/90	ED	1.04	UGL	WA	C1
13DMB	UM21	11/7/88	3/12/90	UB	1.00	UGL	WA	1A
13DMB	UU8	4/20/89	4/21/89	ED	2.90	UGL	WA	1A
13DMB	W8	10/28/85	4/11/88	ES	1.35	UGL	WA	C1
14DIOX	2J	7/23/84	7/23/84	EE	--	UGL	--	NC
236TCP*	UM25	12/6/88	2/23/90	UB	1.70	UGL	WA	1A
245TCP*	UM25	12/6/88	2/23/90	UB	2.80	UGL	WA	1A
246TCP*	2J	8/2/84	8/2/84	EE	--	UGL	--	NC
246TCP*	UM25	12/6/88	2/23/90	UB	3.60	UGL	WA	1A
246TNT*	D1	7/31/88	1/11/85	EE	--	UGL	--	NC
24D*	99	7/16/84	7/16/84	RM	--	UGL	--	NC
24D*	T1	7/16/84	7/16/84	RM	--	UGL	--	NC
24DCLP*	UM25	12/6/88	2/23/90	UB	8.40	UGL	WA	1A
24DMPN*	UM25	12/6/88	2/23/90	UB	4.40	UGL	WA	1A
24DNP*	UM25	12/19/88	2/23/90	UB	176.00	UGL	WA	1A
25HXCB*	99	5/18/79	7/25/79	SC	--	UGL	--	NC
2CLEVE*	UM21	11/7/88	3/12/90	UB	3.50	UGL	WA	1A
2CLP*	UM25	12/6/88	2/23/90	UB	2.80	UGL	WA	1A
2MP	UM25	12/19/88	2/23/90	UB	3.60	UGL	WA	1A
2MPAME*	2J	12/14/84	12/19/84	EE	--	UGL	--	NC
2MTHF*	2J	12/14/84	12/14/84	EE	--	UGL	--	NC
2NP*	UM25	12/6/88	2/23/90	UB	8.20	UGL	WA	1A
4CL3C*	UM25	12/6/88	2/23/90	UB	8.50	UGL	WA	1A
4MP*	UM25	12/19/88	2/23/90	UB	2.80	UGL	WA	1A
4NP*	UM25	12/6/88	2/23/90	UB	96.00	UGL	WA	1A
ACET*	2J	12/7/88	12/20/84	EE	--	UGL	--	NC
ACET*	99	5/17/79	7/25/79	SC	--	UGL	--	NC
ACET*	UM21	11/7/88	3/12/90	UB	8.00	UGL	WA	1A
ACRYLO*	UM21	11/7/88	3/12/90	UB	8.40	UGL	WA	1A
AG*	1B	7/15/84	12/20/84	EE	--	UGL	--	NC
AG*	99	9/6/83	7/16/84	RM	--	UGL	--	NC
AG*	R1	9/6/83	9/6/83	RM	--	UGL	--	NC
AG*	T1	7/16/84	7/16/84	RM	--	UGL	--	NC
ALDRN	2F	7/9/84	1/11/55	EE	--	UGL	--	NC
ALDRN	4T	11/7/85	11/7/85	RM	--	UGL	--	NC
ALDRN	99	12/13/84	11/27/85	RM	--	UGL	--	NC
ALDRN	BB8	4/2/86	10/13/87	ES	4.70	UGL	WA	1A
ALDRN	EB8	9/28/88	9/28/88	EN	11.30	UGL	WA	1A
ALDRN	JJ8	9/22/86	11/29/88	UB	7.50	UGL	WA	1A
ALDRN	KK8	5/18/86	3/14/90	UB	0.05	UGL	WA	C1
ALDRN	MM8	8/27/86	1/21/87	ED	0.088	UGL	WA	C1
ALDRN	MM8A	3/20/87	4/7/88	ED	0.083	UGL	WA	C1
ALDRN	R1	10/21/77	4/22/85	RM	--	UGL	--	NC
ALDRN	RJ8	3/18/88	6/17/88	RL	5.50	UGL	WA	1A
ALDRN	S8	10/29/85	4/13/88	ES	0.07	UGL	WA	C1
ALDRN	T1	5/5/75	1/17/85	RM	--	UGL	--	NC
ALDRN	UM25	12/9/88	2/23/90	UB	13.00	UGL	WA	1A
ALDRN	X1	12/17/84	2/15/85	MW	--	UGL	--	NC
ALHMW*	K1	1/8/85	1/8/85	EE	--	UGL	--	NC
ALK*	00	4/30/85	11/18/85	RM	--	UGL	--	NC

Note: Explanations of footnotes begin on Page 16 of this Attachment

Analyte[1]	Method[2]	First Use	Last Use	Lab[3]	CRL	Unit[4]	Media[5]	Certification[6]
C6H6	99	5/17/79	6/26/84	RM	--	UGL	--	NC
C6H6	AV8	5/11/88	2/6/90	UB	1.05	UGL	WA	C1
C6H6	C8	5/15/86	3/2/88	CL	1.70	UGL	WA	C1
C6H6	J8	9/18/86	5/12/88	CL	1.00	UGL	WA	1A
C6H6	M8	4/3/86	10/8/87	ES	1.10	UGL	WA	1A
C6H6	RM8A	2/25/88	5/13/88	RL	6.10	UGL	WA	1A
C6H6	SS8	9/24/86	1/10/90	ED	1.92	UGL	WA	C1
C6H6	T1	4/14/83	10/3/84	RM	--	UGL	--	NC
C6H6	UM21	11/7/88	3/12/90	UB	1.00	UGL	WA	1A
C6H6	UU8	4/20/89	4/21/89	ED	2.70	UGL	WA	1A
C6H6	W8	10/28/85	4/11/88	ES	1.34	UGL	WA	C1
C9*	2J	12/7/84	12/7/84	EE	--	UGL	--	NC
CA*	6G	10/18/77	11/6/85	RM	--	UGL	--	NC
CA*	99	6/9/77	1/11/83	RM	--	UGL	--	NC
CA*	B8	3/18/86	4/15/88	ES	500.00	UGL	WA	C1
CA*	GG8	6/25/86	9/6/89	UB	500.00	UGL	WA	C1
CA*	R1	8/6/79	3/26/85	RM	--	UGL	--	NC
CA*	R9D	12/22/89	1/11/90	ED	50.00	UGL	WA	C1
CA*	SS06	9/27/89	9/27/89	ME	22.60	UGL	WA	C1
CA*	SS12	10/3/89	3/21/90	UB	105.00	UGL	WA	C1
CA*	T1	4/25/77	10/18/77	RM	--	UGL	--	NC
CALLMW*	2J	12/14/84	12/19/84	EE	--	UGL	--	NC
CCL3F*	2J	6/25/84	6/25/84	EE	--	UGL	--	NC
CCL3F*	UM21	11/7/88	3/12/90	UB	1.00	UGL	WA	1A
CCL4	7D	12/21/84	11/4/85	ES	--	UGL	--	NC
CCL4	99	5/18/79	6/26/84	RM	--	UGL	--	NC
CCL4	J8	9/18/86	5/12/88	CL	2.10	UGL	WA	1A
CCL4	M8	4/3/86	10/8/87	ES	1.50	UGL	WA	1A
CCL4	N8	5/16/86	3/23/90	UB	0.99	UGL	WA	C1
CCL4	RM8A	2/25/88	5/13/88	RL	6.30	UGL	WA	1A
CCL4	T1	4/14/88	10/3/84	RM	--	UGL	--	NC
CCL4	TT8	9/16/86	1/10/90	ED	1.69	UGL	WA	C1
CCL4	UM21	11/7/88	3/12/90	UB	1.00	UGL	WA	1A
CCL4	UU8	4/20/89	4/21/89	ED	4.90	UGL	WA	1A
CCL4	Y8	10/9/85	4/8/88	ES	2.40	UGL	WA	C1
CD	1M	10/13/77	12/26/84	RM	--	UGL	--	NC
CD	99	6/9/77	7/16/84	RM	--	UGL	--	NC
CD	B8	3/18/86	4/15/88	ES	5.16	UGL	WA	C1
CD	GG8	6/26/86	9/6/89	UB	8.40	UGL	WA	C1
CD	R9D	7/6/89	1/11/90	ED	5.00	UGL	WA	C1
CD	SS06	9/27/89	9/27/89	ME	4.09	UGL	WA	C1
CD	SS12	10/3/89	3/21/90	UB	6.78	UGL	WA	C1
CD	T1	4/25/77	7/16/84	RM	--	UGL	--	--
CH2CL2	2J	6/25/84	12/20/84	EE	--	UGL	--	--
CH2CL2	J8	9/18/86	5/12/88	CL	4.00	UGL	WA	1A
CH2CL2	M8	4/3/86	10/8/87	ES	4.80	UGL	WA	1A
CH2CL2	N8	5/16/86	3/23/90	UB	7.40	UGL	WA	C1
CH2CL2	RM8A	2/25/88	5/13/88	RL	2.70	UGL	WA	1A
CH2CL2	TT8	2/24/88	1/10/90	ED	2.48	UGL	WA	C1
CH2CL2	UM21	11/7/88	3/12/90	UB	1.00	UGL	WA	1A
CH2CL2	UU8	4/20/89	4/21/89	ED	--	UGL	--	1A
CH2CL2	Y8	12/9/85	4/8/88	ES	5.00	UGL	WA	C1
CH3BR*	UM21	11/7/88	3/12/90	UB	14.00	UGL	WA	1A

Note: Explanations of footnotes begin on Page 16 of this Attachment

Analyte[1]	Method[2]	First Use	Last Use	Lab[3]	CRL	Unit[4]	Media[5]	Certification[6]
ALK*	99	5/3/82	12/28/84	RM	--	UGL	--	NC
ALK*	R1	5/3/82	5/1/85	RM	--	UGL	--	NC
ALK*	T1	7/2/82	11/13/84	RM	--	UGL	--	NC
AS	1B	7/5/84	1/2/85	EE	--	UGL	--	NC
AS	99	6/9/77	7/17/84	RM	--	UGL	--	NC
AS	A8	2/24/86	4/20/87	ES	3.88	UGL	WA	C1
AS	A8A	8/25/87	1/8/88	ES	3.07	UGL	WA	C1
AS	AX8	10/27/88	3/15/90	UB	2.35	UGL	WA	C1
AS	RR8	7/30/86	9/23/88	CL	2.50	UGL	WA	C1
AS	SD11	9/27/89	9/27/89	ME	2.92	UGL	WA	C1
AS	T1	4/25/77	7/17/84	RM	--	--	--	NC
AS	VV8	1/21/87	1/11/90	ED	2.50	UGL	WA	C1
ASTOT*	6F	9/9/83	2/1/85	RM	--	UGL	--	NC
ASTOT*	99	8/18/77	9/9/83	RM	--	UGL	--	NC
ASTOT*	R1	6/1/79	11/24/81	RM	--	UGL	--	NC
ASTOT*	T1	8/18/77	10/12/77	RM	--	UGL	--	NC
ATZ	99	5/18/79	7/25/79	SC	--	UGL	--	NC
ATZ	BB8	4/2/86	10/13/87	ES	5.90	UGL	WA	1A
ATZ	EB8	9/28/88	9/28/88	EN	14.30	UGL	WA	1A
ATZ	H8	6/4/86	9/25/88	CL	0.79	UGL	WA	C1
ATZ	JJ8	9/22/86	11/29/88	UB	5.60	UGL	WA	1A
ATZ	RJ8	3/18/88	6/17/88	RL	2.60	UGL	WA	1A
ATZ	UH11	10/26/88	3/8/90	UB	4.03	UGL	WA	C1
ATZ	UM25	12/9/88	2/23/90	UB	5.90	UGL	WA	1A
B2EHP*	K1	7/5/84	1/19/85	EE	--	UGL	--	NC
B2EHP*	UM25	12/13/89	1/4/90	UB	7.70	UGL	WA	1A
BA*	1M	6/27/84	1/4/85	EE	---	UGL	--	NC
BA*	99	7/16/84	7/16/84	RM	--	UGL	--	NC
BA*	T1	7/16/84	7/16/84	RM	--	UGL	--	NC
BCHPD	99	5/17/79	6/26/84	RM	--	UGL	--	NC
BCHPD	J8	9/18/86	5/12/88	CL	1.20	UGL	WA	1A
BCHPD	M8	4/3/86	10/8/87	ES	1.00	UGL	WA	1A
BCHPD	P8	6/2/86	3/12/90	UB	5.90	UGL	WA	C1
BCHPD	RM8A	2/25/88	5/13/88	RL	1.30	UGL	WA	1A
BCHPD	T1	4/14/83	10/3/84	RM	--	UGL	--	NC
BCHPD	UU8	4/20/89	4/21/89	ED	1.80	UGL	WA	1A
BLDX*	99	5/17/79	7/25/79	SC	--	UGL	--	NC
BRDCLM*	UM21	11/7/88	3/12/90	UB	1.00	UGL	WA	1A
BTA**	4P	4/22/82	6/7/82	RM	--	UGL	--	NC
BTA**	99	3/29/82	1/3/83	RM	--	UGL	--	NC
BTA**	T1	4/16/82	4/16/82	RM	--	UGL	--	NC
BTZ**	AAA8	1/12/88	3/8/90	UB	5.00	UGL	WA	C1
BTZ**	PP8A	3/24/87	1/29/90	ED	1.14	UGL	WA	C1
BTZ**	U8	2/25/87	4/18/88	ES	1.97	UGL	WA	C1
C16ABE*	K1	1/19/85	1/19/85	EE	--	UGL	--	NC
C18ABE*	K1	1/19/85	1/19/85	EE	--	UGL	--	NC
C1ADME*	2J	12/7/84	12/19/84	EE	--	UGL	--	NC
C2H3CL*	N8	3/23/90	3/23/90	UB	1.01	UGL	WA	C1
C2H3CL*	UG05	11/22/89	11/22/89	AL	0.46	UGL	WA	C1
C2H3CL*	UM21	11/7/88	3/12/90	UB	12.00	UGL	WA	1A
C2H5CL*	UM21	11/7/88	3/12/90	UB	8.00	UGL	WA	1A
C6H6	2J	6/25/84	12/7/84	EE	--	UGL	--	NC
C6H6	7K	12/21/84	2/1/85	ES	--	UGL	--	NC

Note: Explanations of footnotes begin on Page 16 of this Attachment

Analyte[1]	Method[2]	First Use	Last Use	Lab[3]	CRL	Unit[4]	Media[5]	Certification[6]
CH3CL*	UM21	11/7/88	3/12/90	UB	1.20	UGL	WA	1A
CHBR3*	99	11/23/86	6/26/84	RM	--	UGL	--	NC
CHBR3*	T1	2/14/84	10/3/84	RM	--	UGL	--	NC
CHBR3*	UM21	11/7/88	3/12/90	UB	11.00	UGL	WA	1A
CHCL3	2J	7/23/84	7/23/84	EE	--	UGL	--	NC
CHCL3	7D	12/21/84	11/4/85	ES	--	UGL	--	NC
CHCL3	99	5/17/79	6/26/84	RM	--	UGL	--	NC
CHCL3	J8	9/18/86	5/12/88	CL	1.10	UGL	WA	1A
CHCL3	M8	4/3/86	10/8/87	ES	1.00	UGL	WA	1A
CHCL3	N8	5/16/86	3/23/90	UB	0.50	UGL	WA	C1
CHCL3	R1	8/3/79	8/3/79	RM	--	UGL	--	NC
CHCL3	RM8A	2/25/88	5/13/88	RL	1.50	UGL	WA	1A
CHCL3	T1	4/14/86	4/8/89	RM	--	UGL	--	NC
CHCL3	TT8	9/16/86	1/10/90	ED	1.88	UGL	WA	C1
CHCL3	UM21	11/7/88	3/12/90	UB	1.00	UGL	WA	1A
CHCL3	UU8	4/20/89	4/21/89	ED	1.70	UGL	WA	1A
CHCL3	Y8	10/9/85	4/8/88	ES	1.40	UGL	WA	C1
CL*	6H	1/22/82	--	RM	--	UGL	--	NC
CL*	99	11/7/85	11/8/85	RM	--	UGL	--	NC
CL*	AR	8/13/81	8/13/81	RM	--	UGL	--	NC
CL*	EC8	9/9/88	9/9/88	EN	1380.00	UGL	WA	C1
CL*	HH8	5/29/86	5/29/86	UB	2500.00	UGL	WA	C1
CL*	HH8A	12/14/87	8/16/89	UB	720.00	UGL	WA	C1
CL*	NN8	1/16/87	1/11/90	ED	1590.00	UGL	WA	C1
CL*	R1	6/4/79	4/19/85	RM	--	UGL	--	NC
CL*	RX8	3/10/88	5/16/88	RL	1500.00	UGL	WA	C1
CL*	T1	1/5/83	1/5/83	RM	--	UGL	--	NC
CL*	TT06	9/19/89	9/19/89	ME	114.00	UGL	WA	C1
CL*	TT09	10/23/89	3/9/90	UB	278.00	UGL	WA	C1
CL*	X8	3/9/87	10/27/87	ES	4800.00	UGL	WA	C1
CL2BZ*	T1	4/7/83	10/3/84	RM	--	UGL	--	NC
CL3P	T1	3/27/85	3/27/85	RM	--	UGL	--	NC
CL6CP	BB8	5/20/87	10/13/87	ES	11.00	UGL	WA	1A
CL6CP	EB8	9/25/88	9/28/88	EN	4.20	UGL	WA	1A
CL6CP	JJ8	9/22/86	11/29/88	UB	21.00	UGL	WA	1A
CL6CP	KK8	5/18/86	3/14/90	UB	0.048	UGL	WA	C1
CL6CP	MM8	12/30/86	1/19/87	ED	0.147	UGL	WA	C1
CL6CP	MM8A	3/20/87	4/7/88	ED	0.083	UGL	WA	C1
CL6CP	RJ8	3/18/88	6/17/88	RL	4.20	UGL	WA	1A
CL6CP	S8	5/30/86	4/13/88	ES	0.07	UGL	WA	C1
CL6CP	UM25	12/9/88	2/23/90	UB	54.00	UGL	WA	1A
CLC6H5*	J8	9/18/86	5/12/88	CL	1.10	UGL	WA	1A
CLC6H5*	M8	5/22/87	10/8/87	ES	2.10	UGL	WA	1A
CLC6H5*	N8	5/16/86	3/23/90	UB	0.82	UGL	WA	C1
CLC6H5*	RM8A	2/25/88	5/13/88	RL	5.10	UGL	WA	1A
CLC6H5*	T1	4/7/83	10/3/84	RM	--	UGL	--	NC
CLC6H5*	TT8	2/24/87	1/10/90	ED	1.36	UGL	WA	C1
CLC6H5*	UM21	11/7/88	3/12/90	UB	1.00	UGL	WA	1A
CLC6H5*	UU8	4/20/89	4/21/89	ED	1.80	UGL	WA	1A
CLC6H5*	Y8	4/23/87	4/8/88	ES	0.58	UGL	WA	C1
CLDAN*	BB8	5/20/87	10/13/87	ES	5.10	UGL	WA	1A
CLDAN*	EB8	9/28/88	9/28/88	EN	11.50	UGL	WA	1A
CLDAN*	JJ8	12/23/87	11/29/88	UB	9.40	UGL	WA	1A

Analyte[1]	Method[2]	First Use	Last Use	Lab[3]	CRL	Unit[4]	Media[5]	Certification[6]
CLDAN*	KK8	5/18/86	3/14/90	UB	0.095	UGL	WA	C1
CLDAN*	MM8	12/30/86	1/19/87	ED	0.234	UGL	WA	C1
CLDAN*	MM8A	3/20/87	4/7/88	ED	0.152	UGL	WA	C1
CLDAN*	RJ8	3/18/88	6/17/88	RL	19.00	UGL	WA	1A
CLDAN*	UM25	12/9/88	2/23/90	UB	37.00	UGL	WA	1A
COND*	00	11/18/75	11/18/85	RM	--	UGL	--	NC
COND*	6J	2/3/82	5/3/85	RM	--	UGL	--	NC
COND*	R1	4/6/79	3/25/85	RM	--	UGL	--	NC
COND*	T1	7/14/82	1/11/85	RM	--	UGL	--	NC
CPMS	4P	9/26/77	11/12/85	MW	--	UGL	--	NC
CPMS	99	6/9/77	1/3/83	RM	--	UGL	--	NC
CPMS	AAA8	1/12/88	3/8/90	UB	5.69	UGL	WA	C1
CPMS	BB8	7/3/86	10/13/87	ES	14.00	UGL	WA	1A
CPMS	D8	6/11/86	6/25/86	CL	7.50	UGL	WA	C1
CPMS	EB8	9/28/88	9/28/88	EN	5.50	UGL	WA	1A
CPMS	JJ8	9/22/86	11/29/88	UB	17.00	UGL	WA	1A
CPMS	PP8	8/20/86	1/21/87	ED	1.00	UGL	WA	C1
CPMS	PP8A	3/24/87	1/29/90	ED	1.08	UGL	WA	C1
CPMS	R1	6/15/79	4/22/85	RM	--	UGL	--	NC
CPMS	RJ8	3/18/88	6/17/88	RL	2.60	UGL	WA	1A
CPMS	T1	3/30/76	2/20/85	SC	--	UGL	--	NC
CPMS	U8	11/26/85	4/18/88	ES	1.26	UGL	WA	C1
CPMS	UM25	12/9/88	2/23/90	UB	10.00	UGL	WA	1A
CPMSO	4P	9/27/77	11/14/85	MW	--	UGL	--	NC
CPMSO	99	6/9/77	1/3/83	RM	--	UGL	--	NC
CPMSO	AAA8	1/12/88	3/8/90	UB	11.50	UGL	WA	C1
CPMSO	BB8	4/2/86	10/13/87	ES	17.00	UGL	WA	1A
CPMSO	D8	6/11/86	6/25/86	CL	4.20	UGL	WA	C1
CPMSO	EB8	9/28/88	9/28/88	EN	23.80	UGL	WA	1A
CPMSO	JJ8	9/22/86	11/29/88	UB	29.00	UGL	WA	1A
CPMSO	PP8	8/20/86	1/21/87	ED	3.20	UGL	WA	C1
CPMSO	PP8A	3/24/87	1/29/90	ED	1.98	UGL	WA	C1
CPMSO	R1	6/15/79	4/22/85	RM	--	UGL	--	NC
CPMSO	RJ8	3/18/88	6/17/88	RL	2.60	UGL	WA	1A
CPMSO	T1	3/29/76	4/22/82	SC	--	UGL	--	NC
CPMSO	U8	11/26/85	4/18/88	ES	4.23	UGL	WA	C1
CPMSO	UM25	12/9/88	2/23/90	UB	15.00	UGL	WA	1A
CPMSO2	4P	9/27/77	11/14/85	MW	--	UGL	--	NC
CPMSO2	99	6/9/77	1/3/83	RM	--	UGL	--	NC
CPMSO2	AAA8	1/12/88	3/8/90	UB	7.46	UGL	WA	C1
CPMSO2	BB8	4/2/86	10/13/87	ES	8.00	UGL	WA	1A
CPMSO2	D8	6/11/86	6/25/86	CL	11.50	UGL	WA	C1
CPMSO2	EB8	9/28/88	9/28/88	EN	3.40	UGL	WA	1A
CPMSO2	JJ8	9/22/86	11/29/88	UB	7.20	UGL	WA	1A
CPMSO2	PP8	8/20/86	1/21/87	ED	2.60	UGL	WA	C1
CPMSO2	PP8A	3/24/87	1/29/90	ED	2.24	UGL	WA	C1
CPMSO2	R1	6/15/79	4/22/85	RM	--	UGL	--	NC
CPMSO2	RJ8	3/18/88	6/17/88	RL	2.60	UGL	WA	1A
CPMSO2	T1	3/29/76	5/11/84	SC	--	UGL	--	NC
CPMSO2	U8	11/26/85	4/18/88	ES	4.66	UGL	WA	C1
CPMSO2	UM25	12/9/88	2/23/90	UB	5.30	UGL	WA	1A
CR	1B	7/2/84	12/20/84	EE	--	UGL	--	NC
CR	99	9/29/83	7/16/84	RM	--	UGL	--	NC

Analyte[1]	Method[2]	First Use	Last Use	Lab[3]	CRL	Unit[4]	Media[5]	Certification[6]
CR	B8	3/18/86	4/15/88	ES	5.96	UGL	WA	C1
CR	GG8	6/26/86	9/6/89	UB	24.00	UGL	WA	C1
CR	R9D	7/6/89	1/11/90	ED	22.00	UGL	WA	C1
CR	SS06	9/27/89	9/27/89	ME	4.44	UGL	WA	C1
CR	SS12	10/3/89	3/21/90	UB	16.80	UGL	WA	C1
CR	T1	9/29/83	7/16/84	RM	--	UGL	--	NC
CRHEX*	9Z	6/20/84	12/12/84	EE	--	UGL	--	NC
CU	1B	8/2/84	12/26/84	EE	--	UGL	--	NC
CU	99	6/9/77	7/25/79	RM	--	UGL	--	NC
CU	B8	3/18/86	4/15/88	ES	7.93	UGL	WA	C1
CU	GG8	6/26/86	9/6/89	UB	26.00	UGL	WA	C1
CU	R9D	7/6/89	1/11/90	ED	10.00	UGL	WA	C1
CU	SS06	9/27/89	9/27/89	ME	6.20	UGL	WA	C1
CU	SS12	10/3/89	3/21/90	UB	18.80	UGL	WA	C1
CU	T1	5/28/75	6/21/77	RM	--	UGL	--	NC
CUTOT*	99	8/11/77	10/30/79	RM	--	UGL	--	NC
CUTOT*	R1	9/19/79	10/30/79	RM	--	UGL	--	NC
CUTOT*	T1	8/11/77	4/7/78	RM	--	UGL	--	NC
CYHX*	2J	7/23/84	7/23/84	EE	--	UGL	--	NC
CYN*	CN1	12/18/89	1/11/90	ED	8.90	UGL	WA	C1
CYN*	TF18	5/9/89	6/27/89	ES	2.50	UGL	WA	1B
CYN*	TF19	9/19/89	9/19/89	ME	5.00	UGL	WA	C1
CYN*	TF20	11/3/88	3/12/90	UB	5.00	UGL	WA	C1
CYOCTE*	T1	3/27/85	3/27/85	RM	--	UGL	--	NC
DBCP	4Q	1/26/82	1/28/85	RM	--	UGL	--	NC
DBCP	84	3/12/84	3/12/84	RM	--	UGL	--	NC
DBCP	99	5/18/79	11/28/85	RM	--	UGL	--	NC
DBCP	AY8	5/10/88	3/6/90	UB	0.195	UGL	WA	C1
DBCP	BB8	4/2/86	10/13/87	ES	15.00	UGL	WA	1A
DBCP	E1	12/19/84	2/14/85	MW	--	UGL	--	NC
DBCP	E8	5/27/86	3/10/88	CL	0.19	UGL	WA	C1
DBCP	EB8	9/28/88	9/28/88	EN	10.10	UGL	WA	1A
DBCP	J8	9/18/86	5/12/88	CL	3.00	UGL	WA	1A
DBCP	JJ8	9/22/86	11/29/88	UB	19.00	UGL	WA	1A
DBCP	M8	4/3/86	10/8/87	ES	4.00	UGL	WA	1A
DBCP	Q8	10/4/85	1/23/90	ED	0.13	UGL	WA	C1
DBCP	R1	11/3/77	4/22/85	RM	--	UGL	--	NC
DBCP	RI	6/5/80	6/6/80	RM	--	UGL	--	NC
DBCP	RJ8	3/18/88	6/17/88	RL	2.60	UGL	WA	1A
DBCP	RV8	1/25/89	3/23/89	RL	0.04	UGL	WA	C1
DBCP	T1	8/19/77	6/24/84	CH	--	UGL	--	NC
DBCP	UM25	12/9/88	2/23/90	UB	12.00	UGL	WA	1A
DBCP	UU8	4/20/89	4/21/89	ED	5.60	UGL	WA	1A
DBRCLM*	UM21	11/7/88	3/12/90	UB	1.00	UGL	WA	1A
DCLB*	UM21	11/7/88	3/12/90	UB	2.00	UGL	WA	1A
DCPD	01	--	--	RM	--	UGL	--	NC
DCPD	0	2/20/82	2/20/82	RM	--	UGL	--	NC
DCPD	01	9/27/77	10/18/77	RM	--	UGL	--	NC
DCPD	02	9/27/77	10/18/77	RM	--	UGL	--	NC
DCPD	4R	1/4/85	2/22/85	MW	--	UGL	--	NC
DCPD	99	5/17/79	12/12/85	RM	--	UGL	--	NC
DCPD	BB8	4/2/86	10/13/87	ES	4.70	UGL	WA	1A
DCPD	EB8	9/28/88	9/28/88	EN	7.20	UGL	WA	1A

Note: Explanations of footnotes begin on Page 16 of this Attachment

Analyte[1]	Method[2]	First Use	Last Use	Lab[3]	CRL	Unit[4]	Media[5]	Certification[6]
DCPD	J8	9/18/86	5/12/88	CL	1.50	UGL	WA	1A
DCPD	JJ8	9/22/86	11/29/88	UB	7.30	UGL	WA	1A
DCPD	M8	4/3/86	10/8/87	ES	1.10	UGL	WA	1A
DCPD	P8	6/2/86	3/12/90	UB	5.00	UGL	WA	C1
DCPD	R1	9/27/77	4/15/85	RM	--	UGL	--	NC
DCPD	R8	10/3/85	1/12/90	ED	9.31	UGL	WA	C1
DCPD	RJ8	3/18/88	6/17/88	RL	6.20	UGL	WA	1A
DCPD	T1	5/5/75	4/8/89	RM	--	UGL	--	NC
DCPD	T2	7/16/75	7/19/78	RM	--	UGL	--	NC
DCPD	UM25	12/9/88	2/23/90	UB	5.50	UGL	WA	1A
DCPD	UU8	4/20/89	4/21/89	ED	3.70	UGL	WA	1A
DDVP	99	5/18/79	7/25/79	SC	--	UGL	--	NC
DDVP	BB8	4/2/86	10/13/87	ES	9.00	UGL	WA	1A
DDVP	EB8	9/28/88	9/28/88	EN	17.30	UGL	WA	1A
DDVP	H8	6/4/86	9/25/87	CL	0.89	UGL	WA	C1
DDVP	JJ8	9/22/86	11/29/88	UB	17.00	UGL	WA	1A
DDVP	RJ8	3/18/88	6/17/88	RL	2.60	UGL	WA	1A
DDVP	UH11	10/26/88	3/8/90	UB	0.384	UGL	WA	C1
DDVP	UM25	12/9/88	2/23/90	UB	8.50	UGL	WA	1A
DIACAL**	K1	1/3/85	1/8/85	EE	--	UGL	--	NC
DIMP	01	9/27/77	9/27/77	RM	--	UGL	--	NC
DIMP	4S	1/21/82	11/26/85	RM	--	UGL	--	NC
DIMP	99	5/18/79	7/25/79	SC	--	UGL	--	NC
DIMP	AT8	11/3/88	3/13/90	UB	0.392	UGL	WA	C1
DIMP	BB8	4/2/86	10/13/87	ES	5.70	UGL	WA	1A
DIMP	EB8	9/28/88	9/28/88	EN	14.70	UGL	WA	1A
DIMP	F8	5/16/86	9/22/88	CL	18.50	UGL	WA	C1
DIMP	JJ8	9/22/86	11/29/88	UB	14.00	UGL	WA	1A
DIMP	QQ8	8/31/87	1/11/90	ED	10.10	UGL	WA	C1
DIMP	R1	10/17/76	4/18/85	RM	--	UGL	--	NC
DIMP	R3	12/7/77	12/8/77	RM	--	UGL	--	NC
DIMP	RJ8	3/18/88	6/17/88	RL	4.90	UGL	WA	1A
DIMP	T1	5/8/75	5/24/85	ES	--	UGL	--	NC
DIMP	T8	10/17/85	5/7/88	ES	10.50	UGL	WA	C1
DIMP	UM25	12/6/88	2/23/90	UB	21.00	UGL	WA	1A
DIOP*	K1	1/19/85	1/19/85	EE	--	UGL	--	NC
DITH	4P	9/27/77	11/12/85	MW	--	UGL	--	NC
DITH	99	6/9/77	11/14/85	RM	--	UGL	--	NC
DITH	AAA8	1/12/88	3/8/90	UB	1.34	UGL	WA	C1
DITH	BB8	7/3/86	10/13/87	ES	11.00	UGL	WA	1A
DITH	D8	6/11/86	6/25/86	CL	11.20	UGL	WA	C1
DITH	EB8	9/28/88	9/28/88	EN	6.10	UGL	WA	1A
DITH	JJ8	9/22/86	11/29/88	UB	21.00	UGL	WA	1A
DITH	PP8	8/20/86	1/21/87	ED	1.60	UGL	WA	C1
DITH	PP8A	3/24/87	1/29/90	ED	3.34	UGL	WA	C1
DITH	R1	6/15/79	4/22/85	RM	--	UGL	--	NC
DITH	RJ8	3/18/88	6/17/88	RL	2.60	UGL	WA	1A
DITH	T1	4/25/77	4/22/82	RM	--	UGL	--	NC
DITH	U8	11/26/85	4/18/88	ES	1.11	UGL	WA	C1
DITH	UM25	12/9/88	2/23/90	UB	3.30	UGL	WA	1A
DLDRN	2F	7/9/84	1/11/85	EE	--	UGL	--	NC
DLDRN	4T	8/23/85	11/27/85	RM	--	UGL	--	NC
DLDRN	99	5/18/79	11/27/85	RM	--	UGL	--	NC

Analyte[1]	Method[2]	First Use	Last Use	Lab[3]	CRL	Unit[4]	Media[5]	Certification[6]
DLDRN	BB8	4/2/86	10/13/87	ES	4.70	UGL	WA	1A
DLDRN	EB8	9/28/88	9/28/88	EN	4.40	UGL	WA	1A
DLDRN	JJ8	9/22/86	11/29/88	UB	4.70	UGL	WA	1A
DLDRN	KK8	5/18/86	3/14/90	UB	0.05	UGL	WA	C1
DLDRN	MM8	8/20/86	1/21/87	ED	0.054	UGL	WA	C1
DLDRN	MM8A	3/20/87	4/7/88	ED	0.0539	UGL	WA	C1
DLDRN	R1	10/21/77	4/30/85	RM	--	UGL	--	NC
DLDRN	RJ8	3/18/88	6/17/88	RL	2.60	UGL	WA	1A
DLDRN	S8	10/29/85	4/13/88	ES	0.06	UGL	WA	C1
DLDRN	T1	5/5/75	1/22/85	RM	--	UGL	--	NC
DLDRN	UM25	12/9/88	2/23/90	UB	26.00	UGL	WA	1A
DLDRN	X1	12/17/84	2/15/85	MW	--	UGL	--	NC
DMDS*	99	5/17/79	7/25/79	SC	--	UGL	--	NC
DMDS*	AAA8	1/12/88	3/8/90	UB	0.55	UGL	WA	C1
DMDS*	D8	6/11/86	6/25/86	CL	8.00	UGL	WA	C1
DMDS*	J8	9/18/86	5/12/88	CL	13.50	UGL	WA	1A
DMDS*	M8	4/3/86	10/8/87	ES	2.50	UGL	WA	1A
DMDS*	PP8	8/20/86	7/24/87	ED	1.70	UGL	WA	C1
DMDS*	PP8A	3/24/87	1/29/90	ED	1.16	UGL	WA	C1
DMDS*	RM8A	2/25/88	5/13/88	RL	11.00	UGL	WA	1A
DMDS*	U8	1/3/86	4/18/88	ES	1.77	UGL	WA	C1
DMDS*	UU8	4/20/89	4/21/89	ED	3.70	UGL	WA	1A
DMMP	99	4/16/82	1/4/83	RM	--	UGL	--	NC
DMMP	AT8	11/3/88	3/13/90	UB	0.188	UGL	WA	C1
DMMP	F8	5/16/86	9/22/88	CL	29.30	UGL	WA	C1
DMMP	JJ8	9/22/86	11/29/88	UB	33.00	UGL	WA	1A
DMMP	QQ8	8/31/87	1/11/90	ED	16.30	UGL	WA	C1
DMMP	RJ8	3/18/88	6/17/88	RL	7.60	UGL	WA	1A
DMMP	T1	4/21/82	2/4/85	ES	--	UGL	--	NC
DMMP	T8	11/18/85	11/19/87	ES	15.20	UGL	WA	C1
DMMP	UM25	12/9/88	2/23/90	UB	130.00	UGL	WA	1A
DNBP*	2J	8/2/84	8/2/84	EE	--	UGL	--	NC
DNBP*	K1	1/3/85	1/19/85	EE	--	UGL	--	NC
DNOP*	K1	1/8/85	1/8/85	EE	--	UGL	--	NC
DOAD*	K1	7/5/84	1/11/85	EE	--	UGL	--	NC
ENDRN	2F	7/9/84	1/11/85	EE	--	UGL	--	NC
ENDRN	4T	11/5/85	11/27/85	RM	--	UGL	--	NC
ENDRN	99	12/13/84	11/27/85	RM	--	UGL	--	NC
ENDRN	BB8	4/2/86	10/13/87	ES	7.60	UGL	WA	1A
ENDRN	EB8	9/28/88	9/28/88	EN	10.00	UGL	WA	1A
ENDRN	JJ8	9/22/86	11/29/88	UB	8.00	UGL	WA	1A
ENDRN	KK8	5/18/86	3/14/90	UB	0.05	UGL	WA	C1
ENDRN	MM8	8/20/86	1/21/87	ED	0.063	UGL	WA	C1
ENDRN	MM8A	3/20/87	4/7/88	ED	0.06	UGL	WA	C1
ENDRN	R1	10/21/77	4/22/85	RM	--	UGL	--	NC
ENDRN	RJ8	3/18/88	6/17/88	RL	5.90	UGL	WA	1A
ENDRN	S8	10/29/85	4/13/88	ES	0.052	UGL	WA	C1
ENDRN	T1	5/5/75	1/22/85	RM	--	UGL	--	NC
ENDRN	UM25	12/9/88	2/23/90	UB	18.00	UGL	WA	1A
ENDRN	X1	12/17/84	2/15/85	MW	--	UGL	--	NC
ETC6H5	AV8	8/19/88	2/6/90	UB	1.37	UGL	WA	C1
ETC6H5	C8	5/15/86	3/2/88	CL	1.40	UGL	WA	C1
ETC6H5	J8	9/18/86	5/12/88	CL	1.20	UGL	WA	1A

Analyte[1]	Method[2]	First Use	Last Use	Lab[3]	CRL	Unit[4]	Media[5]	Certification[6]
ETC6H5	M8	4/3/86	10/8/87	ES	1.00	UGL	WA	1A
ETC6H5	RM8A	2/25/88	5/13/88	RL	11.00	UGL	WA	1A
ETC6H5	SS8	9/24/86	1/10/90	ED	0.62	UGL	WA	C1
ETC6H5	UM21	11/7/88	3/12/90	UB	1.00	UGL	WA	1A
ETC6H5	UU8	4/20/89	4/21/89	ED	2.40	UGL	WA	1A
ETC6H5	W8	12/9/85	4/11/88	ES	1.28	UGL	WA	C1
F*	4V	9/29/77	12/5/85	RM	--	UGL	--	NC
F*	99	4/7/78	11/27/85	RM	--	UGL	--	NC
F*	HH8	5/29/86	5/29/86	UB	560.00	UGL	WA	C1
F*	HH8A	12/14/87	8/16/89	UB	482.00	UGL	WA	C1
F*	NN8	9/10/86	1/11/90	ED	1000.00	UGL	WA	C1
F*	R1	6/1/79	4/18/85	RM	--	UGL	--	NC
F*	RF8	4/11/88	5/9/88	RL	50.00	UGL	WA	C1
F*	T1	5/5/75	1/4/83	RM	--	UGL	--	NC
F*	TT06	9/19/89	9/19/89	ME	50.00	UGL	WA	C1
F*	TT09	9/23/89	3/9/90	UB	153.00	UGL	WA	C1
F*	U1	1/9/85	1/31/85	ES	--	UGL	--	NC
F*	X8	10/18/85	10/27/87	ES	1220.00	UGL	WA	C1
FARN*	K1	1/8/85	1/8/85	EE	--	UGL	--	NC
FE*	1M	10/1/80	3/14/85	RM	--	UGL	--	NC
FE*	99	5/30/84	9/3/85	RM	--	UGL	--	NC
FE*	R1	10/1/80	10/3/80	RM	--	UGL	--	NC
FE*	SS12	2/9/90	2/25/90	UB	77.50	UGL	WA	C1
FE*	T1	5/30/84	11/16/84	RM	--	UGL	--	NC
HARD*	00	5/5/75	11/22/85	RM	--	UGL	--	NC
HARD*	6K	1/26/82	5/10/85	RM	--	UGL	--	NC
HARD*	R1	8/3/79	3/27/85	RM	--	UGL	--	NC
HARD*	RF	6/29/81	6/29/81	RM	--	UGL	--	NC
HCBD*	99	5/18/79	7/25/79	SC	--	UGL	--	NC
HCNB*	99	5/18/79	7/25/79	SC	--	UGL	--	NC
HCO3*	99	5/8/79	3/17/82	RM	--	UGL	--	NC
HCO3*	R1	7/5/79	2/19/82	RM	--	UGL	--	NC
HEXANE*	2J	6/26/84	12/14/84	EE	--	UGL	--	NC
HG	1D	6/26/84	12/19/84	RM	--	UGL	--	NC
HG	99	6/9/77	7/25/79	RM	--	UGL	--	NC
HG	CC8	5/20/86	3/30/90	UB	0.10	UGL	WA	C1
HG	EL8	9/6/88	9/6/88	EN	0.50	UGL	WA	C1
HG	L8	1/21/86	11/5/87	ES	0.242	UGL	WA	C1
HG	R1	7/18/84	7/18/84	RM	--	UGL	--	NC
HG	SB10	9/22/89	9/22/89	ME	0.10	UGL	WA	C1
HG	T1	4/25/77	6/21/77	RM	--	UGL	--	NC
HG	WW8	4/16/87	1/11/90	ED	0.50	UGL	WA	C1
HGTOT*	1D	9/1/83	1/21/85	RM	--	UGL	--	NC
HGTOT*	99	8/9/77	9/1/83	RM	--	UGL	--	NC
HGTOT*	R1	10/14/80	10/14/80	RM	--	UGL	--	NC
HGTOT*	T1	7/29/77	10/11/77	RM	--	UGL	--	NC
HXMTSX*	2J	12/18/84	12/20/84	EE	--	UGL	--	NC
HYDRZ	DD8	5/14/86	5/16/86	UB	2.50	UGL	WA	C1
HYDRZ	ZZ8A	6/2/88	6/3/88	UB	30.60	UGL	WA	C1
IDRN	BB8	4/2/86	6/4/86	ES	--	UGL	--	NC
ISODR	4T	10/21/77	11/20/85	RM	--	UGL	--	NC
ISODR	99	6/9/77	11/27/85	RM	--	UGL	--	NC
ISODR	BB8	6/11/86	10/13/87	ES	5.90	UGL	WA	1A

Note: Explanations of footnotes begin on Page 16 of this Attachment

Analyte[1]	Method[2]	First Use	Last Use	Lab[3]	CRL	Unit[4]	Media[5]	Certification[6]
ISODR	EB8	9/28/88	9/28/88	EN	8.30	UGL	WA	1A
ISODR	JJ8	9/22/86	11/29/88	UB	3.70	UGL	WA	1A
ISODR	KK8	5/18/86	3/14/90	UB	0.051	UGL	WA	C1
ISODR	MM8	8/20/86	1/21/87	ED	0.072	UGL	WA	C1
ISODR	MM8A	3/20/87	4/7/88	ED	0.056	UGL	WA	C1
ISODR	R1	6/14/79	4/22/85	RM	--	UGL	--	NC
ISODR	R2	10/3/80	10/3/80	RM	--	UGL	--	NC
ISODR	RJ8	3/18/88	6/17/88	RL	4.70	UGL	WA	1A
ISODR	S8	10/29/85	4/13/88	ES	0.06	UGL	WA	C1
ISODR	T1	4/25/77	1/17/85	RM	--	UGL	--	NC
ISODR	UM25	12/14/88	2/23/90	UB	7.80	UGL	WA	1A
ISODR	X1	12/17/84	2/15/85	MW	--	UGL	--	NC
K*	99	6/9/77	1/12/83	RM	--	UGL	--	NC
K*	AA8	3/10/86	11/12/87	ES	1256.00	UGL	WA	C1
K*	GG8	6/30/86	9/6/89	UB	250.00	UGL	WA	C1
K*	R1	5/31/79	3/25/85	RM	--	UGL	--	NC
K*	SS06	9/27/89	9/27/89	ME	794.00	UGL	WA	C1
K*	SS12	10/3/89	3/21/90	UB	1240.00	UGL	WA	C1
K*	T1	4/25/77	10/5/77	RM	--	UGL	--	NC
K*	XX8	3/24/87	1/11/90	ED	590.00	UGL	WA	C1
LIN*	99	7/16/84	7/16/84	RM	--	UGL	--	NC
LIN*	T1	7/16/84	7/16/84	RM	--	UGL	--	NC
ME2HG*	RM8A	2/25/88	5/13/88	RL	16.00	UGL	WA	1A
MEC6H5	2J	6/26/84	12/20/84	EE	--	UGL	--	NC
MEC6H5	7K	12/20/84	2/1/85	ES	--	UGL	--	NC
MEC6H5	99	5/17/79	6/26/84	RM	--	UGL	--	NC
MEC6H5	AV8	5/11/88	2/6/90	UB	1.47	UGL	WA	C1
MEC6H5	C8	5/15/86	3/2/88	CL	2.80	UGL	WA	C1
MEC6H5	J8	9/18/86	5/12/88	CL	1.00	UGL	WA	1A
MEC6H5	K1	1/19/85	1/19/85	EE	--	UGL	--	NC
MEC6H5	M8	4/3/86	10/8/87	ES	1.00	UGL	WA	1A
MEC6H5	RM8A	2/25/88	5/13/88	RL	7.80	UGL	WA	1A
MEC6H5	SS8	9/24/86	1/10/90	ED	2.10	UGL	WA	C1
MEC6H5	T1	4/14/83	3/14/85	RM	--	UGL	--	NC
MEC6H5	UM21	11/7/88	3/12/90	UB	1.00	UGL	WA	1A
MEC6H5	UU8	4/20/89	4/21/89	ED	3.50	UGL	WA	1A
MEC6H5	W8	10/28/85	4/11/88	ES	1.21	UGL	WA	C1
MEK*	2J	12/7/84	12/9/84	EE	--	UGL	--	NC
MEK*	UM21	11/7/88	3/12/90	UB	10.00	UGL	WA	1A
MEXCLR*	99	7/16/84	7/16/84	RM	--	UGL	--	NC
MEXCLR*	T1	7/16/84	7/16/84	RM	--	UGL	--	NC
MG*	1M	5/3/79	10/30/85	RM	--	UGL	--	NC
MG*	99	1/6/83	11/12/85	RM	--	UGL	---	NC
MG*	B8	3/18/86	4/15/88	ES	500.00	UGL	WA	C1
MG*	GG8	6/26/86	9/6/89	UB	500.00	UGL	WA	C1
MG*	R1	6/5/79	3/25/85	RM	--	UGL	--	NC
MG*	R9D	12/22/89	1/11/90	ED	89.20	UGL	WA	C1
MG*	SS06	10/27/89	10/27/89	ME	110.00	UGL	WA	C1
MG*	SS12	10/3/89	3/21/90	UB	135.00	UGL	WA	C1
MHYDRZ	EE8	5/14/86	5/16/86	UB	20.00	UGL	WA	C1
MHYDRZ	ZZ8A	6/2/88	6/3/88	UB	2970.00	UGL	WA	C1
MIBK	99	5/17/79	6/26/84	RM	--	UGL	--	NC
MIBK	J8	9/18/86	5/12/88	CL	1.00	UGL	WA	1A

Note: Explanations of footnotes begin on Page 16 of this Attachment

Analyte[1]	Method[2]	First Use	Last Use	Lab[3]	CRL	Unit[4]	Media[5]	Certification[6]
MIBK	M8	4/3/86	10/8/87	ES	2.00	UGL	WA	1A
MIBK	P8	6/2/86	3/12/90	UB	4.90	UGL	WA	C1
MIBK	R8	12/4/85	1/12/90	ED	12.90	UGL	WA	C1
MIBK	RM8A	2/25/88	5/13/88	RL	8.00	UGL	WA	1A
MIBK	T1	4/14/83	10/3/84	RM	--	UGL	--	NC
MIBK	UM21	11/7/88	3/12/90	UB	1.40	UGL	WA	1A
MIBK	UU8	4/20/89	4/21/89	ED	1.20	UGL	WA	1A
MLTHN	BB8	4/2/86	10/13/87	ES	7.60	UGL	WA	1A
MLTHN	EB8	9/28/88	9/28/88	EN	21.20	UGL	WA	1A
MLTHN	H8	6/4/86	10/13/87	CL	0.58	UGL	WA	C1
MLTHN	JJ8	9/22/86	11/29/88	UB	14.00	UGL	WA	1A
MLTHN	RJ8	3/18/88	6/17/88	RL	2.60	UGL	WA	1A
MLTHN	T1	5/13/75	10/13/76	CH	--	UGL	--	NC
MLTHN	UH11	10/26/88	3/8/90	UB	0.373	UGL	WA	C1
MLTHN	UM25	12/9/88	2/23/90	UB	21.00	UGL	WA	1A
MN*	1M	3/1/78	3/14/85	RM	--	UGL	--	NC
MN*	99	5/30/84	9/3/85	RM	--	UGL	--	NC
MN*	SS12	2/9/90	2/25/90	UB	9.67	UGL	WA	C1
MN*	T1	5/30/84	11/16/84	RM	--	UGL	--	NC
NA*	6G	10/12/77	11/7/85	RM	--	UGL	--	NC
NA*	99	7/1/76	9/16/85	RM	--	UGL	--	NC
NA*	B8	3/18/86	4/17/88	ES	764.00	UGL	WA	C1
NA*	GG8	6/30/86	9/6/89	UB	940.00	UGL	WA	C1
NA*	R1	6/19/79	3/27/85	RM	--	UGL	--	NC
NA*	R9D	12/22/89	1/11/90	ED	251.00	UGL	WA	C1
NA*	SS06	9/27/89	9/27/89	ME	91.30	UGL	WA	C1
NA*	SS12	10/3/89	3/21/90	UB	279.00	UGL	WA	C1
NA*	T1	5/15/75	10/12/77	RM	--	UGL	--	NC
NC*	1P	8/3/84	12/10/84	EE	--	UGL	--	NC
NIT*	1U	1/27/82	9/24/85	RM	--	UGL	--	NC
NIT*	99	4/7/76	11/22/85	RM	--	UGL	--	NC
NIT*	K8	1/23/86	4/12/88	ES	10.00	UGL	WA	C1
NIT*	LL8	5/15/86	1/31/90	UB	10.00	UGL	WA	C1
NIT*	R1	5/29/79	3/25/85	RM	--	UGL	--	NC
NIT*	T1	5/5/75	1/3/83	RM	--	UGL	--	NC
NIT*	TF22	5/12/89	6/21/89	ES	10.00	UGL	WA	C1
NNDMEA*	G8	5/28/86	5/29/86	UB	0.20	UGL	WA	C1
NNDMEA*	RJ8	3/18/88	6/17/88	RL	2.60	UGL	WA	1A
NNDNPA*	G8	5/28/86	5/29/86	UB	0.14	UGL	WA	C1
NO3*	1U	7/6/84	7/6/84	EE	--	UGL	--	NC
NO3*	LL8	5/1/87	5/18/87	UB	--	UGL	--	NC
OPDDE*	T1	5/27/75	10/13/76	CH	--	UGL	--	NC
OPDDT*	T1	8/25/75	8/25/75	CH	--	UGL	--	NC
OPO4*	T1	9/2/75	10/13/76	CH	--	UGL	--	NC
OXAT	4P	9/27/77	11/12/85	MW	--	UGL	--	NC
OXAT	99	6/9/77	8/29/85	RM	--	UGL	--	NC
OXAT	AAA8	1/12/88	3/8/90	UB	2.38	UGL	WA	C1
OXAT	BB8	7/3/86	10/13/87	ES	6.10	UGL	WA	1A
OXAT	D8	6/11/86	6/25/86	CL	10.00	UGL	WA	C1
OXAT	EB8	9/28/88	9/28/88	EN	12.00	UGL	WA	1A
OXAT	JJ8	9/22/86	11/29/88	UB	7.90	UGL	WA	1A
OXAT	PP8	8/20/86	1/21/87	ED	1.40	UGL	WA	C1
OXAT	PP8A	3/24/87	1/29/90	ED	1.35	UGL	WA	C1

Note: Explanations of footnotes begin on Page 16 of this Attachment

Analyte[1]	Method[2]	First Use	Last Use	Lab[3]	CRL	Unit[4]	Media[5]	Certification[6]
OXAT	R1	1/9/79	4/22/85	RM	--	UGL	--	NC
OXAT	RJ8	3/18/88	6/17/88	RL	2.60	UGL	WA	1A
OXAT	T1	4/25/77	9/27/77	RM	--	UGL	--	NC
OXAT	U8	11/26/85	4/18/88	ES	1.61	UGL	WA	C1
OXAT	UM25	12/9/88	2/23/90	UB	27.00	UGL	WA	1A
PB	1B	7/3/84	12/28/84	EE	--	UGL	--	NC
PB	99	8/22/83	7/16/84	RM	--	UGL	--	NC
PB	B8	3/18/86	4/15/88	ES	18.60	UGL	WA	C1
PB	GG8	6/26/86	9/6/89	UB	74.00	UGL	WA	C1
PB	R1	9/15/80	8/22/83	RM	--	UGL	--	NC
PB	R9D	7/6/89	1/11/90	ED	52.00	UGL	WA	C1
PB	SS06	9/27/89	9/27/89	ME	45.10	UGL	WA	C1
PB	SS12	10/3/89	3/21/90	UB	43.40	UGL	WA	C1
PB	T1	9/24/80	7/16/84	RM	--	UGL	--	NC
PCP*	UM25	12/6/88	2/23/90	UB	9.10	UGL	WA	1A
PH*	00	5/5/75	10/24/85	RM	--	--	--	NC
PH*	4J	1/27/82	4/26/85	RM	--	--	--	NC
PH*	R1	8/1/79	3/20/85	RM	--	--	--	NC
PH*	T1	2/8/85	2/8/85	RM	--	--	--	NC
PHENOL*	UM25	12/6/88	2/23/90	UB	2.20	UGL	WA	1A
PHTHL*	K1	1/19/85	1/19/85	EE	--	UGL	--	NC
PPDDE	4T	10/21/77	11/15/78	RM	--	UGL	--	NC
PPDDE	99	6/14/77	10/4/77	RM	--	UGL	--	NC
PPDDE	BB8	4/2/86	10/13/87	ES	4.70	UGL	WA	1A
PPDDE	EB8	9/28/88	9/28/88	EN	1.60	UGL	WA	1A
PPDDE	JJ8	9/22/86	11/29/88	UB	6.10	UGL	WA	1A
PPDDE	KK8	5/18/86	3/14/90	UB	0.054	UGL	WA	C1
PPDDE	MM8	8/20/86	1/21/87	ED	0.071	UGL	WA	C1
PPDDE	MM8A	3/20/87	4/7/88	ED	0.046	UGL	WA	C1
PPDDE	R1	1/30/78	1/30/78	RM	--	UGL	--	NC
PPDDE	RJ8	3/18/88	6/17/88	RL	2.60	UGL	WA	1A
PPDDE	S8	12/23/85	4/13/88	ES	0.053	UGL	WA	C1
PPDDE	T1	6/16/77	1/17/85	RM	--	UGL	--	NC
PPDDE	UM25	12/9/88	2/23/90	UB	14.00	UGL	WA	1A
PPDDT	4T	10/21/77	11/15/78	RM	--	UGL	--	NC
PPDDT	99	7/29/77	10/4/77	RM	--	UGL	--	NC
PPDDT	BB8	4/2/86	10/13/87	ES	10.00	UGL	WA	1A
PPDDT	EB8	9/28/88	9/28/88	EN	8.80	UGL	WA	1A
PPDDT	JJ8	9/22/86	11/29/88	UB	9.20	UGL	WA	1A
PPDDT	KK8	5/18/86	3/14/90	UB	0.049	UGL	WA	C1
PPDDT	MM8	8/27/86	1/21/87	ED	0.066	UGL	WA	C1
PPDDT	MM8A	3/20/87	4/7/88	ED	0.059	UGL	WA	C1
PPDDT	RJ8	3/18/88	6/17/88	RL	2.60	UGL	WA	1A
PPDDT	S8	12/23/85	4/3/88	ES	0.07	UGL	WA	C1
PPDDT	T1	7/28/77	1/17/85	RM	--	UGL	--	NC
PPDDT	UM25	12/9/88	2/23/90	UB	18.00	UGL	WA	1A
PRTHN	BB8	7/11/86	10/13/87	ES	14.00	UGL	WA	1A
PRTHN	EB8	9/28/88	9/28/88	EN	21.60	UGL	WA	1A
PRTHN	H8	6/4/86	9/25/87	CL	0.45	UGL	WA	C1
PRTHN	JJ8	9/22/86	11/29/88	UB	19.00	UGL	WA	1A
PRTHN	RJ8	3/18/88	6/17/88	RL	2.60	UGL	WA	1A
PRTHN	T1	5/21/75	10/13/76	SC	--	UGL	--	NC
PRTHN	UH11	10/26/88	3/8/90	UB	0.647	UGL	WA	C1

Note: Explanations of footnotes begin on Page 16 of this Attachment

Analyte[1]	Method[2]	First Use	Last Use	Lab[3]	CRL	Unit[4]	Media[5]	Certification[6]
PRTHN	UM25	12/9/88	2/23/90	UB	37.00	UGL	WA	1A
PRTHN	UN07	5/19/89	1/18/90	ES	0.25	UGL	WA	C1
SE*	1B	6/27/84	12/28/84	EE	--	UGL	--	NC
SE*	99	7/16/84	7/16/84	RM	--	UGL	--	NC
SE*	T1	7/16/84	7/16/84	RM	--	UGL	--	NC
SILVEX*	99	7/16/84	7/16/84	RM	--	UGL	--	NC
SILVEX*	T1	7/16/84	7/16/84	RM	--	UGL	--	NC
SO4*	4U	9/30/77	12/19/85	RM	--	UGL	--	NC
SO4*	99	4/7/76	7/3/85	RM	--	UGL	--	NC
SO4*	HH8	5/29/86	5/29/86	UB	5000.00	UGL	WA	C1
SO4*	HH8A	12/14/87	8/16/89	UB	251.00	UGL	WA	C1
SO4*	NN8	9/11/86	1/11/90	ED	5000.00	UGL	WA	C1
SO4*	R1	8/3/79	4/1/85	RM	--	UGL	--	NC
SO4*	T1	5/5/75	10/20/77	RM	--	UGL	--	NC
SO4*	TT06	9/19/89	9/19/89	ME	223.00	UGL	WA	C1
SO4*	TT09	10/23/89	3/9/90	UB	175.00	UGL	WA	C1
SO4*	X8	1/31/86	10/27/87	ES	10000.00	UGL	WA	C1
SUPONA	BB8	4/2/86	10/13/87	ES	6.50	UGL	WA	1A
SUPONA	H8	6/4/86	9/25/87	CL	0.68	UGL	WA	C1
SUPONA	JJ8	9/22/86	11/29/88	UB	9.30	UGL	WA	1A
SUPONA	RJ8	3/18/88	6/17/88	RL	3.90	UGL	WA	1A
SUPONA	UH11	10/26/88	3/8/90	UB	0.787	UGL	WA	C1
SUPONA	UM25	12/9/88	2/23/90	UB	19.00	UGL	WA	1A
TCLEA**	RM8A	2/24/88	5/13/88	RL	14.00	UGL	WA	1A
TCLEA**	UM21	11/7/88	3/12/90	UB	1.50	UGL	WA	1A
TCLEE	7D	12/21/84	11/4/85	ES	--	UGL	--	NC
TCLEE	99	5/17/79	6/26/84	RM	--	UGL	--	NC
TCLEE	J8	9/18/86	5/12/88	CL	1.30	UGL	WA	1A
TCLEE	M8	4/3/86	10/8/87	ES	1.00	UGL	WA	1A
TCLEE	N8	5/16/86	3/23/90	UB	0.75	UGL	WA	C1
TCLEE	RM8A	2/24/88	5/13/88	RL	9.40	UGL	WA	1A
TCLEE	T1	4/14/83	3/14/85	RM	--	UGL	--	NC
TCLEE	TT8	2/24/87	1/10/90	ED	2.76	UGL	WA	C1
TCLEE	UM21	11/7/88	3/12/90	UB	1.00	UGL	WA	1A
TCLEE	UU8	4/20/89	4/21/89	ED	2.90	UGL	WA	1A
TCLEE	Y8	10/9/85	4/8/88	ES	1.30	UGL	WA	C1
TDGCL	AZ8	5/9/88	8/14/89	UB	6.69	UGL	WA	C1
TDGCL	YY8	1/20/88	1/20/88	ES	65.90	UGL	WA	C1
TDS*	T1	5/5/76	5/17/76	CH	--	UGL	--	NC
TMP*	RJ8	5/18/88	6/17/88	RL	2.60	UGL	WA	1A
TOC*	00	5/9/79	9/20/89	RM	--	UGL	--	NC
TOC*	7X	7/9/82	2/19/85	RM	--	UGL	--	NC
TOC*	R1	7/31/79	5/20/81	RM	--	UGL	--	NC
TPO4*	T1	9/2/75	7/28/76	CH	--	UGL	--	NC
TRCLE	7D	12/21/84	11/4/85	ES	--	UGL	--	NC
TRCLE	99	5/17/79	6/26/84	RM	--	UGL	--	NC
TRCLE	J8	9/18/86	5/12/88	CL	1.40	UGL	WA	1A
TRCLE	M8	4/3/86	10/8/87	ES	1.00	UGL	WA	1A
TRCLE	N8	5/16/86	3/23/90	UB	0.56	UGL	WA	C1
TRCLE	RM8A	2/24/88	5/13/88	RL	5.20	UGL	WA	1A
TRCLE	T1	4/14/83	3/14/85	RM	--	UGL	--	NC
TRCLE	TT8	9/17/86	1/10/90	ED	1.31	UGL	WA	C1
TRCLE	UM21	11/7/88	3/12/90	UB	1.00	UGL	WA	1A

Note: Explanations of footnotes begin on Page 16 of this Attachment

Analyte[1]	Method[2]	First Use	Last Use	Lab[3]	CRL	Unit[4]	Media[5]	Certification[6]
TRCLE	UU8	4/20/89	4/21/89	ED	2.00	UGL	WA	1A
TRCLE	Y8	10/9/85	4/8/88	ES	1.10	UGL	WA	C1
TXPHEN*	99	7/16/84	7/16/84	RM	--	UGL	--	NC
TXPHEN*	T1	7/16/84	7/16/84	RM	--	UGL	--	NC
UDMH	FF8	5/14/86	5/16/86	UB	25.00	UGL	WA	C1
UDMH	ZZ8A	6/2/88	6/3/88	UB	23.00	UGL	WA	C1
WP*	2K	10/31/84	12/18/84	EE	--	UGL	--	NC
XYLEN	2J	12/18/84	12/18/84	EE	--	UGL	--	NC
XYLEN	7K	12/21/84	2/1/85	ES	--	UGL	--	NC
XYLEN	99	4/7/83	6/26/84	RM	--	UGL	--	NC
XYLEN	AV8	5/11/88	2/6/90	UB	1.36	UGL	WA	C1
XYLEN	C8	5/15/86	3/2/88	CL	3.20	UGL	WA	C1
XYLEN	J8	9/18/86	5/12/88	CL	1.40	UGL	WA	1A
XYLEN	M8	4/3/86	10/8/87	ES	2.00	UGL	WA	1A
XYLEN	RM8A	2/24/88	5/13/88	RL	19.00	UGL	WA	1A
XYLEN	SS8	9/24/86	1/10/90	ED	1.34	UGL	WA	C1
XYLEN	T1	4/14/83	10/3/84	RM	--	UGL	--	NC
XYLEN	UM21	11/7/88	3/12/90	UB	2.00	UGL	WA	1A
XYLEN	UU8	4/20/89	4/21/89	ED	2.40	UGL	WA	1A
XYLEN	W8	10/28/85	4/11/88	ES	2.47	UGL	WA	C1
ZN	1M	6/27/84	12/27/84	EE	--	UGL	--	NC
ZN	B8	3/18/86	4/15/88	ES	20.10	UGL	WA	C1
ZN	GG8	6/26/86	9/6/89	UB	22.00	UGL	WA	C1
ZN	R9D	7/6/89	1/11/90	ED	20.00	UGL	WA	C1
ZN	SS06	9/27/89	9/27/89	ME	5.35	UGL	WA	C1
ZN	SS12	10/3/89	3/21/90	UB	18.00	UGL	WA	C1

FOOTNOTES FOR TABLE RISR B.2-1

1 - Analyte Abbreviations:

ACET* - Acetone*
ACRYLO* - Acrylonitrile*
AG* - Silver*
ALDRN - Aldrin
ALHMW* - Alcohols (high molecular weight)*
ALK* - Alkalinity*
AS - Arsenic
ASTOT* - Arsenic, total*
ATZ - Atrazine
BA* - Barium*
BCHPD - Bicyclo [2,2,1] hepta-2,5-diene
BLDX* - Bladex*
BRDCLM* - Bromodichloromethane*
BTA** - Benzothiazole**
BTZ** - Benzothiazole**
B2EHP* - bis (2-Ethylhexyl) phthalate*
CA* - Calcium*
CALLMW* - Hydrocarbons (all molecular weights)
CCL3F* - Trichlorofluoromethane*
CCL4 - Carbon tetrachloride
CD - Cadmium
CHBR3* - Bromoform*
CHCL3 - Chloroform
CH2CL2 - Methylene chloride
CH3BR* - Bromomethane*
CH3CL* - Chloromethane*
CL* - Chloride*
CLC6H5* - Chlorobenzene*
CLDAN* - Chlordane*
CL2BZ* - Dichlorobenzenes*
CL3P - Trichlorophenols*
CL6CP - Hexachlorocyclopentadiene
COND* - Specific conductivity*
CPMS - 4-Chlorophenylmethyl sulfide
CPMSO - 4-Chlorophenylmethyl sulfoxide
CPMSO2 - 4-Chlorophenylmethyl sulfone
CR - Chromium
CRHEX* - Hexavalent chromium*
CU - Copper
CUTOT* - Copper, total*
CYHX* - Cyclohexane*
CYN* - Cyanide*
CYOCTE* - Cyclooctatetraene*
C1ADME* - Carbonic acid, dimethyl ester*
C16ABE* - Hexadecanoic acid, butyl ester*
C18ABE* - Octadecanoic acid, butyl ester*
C2H3CL* - Chloroethene / vinyl chloride*
C2H5CL* - Chloroethane*
C6H6 - Benzene

* - Tentatively identified compound
** - Former nontarget analyte

C9* - Nonane*
DBCP - Dibromochloropropane
DBRCLM* - Dibromochloromethane*
DCLB* - Dichlorobenzene*
DCPD - Dicyclopentadiene
DDVP - Vapona
DIACAL** - Diacetone alcohol / 4-Hydroxy-4-methyl-2-pentanone**
DIMP - Diisopropylmethyl phosphonate
DIOP* - Diisooctyl phthalate*
DITH - Dithiane
DLDRN - Dieldrin
DMDS* - Dimethyl disulfide*
DMMP - Dimethylmethyl phosphonate
DNBP* - di-n-Butyl phthalate*
DNOP* - di-n-Octyl phthalate*
DOAD* - Dioctyl adipate*
ENDRN - Endrin
ETC6H5 - Ethylbenzene
F* - Fluoride*
FARN* - Farnesol*
FE* - Iron*
HARD* - Total hardness*
HCBD** - Hexachlorobutadiene**
HCNB* - Hexachloronorbornadiene*
HCO3* - Bicarbonate*
HEXANE* - Hexane*
HG - Mercury
HGTOT* - Mercury, total*
HXMTSX* - Hexamethylcyclotrisiloxane*
HYDRZ - Hydrazine
IDRN - Isodrin
ISODR - Isodrin
K* - Potassium*
LIN* - Lindane/ gama-Benzenehexachloride/ gamma-Hexachlorocyclohexane*
MEC6H5 - Toluene
MEK* - Methylethyl ketone/2-Butanone*
MEXCLR* - Methoxychlor*
ME2HG* - Dimethyl mercury*
MG* - Magnesium*
MHYDRZ - Methylhydrazine
MIBK - Methylisobutyl ketone
MLTHN - Malathion
MN* - Manganese*
NA* - Sodium*
NC* - Nitrocellulose*
NIT* - Nitrite, Nitrate-non specific*
NNDMEA* - n-Nitroso dimethylamine*
NO3* - Nitrate*
OPDDE* - 2-(Ortho-Chlorophenyl)-2-(para-chlorophenyl)-1,1-dichloroethene*
OPDDT* - 2-(Ortho-Chlorophenyl)-2-(para-chlorophenyl)-1,1,1-trichloroethane*
OPO4* - Organophosphates*
OXAT - 1,4-Oxathiane
PB - Lead
PCP* - Pentachlorophenol*

* - Tentatively identified compound
** - Former nontarget analyte

PH* - pH*
PHENOL* - Phenol*
PHTHL* - Phthalates*
PPDDE - 2,2-bis (Para-chlorophenyl)-1,1-dichloroethene
PPDDT - 2,2-bis (Para-chlorophenyl)-1,1,1-trichloroethane
PRTHN - Parathion
SE* - Selenium*
SILVEX * - Silvex*
SO4* - Sulfate*
SUPONA - Supona/ 2-Chloro-1-(2,4-dichlorophenyl) vinyl diethyl phosphate
TCLEA** - 1,1,2,2-Tetrachloroethane**
TCLEE - Tetrachloroethylene/ tetrachloroethene
TDGCL - Thiodiglycol
TDS* - Total dissolved solids*
TMP* - Trimethyl phosphate*
TOC* - Total organic carbon*
TPO4* - Total phosphates*
TRCLE - Trichloroethylene/ trichloroethene
TXPHEN* - Toxaphene*
UDMH - Unsymmetrical dimethylhydrazine
WP* - White phosphorus*
XYLEN - o- and p-Xylenes
ZN - Zinc
11DCE - 1,1-Dichloroethylene/ 1,1-Dichloroethene
11DCLE - 1,1-Dichloroethane
111TCE - 1,1,1-Trichloroethane
112TCE - 1,1,2-Trichloroethane
12DCE - 1,1-Dichloroethylenes (cis and trans isomers)
12DCLE - 1,2-Dichloroethane
12DCLP* - 1,1-Dichloropropane*
13DCLB * - 1,3-Dichlorobenzene*
13DCP* - 1,3-Dichloropropane*
13DMB - 1,3-Dimethylbenzene/ m-Xylene
14DIOX - 1,4-Dioxane
2CLEVE* - 2-Chloroethylvinyl ether/ (2-chloroethoxy) ethene*
2CLP* - 2-Chlorophenol*
2MP* - 2-Methylphenol/ 2-cresol*
2MPAME* - 2-Methylpropanoic acid, Methyl ester*
2MTHF* - 2-Methyltetrahydrofuran*
2NP* - 2-Nitrophenol*
236TCP* - 2,3,6-Trichlorophenol*
24D* - 2,4-Dichlorophenoxyacetic acid*
24DCLP* - 2,4-Dichlorophenol*
24DMPN* - 2,4-Dimethylphenol*
24DNP* - 2,4-Dinitrophenol*
245TCP* - 2,4,5-Trichlorophenol*
246TCP* - 2,4,6-Trichlorphenol*
246TNT* - 2,4,6-Trinitrotoluene*
25HXCB* - 2,2',3,4,5,5'-Hexachlorobiphenyl*
4CL3C* - 4-Chloro-3-cresol/ 3-methyl-4-chlorophenol*
4MP* - 4-Methylphenol/ 4-cresol*
4NP* - 4-Nitrophenol*

* - Tentatively identified compound
** - Former nontarget analyte
2 - Number designates analytical method used by respective lab.

3 - Laboratories performing analyses:

AL	Arthur D. Little
CH	Colorado State Department of Health
CL	California Analytical Laboratories, Inc.
ED	Environmental Science & Engineering, Inc. (Denver, CO)
EE	Envirodyne Engineers, Inc.
EN	Environmental Testing and Certification Corp. (Edison, NJ)
ES	Environmental Science & Engineering, Inc. (Gainesville, FL)
ME	Metratrace, Inc. (St. Louis, MO)
MW	Midwest Research Institute
RL	Rocky Mountain Analytical Lab (Currently ENSECO-Denver, CO)
RM	Rocky Mountain Arsenal
SC	Shell Chemical, Rocky Mountain Arsenal
UB	Datachem, Inc.

4 - micrograms per liter

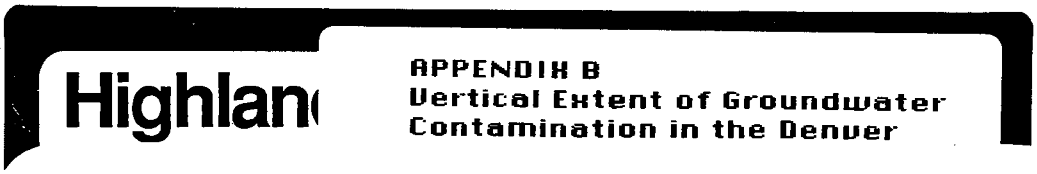
5 - WA = Water

6 - 1A = certification for GCMS method
1B = certification for low sample through put - not GCMS method
C1 = certification for quantitative method
NC = method not USATHAMA certified

APPENDIX B
Attachment 2 - Database Diskette
Remedial Investigation Summary Report

Attachment 2 contains the following dBASE files:

VEC.DBF	Unique Vertical Extent of Contamination Data
HITSABC.DBF	Excluded Detections
SUB-GP.DBF	Concentrations of the Five Analyte Groups
ALLDEN.DBF	Well Data for all Considered Wells



APPENDIX B
Vertical Extent of Groundwater
Contamination in the Denver

Highland™
diskettes

FINAL REMEDIAL INVESTIGATION (RI) SUMMARY REPORT APPENDIX B VERTICAL EXTENT OF GROUNDWATER CONTAMINATION IN THE DENVER AQUIFER VERSION 3.2 CONTRACT NUMBER DAAA15-88-D-0024

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