LONGHORN ARMY AMMUNITION PLANT

KARNACK, TEXAS

ADMINISTRATIVE RECORD

VOLUME 5 of 10

1995

Bate Stamp Numbers
012865 - 015323

Prepared for:

Department of the Army
Longhorn Army Ammunition Plant
Marshall, Texas 75671-1059

1995

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J. Title: Final Report - DERPMIS / RMIS Resolution Document for Longhorn Army Ammunition Plant
Group(s): All
Site(s): General
Location: Longhorn Army Ammunition Plant, Marshall, Texas
Agency: Department Of The Army, Longhorn Army Ammunition Plant
Author(s): U.S. Army Corps of Engineers, Tulsa District
Recipient: U.S. Army Corps of Engineers
Date: June, 1995
Bate Stamp: 012865 - 012934

K. Title: Final Report - Groundwater Background Concentration Report
Group(s): Landfill Caps Interim Action
Site(s): LHAAP-12 Active Landfill
LHAAP-16 Old Landfill
Location: Longhorn Army Ammunition Plant, Marshall, Texas
Agency: U.S. Army Corps of Engineers
Author(s): U.S. Army Corps of Engineers, Tulsa District
Recipient: U.S. Army, Longhorn Army Ammunition Plant
Date: June, 1995
Bate Stamp: 012935 - 013162

L. Title: Letter - Subject: Request for Approval of Final Disposition of CERCLA Investigative - Derived Solid Material at the Old Landfill, Site 16
Group(s): Landfill Caps Interim Action
Site(s): LHAAP-16 Old Landfill
Location: Longhorn Army Ammunition Plant, Marshall, Texas
Agency: Department Of The Army, Longhorn Army Ammunition Plant
Author(s): Mr. Lawrence J. Sowa, Lieutenant Colonel, U.S. Army
Recipient: Mr. Michael A. Moore, RI / FS II Unit, Superfund Investigation Section
Date: June 6, 1995
Bate Stamp: 013163

M. Title: Letter - Subject: Management of Investigation Derived Waste
Group(s): Landfill Caps Interim Action
Site(s): LHAAP-16 Old Landfill
Location: Longhorn Army Ammunition Plant, Marshall, Texas
Agency: Department Of The Army, Longhorn Army Ammunition Plant
Author(s): Mr. Michael A. Moore, RI / FS II Unit, Superfund Investigation Section
Recipient: Mr. David Tolbert, Project Manager, Longhorn Army Ammunition Plant
Date: June 7, 1995
Bate Stamp: 013164

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N. **Title:** Letter - Subject: Volume I Final Hydrogeological Assessment Report for LHAAP
Group(s): All - Hydrogeological Assessment, Soil and Groundwater Background Studies
Site(s): General
Location: Longhorn Army Ammunition Plant, Marshall, Texas
Agency: Department Of The Army, Longhorn Army Ammunition Plant
Author(s): Mr. Lawrence J. Sowa, Lieutenant Colonel, U.S. Army
Recipient: Lisa Price, Remedial Project Manager, Superfund Texas Enforcement
Date: June 13, 1995
Bate Stamp: 013165

O. **Title:** Letter - Subject: Volume I Final Hydrogeological Assessment Report for LHAAP
Group(s): All - Hydrogeological Assessment, Soil and Groundwater Background Studies
Site(s): General
Location: Longhorn Army Ammunition Plant, Marshall, Texas
Agency: Department Of The Army, Longhorn Army Ammunition Plant
Author(s): Mr. Lawrence J. Sowa, Lieutenant Colonel, U.S. Army
Recipient: Mr. Michael A. Moore, RI / FS II Unit, Superfund Investigation Section
Date: June 13, 1995
Bate Stamp: 013166

P. **Title:** Letter - DERPMIS / RMIS Resolution Document for Longhorn Army Ammunition Plant
Group(s): All
Site(s): General
Location: Longhorn Army Ammunition Plant, Marshall, Texas
Agency: Department Of The Army, Longhorn Army Ammunition Plant
Author(s): Mr. Lawrence J. Sowa, Lieutenant Colonel, U.S. Army
Recipient: Lisa Price, Remedial Project Manager, Superfund Texas Enforcement
Date: June 13, 1995
Bate Stamp: 013167

Q. **Title:** Letter - DERPMIS / RMIS Resolution Document for Longhorn Army Ammunition Plant
Group(s): All
Site(s): General
Location: Longhorn Army Ammunition Plant, Marshall, Texas
Agency: Department Of The Army, Longhorn Army Ammunition Plant
Author(s): Mr. Lawrence J. Sowa, Lieutenant Colonel, U.S. Army
Recipient: Mr. Michael A. Moore, RI / FS II Unit, Superfund Investigation Section
Date: June 13, 1995
Bate Stamp: 013168

R. **Title:** Letter - Subject: Schedules for Longhorn Army Ammunition Plant
Group(s): All
Site(s): General
Location: Longhorn Army Ammunition Plant, Marshall, Texas

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Agency: Department Of The Army, Longhorn Army Ammunition Plant
Author(s): Mr. Lawrence J. Sowa, Lieutenant Colonel, U.S. Army
Recipient: Lisa Price, Remedial Project Manager, Superfund Texas Enforcement
Date: June 15, 1995
Bate Stamp: 013169

S. **Title:** Letter - Subject: Schedules for Longhorn Army Ammunition Plant
Group(s): All
Site(s): General
Location: Longhorn Army Ammunition Plant, Marshall, Texas
Agency: Department Of The Army, Longhorn Army Ammunition Plant
Author(s): Mr. Lawrence J. Sowa, Lieutenant Colonel, U.S. Army
Recipient: Mr. Michael A. Moore, RI / FS II Unit, Superfund Investigation Section
Date: June 15, 1995
Bate Stamp: 013170

T. **Title:** Letter - Subject: Schedules for Longhorn Army Ammunition Plant
Group(s): All
Site(s): General
Location: Longhorn Army Ammunition Plant, Marshall, Texas
Agency: Department Of The Army, Longhorn Army Ammunition Plant
Author(s): Mr. Lawrence J. Sowa, Lieutenant Colonel, U.S. Army
Recipient: Mr. H. L. Jones, Texas Natural Resource Conservation Commission
Date: June 15, 1995
Bate Stamp: 013171

U. **Title:** Memorandum - Subject: Review of the Draft Record of Decision for Early Interim Remedial Action at Landfill Sites 12 and 16
Group(s): Landfill Caps Interim Action
Site(s): LHAAP-12 Active Landfill
LHAAP-16 Old Landfill
Location: Longhorn Army Ammunition Plant, Marshall, Texas
Agency: Department Of The Army, Longhorn Army Ammunition Plant
Author(s): Arthur P. Lee, P.E. Program Manager, Health, Risk Assessment and Risk Communication
Recipient: Commander, U.S. Army Corps of Engineers, Tulsa District, Attention: Jonna Polk
Date: June 21, 1995
Bate Stamp: 013172

V. **Title:** Memorandum - Subject: Review of Schedules for Longhorn Army Ammunition Plant
Group(s): All
Site(s): General
Location: Longhorn Army Ammunition Plant, Marshall, Texas
Agency: Department Of The Army, Longhorn Army Ammunition Plant

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Author(s): Arthur P. Lee, P.E. Program Manager, Health Risk Assessment and Risk Communication
Recipient: Jonna Polk, U.S. Army Corps of Engineers, Tulsa District
Date: June 22, 1995
Bate Stamp: 013173

W. **Title:** Letter- Subject: Approval of Schedules for Longhorn Army Ammunition Plant
Group(s): All
Site(s): General
Location: Longhorn Army Ammunition Plant, Marshall, Texas
Agency: Department Of The Army, Longhorn Army Ammunition Plant
Recipient: Lisa Price, Remedial Project Manager, Superfund Texas Enforcement
Author(s): Darrell W. Chinn, Captain, U.S. Army Executive Officer
Date: June 29, 1995
Bate Stamp: 013174

X. **Title:** Letter- Subject: Approval of Schedules for Longhorn Army Ammunition Plant
Group(s): All
Site(s): General
Location: Longhorn Army Ammunition Plant, Marshall, Texas
Agency: Department Of The Army, Longhorn Army Ammunition Plant
Recipient: Mr. David Tolbert, Project Manager, Longhorn Army Ammunition Plant
Author(s): Michael A. Moore, RI / FS II Unit, Superfund Investigation Section
Date: June 28, 1995
Bate Stamp: 015321

Note: Bate Stamp numbers are out of sequence due to receiving documents after the July update

Y. **Title:** Letter - Subject: Draft Work Plan For Phase III of Interim Remedial Action at Burning Ground No. 3 and UEP, LHAAP 18 & 24 for Longhorn Army Ammunition Plant - Transmittal of Full-Size Drawings
Group(s): Early Interim Action At Burning Ground No. 3
Site(s): LHAAP-18 & LHAAP-24 Burning Ground / Washout Pond & Unlined Evaporation Pond
Location: Longhorn Army Ammunition Plant, Karnack, Texas
Recipient: Lisa Price, Remedial Project Manager, Superfund Texas Enforcement
Agency: U. S. Army Corps Of Engineer
Author(s): Darrell W. Chinn, Captain, U.S. Army
Date: June 29, 1995
Bate Stamp: 015322

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Z. **Title:** Letter - Subject: **Draft Work Plan For Phase III of Interim Remedial Action at Burning Ground No. 3 and UEP, LHAAP 18 & 24 for Longhorn Army Ammunition Plant - Transmittal of Full-Size Drawings**
Group(s): Early Interim Action At Burning Ground No. 3
Site(s): LHAAP-18 & LHAAP-24 Burning Ground / Washout Pond & Unlined Evaporation Pond
Location: Longhorn Army Ammunition Plant, Karnack, Texas
Recipient: Michael A. Moore, RI / FS II Unit, Superfund Investigation Section
Agency: U. S. Army Corps Of Engineer
Author(s): Darrell W. Chinn, Captain, U.S. Army
Date: June 29, 1995
Bate Stamp: 015323

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A. Title: **Letter - Subject: Draft Work Plan For Phase III of Interim Remedial Action at Burning Ground No. 3 and UEP, LHAAP 18 & 24 for Longhorn Army Ammunition Plant - Transmittal of Full-Size Drawings**
Group(s): **Early Interim Action At Burning Ground No. 3**
Site(s): **LHAAP-18 & LHAAP-24 Burning Ground / Washout Pond & Unlined Evaporation Pond**
Location: **Longhorn Army Ammunition Plant, Karnack, Texas**
Recipient: **Mr. H. L. Jones, Texas Natural Resource Conservation Commission**
Agency: **U. S. Army Corps Of Engineer**
Author(s): **Darrell W. Chinn, Captain, U.S. Army**
Date: **June 29, 1995**
Bate Stamp: **015324**

B. Title: **Letter - Subject: Final Record of Decision for Early Interim Remedial Action at Landfill Sites 12 and 16**
Group(s): **Landfill Caps Interim Action**
Site(s): **LHAAP-12 Active Landfill**
LHAAP-16 Old Landfill
Location: **Longhorn Army Ammunition Plant, Marshall, Texas**
Agency: **Department Of The Army, Longhorn Army Ammunition Plant**
Author(s): **Darrell W. Chinn, Captain, U.S. Army**
Recipient: **Lisa Marie Price, Remedial Project Manager, Superfund Texas Enforcement**
Date: **July 10, 1995**
Bate Stamp: **015325**

C. Title: **Letter - Subject: Final Record of Decision for Early Interim Remedial Action at Landfill Sites 12 and 16**
Group(s): **Landfill Caps Interim Action**
Site(s): **LHAAP-12 Active Landfill**
LHAAP-16 Old Landfill
Location: **Longhorn Army Ammunition Plant, Marshall, Texas**
Agency: **Department Of The Army, Longhorn Army Ammunition Plant**
Author(s): **Darrell W. Chinn, Captain, U.S. Army**
Recipient: **Michael A. Moore, RI / FS II Unit, Superfund Investigation Section**
Date: **July 10, 1995**
Bate Stamp: **015326**

D. Title: **Letter - Subject: Final Record of Decision for Early Interim Remedial Action at Landfill Sites 12 and 16**
Group(s): **Landfill Caps Interim Action**
Site(s): **LHAAP-12 Active Landfill**
LHAAP-16 Old Landfill
Location: **Longhorn Army Ammunition Plant, Marshall, Texas**

012865

LONGHORN ARMY AMMUNITION PLANT

Marshall, Texas 75671-1059

FINAL

DERPMIS/RMIS RESOLUTION DOCUMENT

PREPARED BY:

U.S. ARMY CORPS OF ENGINEERS

TULSA DISTRICT

JUNE 1995

US Army Corps
of Engineers

Tulsa District

012866

LONGHORN ARMY AMMUNITION PLANT

Marshall, Texas 75671-1059

FINAL
DERPMIS/RMIS
RESOLUTION
DOCUMENT

PREPARED BY:

U.S. ARMY CORPS OF ENGINEERS
TULSA DISTRICT

JUNE 1995

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PREFACE

The Restoration Management Information System (RMIS) is the modified version of the Defense Environmental Restoration Program Management Information System (DERPMIS). RMIS captures the site information for operating military installations and properties under the control of the Department of Defense (DOD) components. The RMIS information is used by the DOD to provide status of the Defense Environmental Restoration Program (DERP) in the Annual Report to Congress. The Army uses the RMIS to report to DOD on sites that are addressed int he Installation Action Plan (IAP), except the cost estimating section has been removed, since it contains procurement-sensitive information. The IAP is the Army's program planning tool for all sites in the DERP.

The DERPMIS/RMIS Resolution Document has been prepared to provide the regulatory community information on active and potential hazardous, toxic, and radioactive waste (HTRW) sites at Longhorn Army Ammunition Plant (LHAAP). When DERPMIS was initially developed primarily using the "Installation Assessment of Longhorn Army Ammunition Plant Report No. 150, February 1980". A copy of this document is included in the LHAAP's Administrative Record.

The RMIS list had not been thoroughly reviewed for accuracy until recently. The RMIS has been updated to remove duplicate sites, sites contained within other sites, sites that are not a part of the restoration program, and sites that never existed. The numbering system in the RMIS has also been changed to reflect those assigned by the Texas Natural Resource Conservation Commission (TNRCC) during the Resource Conservation and Recovery Act Facility Assessment (RFA) in April 1988. The numbering change prohibits one identifier from representing two different sites. The data sheets from the RFA are also located in the Administrative Record.

ABBREVIATIONS AND ACRONYMS

CERCLA	Comprehensive Environmental, Response, Compensation and Liability Act
DERA	Defense Environmental Restoration Account
DERP	Defense Environmental Restoration Program
DERPMIS	Defense Environmental Restoration Program/ Management Information System
DRMS	Defense Reutilization and Marketing Service
EPA	Environmental Protection Agency
FFA	Federal Facility Agreement
FS	Feasibility Study
FY	Fiscal Year
GOCO	Government Owned, Contractor Operated
IAG	Interagency Agreement
IAP	Installation Action Plan
INF	Intermediate-Range Nuclear Force
IRA	Interim Remedial Action
IRP	Installation Restoration Program
LAP	Load, Assemble, and Pack
LTM	Long-Term Monitoring
LHAAP	Longhorn Army Ammunition Plant
NPL	National Priority List
OB/OD	Open Burn/Open Detonation
PA	Preliminary Assessment
PCB	Polychlorinated Biphenyls
PVC	Polyvinyl Chloride
Qtr.	Quarter
RA	Remedial Action
RC	Response Complete
RCRA	Resource Conservation and Recovery Act
RD	Remedial Design
RFA	RCRA Facility Agreement
RI	Remedial Investigation
RMIS	Restoration Management Information System
SI	Site Investigation
SWMU	Solid Waste Management Unit
TNRCC	Texas Natural Resource Conservation Commission
TNT	Trinitrotoluene
TWC	Texas Water Commission
UEP	Unlined Evaporation Pond
U.S.	United States
UST	Underground Storage Tank

RESTORATION MANAGEMENT INFORMATION SYSTEM SUMMARY FOR LONGHORN ARMY AMMUNITION PLANT

I. INSTALLATION INFORMATION

A. LOCALE

Longhorn Army Ammunition Plant (LHAAP) is located in central east Texas in the northeast corner of Harrison County, approximately 14 miles northeast of Marshall, Texas, and approximately 40 miles west of Shreveport, Louisiana. The installation occupies 8,493 acres between State Highway 43 and the western shore of Caddo Lake. Approximately 1,700 to 2,000 personnel are employed at LHAAP. The area surrounding LHAAP is primarily rural and consists of forest lands; the small town of Karnack, Texas; Caddo Lake; and Caddo Lake State Park.

B. COMMAND ORGANIZATION

- Major Command: U.S. Army Material Command, Environmental Quality Division
- Subcommand: U.S. Army Armament, Munitions, and Chemical Command, Environmental Quality Directorate
- Installation: LHAAP, Environmental Office

C. INSTALLATION RESTORATION PROGRAM (IRP) EXECUTING AGENCY

- Investigation Phase Executing Agency: U.S. Army Corps of Engineers, Tulsa District
- Remedial Design/Action Phase Executing Agency: U.S. Army Corps of Engineers, Tulsa District and Fort Worth District

D. REGULATOR PARTICIPATION

- Federal: U.S. Environmental Protection Agency, Region VI
- State: Texas Natural Resource Conservation Commission

E. REGULATORY STATUS

- National Priorities List Installation with Interagency Agreement (IAG)
- Technical Review Committee, March 1992
- Interagency Agreement, December 1991
- Federal Facility Agreement, 1991

II. INSTALLATION DESCRIPTION

A. CURRENT ACTIVITY

LHAAP is an active government-owned, contractor operated (GOCO) U.S. Army Armament, Munitions, and Chemical Command Facility. The primary mission of LHAAP is to load, assemble, and pack (LAP) pyrotechnic and illuminating/signal ammunition and solid propellant rocket motors. The Longhorn Division of Thiokol Corporation is the current operating contractor. Thiokol signed a Facilities Contract with the U.S. Army to operate LHAAP beginning 1 October 1993.

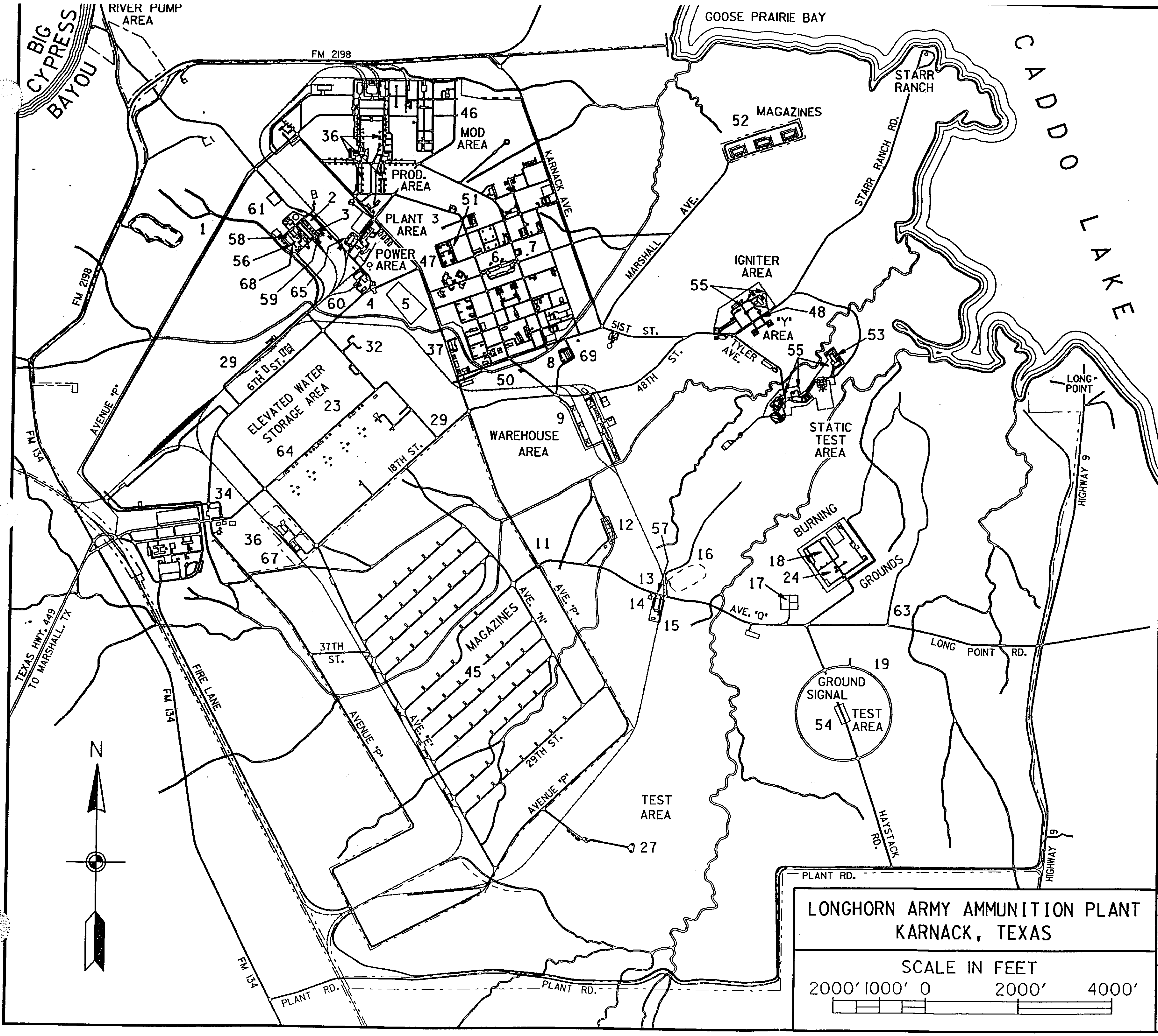
B. HISTORIC ACTIVITY

LHAAP was established in October 1942 with the primary mission of producing 2,4,6-trinitrotoluene (2,4,6-TNT) flake. Monsanto Chemical Company was the first contract operator of the plant. Production of 2,4,6-TNT continued through World War II until August 1945 when the plant went on standby status until February 1952. From 1952 until 1956, Universal Match Corporation was the contracting operator, producing such pyrotechnic ammunition as photoflash bombs, simulators, hand signals, and tracers for 40 mm. Thiokol assumed this responsibility with the departure of Universal Match Corporation in 1956. Production of rocket motors continued to be the primary mission of LHAAP until 1965 when the production of pyrotechnic and illuminating ammunition was re-established.

Current operations consist of compounding pyrotechnic and propellant mixtures, LAP activities, accommodating receipt and shipment of containerized cargo, and maintenance and/or layaway of standby facilities and equipment as they apply to mobilization planning. The installation has also been responsible for static firing and elimination of Pershing I and II rocket motors in compliance with the Intermediate-Range Nuclear Force (INF) Treaty in effect between the United States and the former USSR.

C. REGULATORY STATUS

LHAAP was placed on the National Priorities List (NPL) on August 30, 1990, as a result of a contaminant release to the environment at the installation. After being listed on the NPL, the LHAAP, the U.S. Environmental Protection Agency (EPA), and the Texas Water Commission (TWC) (now called the Texas Natural Resource Conservation Commission [TNRCC]) entered into a Comprehensive Environmental, Response, Compensation and Liability Act (CERCLA) Section 120 Agreement for remedial activities at LHAAP. The CERCLA Section 120 Agreement, referred to as the Federal Facility Agreement (FFA), became effective December 30, 1991. The FFA specifies that remedial activities be conducted at 13 areas on LHAAP.



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RMIS	LHAAP #
1	Inert Burning Ground.
2	Vacuum Truck Overnight Parking Lot.
3	Building 722 - Paint Shop.
4	Pilot Waste Water Treatment Plant.
5	Power House Boiler Pond.
6	Building 54F Solvent.
7	Building 50G Drum Processing.
8	Sewage Treatment Plant.
9	Building 31W Drum Storage.
11	Suspected TNT Burial Site at P&Q Ave.
12	Active Landfill.
13	Suspected TNT Burial Between Active and Old Landfill.
14	Area 54W Burial Site.
15	Area 49W Drum Storage.
16	Old Landfill.
17	No. 2 Flashing Area Burning Ground.
18	a) Burning Ground #3, b) 24X Holding Area, c) Air Curtain Destructor, d) Building 41X, e) Building 43X, f) 25X Washout Pad, g) Open Burning Cage, h) Open Burning Pan.
19	Construction Materials Landfill.
23	Building 707 - Storage Area PCB's.
24	Former Unlined Evaporation Pond.
27	South Test Area / Bomb Test Area.
29	a) Former TNT Production Area, b) TNT Red Water Pipeline, c) Former Acid Plant.
32	Former TNT Waste Disposal Plant.
34	Building 701 - PCP Storage.
35	Various Sumps (Located Throughout Facility).
36	Explosive Waste Pads.
37	Quality Assurance Laboratory Building 29A.
45	Magazine Area (Other-Than Plant 1).
46	Plant 2 / Pyrotechnic Operation.
47	Plant 3 / Produces Hand Signal Assemblies.
48	Y Area / Produces Hand Signal Assemblies.
50	Former Waste Disposal Facility.
51	Photographic Laboratory Building 60B.
52	Magazine Area (Plant 1).
53	Static Test Area.
54	Ground Signal Test Area.
55	Septic Tank.
56	Vehicle Wash Rack & Oil/Water Seperator.
57	Rubble Burial Site.
58	Maintenance Complex.
59	Storage Building 725.
60	Former Storage Building 411 and 714.
61	Water Treatment Plant.
63	Burial Pits.
64	Transformer Storage.
65	Building 209.
66	Transformers (Located Throughout Facility).
67	Above Ground Storage Tank.
68	Mobile Storage Tank.
69	Underground Storage Tank.

U.S. ARMY CORPS OF ENGINEERS
TULSA DISTRICT

LHRCN7-1.DGN - 06FEB1995 RBP

In addition to the site listing of the FFA, an Installation Assessment by the Army in February 1980, and the RFA in April 1988 identified additional potential sites of concern. The DERPMIS identified 59 sites in the 1992 list. The RMIS has been updated to remove duplicate sites, sites contained within other sites, sites that are not a part of the restoration program, and sites that never existed. As a result, 9 sites were identified as sites that were contained within other sites. The RMIS has identified 50 sites. Below is a DERPMIS/RMIS cross reference table.

TABLE 1 DERPMIS/RMIS CROSS REFERENCE TABLE

SITE DESCRIPTION	DERPMIS LHAAP#	RMIS LHAAP#	STATUS
Inert Burning Ground	001	1*	RI/FS
Vacuum Truck Overnight Parking Lot	002	2	NFA
Building 722 - Paint Shop	003	3	NFA
Pilot Waste Water Treatment Plant	004	4	NFA
Power House Boiler Pond	005	5	NFA
Building 54F Solvent	006	6	NFA
Building 50G Drum Processing	007	7	NFA
Sewage Treatment Plant	008	8	NFA
Building 31-W Drum Storage	009	9	NFA
Suspected TNT Burial Site at P&Q Avenue	010	11*	RI/FS
Active Landfill	011	12*	RI/FS
Suspected TNT Burial Between Active and Old Landfill	012	13*	RI/FS
Area 54W Burial Site	013	14*	RI/FS
Area 49W Drum Storage	014	15	NFA
Old Landfill	015	16*	RI/FS
No. 2 Flashing Area Burning Ground	016	17*	RI/FS
Burning Ground/Rocket Motor Washout Pond	017	18*	RI/FS
Construction Materials Landfill	018	19	NFA
South Test Area/Bomb Test Area	019	27*	RI/FS
Former TNT Production Area	021	29*	RI/FS

TNT Red Water Pipeline	022	29	RI/FS
Building 707 Storage Area PCBs	023	23	NFA
Former TNT Waste Disposal Plant	024	32*	RI/FS
Building 701 PCB Storage	034	34	NFA
Sumps Various	035	35	RI/FS
Explosive Waste Pads	036	36	NFA
Quality Assurance Laboratory Building 29-A	037	37	NFA
24X Holding Area	038	18	IRA
25X Washout Pad	039	18	IRA
Air Curtain Destructor	040	18	IRA
Open Burning Cage	041	18	IRA
Open Burning Pan	041	18	IRA
Former Unlined Evaporation Pond	043	24*	IRA
Building 41-X	044	18	IRA
Magazine Area	045	45	NFA
Plant 2/Pyrotechnic Operation	046	46	NFA
Plant 3/Produces Hand Signal Assemblies	047	47	NFA
Y Area/Produces Hand Signal Assemblies	048	48	NFA
Former Acid Plant	049	29	RI/FS
Former Waste Disposal Facility	050	50	SI
Photographic Laboratory Building 60B	051	51	NFA
Magazine Area	052	52	SI
Static Test Area	053	53	NFA
Ground Signal Test Area	054	54*	RI/FS
Septic Tank	055	55	NFA
Vehicle Wash Rack & Oil/Water Separator	056	56	RI/FS
Rubble Burial Site	057	57	NFA
Maintenance Complex	058	58	NFA

Storage Building #725	059	59	RI/FS
Former Storage Building $411 and #714	060	60	SI
Water Treatment Plant	061	61	NFA
Building #43X	062	18	IRA
Burial Pits	063	63	SI
Transformer Storage	064	64	NFA
Building #209	065	65	RI/FS
Transformers	066	66	NFA
Above Ground Storage Tank	067	67	NFA
Mobile Storage Tank	068	68	NFA
Underground Storage Tank	069	69	NFA

(*) FFA Sites.

III. CONTAMINATION ASSESSMENT

A. ASSESSMENT OVERVIEW

In February 1980, the U.S. Army Environmental Center (AEC), formerly the U.S. Army Toxic and Hazardous Materials Agency, conducted an on-site installation assessment to determine the presence of any toxic or hazardous materials and to assess the potential for off-post migration. The assessment identified major areas of potential contamination as burial sites, testing areas, the TNT production area, the LAP areas, and the burning grounds. The major contaminants suspected included pyrotechnic ingredients, TNT scrap, red water, and explosive contamination scrap. The assessment identified the most likely route of any potential off-post migration as groundwater flow and surface runoff into the bayou which feed Caddo Lake.

Numerous studies followed this preliminary assessment to investigate waste management, groundwater and soil contamination. The most extensive studies were conducted at the burning ground and landfill areas. Attachment I provides a list of all studies conducted to date at LHAAP. The reports generally concluded that the groundwater is the major media of concern.

Groundwater at LHAAP generally occurs under unconfined conditions in alluvial or Wilcox materials and can be encountered within one foot to 20-30 feet or more below the ground surface. Perched and locally confined conditions frequently occur within the Wilcox due to its highly variable stratigraphy, with frequent clay lenses. Recharge is primarily by precipitation infiltration from the surface and can effect the groundwater elevation as much as two feet in a six-month period. The contamination exists in the groundwater. The main contaminates of concern are methylene chloride, trichloroethylene (TCE), explosives, and metals.

LHAAP is currently under Remedial Investigation/Feasibility Study (RI/FS) phases on 13 sites listed in the FFA and the installation-wide sumps. The current investigations have been divided into five groups. The sites are identified by group number under the individual site descriptions in Section III B of this report. **Group 1** includes sites that have historically showed little contamination or little potential for contamination. **Group 2** sites are considered to be more contaminated than the Group 1 sites. **Group 3** sites include two sites where no contamination has been found and will proceed to a no action record of decision. **Group 4** sites are the installation-wide sumps. The **Group 5** sites have been identified as potential sites of concern in a recent re-evaluation of previous reports and will undergo a site investigation in FY 95.

Early Interim Remedial Action (IRA) have been initiated to extract contaminated groundwater underneath Burning Ground No. 3 and the former Unlined Evaporation Pond and to construct landfill caps at the former cells of the Active Landfill and the Old Landfill. High concentrations of TCE and methylene chloride were detected in the shallow groundwater underneath these sites.

B. SITE DESCRIPTIONS

LHAAP currently has 50 sites in the RMIS. A summary of all 50 sites listed in the RMIS is given below and provided in the site summary chart.

LHAAP-1 INERT BURNING GROUNDS

This site is used for the burning of trash, ashes, scrap lumber, and waste from burned TNT. Universal Match Corporation used this site during the 1950's for burning photoflash powder and other discarded materials. In 1982, investigations at this site included completion and sampling of one groundwater well and three surface soil samples. Contamination by metals, chloride, sulfate, and two explosive compounds was detected. Very low-level explosive contamination was detected here in a downgradient well in 1988. This site is included in the FFA.

Contaminant of concern: Explosive chemicals/inert materials
Media of concern: Soil/Groundwater
Completed IRP Phase: Preliminary Assessment Site Investigation (PA/SI)
Current IRP Phase: RI/FS -- Group #1
Future IRP Phase: Remedial Design/Remedial Action (RD/RA)

LHAAP-2 VACUUM TRUCK OVERNIGHT PARKING LOT

This site is a vacuum truck overnight parking lot. Tanker trucks containing industrial wastewater are sometimes left at this location overnight. This parking lot is located next to Building 704D. Although this site was identified as a Solid Waste Management Unit (SWMU) in the RFA, the TNRCC determined that there were no additional investigations required at this site. Based on this determination and historical information, the Army has placed this site into a No Further Action category.

Contaminant of concern: Unknown (industrial wastewaters)
Media of concern: Surface Water/Groundwater
Completed IRP Phase: PA
Current IRP Phase: No Further Action (NFA)
Future IRP Phase: NFA

LHAAP-3 BUILDING 722 - PAINT SHOP

This site is used for collection of waste produce from the paint shop. Wastes may include paint thinner, paints, and kerosene. The site consists of one 55-gallon drum set on a gravel pad in an open-sided shed, with a galvanized metal roof. Waste is put into a 55-gallon drum until the drum is full. The drum is then taken to Building 31-W. This site has been active since the early 1970's and is active today. Although this site was identified as an SWMU in the RFA, the TNRCC determined that there were no additional investigations required at this site. Based on this determination and historical information, the Army has placed this site into a No Further Action category.

Contaminant of concern: Paint and solvents
Media of concern: Soil/Groundwater/Surface Water
Completed IRP Phase: PA
Current IRP Phase: NFA
Future IRP Phase: NFA

LHAAP-4 PILOT WASTEWATER TREATMENT PLANT

This plant receives all the wastewater from all sumps on the installation. After settlement, the wastewater is transferred to one of two storage tanks and then pumped through a heat exchanger to an evaporation tower. Solids are shipped off site, and sludges from the settling tank are blown down and drummed on a weekly basis and burned at Burning Ground No. 3. Although this site was identified as an SWMU in the RFA, the TNRCC determined that there were no additional investigations required at this site. Based on this determination and historical information, the Army has placed this site into a No Further Action category.

Contaminant of concern: Ordnance Comp./Industrial Wastewater
Media of concern: Groundwater/Surface Water/Air
Completed IRP Phase: PA
Current IRP Phase: NFA
Future IRP Phase: NFA

LHAAP-5 POWER HOUSE BOILER POND

This site has been in operation since 1978. It consists of a 4-foot-deep earthen lagoon lined with a polyvinyl chloride (PVC) liner. The lagoon receives approximately 3,000 gallons per day of backwash water from zeolite treatment units at the Building 401 Powerhouse. Water is either evaporated from the lagoon or discharged to the sewage treatment plant. Although this site was identified as an SWMU in the RFA, the TNRCC determined that there were no additional investigations required at this site. Based on this determination and historical information, the Army has placed this site into a No Further Action category.

Contaminant of concern: Unknown (backwash from zeolite treatment)
Media of concern: Groundwater/Surface Water
Completed IRP Phase: PA
Current IRP Phase: NFA
Future IRP Phase: NFA

LHAAP-6 BUILDING 54F

This site serves as a collection point for waste solvents from production processes. The site consists of a single 55-gallon drum stored in a three-sided shed, approximately 8 by 10 feet in size, with fiberglass siding and a roof of galvanized metal and fiberglass. The shed is set on a curbless concrete pad. Full drums are taken to Building 31-W. This site has been in operation since mid-1985 and is currently active. Although this site was identified as an SWMU in the RFA, the TNRCC determined that there were no additional investigations required at this site. Based on this determination and historical information, the Army has placed this site into a No Further Action category.

Contaminant of concern: Acid
Media of concern: Soil/Groundwater
Completed IRP Phase: PA
Current IRP Phase: NFA
Future IRP Phase: NFA

LHAAP-7 BUILDING 50G - DRUM PROCESSING

This site is a washdown area for empty drums used in production. The site consists of a wooden frame building 30 by 100 feet in size, set on concrete and having transite walls.

Main washdown takes place in a separate bay, 20 by 30 feet in size. All washdown water drains to a 3,000-gallon sump outside Sump No. 70. Empty drums are either reused or flashed at the Air Curtain Destructor and sent to Building 49-W for disposal as scrap. Although this site was identified as an SWMU in the RFA, the TNRCC determined that there were no additional investigations required at this site. Based on this determination and historical information, the Army has placed this site into a No Further Action category.

Contaminant of concern: Petroleum/Oil Lubricants
Media of concern: Soil/Groundwater
Completed IRP Phase: PA
Current IRP Phase: NFA
Future IRP Phase: NFA

LHAAP-8 SEWAGE TREATMENT PLANT

This site is a sewage treatment plant consisting of an Imhoff tank, a sand filter, and three sludge beds. Sludge is dried on sand beds then shipped to the active landfill. This site has been active from 1942 to the present. Although this site was identified as an SWMU in the RFA, the TNRCC determined that there were no additional investigations required at this site. Based on this determination and historical information, the Army has placed this site into a No Further Action category.

Contaminant of concern: Residues from production material
Media of concern: Groundwater/Soil/Air
Completed IRP Phase: PA
Current IRP Phase: NFA
Future IRP Phase: NFA

LHAAP-9 BUILDING 31-W - DRUM STORAGE

Building 31-W is a storage area for containers of liquid hazardous waste. The building consists of two adjoining areas. The original area is a 100 by 50 foot structure with transite siding. The building has been in existence since at least the 1950's. The newer area consists of a structure approximately 80 by 50 feet in size, enclosed with galvanized metal siding that was completed in April 1987. Within the older area are three concrete troughs, 6 feet by 31 feet with 6-inch curbs, that were used for polychlorinated biphenyls (PCB) storage. No PCB is presently being stored there, but the area is used for various chemicals held in the lab pack for disposal. The newer area consists of eight concrete pads enclosed by 6-inch concrete curbs, 20 feet 1 inch by 25 feet 10 inches in size. Drums on pallets are stored on the pads. This site was used for liquid waste storage during the early 1950's and has been used for hazardous waste storage since 1984. Although this sie was identified as an SWMU in the RFA, the TNRCC determined that there were no additional investigations required at this site. Based on this determination and historical information, the Army has placed this site into a No Further Action category.

Contaminant of concern: Petroleum/Oil/Lubricants and Unknown
Media of concern: Soil/Groundwater
Completed IRP Phase: PA
Current IRP Phase: NFA
Future IRP Phase: NFA

LHAAP-11 SUSPECTED TNT BURIAL SITE AT AVENUES P AND Q

Burial of contaminated wastes occurred in the general area just north of Avenue Q, bounded by Avenue P on the west and the explosive burning ground on the east. An area near the intersection of Avenues Q and P was identified as a possible TNT disposal site in use during the 1940's. A concrete block was discovered in this area during an assessment conducted in 1980, but its purpose is unknown. There is an area a few hectare in size located just west of the intersection of track 3-A and Avenue Q. This area was used during the late 1940's and early 1950's for the disposal of acids, building rubble, and other trash. Surface and subsurface soil samples were collected in 1984 and 1988. Low levels of explosive contamination were detected in both soil sampling events. This site is included in the FFA. Site investigations conducted in 1993 concluded that further field investigation is needed at this site to complete the site characterization report.

Contaminant of concern: Unknown (TNT residues)
Media of concern: Soil/Groundwater
Completed IRP Phase: PA/SI
Current IRP Phase: RI/FS -- Group #1
Future IRP Phase: RD/RA

LHAAP-12 ACTIVE LANDFILL

The Active Landfill is currently used for disposal of non-hazardous industrial waste. The landfill has been used intermittently since 1963. Continuous use of the landfill began in approximately 1978. Four groundwater wells were installed in 1980 and two in 1982. Groundwater analyses showed some metals, chlorides, and an explosive compound were present. In 1991, surface water and sediment samples were collected from one location near the landfill. These samples contained elevated levels of metals and trace amounts of some explosive and volatile organic compounds. This site is included in the FFA. Site investigations conducted in 1993 concluded that an Early Interim Remedial Action (Landfill Cap) is necessary to reduce further contamination to the groundwater. Additional field investigation (Phase II, RI/FS) is also required at this site.

Contaminant of concern: Asbestos/Refuse without Hazardous Waste/Unknown
Media of concern: Soil/Groundwater/Surface Water
Completed IRP Phase: PA/SI
Current IRP Phase: RI/FS -- Group #2
Future IRP Phase: IRA and RD/RA

LHAAP-13 SUSPECTED TNT BURIAL BETWEEN ACTIVE LANDFILL AND OLD LANDFILL

The Suspected TNT Burial Site/Acid Dump is an undocumented location where it is suspected that TNT or waste acids may have been disposed sometime during the history of the installation. Other than this suspected one-time disposal, no other activities have taken place at this site. Evidence of possible TNT burial or acid waste disposal at the site consists of several areas of little or no vegetation which is consistent with the suspicion that some form of waste disposal has occurred at this location. Examination of aerial photographs dated 1963 show these same locations stripped of vegetation with some type of activity being performed at the site. These locations are not evident in 1954 photos, and most of the area appears to be revegetated and inactive in 1970 photos. This site is included in the FFA. Completion of a remedial investigation conducted in 1993 concluded that no further investigation is needed at this site.

Contaminant of concern: TNT/Waste Acid
Media of concern: Soil/Groundwater
Completed IRP Phase: PA/SI
Current IRP Phase: RI/FS -- Group #3
Future IRP Phase: NFA

LHAAP-14 AREA 54 - BURIAL GROUND

The Area 54 Burial Ground is an undocumented location where it is suspected that demolition debris, building rubble, explosives, and acidic wastes were disposed during the 1940's and early 1950's. The disposal site is reportedly beneath the asphalt parking area adjacent to Building 49-W. Other than this period of operation, no other waste activities have taken place at the site. This site is included in the FFA. Site investigations conducted in 1993 concluded that no further investigation is needed at this site.

Contaminant of concern: Acid/Ordnance Components
Media of concern: Soil/Groundwater
Completed IRP Phase: PA/SI
Current IRP Phase: RI/FS -- Group #3
Future IRP Phase: NFA

LHAAP-15 AREA 49W - DRUM STORAGE

This site is a drummed waste storage shed containing solid and hazardous waste. It consists of a metal building 50 feet by 100 feet by 10/16 feet (sloped), with a concrete floor. Drums are stacked three high on pallets and held for shipment to the Defense Reutilization and Marketing Service (DRMS). This site has been in operation since 1984 and is still active today. Although this site was identified as an SWMU in the RFA, the TNRCC determined that there were no additional investigations required at this site. Based on this determination and historical information, the Army has placed this site into a No Further Action category.

Contaminant of concern: Unknown/Brine/Oil/Ash
Media of concern: Soil/Groundwater
Completed IRP Phase: PA
Current IRP Phase: NFA
Future IRP Phase: NFA

LHAAP-16 OLD LANDFILL

The Old Landfill was originally used for disposal of products generated from the TNT Waste Disposal Plant. However, a variety of waste was disposed of in the landfill until the 1980's. Burned rocket motor casings, substandard TNT, barrels of chemicals, oil, paint, scrap iron, and wood may have been disposed of in the Old Landfill. Contamination from explosives, solvents, and metals is suspected in the soil, surface water, and groundwater around the Old Landfill.

Investigations were conducted at this site in 1980, 1982, and 1988. Five monitoring wells were installed in 1980. One well installation, well sampling, sediment and surface water sampling, and soil sampling were conducted in 1982. In 1988, wells were sampled and additional soil sampling was conducted. Explosive contamination was detected in the groundwater, sediments, and soil samples. Vinyl chloride was also detected in one monitoring well. This site is no longer in operation and is included in the FFA. Site investigations conducted in 1993 concluded that an Early IRA (Landfill Cap) is necessary to reduce further contamination to the groundwater. Additional field investigation (Phase II, RI/FS) is also required at this site.

Contaminant of concern: Ordnance Components and Unknown
Media of concern: Soil/Groundwater
Completed IRP Phase: PA/SI
Current IRP Phase: RI/FS -- Group #2
Future IRP Phase: IRA and RD/RA

LHAAP-17 NO. 2 FLASHING AREA/BURNING GROUND

This site was used for burning bulk TNT, photoflash powder, and reject material from Universal Match Corporation's production processes. The site was operated as a burning ground from 1959 until 1980. There is evidence of bulk burial of TNT prior to 1954. Two burning pads are enclosed in a 2-acre fenced area surrounded by a flat grass area. Burning Ground No. 2 is situated approximately 400-500 feet southwest of Burning Ground No. 3, on adjoining property. Waste residues were removed in 1984 and the area grassed over. This site is no longer active and is included in the FFA. This site was investigated in 1984, 1986, and 1988. Contamination of the groundwater was found in the first two sampling events, and explosive compounds were detected int he soil sampling event in 1988. Site investigations conducted in 1993 concluded that further field investigation is needed at this site to complete the site characterization report.

Contaminant of concern: Explosives and Unknown
Media of concern: Soil/Groundwater
Completed IRP Phase: PA/SI
Current IRP Phase: RI/FS -- Group #2
Future IRP Phase: RD/RA

LHAAP-18 & 24 BURNING GROUND/WASHOUT POND & UNLINED EVAPORATION POND

Burning Ground No. 3 has been in operation since 1955. It has been used for the treatment, storage, and disposal of solid and liquid explosives, pyrotechnics, and combustible solvent wastes by open burning, incineration, evaporation, and burial. The Unlined Evaporation Pond (UEP) was constructed in 1963 in Burning Ground No. 3. Various types of waste have been disposed of in the UEP since 1963. Explosive waste, solvents, metallic materials, and nitrogen and phosphorous compounds are the suspected contaminants. In 1986, waste from the UEP was removed and the UEP capped. Burning of waste is still conducted in the Burning Ground No. 3 area.

Several investigations have been conducted at this site. In 1980, 13 monitoring wells were completed. In 1984, samples were collected to characterize the waste in portions of the site. Nine additional wells were installed in 1982. Explosives, metals, and organic solvents contamination was detected in groundwater at the site. In 1984, eight additional wells were installed around the UEP. To further characterize the UEP, 10 additional wells were installed around the area. In 1987, a soil gas survey, soil sampling, installation and sampling of 15 new groundwater wells, and sampling of 10 existing wells were conducted to identify additional contamination sources in the area. Contamination by volatile organic compounds, metals, chlorides, nitrates, and some explosives was found in the area. In 1989, additional wells were completed, along with soil and surface water sampling to determine the extent of groundwater contamination. Quarterly monitoring has been conducted at the site since closure of the UEP. This site is included in the FFA.

Based on the results of the latest round of water sampling which indicated the zone of contaminated groundwater is expanding, a Proposed Plan of an Early IRA was issued to the public in September 1994. The purpose of this IRA is to extract, treat, and contain contaminated groundwater underneath this site. Additional field investigation (Phase II, RI/FS) is also required at this site.

Contaminant of concern: Petroleum/Oil/Lubricants/Unknown Solvents and Heavy Metals
Media of concern: Soil/Groundwater/Surface Water
Completed IRP Phase: PA/SI
Current IRP Phase: RI/FS -- Group #2
Future IRP Phase: IRA and RD/RA

LHAAP-19 CONSTRUCTION MATERIALS LANDFILL

This site is used as a landfill. It is a fenced area 400 by 800 feet in size. Operation is trench and burial. This site has been in operation from 1985 until the present. Although this site has been identified as an SWMU in the RFA, the TNRCC determined that there were no additional investigations required at this site. Based on this determination and historical information, the Army has placed this site into a No Further Action category.

Contaminant of concern: Refuse without hazardous waste
Media of concern: Soil/Groundwater
Completed IRP Phase: PA/SI
Current IRP Phase: NFA
Future IRP Phase: NFA

LHAAP-22 TNT RED WATER PIPELINE

This site is being investigated under LHAAP 29 and 32 which are under RI/FS phases.

Contaminant of concern: Ordnance Components
Media of concern: Soil/Groundwater/Surface Water/Sediment
Completed IRP Phase: PA/SI
Current IRP Phase: RI/FS -- Group #2
Future IRP Phase: RD/RA

LHAAP-23 BUILDING 707 - STORAGE AREA FOR PCBs

This site consists of a wooden storage building 30 by 150 feet in size, with shingle siding and a concrete floor. Drums or transformers containing PCB-contaminated oil were stored in galvanized steel cattle watering troughs inside the building.

The building was empty except for the used cattle troughs. This site was in operation from 1980 until March 1986. Although this site was identified as an SWMU in the RFA, the TNRCC determined that there were no additional investigations required at this site. Based on this determination and historical information, the Army has placed this site into a No Further Action category.

Contaminant of concern: Unknown
Media of concern: Contamination of Building
Completed IRP Phase: PA/SI
Current IRP Phase: NFA
Future IRP Phase: NFA

LHAAP-27 SOUTH TEST AREA

The South Test Area was constructed in 1954 for testing of photoflash bombs. During the late 1950's, illuminating signal devices were also demilitarized within pits at the site. In the early 1980's, photoflash cartridges were demilitarized in the area. In 1982, investigations included installation and sampling of two wells and three shallow soil samples. Metals above background levels, explosives, and chloride and sulfate were detected above background levels in the groundwater. This site is no longer in operation and is included in the FFA. Site investigations conducted in 1993 concluded that further field investigation is needed at this site to complete the site characterization report.

Contaminant of concern: Ordnance Components
Media of concern: Soil/Groundwater
Completed IRP Phase: PA/SI
Current IRP Phase: RI/FS -- Group #1
Future IRP Phase: RD/RA

LHAAP-29 FORMER TNT PRODUCTION AREA

The Former TNT Production Area was in operation from April 1943 to August 1945 as a six-line plant with a supporting acid plant. The plant produced 180 million kilograms of TNT throughout the period of operation. A bulk toluene storage area servicing the TNT Production Area was located adjacent to the production area. TNT wastewater (red water) from the production of the TNT was sent through wooden pipelines to a storage tank and pumphouse, and then to the TNT Disposal Plant. Cooling water (blue water) from the production area ran through main lines and into an open ditch. Acidic waste were neutralized and discharged into a drainage ditch. The entire site, except for the foundations, was demolished and removed in 1959.

Six groundwater wells were completed and sampled in 1984 along with surface water/sediment samples from four locations. In 1988, the 6 wells, additional surface water, and 35 soil borings were sampled. Explosive contamination was detected in soil and surface water/sediment samples. This site is no longer in operation and is included in the FFA. Site investigations conducted in 1993 concluded that further field investigation is needed at this site to complete the site characterization report.

Contaminant of concern: Ordnance Components
Media of concern: Soil/Groundwater/Surface Water/Sediment
Completed IRP Phase: PA/SI
Current IRP Phase: RI/FS -- Group #2
Future IRP Phase: RD/RA

LHAAP-32 FORMER TNT WASTE DISPOSAL PLANT

The TNT Waste Disposal Plant was constructed in 1942 to treat and dispose of wastewaters generated at the TNT Production Area. The plant was in operation from April 1943 until August 1945. In 1959, most of the facilities at the Disposal Plant were removed. The suspected contaminants are explosive compounds and metals contained in explosive manufacturing residues.

One groundwater well was completed and sampled in 1982. Surface water and sediment samples were also collected in the area. One explosive compound was detected along with some elevated levels of metals. A surface water sample was collected in 1991, and the analyses detected low levels of explosive compounds. This site is no longer active and is included in the FFA. Site investigations conducted in 1993 concluded that further field investigation is needed at this site to complete the site characterization report.

Contaminant of concern: Ordnance Components
Media of concern: Groundwater/Surface Water/Sediment
Completed IRP Phase: PA/SI
Current IRP Phase: RI/FS -- Group #2
Future IRP Phase: RD/RA

LHAAP-34 BUILDING 701 - PCB STORAGE

This site consists of a building formerly used for storage of PCB-contaminated material from the cleanup of transformer spills in 30- and 55-gallon drums. The site consists of a wooden framed building with shingles and a concrete floor, approximately 25 by 110 feet in dimension. Only the north half of the building was used for storage. This site was in operation from 1980 until 1984. Although this site was identified as an SWMU in the RFA, the TNRCC determined that there were no additional investigations required at this site. Based on this determination and historical information, the Army has placed this site into a No Further Action category.

Contaminant of concern: Polychlorinated Biphenyls
Media of concern: Contamination of Building
Completed IRP Phase: PA/SI

Current IRP Phase: NFA
Future IRP Phase: NFA

LHAAP-35 PROCESS WASTEWATER SUMPS - VARIOUS

This site consists of 24 industrial wastewater sumps. These sumps are located in different locations within LHAAP. Site investigations conducted in 1993 concluded that further field investigations is needed at this site to complete the site characterization report.

Contaminant of concern: Heavy Metals
Media of concern: Groundwater
Completed IRP Phase: PA/SI
Current IRP Phase: RI/FS -- Group #4
Future IRP Phase: RD/RA

LHAAP-36 EXPLOSIVE WASTE PADS

This site is a compilation of approximately 20 waste pads. These waste pads consist of a galvanized metal roof set over a concrete 4- by 8-foot pad with a 6-inch curb. The waste pads are drained by concrete troughs into sumps. Explosive waste is desensitized with diesel fuel and placed in 5-gallon, galvanized, lidded, metal garbage pails with plastic bag liners. Full garbage pails are stored in a metal rack approximately 1.5 feet above the ground. The site has been in operation from 1985 until the present. Although this site was identified as an SWMU in the RFA, the TNRCC determined that there were no additional investigations required at this site. Based on this determination and historical information, the Army has placed this site into a No Further Action category.

LHAAP-37 QUALITY ASSURANCE LABORATORY - BUILDING 29A

This site serves as a collection point for spent solvents from the Quality Assurance Laboratory. The site consists of one 55-gallon, plastic, DOT-approved drum set on a concrete pad. Each full drum is sent to Building 31-W. This site has been in operation from 1985 until the present. Although this site was identified as an SWMU in the RFA, the TNRCC determined that there were no additional investigations required at this site. Based on this determination and historical information, the Army has placed this site into a No Further Action category.

Contaminant of concern: Solvent
Media of concern: Soil/Groundwater/Surface Water/Air
Completed IRP Phase: PA
Current IRP Phase: NFA
Future IRP Phase: NFA

LHAAP-38 24X HOLDING AREA, LHAAP-39 25X WASHOUT PAD, LHAAP-40 AIR CURTAIN DESTRUCTOR, LHAAP-41 OPEN BURNING CAGE, LHAAP-42 OPEN BURNING PAN, LHAAP-44 BUILDING 41X

These sites are located within LHAAP 18 which is under IRA and RI/FS phases.

Contaminant of concern: Petroleum/Oil/Lubricants/Unknown Solvents and Heavy Metals
Media of concern: Soil/Groundwater/Surface Water
Completed IRP Phase: PA/SI
Current IRP Phase: RI/FS -- Group #2
Future IRP Phase: IRA and RD/RA

LHAAP-45 MAGAZINE AREA

This site has been used for the storage of munitions. The total enclosed area is over 800 acres. Located within this area are 58 bunkers and 2 buildings. Each bunker consists of three concrete walls and a concrete-floored structure 26 by 60 by 10 feet in size, with a wooden roof and doors. If stored munitions are designated for disposal, they are taken to Building 811-1 where they are processed out. In operation since 1942, this site is still active. Although this site was identified as an SWMU in the RFA, the TNRCC determined that there were no additional investigations required at this site. Based on this determination and historical information, the Army has placed this site into a No Further Action category.

Contaminant of concern: Unexploded Ordnance
Media of concern: Soil/Building
Completed IRP Phase: PA
Current IRP Phase: NFA
Future IRP Phase: NFA

LHAAP-46 PLANT 2/PYROTECHNIC OPERATION - SUMPS

Plant 2 is the main site of pyrotechnic operations. The plant operated from June 1952 to 1956 and from April 1963 until the present. Wastewater from washdown activities is collected in 44 waste sumps and transferred to the pilot wastewater treatment plant. Site investigations conducted in 1993 concluded that further field investigation is needed at this site to complete the site characterization report.

Contaminant of concern: Heavy Metals
Media of concern: Groundwater
Completed IRP Phase: PA/SI
Current IRP Phase: RI/FS -- Group #4
Future IRP Phase: RD/RA

LHAAP-47 PLANT 3/PRODUCES MOTOR ASSEMBLIES - SUMPS

This site exists for the production of simulator and illuminating motor assemblies. Polysulfide polymer solid propellant rocket motors have been produced in the Plant 3 Area since 1955. Operations integral to this activity are vapor degreasing, grit blasting, particle size reduction, mixing and blending, teflon coating, and vacuum and pressure casting of solid fuel rocket motors. Wastewater from washdown activities is collected in the 48 waste sumps and transferred to the pilot wastewater treatment plant. Site investigations conducted in 1993 concluded that further field investigation is needed at this site to complete the site characterization report.

Contaminant of concern: Heavy Metals
Media of concern: Groundwater
Completed IRP Phase: PA/SI
Current IRP Phase: RI/FS -- Group #4
Future IRP Phase: RD/RA

LHAAP-48 Y AREA/PRODUCES HAND SIGNAL ASSEMBLIES - SUMPS

This site is a former rocket motor igniter facility. Wastewater is collected in nine waste sumps and transferred to the pilot wastewater treatment plant. Site investigations conducted in 1993 concluded that further field investigation is needed at this site to complete the site characterization report.

Contaminant of concern: Heavy Metals
Media of concern: Groundwater
Completed IRP Phase: PA/SI
Current IRP Phase: RI/FS -- Group #4
Future IRP Phase: RD/RA

LHAAP-49 FORMER ACID PLANT

This site is being investigated under LHAAP 29 and 32 which are under RI/FS phases.

Contaminant of concern: Ordnance Components
Media of concern: Soil/Groundwater/Surface Water/Sediment
Completed IRP Phase: PA/SI
Current IRP Phase: RI/FS -- Group #2
Future IRP Phase: RD/RA

LHAAP-50 FORMER WASTE DISPOSAL FACILITY

This site has received wastewaters from several sumps at Plants 3 and 2 during periods of sufficient flow from 1955 to the early 1970's. Washout of ammonium perchlorate containers was performed on site. Findings from the Army's preliminary assessment and recent re-evaluation concluded that an SI will be initiated in FY 95.

Contaminant of concern: Industrial Liquid Waste/Heavy Metals/Chlorinated Solvents
Media of concern: Soil/Groundwater
Completed IRP Phase: PA
Current IRP Phase: SI -- Group #5
Future IRP Phase: RI/FS

LHAAP-51 PHOTOGRAPHIC LABORATORY/BUILDING 60B

Building 60B is the location for processing of x-ray film. The building has a concrete floor without a floor drain. Spent developing waste is drummed and transferred to Building 31-W. Findings from the Army's preliminary assessment concluded that no further action is necessary at this time.

Contaminant of concern: Acid/Base
Media of concern: Soil/Building
Completed IRP Phase: PA
Current IRP Phase: NFA
Future IRP Phase: NFA

LHAAP-52 MAGAZINE AREA

The Plant 1 Magazine Area contains 58 Richmond-type magazines and two aboveground magazines, all of which had been used for the storage of TNT. A standpipe near the intersection of Avenue E and 19th Street was used to wash out trucks used for the transport of TNT. Waste waters from this operation may have flowed onto the ground. Findings from the Army's preliminary assessment and recent re-evaluation concluded that an SI will be initiated in FY 95.

Contaminant of concern: Explosive Chemicals
Media of concern: Soil
Completed IRP Phase: PA
Current IRP Phase: SI -- Group #5
Future IRP Phase: RI/FS

LHAAP-53 STATIC TEST AREA

This static test area also has a candle test area. The site was formerly used for rocket motor, red phosphorus smoke wedge, and illuminating candle testing. The current activity of this site is demilitarization by ignition of Pershing rocket motors performed on test stands. Findings rom the Army's preliminary assessment concluded that no further action is necessary at this site.

Contaminant of concern: Propellant/Explosive Chemicals
Media of concern: Soil/Groundwater
Completed IRP Phase: PA
Current IRP Phase: NFA
Future IRP Phase: NFA

LHAAP-54 GROUND SIGNAL TEST AREA

The Ground Signal Test Area is currently used for aerial and on-ground testing of pyrotechnic, illuminators, and signal devices manufactured at the facility. Since 1988, burnout of Pershing missiles has been conducted at this site in accordance with the Intermediate-Range Nuclear Forces Treaty. The site has been used intermittently since 1963 for various types of testing and destruction of many explosive devices. In 1982, investigations included installation and sampling of two groundwater wells and three surface samples. Elevated levels of some metals were detected in the soil and groundwater. Elevated levels of chloride and sulfate were detected in the groundwater. This site is included in the FFA. Site investigations conducted in 1993 concluded that further field investigation is needed at this site to complete the site characterization report.

Contaminant of concern: Propellant/Explosive Chemicals
Media of concern: Soil/Groundwater
Completed IRP Phase: PA/SI
Current IRP Phase: RI/FS -- Group #1
Future IRP Phase: RD/RA

LHAAP-55 SEPTIC TANK

This site contains ten septic tanks which serve outlying areas, with outfalls to ditches. The effluent is chlorinated prior to discharge. Contents of septic tanks are pumped out and transferred to the sewage treatment plant as needed. There is no history of industrial waste being put into these septic tanks. Findings from the Army's preliminary assessment concluded that no further action is necessary at this site.

Contaminant of concern: Refuse without hazardous waste
Media of concern: Soil/Groundwater
Completed IRP Phase: PA
Current IRP Phase: NFA
Future IRP Phase: NFA

LHAAP-56 VEHICLE WASH RACK & OIL SEPARATOR

This site consists of a concrete wash rack sloped to drain, connected to an oil/water separator. The site does have permitted discharge to a drainage ditch. The extent of separator maintenance is unknown.' Although this site will require further investigations, response is complete under DERA since the site is still active. The sumps on this site is being investigated under LHAAP #35.

Contaminant of concern: Heavy Metals
Media of concern: Groundwater
Completed IRP Phase: PA/SI
Current IRP Phase: RI/FS -- Group #4

Future IRP Phase: RD/RA

LHAAP-57 RUBBLE BURIAL SITE

This site is used for burial of inert materials that were cleared from property after acquisition. Findings from the Army's preliminary assessment concluded that no further action is necessary at this site.

Contaminant of concern: Unknown
Media of concern: Soil
Completed IRP Phase: PA
Current IRP Phase: NFA
Future IRP Phase: NFA

LHAAP-58 MAINTENANCE COMPLEX

This site is a maintenance complex with concrete floors and no curbs at the doorways. Floor drains are connected to the sanitary sewer. Lubricants are stored on drum racks outside over a gravel surface. No curbing or other containment is present. Waste oil and solvents are transferred to Building 31-W. Findings from the Army's preliminary assessment concluded that no further action is necessary at this site.

Contaminant of concern: Petroleum/Oil/Lubricants/Solvents
Media of concern: Soil
Completed IRP Phase: PA
Current IRP Phase: NFA
Future IRP Phase: NFA

LHAAP-59 STORAGE BUILDING NO. 725

This site is a building used for storage of pesticides and herbicides. Building 725 has a concrete floor that slopes to floor drains discharging to a nearby sump. Contents of the sump are pumped out as required and transferred to the pilot wastewater treatment system via vacuum truck. This site is still active. The sumps on this site are being investigated under LHAAP #35.

Contaminant of concern: Heavy Metals
Media of concern: Groundwater
Completed IRP Phase: PA/SI
Current IRP Phase: RI/FS -- Group #4
Future IRP Phase: RD/RA

LHAAP-60 FORMER STORAGE BUILDING 411 AND 714

This site is comprised of two buildings formerly used for storage of pesticides and herbicides (Building 411 and 714). Pesticides were originally stored in Building 714. In 1970, the stock was moved to Building 411. Both buildings have concrete floors with no curbs present at the doorways. Findings from the Army's preliminary assessment and recent re-evaluation concluded that an SI will be initiated in FY 95.

Contaminant of concern: Pesticides
Media of concern: Soil
Completed IRP Phase: PA
Current IRP Phase: SI -- Group #5
Future IRP Phase: RI

LHAAP-61 WATER TREATMENT PLANT EFFLUENT SETTLING POND

This facility consists of two adjacent ponds each 0.1 hectare by 1.5 meters deep. The ponds are located just north of the shops area. Synthetic waterproof sheeting with soil cover constitutes the pond liner. The purpose of the facility is to settle out solids from backwashing water treatment sand filters. Drainage is to Goose Prairie Bayou. Findings from the Army's preliminary assessment concluded that no further action is necessary at this site.

Contaminant of concern: Industrial Sludge
Media of concern: Soil/Groundwater
Completed IRP Phase: PA
Current IRP Phase: NFA
Future IRP Phase: NFA

LHAAP-62 BUILDING 43X

This site, known as Building 43X, is a shed used for storage of materials prior to incineration. The shed has a concrete floor, but has no curb or other containment. This site is located withiin LHAAP 18 which is under IRA and RI/FS phases.

Contaminant of concern: Petroleum/Oil/Lubricants/Unknown Solvents and Heavy Metals
Media of concern: Soil/Groundwater/Surface Water
Completed IRP Phase: PA/SI
Current IRP Phase: RI/FS -- Group #2
Future IRP Phase: IRA and RD/RA

LHAAP-63 BURIAL PITS

Pits are located along Bobby Jones Road (location 14) approximately 30 meters north of Long Point Road and east of the explosive burning ground. These pits were used in the late 1950's for the detonation of Plant 3 reject materials of unknown composition. Findings from the Army's preliminary assessment and recent re-evaluation concluded that an SI will be initiated in FY 95.

Contaminant of concern: Explosives
Media of concern: Soil/Groundwater

Completed IRP Phase: PA
Current IRP Phase: SI -- Group #5
Future IRP Phase: RI/FS

LHAAP-64 TRANSFORMER STORAGE

This site was used for storage of transformer oil. Approximately 20 out-of-service non-PCB transformers are stored on pallets outside, with no curb or other containment. Site investigation is being planned. This site is still active. Findings from the Army's preliminary assessment concluded that no further action is necessary at this site.

Contaminant of concern: Petroleum/Oil/Lubricants/ Polychlorinated Biphenyls
Media of concern: Soil/Groundwater
Completed IRP Phase: PA
Current IRP Phase: NFA
Future IRP Phase: NFA

LHAAP-65 BUILDING NO. 209

Building 209 is used for chemical storage for items such as paint and solvents. This building has a concrete floor with floor drains connected to sumps. The sumps on this site are being investigated under LHAAP #35.

Contaminant of concern: Heavy Metals
Media of concern: Groundwater
Completed IRP Phase: PA/SI
Current IRP Phase: RI/FS -- Group #4
Future IRP Phase: RD/RA

LHAAP-66 TRANSFORMER AT BUILDING 401

A transformer at Building 401 dripped oil continuously for approximately 1 year. The transformer did not contain any polychlorinated biphenyls. Findings from the Army's preliminary assessment concluded that no further action is necessary at this site.

Contaminant of concern: Oil
Media of concern: Soil
Completed IRP Phase: PA
Current IRP Phase: NFA
Future IRP Phase: NFA

LHAAP-67 ABOVEGROUND STORAGE TANK

This site consists of seven aboveground storage tanks containing Number 2 fuel oil and kerosene. Tanks have earthen dikes sufficient to contain potential spill. Motor fuel tanks are registered with the state. There is no history of spills at this location. Findings from the Army's preliminary assessment concluded that no further action is necessary at this site.

Contaminant of concern: Petroleum/Oil Lubricants/Other
Media of concern: Soil
Completed IRP Phase: PA
Current IRP Phase: NFA
Future IRP Phase: NFA

LHAAP-68 MOBILE STORAGE TANK PARKING AREA

This site contains two mobile storage tank (600 gallon) compartments on a tank truck. These vehicles are used throughout the facility and are parked onthe asphalt surface at the maintenance complex. No curb or other containment is present at the parking facility. Mobile storage tanks contain Number 2 diesel and gasoline. Findings from the Army's preliminary assessment concluded that no further action is necessary at this site.

Contaminant of concern: Petroleum/Oil Lubricants
Media of concern: Soil
Completed IRP Phase: PA
Current IRP Phase: NFA
Future IRP Phase: NFA

LHAAP-69 SERVICE STATION UNDERGROUND STORAGE TANKS

This site has six leaking underground storage tanks (USTs) that were leak tested in 1989. These tanks contained gasoline. The tanks were replaced in 1993, and the site has been remediated. No further action is needed at this site.

Contaminant of concern: Petroleum/Oil/Lubricants
Media of concern: Soil/Groundwater
Completed IRP Phase: RD/RA
Current IRP Phase: NFA
Future IRP Phase: NFA

IV. RMIS SITE SUMMARY CHART

An RMIS Site Summary Chart showing the status of each site is provided on the following pages.

TABLE 2

LONGHORN ARMY AMMUNITION PLANT

RESTORATION MANAGEMENT INFORMATION SYSTEM
SITE SUMMARY CHART

RMIS SITE NO.	CHEMICALS OF CONCERN	PHASE OF INVESTIGATION COMPLETED	CURRENT	FUTURE	COMPLETED IRA/RA
LHAAP-001	INERT MATERIALS EXPLOSIVE CHEMICALS	PA/SI	RI/FS	RD/RA	NONE
LHAAP-002	UNKNOWN (INDUSTRIAL WASTEWATER)	PA	NFA	NFA	NONE
LHAAP-003	PAINT/SOLVENT	PA	NFA	NFA	NONE
LHAAP-004	ORDNANCE COMP/INDUSTRIAL WASTEWATERS	PA	NFA	NFA	NONE
LHAAP-005	UNKNOWN (BACKWASH FROM ZEOLITE TREATMENT	PA	NFA	NFA	NONE
LHAAP-006	ACID	PA	NFA	NFA	NONE
LHAAP-007	PETROLEUM/OIL/LUBRICANTS	PA	NFA	NFA	NONE
LHAAP-008	RESIDUES FROM PRODUCTION MATERIALS	PA	NFA	NFA	NONE
LHAAP-009	PETROLEUM/OIL/LUBRICANTS UNKNOWN	PA	NFA	NFA	NONE
LHAAP-011	UNKNOWN (TNT RESIDUES)	PA/SI	RI/FS	RD/RA	NONE
LHAAP-012	ASBESTOS REFUSE w/o HAZARDOUS WASTE	PA/SI	RI/FS	IRA, RD/RA	NONE
LHAAP-013	TNT/WASTE ACID	PA/SI	RI/FS	NFA	NONE
LHAAP-014	ACID/ORDNANCE COMP	PA/SI	RI/FS	NFA	NONE
LHAAP-015	UNKNOWN/BRINE/OIL/ASH	PA	NFA	NFA	NONE
LHAAP-016	ORDNANCE COMPONENTS	PA/SI	RI/FS	IRA, RD/RA	NONE
LHAAP-017	EXPLOSIES AND UNKNOWNS	PA/SI	RI/FS	RD/RA	NONE
LHAAP-018	PETROLEUM/SOLVENTS/HEAVY METALS	PA/SI	RI/FS	IRA, RD/RA	NONE
LHAAP-019	REFUSE w/o HAZARDOUS WASTE	PA/SI	NFA	NFA	NONE
LHAAP-022	ORDNANCE COMP	PA/SI	RI/FS	RD/RA	NONE
LHAAP-023	UNKNOWN	PA/SI	NFA	NFA	NONE
LHAAP-024	PETROLEUM/SOLVENTS/HEAVY METALS	PA/SI	RI/FS	IRA, RD/RA	CAPPED
LHAAP-027	ORDNANCE COMP	PA/SI	RI/FS	RD/RA	NONE
LHAAP-029	ORDNANCE COMP	PA/SI	RI/FS	RD/RA	NONE

TABLE 2

LONGHORN ARMY AMMUNITION PLANT

RESTORATION MANAGEMENT INFORMATION SYSTEM
SITE SUMMARY CHART

RMIS SITE NO.	CHEMICALS OF CONCERN	PHASE OF INVESTIGATION COMPLETED	CURRENT	FUTURE	COMPLETED IRA/RA
LHAAP-001	INERT MATERIALS EXPLOSIVE CHEMICALS	PA/SI	RI/FS	RD/RA	NONE
LHAAP-002	UNKNOWN (INDUSTRIAL WASTEWATER)	PA	NFA	NFA	NONE
LHAAP-003	PAINT/SOLVENT	PA	NFA	NFA	NONE
LHAAP-004	ORDNANCE COMP/INDUSTRIAL WASTEWATERS	PA	NFA	NFA	NONE
LHAAP-005	UNKNOWN (BACKWASH FROM ZEOLITE TREATMENT	PA	NFA	NFA	NONE
LHAAP-006	ACID	PA	NFA	NFA	NONE
LHAAP-007	PETROLEUM/OIL/LUBRICANTS	PA	NFA	NFA	NONE
LHAAP-008	RESIDUES FROM PRODUCTION MATERIALS	PA	NFA	NFA	NONE
LHAAP-009	PETROLEUM/OIL/LUBRICANTS UNKNOWN	PA	NFA	NFA	NONE
LHAAP-011	UNKNOWN (TNT RESIDUES)	PA/SI	FI/FS	RD/RA	NONE
LHAAP-012	ASBESTOS REFUSE w/o HAZARDOUS WASTE	PA/SI	RI/FS	IRA, RD/RA	NONE
LHAAP-013	TNT/WASTE ACID	PA/SI	RI/FS	NFA	NONE
LHAAP-014	ACID/ORDNANCE COMP	PA/SI	RI/FS	NFA	NONE
LHAAP-015	UNKNOWN/BRINE/OIL/ASH	PA	NFA	NFA	NONE
LHAAP-016	ORDNANCE COMPONENTS	PA/SI	RI/FS	IRA, RD/RA	NONE
LHAAP-017	EXPLOSIES AND UNKNOWNS	PA/SI	RI/FS	RD/RA	NONE
LHAAP-018	PETROLEUM/SOLVENTS/HEAVY METALS	PA/SI	RI/FS	IRA, RD/RA	NONE
LHAAP-019	REFUSE w/o HAZARDOUS WASTE	PA/SI	NFA	NFA	NONE
LHAAP-022	ORDNANCE COMP	PA/SI	RI/FS	RD/RA	NONE
LHAAP-023	UNKNOWN	PA/SI	NFA	NFA	NONE
LHAAP-024	PETROLEUM/SOLVENTS/HEAVY METALS	PA/SI	RI/FS	IRA, RD/RA	CAPPED
LHAAP-027	ORDNANCE COMP	PA/SI	RI/FS	RD/RA	NONE
LHAAP-029	ORDNANCE COMP	PA/SI	RI/FS	RD/RA	NONE

012899

TABLE 2 (Continued)

LONGHORN ARMY AMMUNITION PLANT

RESTORATION MANAGEMENT INFORMATION SYSTEM
SITE SUMMARY CHART

RMIS SITE NO.	CHEMICALS OF CONCERN	PHASE OF INVESTIGATION COMPLETED	CURRENT	FUTURE	COMPLETED IRA/RA
LHAAP-032	ORDNANCE COMP	PA/SI	RI/FS	RD/RA	NONE
LHAAP-034	POLYCHLORINATED BIPHENYLS	PA/SI	NFA	NFA	NONE
LHAAP-035	HEAVY METALS	PA/SI	RI/FS	RD/RA	NONE
LHAAP-036	POLYCHLORINATED BIPHENYLS	PA/SI	NFA	NFA	NONE
LHAAP-037	SOLVENT	PA	NFA	NFA	NONE
LHAAP-038	PETROLEUM/SOLVENTS/HEAVY METALS	PA/SI	RI/FS	IRA, RD/RA	NONE
LHAAP-039	PETROLEUM/SOLVENTS/HEAVY METALS	PA/SI	RI/FS	IRA, RD/RA	NONE
LHAAP-040	PETROLEUM/SOLVENTS/HEAVY METALS	PA/SI	RI/FS	IRA, RD/RA	NONE
LHAAP-041	PETROLEUM/SOLVENTS/HEAVY METALS	PA/SI	RI/FS	IRA, RD/RA	NONE
LHAAP-042	PETROLEUM/SOLVENTS/HEAVY METALS	PA/SI	RI/FS	IRA, RD/RA	NONE
LHAAP-044	PETROLEUM/SOLVENTS/HEAVY METALS	PA/SI	RI/FS	IRA, RD/RA	NONE
LHAAP-045	UNEXPLODED ORDNANCE	PA	NFA	NFA	NONE
LHAAP-046	HEAVY METALS	PA/SI	RI/FS	RD/RA	NONE
LHAAP-047	HEAVY METALS	PA/SI	RI/FS	RD/RA	NONE
LHAAP-048	HEAVY METALS	PA/SI	RI/FS	RD/RA	NONE
LHAAP-049	ORDNANCE COMPONENTS	PA/SI	RI/FS	RD/RA	NONE
LHAAP-050	INDUSTRIAL LIQUID WASTE/HEAVY METALS/CHLORINATED SOLVENTS	PA	SI	RI/FS	NONE
LHAAP-051	ACID/BASE	PA	NFA	NFA	NONE
LHAAP-052	EXPLOSIVE CHEMICALS	PA	NFA	NFA	NONE
LHAAP-053	PROPELLANT EXPLOSIVE CHEMICALS	PA/SI	RI/FS	RD/RA	NONE
LHAAP-054	PROPELLANT EXPLOSIVE CHEMICALS	PA/SI	RI/FS	RD/RA	NONE
LHAAP-055	REFUSE w/o HAZARDOUS WASTE	PA	NFA	NFA	NONE
LHAAP-056	HEAVY METALS	PA/SI	RI/FS	RD/RA	NONE
LHAAP-057	UNKNOWN	PA	NFA	NFA	NONE

012900

TABLE 2 (Continued)

LONGHORN ARMY AMMUNITION PLANT

RESTORATION MANAGEMENT INFORMATION SYSTEM
SITE SUMMARY CHART

RMIS SITE NO.	CHEMICALS OF CONCERN	PHASE OF INVESTIGATION COMPLETED	CURRENT	FUTURE	COMPLETED IRA/RA
LHAAP-058	PETROLEUM/LUBRICANTS/SOLVENTS	PA	NFA	NFA	NONE
LHAAP-059	HEAVY METALS	PA/SI	RI/FS	RD/RA	NONE
LHAAP-060	PESTICIDES	PA	SI	RI/FS	NONE
LHAAP-061	INDUSTRIAL SLUDGE	PA	NFA	NFA	NONE
LHAAP-062	PETROLEUM/OIL/LUBRICANTS	PA/SI	RI/FS	IRA, RD/RA	NONE
LHAAP-063	EXPLOSIVES	PA	SI	RI/FS	NONE
LHAAP-064	PETROLEUM/OIL/LUBRICANTS	PA	NFA	NFA	NONE
LHAAP-065	HEAVY METALS	PA/SI	RI/FS	RD/RA	NONE
LHAAP-066	POLYCHLORINATED BIPHENYLS	PA	NFA	NFA	NONE
LHAAP-067	PETROLEUM/OIL/LUBRICANTS	PA	NFA	NFA	NONE
LHAAP-068	PETROLEUM/OIL/LUBRICANTS	PA	NFA	NFA	NONE
LHAAP-069	PETROLEUM/OIL/LUBRICANTS	PA	NFA	NFA	NONE

012901

V. SCHEDULE

Various environmental investigations, studies, and reports have been conducted since 1980 to address possible contamination at LHAAP. LHAAP was progressing towards a RCRA permit when the installation was listed on the NPL. An FFA was signed in December 1991, and the RCRA permit was signed in February 1992. A summary of the current project milestones for the remedial activities is given below.

A. PAST PHASE COMPLETION MILESTONES

IRP Phase	Completion Date
Interim Remedial Action (Soil Removal and Capping LHAAP-24)	1986
RFA Installation	April 1988
Groundwater Monitoring System installed at LHAAP 18 & 24	1989
IRP PA Initiation	May 1992
RI/FS Initiated (Group #$1 and other sites)	1993
IRA at LHAAP 18 & 24 Initiated	August 1994

B. PROJECTED MILESTONES BY PHASE

RI/FS Completed (Group #1)	January 1996
RI/FS Completed (Group #2)	August 1996
RI/FS Completed (Group #3)	March 1995
RI/FS Completed (Group #4)	May 1996
SI Initiated (Group #5)	January 1995
SI Completed (Group #5)	September 1995
RI Initiated (Group #5)	August 1995
ROD (Group #1)	June 1998
ROD (Group #2)	August 1998
ROD (Group #3)	September 1995
ROD (Group #4)	June 1998
ROD (IRA LHAAP 18 & 24)	March 1995
ROD (IRA LHAAP 12 & 16)	July 1995

VI. REMOVAL/INTERIM REMEDIAL ACTION/REMEDIAL ACTION/LONG-TERM MONITORING

A. PAST REM/IRA/RA/LTM

★ LHAAP 18 & 24 - Burning Ground No. 3 and Unlined Evaporation Pond, Long-Term Monitoring (LTM) System installed in 1989.

★ LHAAP 18 & 24 - Burning Ground No. 3 and Unlined Evaporation Pond, Interim Remedial Action, Waste Removal and Capping accomplished in 1986.

B. **CURRENT REM/IRA/LTM**

★ LHAAP 18 & 24 - Burning Ground No. 3 and Unlined Evaporation Pond, Long-Term Monitoring System installed in 1989. An IRA was initiated in August 1994 to install a groundwater and soil treatment system. IRA construction is pending the final approval of the ROD. Projects are still in RI/FS phases.

★ LHAAP 12 & 16 - Old and Active Landfills, landfill caps are planned to mitigate groundwater contamination from landfill leachate. A Proposed Plan and Public Meeting are scheduled in March 1995.

C. **FUTURE REM/IRA/LTM POSSIBLE OPPORTUNITIES**

Removal Action is planned for Group #4 (Sumps) and TNT Pipelines. Interim Action is possible at LHAAP 17 (Burning Ground No. 2).

VII. PREVIOUS STUDIES AT LONGHORN ARMY AMMUNITION PLANT

1. The Robert H. Balter Co., 1 April 1979, Assessment of Contaminant Migration, Longhorn Army Ammunition Plant, Harrison County, Texas.

2. The U.S. Army Toxic and Hazardous Materials Agency, February 1980, Installation Assessment of Longhorn Army Ammunition Plant Report No. 150.

3. The U.S. Army Environmental Hygiene Agency (USAEHA), Aberdeen Proving Ground, February 1980, Land Disposal No. 38-26-0104-81, Longhorn Army Ammunition Plant.

4. USAEHA, 26 May 1980, Land Disposal Study No. 38-26-0104-81, Longhorn Army Ammunition Plant, Marshall, Texas, 23 January - 8 February 1980.

5. USAEHA, Regional Div., South, September 1981, Wastewater Engineering Special Study No. 32-62-0182-82.

6. USAEHA, 2-6 November 1981, Hazardous Waste Management Survey No. 37-26-0172-82, Longhorn Army Ammunition Plant, Marshall, Texas.

7. USAEHA, Aberdeen Proving Ground, MD, November 1982, Hazardous Waste Special Study No. 39-26-0215-83.

8. Larry M. Jacobs and Associates, Inc., 27 August 1982, Geotechnical Interim Report for Longhorn Army Ammunition Plant, Marshall, Texas.

9. USAEHA, Aberdeen Proving Ground, MD, November 1982, Hazardous Waste Special Study No. 37-26-0291-84.

10. USAEHA, September 1983, Phase II, Hazardous Waste Management Special Study No. 39-26-0147-83, DARCOM Open-Burning/Open-Detonation Grounds Evaluation, Longhorn Army Ammunition Plant, Marshall, Texas, 31 July - 3 August 1981.

11. Environmental Projection Systems, Inc., March 1983 - May 1984, Contamination Analysis Report for Environmental Contamination Survey of Longhorn Army Ammunition Plant.

12. Kindle, Stone and Associates, Longview, Texas, 15 June 1984, Closure of Unlined Evaporation Pond, Marshall, Texas.

13. Environmental Protection Systems, Inc., June 1984, Longhorn Army Ammunition Plant Contamination Survey, Contract No. DAAA09-78-C-3004.

14. Camp, Dresser and McKee, Inc., 15 May 1985, Groundwater Quality Assessment, Longhorn Army Ammunition Plant, Marshall, Texas, Groundwater Contamination Related to Seepage from an Unlined Evaporation Pond, Contract No. DAC87-830-C-0091, Vol. I, II, and III.

15. EPA, January 1986, EPA Groundwater Monitoring Evaluation, Longhorn Army Ammunition Plant, Marshall, Texas.

16. U.S. Army Corps of Engineers, Fort Worth, June 1986, Closure Report, Unlined Evaporation Pond, Longhorn Army Ammunition Plant, Karnack, Texas.

17. USAEHA, 29 October 1986, Hazardous Waste Consultation No. 37-26-1348-87, AMC Hazardous Waste Minimization Assessment, July - September 1986.

18. USAEHA, 12-22 May 1987, Groundwater Contamination Survey No. 38-26-0851-88, Evaluation of SWMU's, LHAAP, Marshall, Texas.

19. Morton Thiokol, 1988, Longhorn Army Ammunition Plant, Groundwater Analytical Data.

20. Texas Water Commission, 8 April 1988, RCRA Facility Assessment (RFA).

21. Environmental Protection Systems, May 1988, A Study of Suspected TNT Burial Sites of Longhorn Army Ammunition Plant.

22. U.S. Army Corps of Engineers, Fort Worth, February 1989, Groundwater Quality Assessment, Phase I, 4 Volumes.

23. U.S. Army Corps of Engineers, Fort Worth, July 1989, RCRA Facility Investigation, Active Burning Ground and Unlined Evaporation Pond, Phase I, Longhorn Army Ammunition Plant, Karnack, Texas, 5 Volumes.

24. U.S. Army Corps of Engineers, Fort Worth, September 1989, RCRA Facility Investigation, Active Burning Ground and Unlined Evaporation Pond, Phase II, Field Data.

25. Texas Water Commission, November 1989, Longhorn Army Ammunition Plant, Karnack, Texas, Proposed Permit No. HW-50195, Industrial Solid Waste Registration No. 30090.

26. USATHMA, March 1990, USATHMA Installation Restoration Program, Project Management Plan, RCRA Facility Investigation.

27. Weston, 7 August 1990, Weston Report: Longhorn Army Ammunition Plant.

28. Longhorn Army Ammunition Plant, 13 June 1991, 1990 Annual Groundwater Report.

29. U.S. Army Corps of Engineers, March 1992, LHAAP-Initial Remedial Action/Data Quality Objectives.

30. U.S. Army Corps of Engineers, Fort Worth, January 1993, Results of Chemical Analyses, Burning Grounds, Longhorn Army Ammunition Plant, 4 Volumes.

31. U.S. Army Corps of Engineers, Tulsa District, 24 January 1994, Final Project Plan Phase II (Pilot Study) for IRA at Burning Ground No. 3.

32. U.S. Army Corps of Engineers, Tulsa District, January 1994, Draft Final Phase I Field Investigation Summary Report for Group #1.

33. U.S. Army Corps of Engineers, Tulsa District, February 1994, Draft Final Phase I Field Investigation Summary Report for Group #2.

34. U.S. Army Corps of Engineers, Tulsa District, February 1994, Draft Final Phase I Field Investigation Summary Report for 125 Waste Process Sumps and 20 Waste Rack Sumps.

35. U.S. Army Corps of Engineers, Tulsa District, April 1994, Final Work Plan Phase II (Pilot Study) for IRA at Burning Ground No. 3.

36. U.S. Army Corps of Engineers, Tulsa District, May 1994, Draft Final Field Summary Report for Area 1A.

37. U.S. Army Corps of Engineers, Tulsa District, June 1994, Draft Final Work Plan and Chemical Data Acquisition Plan Addendum for Phase II of Group #1.

38. U.S. Army Corps of Engineers, Tulsa District, June 1994, Draft Final Phase Work Plan Addendum for Soil and Groundwater Background Concentration Report.

39. U.S. Army Corps of Engineers, Tulsa District, July 1994, Draft Final Phase II Work Plan of 125 Waste Process Sumps and 20 Waste Rack Sumps.

40. U.S. Army Corps of Engineers, Tulsa District, August 1994, Draft Final Remedial Investigation/Feasibility Study Report for LHAAP #13 & 14.

41. U.S. Army Corps of Engineers, Tulsa District, September 1994, Proposed Plan for the Early IRA at Burning Ground No. 3.

42. U.S. Army Corps of Engineers, Tulsa District, December 1994, Final Phase II Group #2 Work Plan.

43. U.S. Army Corps of Engineers, Tulsa District, January 1995, Draft Final Hydrogeological Assessment.

1. INTRODUCTION

The Army property waste site summary reports included in this document were developed by Roy F. Weston, Inc. (WESTON) under contract DAAA15-88-D-0007 Task Order 2 for the United States Army Toxic and Hazardous Materials Agency (USATHAMA). The primary objective was to establish baseline data reflecting potential waste sites at Army properties. Waste sites for the purposes of this survey were defined broadly to include any location at a facility from which hazardous constituents might be released into the environment, regardless of whether the material in that location is defined as a solid or hazardous waste.

A brief report for each property was compiled with data collected between October 1988 and February 1989. Data was collected through questionnaires distributed to Army personnel familiar with the properties. WESTON conducted a brief (1-day or less) site visit and/or telephone follow-up with the Army personnel completing the questionnaires (and some local water and electric companies) to supplement information obtained in the questionnaires. WESTON did not collect additional independent data, but relied entirely on information from those sources.

These reports will be used as references for all future Installation Restoration Program (IRP) communication. Additionally, they will be the basis for the allocation of funding and resources in support of the IRP. As remediation activities are completed and/or additional information becomes available, updates will be performed.

2. USER GUIDE

2.1 Sample Report

The first page of each property report (see Figure 1) provides general information about the property and its environmental coordinator. Base population estimates contained in general information use the higher of weekday or weekend populations present on base. A summary listing of the total number of waste sites, maximum Installation Scoring Model (ISM) score, and the confidence factor associated with the report is provided at the bottom of the page. Where the Army leases properties from other entities, only Army activities or areas of Army responsibility were evaluated. Where the Army leases parts of a property to another entity (such as the US Navy) waste sites generated by that entity (e.g. Navy activities) were not evaluated. The letters "NPL" appear in the summary listing if the property (or a site on the property) is listed on the National Priority List (NPL). The symbol "*NPL" in the summary listing indicates that the property is part of a site listed on the NPL. The symbol "*" next to a Maximum Score indicates that a waste site with a higher score may exist on the property, but information to accurately assess that site is currently unavailable. That possible waste site is either listed as an unscored waste site in the property's waste site reports, or referenced in the comment section of the property report, depending on the amount of information available.

The subsequent page(s) of each property report (see Figure 2) are used to list and to provide details of each waste site on the property. The site numbers and names are matched, when possible, to site numbers and names as listed in available published reports. The Waste Site Characterization section is used to list specific types of wastes (or a description of the process generating the waste), amount of waste, analytical data, and applicable permits. Underground storage tank registration information is included under permits. Where no permits or registrations are either reported or required, "None" is entered under "Permit".

For properties with multiple sites, a minimum of two waste sites per property were scored, unless scores were not justified by the Installation Scoring Model used (see Section 2.2). The sites with the highest potential scores were scored first, and scoring continued for other sites until significant decreases were noted in the totals. The initial decision as to potential scoring was based both on observations made during inspections of the installations and on documentation supplied to WESTON by the facility or the environmental coordinator, and focused on obvious factors such as degree of containment or constituents of concern.

The comments section is used as needed to further explain processes, to detail releases of contaminants, to list additional analytical data, or to note any special facts. The final section denotes the IRP status by phase as related to each waste site. The phases are: PA = preliminary assessment, SI = site investigation, RI = remedial investigation, FS = feasibility study, and RD = remedial design. Codes used to reflect status include: N = no/none, I = initiated, U = unknown, and C = complete. These phases are filled in as complete only if the formal (CERCLA) PA/SI or RI/FS documentation has been generated. Accordingly informal or internal remediation strategies may be ongoing even if these codes are all "N". Such activities are noted in the comment section.

The following information can be assumed in reading waste site reports. Underground storage tanks are of steel construction without any corrosion protection unless otherwise noted in the comment. Transformers are only listed as a waste site if they contain PCBs (or are likely to contain PCBs due to their age and lack of additional information). Asbestos areas are only listed as a waste site if particularly high hazards are present (such as quarantined areas or buildings, or areas with ripped or shredding asbestos material). Otherwise, any information obtained as to asbestos removal activities is noted in the property report under the comments section. Radon contamination has not been assessed.

2.2 Installation Scoring Model (ISM) and Confidence Factors

The Installation Scoring Model (ISM) used for the study is based on the Environmental Protection Agency (EPA) Hazard Ranking System (HRS). ISM scores are intended to reflect the level of environmental concern posed by a particular waste site and are not to be considered equivalent to an HRS score. Only waste sites determined to be a potential environmental concern were scored.

Each waste site scored was evaluated with respect to containment of the hazardous substance(s), route by which substance(s) could be released, characteristics and amount of harmful substances, and the likely targets. Four scores are reported per waste site: surface water score, groundwater score, air quality score, and total score. The ISM does not at this time include an evaluation for exposure in the work place. Localized contact with potentially hazardous materials is thus not assigned a score. Air quality scores may only be assigned if a specific release of contaminants significantly above background has been documented. Accordingly, no scores for potential air releases are given. No scores are given for any containment releases that are occurring under existing regulatory permits. The ISM scores reflect a minimum waste quantity of approximately 2000 gallons. Many of the sites ranked contain less than that amount of wastes, however.

Reliable scores require considerable information about the property, its surroundings, the hazardous substances present, and the geological character of the area down to the aquifers that may be at risk. As an indicator of reliability, a confidence factor scoring system was developed to provide the user of this document with a measure of the applicable and available information used to characterize and compute the ISM scores for each waste site. The criteria used for development of these confidence factors are displayed in Table 1. It should be noted that Table 1 does not list all possible combinations of information sources, but it does cover the range of available information. As such, it is used as a guideline.

TABLE 1

CONFIDENCE FACTOR DEFINITIONS

Confidence Factor	Site Visit	RI Report Available	Installation Assess. or Equivalent Information*	Questionnaire Completed
A	1	1	1	1
B	1	1+	1	--
C	--	0	1	1
D	--	0	0	1
E	0	0	0	0

* Equivalent information refers to small properties where a site visit or telephone contact may yield as much data as an installation assessment.

\+ If an RI is not applicable to circumstances at the property, a B Confidence Factor score may still be assigned.

1 Information available.

0 Information not available or not submitted.

-- This component not a critical value for this specific Confidence Factor Score.

Figure 1

USATHAMA Property Report

Property Number: 99999
FFIS Number : ZZ-123456789

Name : FORT EXAMPLE
Address: ONE U.S. ARMY AVENUE
ATTN: #UTZ-EC
COMBAT CITY
ZZ 99999-1111

Date of Printing: 03/06/89
Last Update: 01/01/89

Coord.: 99DEG 99MIN N 99DEG 99MIN W

Nearest Town : COMBAT CITY, ZZ
Population : 100

Base Population : 100
Command : MACOM

EPA Region : #

Support Facility: SUPPORT FACILITY NAME

Environmental Coordinator Name : JOHN F DOE
Environmental Coordinator Address: FORT EXAMPLE
ONE U.S. ARMY AVENUE
P. O. BOX 99999
ATTN: #UTS-EC-2
COMBAT CITY
ZZ 99999-1111

Environmental Coordinator Phone : (999)999-9999

Date of Form Response : 12/25/88

Name of Respondee : JOHN L. DOE
Title : ENVIRONMENTAL ENGINEER
Time Associated : 1 YEAR

Surface Water Uses: DESCRIBE SURFACE WATER USE

Ground Water Uses : DESCRIBE GROUND WATER USE

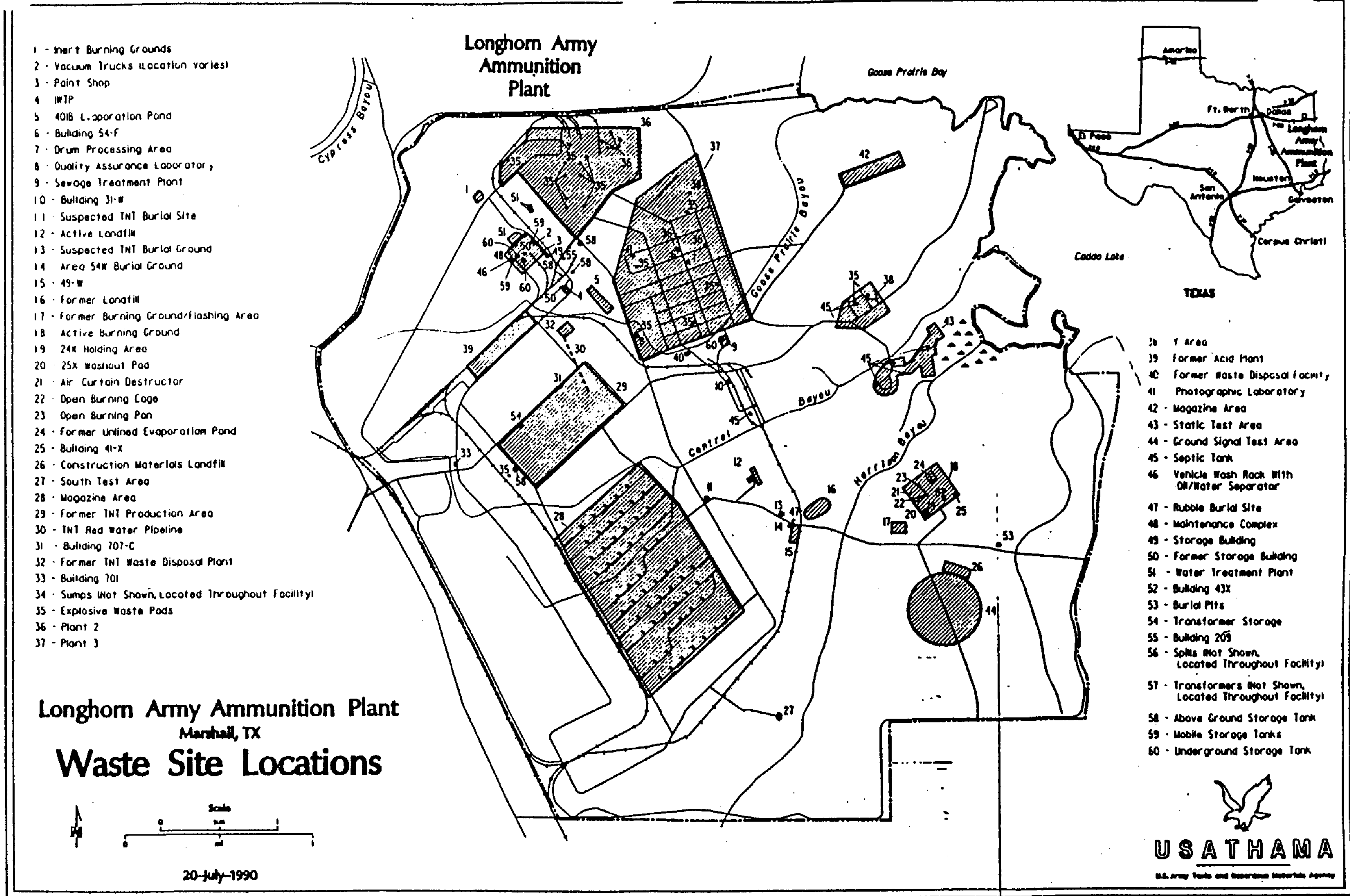
Comments : GENERAL COMMENTS RELEVANT TO THE IDENTIFICATION AND/OR CHARACTERIZATION OF THE PROPERTY WASTE SITES.

Number of Waste Sites: # NPL

Maximum Score : # *

Confidence Factor : A - F

012911


Longhorn Army Ammunition Plant
1 - Inert Burning Grounds
2 - Vacuum Trucks (Location Varies)
3 - Paint Shop
4 - IWTP
5 - 401B Evaporation Pond
6 - Building 54-F
7 - Drum Processing Area
8 - Quality Assurance Laboratory
9 - Sewage Treatment Plant
10 - Building 31-W
11 - Suspected TNT Burial Site
12 - Active Landfill
13 - Suspected TNT Burial Ground
14 - Area 54W Burial Ground
15 - 49-W
16 - Former Landfill
17 - Former Burning Ground/Flashing Area
18 - Active Burning Ground
19 - 24X Holding Area
20 - 25X Washout Pad
21 - Air Curtain Destructor
22 - Open Burning Cage
23 - Open Burning Pan
24 - Former Unlined Evaporation Pond
25 - Building 41-X
26 - Construction Materials Landfill
27 - South Test Area
28 - Magazine Area
29 - Former TNT Production Area
30 - TNT Red Water Pipeline
31 - Building 707-C
32 - Former TNT Waste Disposal Plant
33 - Building 701
34 - Sumps (Not Shown, Located Throughout Facility)
35 - Explosive Waste Pads
36 - Plant 2
37 - Plant 3
38 - Y Area
39 - Former Acid Plant
40 - Former Waste Disposal Facility
41 - Photographic Laboratory
42 - Magazine Area
43 - Static Test Area
44 - Ground Signal Test Area
45 - Septic Tank
46 - Vehicle Wash Rack With Oil/Water Separator
47 - Rubble Burial Site
48 - Maintenance Complex
49 - Storage Building
50 - Former Storage Building
51 - Water Treatment Plant
52 - Building 43X
53 - Burial Pits
54 - Transformer Storage
55 - Building 209
56 - Spills (Not Shown, Located Throughout Facility)
57 - Transformers (Not Shown, Located Throughout Facility)
58 - Above Ground Storage Tank
59 - Mobile Storage Tanks
60 - Underground Storage Tank
Goose Prairie Bay
Cypress Bayou
Goose Prairie Bayou
Central Bayou
Harrison Bayou
Caddo Lake
TEXAS
Amarillo
El Paso
Ft. Worth
Dallas
Longhorn Army Ammunition Plant
San Antonio
Houston
Galveston
Corpus Christi
Longhorn Army Ammunition Plant
Marshall, TX
Waste Site Locations
Scale
20-July-1990
USATHAMA
U.S. Army Toxic and Hazardous Materials Agency

012912

Figure 2

USATHAMA Waste Site Report

Property Number: 99999   Property Name: FT. EXAMPLE

Date of Printing: 03/06/89
Last Update: 03/03/89

Site Number	Site Name	Waste Site Characterization	ISM Scores	Comments	IRP Status
1	WASTE SITE IDENTIFICATION NAME	Type: DESCRIBE THE TYPES OF WASTE WHICH ARE PRESENT OR PROCESSES Qty: (IF KNOWN) Permit: NPDES #1223432-PA, RCRA, OTHER	Ground Water : # Surface Water: # Air Quality : # Total Score : #	INCLUDES RELEVANT INFORMATION AS TO THE CONTAMINATION, POTENTIAL CONTAMINATION, WASTE SITE HISTORY, PROCESSES, ANALYSIS DATA, REMEDIATION, ECT.	NPL PA : C SI : I RI : U FS : N RD : N

012913

USATHAMA Property Report

Property Number: 48315
FFIS Number : TX-213820738

Name : LONGHORN ARMY AMMUNITION PLANT
Address:

MARSHALL
TX 75670-1059

Date of Printing: 08/07/90
Last Update: 08/07/90

Coord.: 32DEG 40MIN N 94DEG 07MIN W

Nearest Town : MARSHALL
Population : 24,900

Base Population : 938
Command : AMCCOM

EPA Region : 6

Support Facility:

Environmental Coordinator Name : DORIS HAYES
Environmental Coordinator Address: LONGHORN ARMY AMMUNITION PLANT

MARSHALL
TX 75670-1059

Environmental Coordinator Phone : (214)679-2804

Date of Form Response : 04/02/90

Name of Respondee : DON MALEY
Title : CHIEF ENGINEER
Time Associated : 10 YEARS

Surface Water Uses: RECREATION: CADDO LAKE BORDERS FACILITY

Ground Water Uses : DRINKING: MUNICPAL WELLS < 1 MILE

Comments : 8490-AC GOCO FAC PERFORMS LOAD,ASSEMBLY & PACK OF PYROTECHNICS & PERSHING ROCKET MOTOR DEMIL. PAST ACTIVITIES INCL TNT & ROCKET MOTOR PROD. TEN SITES IN RCRA PART B APPL REQ RFI WORK. PROPOSED NPL: BURNING GROUND&POSS OTHER SWMUS.

Number of Waste Sites: 60

Maximum Score : 28.4

Confidence Factor : C

012914

USATHAMA Waste Site Report

Property Number: 48315 Property Name: LONGHORN ARMY AMMUNITION PLANT

Date of Printing: 08/07/90
Last Update: 08/07/90

Site Number	Site Name	Waste Site Characterization	ISM Scores	Comments	IRP Status
1	INERT BURNING GROUNDS	Type: RESIDUES FROM BURNING OF TRASH,ASHES,SCRAP LUMBER, TNT AND PHOTO FLASH POWDER Qty: 2 ACRES Permit: EONE	Ground Water :48.7 Surface Water: 5.8 Air Quality : 0.0 Total Score :28.4	1-2 ACRE AREA USED FOR BURNING OF INERT MATERIALS FROM 1942 TO THE EARLY 1950'S IS HEAVILY WOODED AT PRESENT. BULK TNT ALSO REPORTED TO HAVE BEEN BURNED ON SITE. DOWNGRADIENT MONITOR WELL INDICATES GROUNDWATER CONTAMINATION WITH TNT BREAKDOWN PRODUCTS.	PA : C SI : I RI : N FS : N RD : N
2	VACUUM TRUCKS	Type: WASTEWATER CONTAINING HALOGENATED ORGANIC SOLVENTS, HEAVY METALS AND EXPLOSIVES Qty: 5500-GALLONS/TRUCK Permit: NONE	Ground Water :12.2 Surface Water: 1.8 Air Quality : 0.0 Total Score : 7.2	(2) 5500-GALLON CAPACITY TANK TRUCKS USED TO TRANSFER LIQUID WASTES FROM VARIOUS SUMPS (SITE #34) TO IWTP (SITE #4) ARE PARKED OVERNIGHT ON ASPHALT SURFACE. TRUCKS OCCASIONALLY ARE PARKED OVERNIGHT IN FULL CONDITION PRIOR TO TRANSFER TO WASTE IN MORNING. NO CURB OR OTHER CONTAINMENT.	PA : C SI : N RI : N FS : N RD : N
3	PAINT SHOP	Type: PAINT THINNER AND PAINT RESIDUES Qty: (2) 55-GALLON DRUMS Permit: NONE	Ground Water : 8.0 Surface Water: 1.2 Air Quality : 0.0 Total Score : 4.7	BUILDING #722-P. (2) 55-GALLON DRUMS ON GRAVEL PAD IN OPEN SHED ARE TRANSFERRED TO BUILDING #31 (SITE #10) WHEN FULL. NO CURB OR OTHER CONTAINMENT.	PA : C SI : N RI : N FS : N RD : N

012915

Property Number: 48315 Property Name: LONGHORN ARMY AMMUNITION PLANT

Date of Printing: 08/07/90
Last Update: 08/07/90

4	IWTP	Type: WASTEWATER CONTAINING HALOGENATED ORGANIC SOLVENTS, HEAVY METALS AND EXPLOSIVES Qty: 42000 GALLONS EACH Permit: TEXAS WATER COMMISSION PERMIT NO. 02713	Ground Water :13.5 Surface Water: 0.0 Air Quality : 0.0 Total Score : 7.8	WW FROM SUMPS (SITE #34) TRANSFERRED BY VACUUM TRUCK (SITE #2) & STORED IN (2) 42000-GALLON CAP TANKS PRIOR TO EVAPORATION. BRINE WATER/SLUDGE HELD IN 8000-GAL FRP TANK, DRUMMED, TRUCKED TO BLDG #49-W (SITE #15). SETTLING TANK SLUDGE DRUMMED, TRUCKED TO ACTIVE BURNING GRND (SITE #18). AREA HAS EARTHEN BERMS.	PA : C SI : N RI : N FS : N RD : N
5	401B EVAPORATION POND	Type: WATER CONTAINING CALCIUM, MAGNESIUM AND SODIUM CHLORIDE Qty: 3000 GALLONS/DAY Permit: NONE	Ground Water : 3.1 Surface Water: 0.0 Air Quality : 0.0 Total Score : 1.8	5.5-ACRE EARTHEN LAGOON IS 4' DEEP WITH SINGLE PVC LINER. LAGOON RECEIVES BACKWASH WATER FROM ZEOLITE TREATMENT UNITS AT BUILDING #401 POWERHOUSE. WATER IS EITHER EVAPORATED OR DISCHARGED BY PIPELINE TO SEWAGE TREATMENT PLANT (SITE#9).	PA : C SI : N RI : N FS : N RD : N
6	BUILDING #54-F	Type: WASTE ACIDS AND SOLVENTS Qty: NONE CURRENTLY GENERATED Permit: NONE	Ground Water : 7.6 Surface Water: 1.5 Air Quality : 0.0 Total Score : 4.5	HMX PRODUCTION FACILITY INACTIVE SINCE 6/88. WASTE SOLVENTS FROM PRODUCTION PROCESSES WERE COLLECTED IN A 55-GALLON DRUM AND PLACED ON AN UNCURBED CONCRETE PAD UNDER OPEN SHED. FULL DRUMS WERE TRANSFERRED TO BUILDING #31-W (SITE#10). SCORE BASED ON PAST ACTIVITIES.	PA : C SI : N RI : N FS : N RD : N

012916

Property Number: 48315   Property Name: LONGHORN ARMY AMMUNITION PLANT

7	DRUM PROCESSING AREA	Type: HALOGENATED ORGANIC SOLVENTS, OIL AND HEAVY METALS Qty: RESIDUAL IN DRUMS Permit: NONE	Ground Water : 9.0 Surface Water: 1.8 Air Quality : 0.0 Total Score : 5.3	WASHDOWN OF EMPTY DRUMS AT BLDG #50-G IS PERFORMED IN A 20'X 30' BAY WHICH DRAINS TO A 3000-GALLON SUMP (SITE #34) LOCATED OUTSIDE BUILDING. WASHED, EMPTY DRUMS ARE REUSED OR FLASHED AT THE AIR CURTAIN DESTRUCTOR (SITE #21) AND TRANSFERRED TO BLDG #49-W FOR DISPOSAL AS SCRAP. SCORE BASED ON RESIDUAL MATERIAL IN DRUMS.	PA : C SI : N RI : N FS : N RD : N
8	QUALITY ASSURANCE LABORATORY	Type: SPENT SOLVENTS Qty: (2) 55-GALLON DRUMS Permit: NONE	Ground Water : 8.0 Surface Water: 1.5 Air Quality : 0.0 Total Score : 4.7	BUILDING #29-A. DRUMS ON AN UNCURBED CONCRETE PAD RECEIVE SPENT SOLVENTS FROM QUALITY ASSURANCE LABORATORY. FULL DRUMS ARE TRANSFERRED TO BUILDING #31-W (SITE #10) FOR DISPOSAL.	PA : C SI : N RI : N FS : N RD : N
9	SEWAGE TREATMENT PLANT	Type: SANITARY SEWAGE AND STORMWATER INFILTRATION Qty: 0.87 MGD CAPACITY Permit: NPDES TX 0000035	Ground Water : 7.6 Surface Water: 0.0 Air Quality : 0.0 Total Score : 4.4	PLANT CONSISTS OF IMHOFF TANK, SAND FILTER, AND (3) SLUDGE DRYING BEDS. EFFLUENT IS DISCHARGED TO CENTER BAYOU. DRIED SLUDGE IS TRANSFERRED TO THE ACTIVE LANDFILL (SITE #12) FOR DISPOSAL. OCCASIONAL UPSETS DUE TO STORMWATER INFILTRATION REPORTED. SCORE BASED ON POTENTIAL FOR LEAKAGE OF LARGEST TANK.	PA : C SI : N RI : N FS : N RD : N

012917

Date of Printing: 08/07/90
Last Update: 08/07/90

Property Number: 48315 Property Name: LONGHORN ARMY AMMUNITION PLANT

10	BUILDING #31-W	Type: BATTERIES, PCBS & LIQUID WASTES INCLUDING OILS, HALOGENATED SOLVENTS, ACIDS AND HEAVY METALS Qty: 88000-GALLON CAPACITY Permit: HW-50195 DRAFT PART B	Ground Water : 0.0 Surface Water: 0.0 Air Quality : 0.0 Total Score : 0.0	50'X 100' BLDG CA 1950 INCL (3) 6'X 31' CONC TROUGHS W/6" CURBS USED FOR STOR OF PCB TRNSFRMRS & VARIOUS CHEMICALS IN LAB PACK. 80'X 50'ADDITION CA 1987 HAS (8) APPROX 20'X 26' CONC PADS W/6" CURBS FOR STORAGE OF 55-GAL DRUMS ON PALLETS. MATERIALS DISPOSED VIA DRMO TEXARKANA. SCORE BASED ON CONT OF POTENTIAL SPILL.	PA : C SI : N RI : N FS : N RD : N
11	SUSPECTED TNT BURIAL SITE	Type: POTENTIAL FOR BURIED TNT Qty: UNKNOWN Permit: NONE	Ground Water :27.8 Surface Water: 6.4 Air Quality : 0.0 Total Score :16.5	APPROXIMATE 1-1.5-ACRE SITE REPORTEDLY USED FOR BURIAL OF TNT IN 1940'S. AREA IS CURRENTLY REVEGETATED WITH GRASSES AND TREES. LOW LEVELS OF EXPLOSIVES CONTAMINATION OF SOIL DETECTED. EXACT LOCATION AND QUANTITY OF BURIED MATERIAL UNCERTAIN.	PA : C SI : I RI : N FS : N RD : N
12	ACTIVE LANDFILL	Type: TRASH, GARBAGE, ASH AND ASBESTOS Qty: 20 CUBIC YARDS/MONTH Permit: TEXAS WATER COMMISSION PERMIT NO. 30990	Ground Water :42.9 Surface Water: 7.3 Air Quality : 0.0 Total Score :25.1	APPROX 5-ACRE UNLINED LNDFL OPERATED BY TRENCH FILL METHOD FROM CA 1970 TO PRESENT. TRENCHES ARE DUG THE APPROX SIZE OF ONE DAY'S WASTE (10'X 20'X 10') AND COVERED WITH SOIL DAILY. SITE INCLUDES AEHA SWMU #12A ASBESTOS LDFL. MANGANESE, CADMIUM, DICHLOROMETHANE, PENTANE AND DINITROBENZENE DETECTED IN GROUNDWATER.	PA : C SI : I RI : N FS : N RD : N

012918

Property Number: 48315 Property Name: LONGHORN ARMY AMMUNITION PLANT

Date of Printing: 08/07/90
Last Update: 08/07/90

13	SUSPECTED TNT BURIAL SITE	Type: POTENTIAL FOR BURIED TNT Qty: APPROX 2500 SQUARE FEET Permit: NONE	Ground Water :24.2 Surface Water: 4.5 Air Quality : 0.0 Total Score :14.2	50'X 50' GRASSY AREA BETWEEN OLD AND ACTIVE LANDFILLS (SITES #16 AND 12). PREVIOUS SURVEY BY AEHA CONCLUDED LACK OF VEGETATIVE COVER INDICATED POTENTIAL FOR BURIED TNT.	PA : C SI : I RI : N FS : N RD : N
14	AREA 54W BURIAL GROUND	Type: ACIDS, BUILDING RUBBLE AND EXPLOSIVES Qty: EST < 50 CUBIC YARDS Permit: NONE	Ground Water :26.7 Surface Water: 0.0 Air Quality : 0.0 Total Score :15.4	10'X 20' AREA BENEATH PAVED PARKING LOT USED AS BURIAL SITE FROM CA 1940 TO EARLY 1950'S. CHROMIUM AND 1,3,5 TRINITROBENZENE CONTAMINATION OF GROUND-WATER DETECTED IN DOWNGRADIENT WELL.	PA : C SI : I RI : N FS : N RD : N
15	49-W	Type: BRINE SLUDGE, OIL, CONTAMINATED MATERIALS, BATTERIES, MERCURY AND ASH Qty: 72500-GALLON CAPACITY Permit: HW-50195 DRAFT PART B	Ground Water : 6.8 Surface Water: 1.6 Air Quality : 0.0 Total Score : 4.0	50'X 100' METAL BLDG W/CONC FLR. DRUMMED SOLID WASTE HELD FOR SHPMNT TO DRMO TEXARKANA. SCRAP METAL COMPACTED & STOR ON ADJACENT GRND SURFACE PRIOR TO PUBLIC SALE. DRUMMED ASH FROM ACTIVE BURNING GROUND (SITE #18) STORED PENDING EP TOX RESULTS AND SHIPMENT TO ACTIVE LANDFILL (SITE #12). LARGEST CONTAINER 55 GAL.	PA : C SI : N RI : N FS : N RD : N

012919

USATHAMA Waste Site Report

Date of Printing: 08/07/90
Last Update: 08/07/90

Property Number: 48315 Property Name: LONGHORN ARMY AMMUNITION PLANT

16	FORMER LANDFILL	Type: TNT, TNT REDWATER ASH, DRUMMED CHEMICALS, OIL, PAINT, SCRAP IRON, RUBBLE AND ROCKET MOTOR CASINGS Qty: 20 ACRES Permit: NONE	Ground Water :34.7 Surface Water:14.5 Air Quality : 0.0 Total Score :21.7	APROXIMATELY 20-ACRE UNLINED LANDFILL OPERATED FROM 1942 TO 1985. SITE HAS PARTIALLY VEGETATED SOIL COVER. AREA INCLUDES FORMER ARTIFICIAL LAKE USED AS DUMPING SITE. 2,6 DINITROTOLUENE, CHROMIUM, LEAD AND MANGANESE DETECTED IN DOWNGRADIENT MONITORING WELLS AND SURFACE WATER.	PA : C SI : I RI : N FS : N RD : N
17	FRMR BURNING GRND/FLASHNG AREA	Type: BURN RESIDUE FROM TNT, PHOTOFLASH POWDER AND REJECT MATERIAL FROM PRODUCTION PROCESSES Qty: 4 ACRES Permit: NONE	Ground Water : 6.1 Surface Water: 8.7 Air Quality : 0.0 Total Score : 6.2	4-ACRE SITE USED AS BURNING GROUND AND FLASHING AREA FOR DECONTAMINATION OF EXPLOSIVES CONTAMINATED EQUIPMENT FROM 1959 TO 1980. WASTE RESIDUES WERE REMOVED IN 1984 AND AREA GRASSED OVER. BULK BURIAL OF TNT PRIOR TO 1954 REPORTED. BARIUM, LEAD, STRONTIUM, MANGANESE AND CHLOROFORM DETECTED IN GROUNDWATER.	PA : C SI : I RI : N FS : N RD : N
18	ACTIVE BURNING GROUND	Type: PRODUCTION AND LAB WASTE BURN RESIDUE AND BURIED METHYLENE CHLORIDE IMPREGNATED SAWDUST Qty: EST < 2500 CUBIC YARDS Permit: HW-50195 DRAFT PART B	Ground Water : 5.9 Surface Water:10.3 Air Quality : 0.0 Total Score : 6.8	34.5-ACRE AREA ACTIVE SINCE 1950'S INCL SITES #19-25. (18) 10'X 10'X 1' & SEVERAL 100'X 15'X 4' DEEP OPEN BURNING PITS AND METHYLENE CHLORIDE IMPREGNATED SAWDUST PILES & DISPOSAL PITS. METHYLENE CHLORIDE, TCE, CADMIUM, BARIUM, CHROMIUM, MERCURY AND LEAD DETECTED IN GW. SCORE BASED ON REMAINING BURIED SAWDUST PILES.	PA : C SI : I RI : N FS : N RD : N

012920

Date of Printing: 08/07/90
Last Update: 08/07/90

Property Number: 48315 Property Name: LONGHORN ARMY AMMUNITION PLANT

19	24X HOLDING AREA	Type: EXPLOSIVE WASTE,EXPLOSIVE CONTAMINATED WASTE, ASH AND SCRAP METAL Qty: EST < 60 CUBIC YARDS Permit: NONE	Ground Water : 2.7 Surface Water: 6.5 Air Quality : 0.0 Total Score : 4.1	75'X 100' ASPHALT PAD USED FOR SORTING MATERIAL TO BE BURNED AND ASH AND SCRAP METAL FROM BURNING AT OPEN BURNING PADS (SITE #23), CAGES (SITE #22) AND AIR CURTAIN DESTRUCTOR (SITE #21). NO CURB OR OTHER CONTAINMENT.	PA : C SI : N RI : N FS : N RD : N
20	25X WASHOUT PAD	Type: RESIDUES OF EXPLOSIVE WASTE DEACTIVATED WITH FUEL OIL AND EXPLOSIVE CONTAMINATED WASTE Qty: EST < 10 GALLONS Permit: NONE	Ground Water : Surface Water: Air Quality : Total Score :	SEMI-ENCLOSED METAL SHED OVER CONCRETE PAD WITH 6" HIGH CURB. 5-GALLON PAILS AND 30-GALLON DRUMS FROM EXPLOSIVE WASTE PADS (SITE #35) ARE WASHED DOWN. WASH-WATER DRAINS TO SUMP (SITE #34). SITE NOT SCORED BECAUSE WASTE INCLUDED IN SUMPS (SITE #34).	PA : C SI : N RI : N FS : N RD : N
21	AIR CURTAIN DESTRUCTOR	Type: WOOD, PAPER AND EXPLOSIVE CONTAMINATED INERT AND FLAMMABLE WASTE Qty: EST 100 TONS/YR PROCESSED Permit: TEXAS AIR CONTROL BOARD NO. R-6356	Ground Water : 3.6 Surface Water: 8.5 Air Quality : 0.0 Total Score : 5.3	REFRACTORY LINED BURNING CHAMBER IN-STALLED 1980 OPERATES IN BATCH FASHION. BURN RESIDUE IS REMOVED, SAMPLED, DRUM-MED AND SHIPPED TO BUILDING #49-W (SITE #15). RUNOFF FROM SITE IS COLLECTED IN ADJACENT SUMP. ASH IS NOT CONTAINED WITHIN AREA DRAINING TO SUMP.	PA : C SI : N RI : N FS : N RD : N

012921

Date of Printing: 08/07/90
Last Update: 08/07/90

Property Number: 48315 Property Name: LONGHORN ARMY AMMUNITION PLANT

22	OPEN BURNING CAGE	Type: EXPLOSIVE WASTES AND PERSHING ROCKET MOTORS Qty: EST 400 TONS/YR PROCESSED Permit: TEXAS AIR CONTROL BOARD NO. R-6356	Ground Water : 3.6 Surface Water: 8.5 Air Quality : 0.0 Total Score : 5.3	(3) 12'X 12'X 12' STEEL FRAMED CAGES INSTALLED 1984 WITH 1" GRATING ON SIDEWALLS. 4' CLAY LINED PAN OVER GRAVEL SURFACE WITH PLASTIC LINER. TOP OF CAGE IS 6" DEEP STEEL TANK FILLED WITH WATER. WASTES PLACED IN CAGES & IGNITED WITH SAFETY FUSE. SCORE BASED ON INSUFFICIENT CONTAINMENT OF WINDBLOWN ASH.	PA : C SI : N RI : N FS : N RD : N
23	OPEN BURNING PAN	Type: EXPLOSIVE WASTES Qty: EST 150 TONS/YR PROCESSED Permit: TEXAS AIR CONTROL BOARD NO. R-6356	Ground Water : 3.6 Surface Water: 8.5 Air Quality : 0.0 Total Score : 5.3	(2) 2'X 8'X 16' STEEL FRAMED BOXES INSTALLED 1984 WITH GALVANIZED STEEL LIDS. PANS ARE CLAY LINED AND SET ON GRAVEL PADS OVER PLASTIC LINER. STEEL SHEETS PLACED IN FRONT OF PAN TO CATCH ASHES. WASTES PLACED INSIDE PAN & IGNITED WITH SAFETY FUSE. SCORE BASED ON INSUFFICIENT CONTAINMENT OF WINDBLOWN ASH.	PA : C SI : N RI : N FS : N RD : N
24	FRMER UNLINED EVAPORATION POND	Type: HEAVY METALS, HALOGENATED SOLVENTS FROM SUMP WASTEWATER AND ROCKET MOTOR WASHOUT Qty: GROUNDWATER PLUME Permit: HW-50195 DRAFT PART B POST CLOSURE CARE	Ground Water : 6.1 Surface Water: 0.0 Air Quality : 0.0 Total Score : 3.5	FRMER 1.55-AC, 7 MILLION-GAL CAP LAGOON CERTIFIED CLEAN CLOSED 1985 BY TWC. WTR REMOVED & DISPOSED BY OFF-SITE DEEP WELL INJECTION. CONTAMINATED SOIL & SLUDGE DISPOSED IN OFF-SITE APPROVED HAZARDOUS WASTE LANDFILL. LAGOON FILLED, MOUNDED & CAPPED W/4' CLAY, 1'SAND & 1'SODDED TOPSOIL. GW CONTAM PLUME MONITORED QTRLY.	PA : C SI : I RI : N FS : N RD : N

012922

25	BUILDING #41-X	Type: EXPLOSIVE WASTES Qty: EST < 5000 POUNDS Permit: NONE	Ground Water : 1.3 Surface Water: 3.1 Air Quality : 0.0 Total Score : 1.9	8'X 10' STORAGE SHED ON CONCRETE PAD USED TO STORE EXPLOSIVES PRIOR TO INCINERATION IN OPEN BURNING CAGES OR PANS (SITE #22 & 23). NO CURBING OR OTHER CONTAINMENT.	PA : C SI : N RI : N FS : N RD : N
26	CONSTRUCTION MATERIALS LANDFL	Type: CLASS 3 DEMOLITION WASTE Qty: 350-400 CUBIC YARDS/MONTH Permit: NONE	Ground Water : 2.2 Surface Water: 2.8 Air Quality : 0.0 Total Score : 2.1	LANDFILL OPERATED BY TRENCH FILL METHOD FROM 1985 TO PRESENT. 400'X 800' FENCED AREA WITH APPROXIMATELY 400'X 100' AREA IN USE. TRENCHES ARE SIZED TO ACCOMMODATE ONE WEEK'S WASTE AND COVERED AT WEEK END.	PA : C SI : N RI : N FS : N RD : N
27	SOUTH TEST AREA	Type: PHOTOFLASH, BUTTON BOMB, ILLUMINATING DEVICE RESIDUE, BURIED LEAKING PRODUCTION ITEMS Qty: 0.5 ACRE Permit: NONE	Ground Water :33.4 Surface Water: 7.7 Air Quality : 0.0 Total Score :19.8	APPROXIMATELY 1/2 ACRE SITE OPERATED FROM 1942 TO 1953 FOR DEMILITARIZATION AND BURIAL OF MATERIALS. AREA IS CURRENTLY GRASSED OVER. EXPLOSIVES IN SOIL SAMPLES AND ORGANIC SOLVENT CONTAMINATION OF GROUNDWATER REPORTED.	PA : C SI : N RI : N FS : N RD : N

012923

USATHAMA Waste Site Report

Property Number: 48315   Property Name: LONGHORN ARMY AMMUNITION PLANT

Date of Printing: 08/07/90
Last Update: 08/07/90

28	MAGAZINE AREA	Type: MUNITIONS PRODUCTS Qty: 500000-POUND CAPACITY EA Permit: HW-50195 DRAFT PART B MAGAZINE 811-1	Ground Water : 7.7 Surface Water: 1.8 Air Quality : 0.0 Total Score : 4.5	APPROX 800-ACRE FENCED SITE INCL (58) 26'X 60'X 10' MAGAZINES WITH CONC FLRS & WALLS & (2) 150'X75'X 20' STEEL BLDGS W/ CONCRETE FLRS. UNSUITABLE PRODUCT LOTS DETERMINED BY TESTING OR SHELF LIFE ARE STORED AT MAGAZINE 811-1 PRIOR TO REMANUFACTURING OR BURNING AT OPEN BURNING CAGES OR PANS (SITE #22 AND 23).	PA : C SI : N RI : N FS : N RD : N
29	FORMER TNT PRODUCTION AREA	Type: TNT AND INDUSTRIAL WASTE FROM TNT MANUFACTURING Qty: 85 ACRES Permit: NONE	Ground Water :42.2 Surface Water: 9.7 Air Quality : 0.0 Total Score :25.0	APPROX 85-ACRE SITE OF FORMER SIX-LINE TNT PLANT OPERATED FROM 1943-1945. TNT REDWATER TRANSFERRED VIA TNT PIPELINE (SITE #30) TO FRMR TNT WASTE DISPSL PLNT (SITE #32). PLANT RAZED 1959. MATLS & EQUIPMNT WERE BURNED OR FLASHED AT THE OLD BURNING GROUNDS (SITE #17). EXPLSVS DETECTED IN SW, SOIL & SEDIMENT SAMPLES.	PA : C SI : I RI : N FS : N RD : N
30	TNT REDWATER PIPELINE	Type: TNT REDWATER Qty: POTENTIAL RESIDUAL Permit: NONE	Ground Water :29.4 Surface Water: 0.0 Air Quality : 0.0 Total Score :17.0	APPROX 4200' LONG WOODEN UNDERGROUND PIPELINE OF UNKNOWN DIAMETER ABANDONED IN PLACE IN 1946. PIPELINE WAS USED TO TRANSFER REDWATER FROM FORMER TNT PRODUCTION AREA (SITE #29) TO WOODEN TANK 6188 AND PUMPHOUSE 6188 THEN TO FORMER TNT WASTE DISPOSAL PLANT (SITE #32). PIPELINE WAS CLEAR-FLUSHED IN 1946.	PA : C SI : N RI : N FS : N RD : N

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31	BUILDING 707C	Type: PCB CONTAMINATED OIL Qty: NONE CURRENTLY GENERATED Permit: NONE	Ground Water : 0.0 Surface Water: 0.0 Air Quality : 0.0 Total Score : 0.0	30'X 150' WOODEN BUILDING WITH CONCRETE FLOOR WAS USED TO STORE TRANSFORMERS, DRUMS OF PCB CONTAMINATED OILS AND OTHER WASTE MATERIALS FROM 1980 TO 1986. CONTAINERS PLACED IN GALVANIZED STEEL TROUGHS PRIOR TO DISPOSAL VIA DRMO TEXARKANA. SCORE BASED ON CONTAINMENT OF POTENTIAL SPILL DURING PERIOD OF ACTIV.	PA : C SI : N RI : N FS : N RD : N
32	FORMER TNT WASTE DISPOSAL PLNT	Type: TNT REDWATER AND INDUSTRIAL WASTE FROM TNT PRODUCTION Qty: 2 ACRES Permit: NONE	Ground Water :31.2 Surface Water: 5.7 Air Quality : 0.0 Total Score :18.3	PLANT ON 2-ACRE SITE OPERATED 1943-1946 & RAZED IN 1959. TNT REDWATER TREATED IN STEEL & LEAKING WOODEN SETTLING, HOLDING, EQUALIZATION AND EVAPORATION TANKS & AN INCINERATION FACILITY. ASH DISPOSED IN OLD LANDFILL (SITE #16) OR SLURRIED W/CONDENSATE FROM PLANT & DISCHARGED BY DITCH TO GOOSE PRAIRIE BAYOU.	PA : C SI : I RI : N FS : N RD : N
33	BUILDING #701	Type: PCB CONTAMINATED MATERIAL FROM PCB SPILL CLEANUP Qty: POTENTIAL RESIDUAL Permit: NONE	Ground Water :11.6 Surface Water: 2.1 Air Quality : 0.0 Total Score : 6.8	APPROX 25'X 110' WOOD BUILDING WITH CONCRETE FLOOR USED FROM 1980 TO 1984 FOR STORAGE OF PCB CONTAMINATED MATERIAL (MOSTLY SOIL FROM SITE #56) IN 30 AND 55-GALLON DRUMS. MATERIAL DISPOSED VIA DRMO TEXARKANA. SCORE BASED ON PAST ACTIVITY.	PA : C SI : N RI : N FS : N RD : N

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34	SUMPS	Type: WASTEWATER CONTAINING HALOGENATED ORGANIC SOLVENTS, HEAVY METALS AND EXPLOSIVES Qty: 11000 GALLONS EA (MAX) Permit: NONE	Ground Water :36.7 Surface Water: 9.7 Air Quality : 0.0 Total Score :22.0	(124) CONC SUMPS LOCATED THROUGHOUT INSTALLATION OF 19 TO 11000-GALLON CAPACITIES. VACUUM TRUCK (SITE #2) TRANSFERS CONTENTS TO IWTP (SITE #4) ON SCHEDULED BASIS OR UPON DEMAND OF PRODUCTION FOREMAN. SOME SUMPS HAVE BEEN INACTIVATED BY CLEANING AND BACKFILLING WITH SOIL. OVERFLOW OF SUMPS REPORTED PRIOR 1976.	PA : C SI : N RI : N FS : N RD : N
35	EXPLOSIVE WASTE PAD	Type: EXPLOSIVE WASTE Qty: EST < 20 GALLONS EACH Permit: NONE	Ground Water : 0.0 Surface Water: 0.0 Air Quality : 0.0 Total Score : 0.0	(27) 4'X 8' CONC PADS WITH 6" CURBS AND METAL ROOFS LOCATED THROUGHOUT FAC. EXPLOSIVE WASTE DESENSITIZED W/DIESEL FUEL IN 5-GAL GALVANIZED METAL PAILS W/LIDS & PLASTIC BAG LINERS AND PLACED ON METAL RACK. PAILS TRANSF TO ACTIVE BURNING GROUND (SITE #18): SCORE BASED ON CONTAINMENT OF POTNL SPILL W/I CURBED AREA.	PA : C SI : N RI : N FS : N RD : N
36	PLANT 2	Type: HALOGENATED SOLVENTS AND HEAVY METALS Qty: EST < (100) 55-GAL DRUMS Permit: NONE	Ground Water :11.6 Surface Water: 1.8 Air Quality : 0.0 Total Score : 6.8	PLNT 2 IS MAIN SITE OF PYROTECHNIC OPER. CONC FLRS. NO CURBS AT DOORWAYS. WASTEWATER FROM WASHDOWN COLLECTED IN SUMPS (SITE #34) AND TRANSFERRED TO IWTP (SITE #4). EXPLOSIVE WASTES ARE DESENSITIZED W/DIESEL FUEL AND PLACED AT EXPLOSIVE WASTE PAD (SITE #35). SCORE BASED ON LIQUIDS STORED ON SITE IN 55-GAL DRUMS.	PA : C SI : N RI : N FS : N RD : N

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37	PLANT 3	Type: PROPELLANT, OXIDIZERS, HALOGENATED ORGANICS, CHROMIC ACID AND PAINT Qty: EST < (100) 55-GAL DRUMS Permit: NONE	Ground Water :11.6 Surface Water: 2.1 Air Quality : 0.0 Total Score : 6.8	PROD OF SIMULATOR AND ILLUMINATING MOTOR ASSEMBLIES. CONCRETE FLOORS. NO CURBS AT DOORWAYS. WASTEWATER IS COLLECTED IN SUMPS (SITE #34) AND TRANSFERRED TO IWTP (SITE #4). EXPLOSIVE WASTES ARE DESEN-SITIZED W/DIESEL FUEL & PLACED AT EX-PLOSIVE WASTE PAD (SITE #35). SCORE BASED ON LIQUIDS STORED IN 55-GAL DRUMS.	PA : C SI : N RI : N FS : N RD : N
38	Y AREA	Type: HALOGENATED SOLVENTS AND HEAVY METALS Qty: EST < (50) 55-GAL DRUMS Permit: NONE	Ground Water : 9.0 Surface Water: 3.5 Air Quality : 0.0 Total Score : 5.6	FRMR ROCKET MOTOR IGNITER FAC CURRENTLY PRODUCES HAND SIGNAL ASSEMBLIES. CONC FLRS. NO CURBS AT DOORWAYS. WW IS COL-LECTED IN SUMPS (SITE #34) & TRANSFERRED TO IWTP (SITE #4). EXPLOSIVE WASTES DESENSITIZED W/DIESEL AND PLACED AT EX-PLOSIVE WASTE PAD ($ITE #35). SCORE BASED ON LIQUIDS STORED IN 55-GAL DRUMS.	PA : C SI : N RI : N FS : N RD : N
39	FORMER ACID PLANT	Type: ACID Qty: UNKNOWN Permit: NONE	Ground Water : Surface Water: Air Quality : Total Score :	FORMER ACID PLANT OPERATED IN 1940'S IN SUPPORT OF FORMER TNT PRODUCTION AREA (SITE #29). PLANT RAZED 1959. SITE NOT SCORED BECAUSE NO OTHER INFORMATION AVAILABLE.	PA : C SI : N RI : N FS : N RD : N

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40	FORMER WASTE DISPOSAL FACILITY	Type: HEAVY METALS AND ORGANIC SOLVENTS IN WASTEWATER AND AMMONIUM PERCHLORATE Qty: NONE CURRENTLY GENERATED Permit: NONE	Ground Water :10.4 Surface Water: 7.4 Air Quality : 0.0 Total Score : 7.4	WASTEWATERS FROM SUMPS (SITE #34) AT PLANT 3 (SITE #37) & PLANT 2 (SITE #36) WERE DISCHARGED FROM 35000-GAL TANK TO GOOSE PRAIRIE BAYOU DURING PERIODS OF SUFFICIENT FLOW FROM 1955 TO EARLY 1970'S. WASHOUT OF AMMONIUM PERCHLORATE CONTAINERS PERFORMED ON SITE. SCORE BASED ON PAST ACTIVITY.	PA : C SI : N RI : N FS : N RD : N
41	PHOTOGRAPHIC-LABORATORY	Type: WASTE DEVELOPER AND FIXER Qty: EST < 50 GALLONS Permit: NONE	Ground Water :11.6 Surface Water: 1.8 Air Quality : 0.0 Total Score : 6.8	BUILDING #608 PROCESSES X-RAY FILM. CONCRETE FLOOR, NO FLOOR DRAIN & NO CURB AT DOOR. SPENT DEVELOPER DRUMMED & TRANSFERRED TO BUILDING #31-W (SITE #10). LARGEST CONTAINER IS 5 GALLONS.	PA : C SI : N RI : N FS : N RD : N
42	MAGAZINE AREA	Type: MUNITIONS PRODUCTS Qty: 500000-POUND CAPACITY EA Permit: NONE	Ground Water : 7.7 Surface Water: 1.8 Air Quality : 0.0 Total Score : 4.5	(3) MAGAZINES WITH CONCRETE FLOORS. NO CURBS AT DOORWAYS.	PA : C SI : N RI : N FS : N RD : N

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43	STATIC TEST AREA	Type: BURN RESIDUE FROM ROCKET MOTOR AND ILLUMINATING CANDLE TESTING Qty: UNKNOWN Permit: NONE	Ground Water :21.2 Surface Water:13.3 Air Quality : 0.0 Total Score :14.5	STATIC TEST AREA INCLUDES CANDLE TEST AREA. SITE FORMERLY USED FOR ROCKET MOTOR, RED PHOSPHORUS SMOKE WEDGE AND ILLUMINATING CANDLE TESTING. CURRENT ACTIVITY IS DEMILITARIZATION BY IGNITION OF PERSHING ROCKET MOTORS PERFORMED ON (2) TEST STANDS.	PA : C SI : N RI : N FS : N RD : N
44	GROUND SIGNAL TEST AREA	Type: BURN RESIDUE FROM MUNITION AND ILLUMINANT TESTING Qty: UNKNOWN Permit: NONE	Ground Water : 4.9 Surface Water: 6.5 Air Quality : 0.0 Total Score : 4.7	80-ACRE AREA FORMERLY USED FOR RED PHOSPHORUS SMOKE WEDGES, ILLUMINATING SHELLS AND MUNITIONS TESTING AND DEMILITARIZATION OF LEAKING WHITE PHOSPHORUS ITEMS. SITE CURRENTLY USED FOR ILLUMINANT TESTING AND DEMILITARIZATION OF PERSHING ROCKET MOTORS BY IGNITION ON (2) TEST STANDS.	PA : C SI : N RI : N FS : N RD : N
45	SEPTIC TANK	Type: SEWAGE AND SANITARY WASTEWATER Qty: EST < 5000 GALS EA (MAX) Permit: NPDES TX 0000035	Ground Water : 4.8 Surface Water: 0.0 Air Quality : 0.0 Total Score : 2.8	(10) SEPTIC TANKS SERVE OUTLYING AREAS WITH OUTFALLS TO DITCHES. EFFLUENT IS CHLORINATED PRIOR TO DISCHARGE. CONTENTS OF SEPTIC TANKS PUMPED OUT AND TRANSFERRED TO SEWAGE TREATMENT PLANT (SITE #9) AS NEEDED. SCORE BASED ON LARGEST TANK.	PA : C SI : N RI : N FS : N RD : N

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46	VEHICLE WASH RACK & O/W SEP.	Type: OIL AND GREASE FROM VEHICLE WASHWATER Qty: 10 VEHICLES/WEEK Permit: NPDES TX 0000035	Ground Water : Surface Water: Air Quality : Total Score :	CONCRETE WASH RACK SLOPES TO DRAIN CONNECTED TO OIL/WATER SEPARATOR. SITE NOT SCORED DUE TO PERMITTED DISCHARGE TO DRAINAGE DITCH. EXTENT OF SEPARATOR MAINTENANCE UNKNOWN.	PA : C SI : N RI : N FS : N RD : N
47	RUBBLE BURIAL SITE	Type: BARBED WIRE, FENCE POSTS AND OTHER INERT MATERIAL Qty: EST. < 10 CUBIC YARDS Permit: NONE	Ground Water : 3.9 Surface Water: 0.9 Air Quality : 0.0 Total Score : 2.3	SITE USED FOR BURIAL OF INERT MATERIALS THAT WERE CLEARED FROM PROPERTY AFTER ACQUISITION.	PA : C SI : N RI : N FS : N RD : N
48	MAINTENANCE COMPLEX	Type: OIL, GREASE, ANTIFREEZE AND SOLVENTS Qty: EST (50) 55-GAL DRUMS Permit: NONE	Ground Water : 8.0 Surface Water: 1.5 Air Quality : 0.0 Total Score : 4.7	CONCRETE FLOORS. NO CURBS AT DOORWAYS. FLOOR DRAINS CONNECTED TO SANITARY SEWER. LUBRICANTS STORED ON DRUM RACKS OUTSIDE OVER GRAVEL SURFACE. NO CURBING OR OTHER CONTAINMENT. WASTE OIL AND SOLVENTS TRANSFERRED TO BUILDING #31-W (SITE #10). SCORE BASED ON EXTERIOR DRUM STORAGE.	PA : C SI : N RI : N FS : N RD : N

49	STORAGE BUILDING	Type: PESTICIDES AND HERBICIDES Qty: 400 GAL LIQ,1000 LB SOLID Permit: NONE	Ground Water :11.6 Surface Water: 2.1 Air Quality : 0.0 Total Score : 6.8	MATERIAL STORED IN BUILDING #725. CONCRETE FLOOR SLOPES TO FLOOR DRAIN DISCHARGING TO SUMP (SITE #34). NO CURB AT DOOR. CONTENTS OF SUMP PUMPED OUT AS REQUIRED AND TRANSFERRED TO PILOT WASTEWATER TREATMENT SYSTEM (SITE #4) VIA VACUUM TRUCK (SITE #2). LARGEST CONTAINER IS 55-GALLON DRUM.	PA : C SI : N RI : N FS : N RD : N
50	FORMER STORAGE BUILDING	Type: PESTICIDES AND HERBICIDES Qty: POTENTIAL RESIDUAL Permit: NONE	Ground Water :11.6 Surface Water: 2.1 Air Quality : 0.0 Total Score : 6.8	PESTICIDES FORMERLY STORED IN BUILDINGS #411 AND 714. CONCRETE FLOOR. NO CURB AT DOOR. SCORE BASED ON PAST ACTIVITY.	PA : C SI : N RI : N FS : N RD : N
51	WATER TREATMENT PLANT	Type: ALUM AND LIME SLUDGE, FILTER BACKWASH EFFLUENT Qty: 216000 GALLONS EACH Permit: NONE	Ground Water :11.0 Surface Water: 1.0 Air Quality : 0.0 Total Score : 6.4	WATER TREATMENT PLANT PUMPS SLUDGE AND FILTER BACKWASH EFFLUENT TO (2) 216000-GAL CAPACITY POLYETHYLENE LINED EARTHEN PONDS. DRIED SLUDGE IS REMOVED & SPREAD ON FACILITY GROUNDS AS FERTILIZER. SCORE BASED ON LARGEST VOLUME. [redacted] IN SLUDGE.	PA : C SI : N RI : N FS : N RD : N

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52	BUILDING #43X	Type: EXPLOSIVES Qty: EST. < 5000 POUNDS Permit:	Ground Water : 0.9 Surface Water: 2.0 Air Quality : 0.0 Total Score : 1.3	SHED USED FOR STORAGE OF MATERIALS PRIOR TO INCINERATION. CONCRETE FLOOR. NO CURB OR OTHER CONTAINMENT.	PA : C SI : N RI : N FS : N RD : N
53	BURIAL PITS	Type: REJECT MATERIAL OF UNKNOWN COMPOSITON Qty: UNKNOWN Permit: NONE	Ground Water : Surface Water: Air Quality : Total Score :	PITS USED IN LATE 1950'S FOR DETONATION AND BURIAL OF REJECT MATERIAL FROM PLANT 3 (SITE #37). NO OTHER INFORMATION AVAILABLE, SO SITE NOT SCORED.	PA : C SI : N RI : N FS : N RD : N
54	TRANSFORMER STORAGE	Type: TRANSFORMER OIL Qty: EST < 150 GALLONS EACH Permit: NONE	Ground Water : 8.0 Surface Water: 1.2 Air Quality : 0.0 Total Score : 4.7	APPROXIMATELY (20) OUT-OF-SERVICE NON-PCB TRANSFORMERS STORED ON PALLETS OUTSIDE. NO CURB OR OTHER CONTAINMENT. SCORE APPLIED TO EACH UNIT.	PA : C SI : N RI : N FS : N RD : N

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55	BUILDING #209	Type: CHEMICALS, PAINT AND SOLVENTS Qty: EST < (100) 55-GAL DRUMS Permit: NONE	Ground Water : Surface Water: Air Quality : Total Score :	BUILDING #209 IS A CHEMICAL STORAGE AREA WITH CONCRETE FLOOR. FLOOR DRAINS CONNECTED TO SUMPS (SITE #34). MATERIALS STORED IN CURBED AREA. LARGEST CONTAINER IS 55-GALLON DRUM. SITE NOT SCORED. POTENTIAL SPILL WOULD DRAIN TO SUMPS (SITE #34).	PA : C SI : N RI : N FS : N RD : N
56	SPILLS	Type: ACID, LIQUID POLYSULFIDE POLYMER, TNT, OIL AND PCB OIL Qty: 2900 GALLONS Permit: NONE	Ground Water : Surface Water: Air Quality : Total Score :	NUMEROUS SPILLS, FIRES AND EXPLOSIONS OF VARIED MAGNITUDES HAVE OCCURRED THROUGH OUT INSTALLATION FROM 1940'S TO PRESENT. LARGEST REPORTED WAS 2900 GALS POLYSULFIDE POLYMER IN EARLY 1960'S. SPILLS NOT SCORED BECAUSE NO INFORMATION ON CLEANUP ACTIVITIES AVAILABLE.	PA : C SI : N RI : N FS : N RD : N
57	TRANSFORMERS	Type: PCBS IN TRANSFORMER OIL Qty: 220 GALLONS EACH (MAX) Permit: NONE	Ground Water :11.6 Surface Water: 2.3 Air Quality : 0.0 Total Score : 6.9	(201) ARMY-OWNED TRANSFORMERS IN SERVICE THROUGHOUT FAC. CAPACITIES RANGE FROM 3 TO 220 GALS EA. (7) TRANSFORMERS TESTED > 500 PPM. (194) UNITS TESTED BETWEEN 50 PPM AND 500 PPM. TRANSFORMERS TO BE REPLACED ARE TRANSFERRED TO BLDG #31-W (SITE #10) PRIOR TO DISPOSAL VIA DRMO TEXARKANA. SCORE APPLIED TO EACH UNIT.	PA : C SI : N RI : N FS : N RD : N

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58	ABOVE GROUND STORAGE TANK	Type: #2 FUEL OIL, KEROSENE AND ASPHALT Qty: 500000 GALLONS (MAXIMUM) Permit: NONE	Ground Water :11.6 Surface Water: 0.0 Air Quality : 0.0 Total Score : 6.7	(1) 500000-GALLON, (2) 10000-GALLON, (3) 1500-GALLON AND (1) 750-GALLON TANKS WITH EARTHEN DIKES SUFFICIENT TO CONTAIN POTENTIAL SPILL. MOTOR FUEL TANKS REGI-STERED WITH STATE. SCORE BASED ON LRGST TANK AND APPLIED TO EACH TANK.	PA : C SI : N RI : N FS : N RD : N.
59	MOBILE STORAGE TANKS	Type: #2 DIESEL AND GASOLINE Qty: 600 GALLONS EACH Permit: NONE	Ground Water : 8.0 Surface Water: 1.5 Air Quality : 0.0 Total Score : 4.7	(2) 600-GALLON CAPACITY COMPARTMENTS ON TANK TRUCK. VEHICLE USED THROUGHOUT FACILITY AND PARKED ON ASPHALT SURFACE AT MAINTENANCE COMPLEX IN FULL CONDI-TION. NO CURB OR OTHER CONTAINMENT. SCORE APPLIED TO EACH TANK	PA : C SI : N RI : N FS : N RD : N
60	UNDERGROUND STORAGE TANKS	Type: GASOLINE Qty: 17000 GALLONS (MAXIMUM) Permit: NONE	Ground Water : 9.2 Surface Water: 0.0 Air Quality : 0.0 Total Score : 5.3	(1) 17000-GALLON, (1) 12000-GALLON, (1) 10000-GALLON, (2) 1000-GALLON AND (1) 280-GALLON TANKS. LEAK TESTED 1989. NO LEAKS DETECTED.	PA : C SI : N RI : N FS : N RD : N

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LONGHORN ARMY AMMUNITION PLANT

Marshall, Texas 75671-1059

FINAL

GROUNDWATER BACKGROUND CONCENTRATION REPORT

PREPARED BY:
U.S. ARMY CORPS OF ENGINEERS
TULSA DISTRICT

JUNE 1995

US Army Corps
of Engineers
Tulsa District

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LONGHORN ARMY AMMUNITION PLANT

FINAL SUMMARY REPORT

GROUNDWATER BACKGROUND CONCENTRATION REPORT

Prepared For:
Longhorn Army Ammunition Plant
Karnack, Texas

Prepared By:
U.S. Army Corps of Engineers
Tulsa District

JUNE 1995

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LIST OF ACRONYMS

CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
DNB	Dinitrobenzene (an explosive)
DNT	Dinitrotoluene (an explosive)
FFA	Federal Facility Agreement
HMX	Cyclotetramethylenetetranitramine (an explosive)
INF	Intermediate Range Nuclear Force
kg	Kilogram
LHAAP	Longhorn Army Ammunition Plant
mg	Milligram
NPL	National Priority List
RCRA	Resource Conservation and Recovery Act
RDX	Cyclotrimethylenetrinitramine (an explosive)
SQL	Sample Quantitation Limit
TNT	Trinitrotoluene
μg	Microgram
UTL	Upper Tolerance Limit
USACE	United States Army Corps of Engineers
WSC	Caddo Lake Water Supply Corporation

1.0 INTRODUCTION

The purpose of this report is to document background concentrations of naturally occurring metals and anions in the groundwater at the Longhorn Army Ammunition Plant (LHAAP) at Karnack, Texas.

A release of organic contaminants is relatively easy to determine since most organic constituents are not naturally occurring and thus any amount detected can be assumed to be associated with the manufacturing process. Metals and anions (e.g. nitrates/nitrites, sulfates, etc), however, are naturally occurring and therefore may mask the influences of manufacturing processes. For this reason, it is necessary to establish the range of background (or uncontaminated) concentration of selected metals that can naturally occur. Because it is known that concentrations of naturally occurring metals and anions in the groundwater can be highly variable in the Wilcox formation at LHAAP, the findings reported in this document are intended to be used as a relative basis for comparison, or as a "guideline", to determine the impact that reported or suspected site activities and/or production operations may have had on the groundwater in an area or areas under investigation at LHAAP. As additional information is obtained through the course of investigations, background concentrations may be reevaluated, therefore, allowing for the proper identification and delineation of any release of metals and/or anions associated with reported or suspected site activities and/or production operations.

Two U.S. Environmental Protection Agency (EPA) documents, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities: Interim Final Guidance*, April 1989; and *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities: Draft Addendum to Interim Final Guidance*, July 1989, were used as guidance for the statistical evaluation of the analytical results.

1.1 LHAAP Location

LHAAP is located in Harrison County on the northwest shore of Caddo Lake in northeast Texas adjacent to the communities of Karnack and Uncertain. It is approximately 14 miles northeast of Marshall, Texas and 40 miles west of Shreveport, Louisiana (Figure 1-1).

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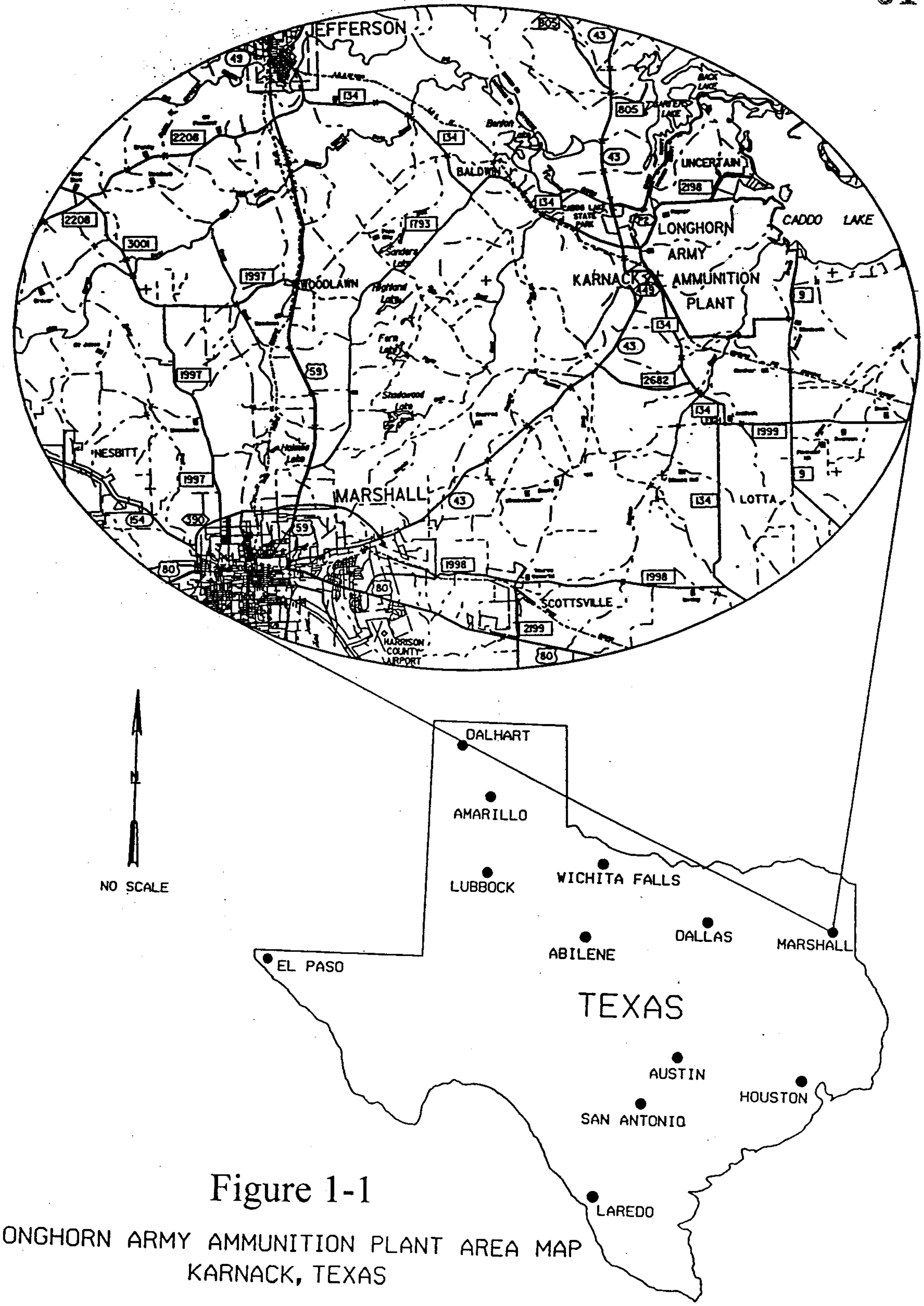


Figure 1-1

LONGHORN ARMY AMMUNITION PLANT AREA MAP
KARNACK, TEXAS

1.2 LHAAP History

The Longhorn Army Ammunition Plant was established in October 1942. The 8,483-acre facility is currently a government-owned, contractor-operated facility (Longhorn Division of Thiokol Corporation) under the jurisdiction of the U.S. Army Armaments, Munitions and Chemical Command. The Plant's primary mission upon it's establishment was the production of 2,4,6-trinitrotoluene (2,4,6-TNT) flake. Production of 2,4,6-TNT continued until August 1945. The Plant was on standby status from August 1945 to February 1952. During the period from February 1952 to the present, the Plant operations have included the production of photoflash bombs, simulators, hand signals, tracers, rocket motors and pyrotechnic and illuminating ammunition. Additionally, the installation has also been responsible for the static firing and elimination of Pershing I and II rocket motors in compliance with the Intermediate-Range Nuclear Force (INF) Treaty in effect between the United States and the former U.S.S.R.

LHAAP was placed on the National Priority List (NPL) on August 30, 1990. After being listed on the NPL, LHAAP, the U.S. Environmental Agency and the Texas Water Commission (since reorganized and named the Texas Natural Resource Conservation Commission) entered into Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Section 120 Agreement for remedial activities at LHAAP. The CERCLA Section 120 Agreement, referred to as the Federal Facility Agreement (FFA), became effective December 30, 1991.

1.3 Geological/Hydrogeological Setting

The LHAAP is located on the northwest flank of the Sabine Uplift, which is an area where broad doming of strata causes exposure of the Midway and Wilcox Groups in a nearly circular area about 80 miles in diameter.

The Wilcox Group is the bedrock unit beneath more than 99% of LHAAP. The Wilcox consists of interbedded sandstones, siltstones, and shales that are variously light gray, red, brown, and/or tan. Sands were deposited mainly in alluvial channels that flowed to the south and south-southwest across eastern Harrison County.

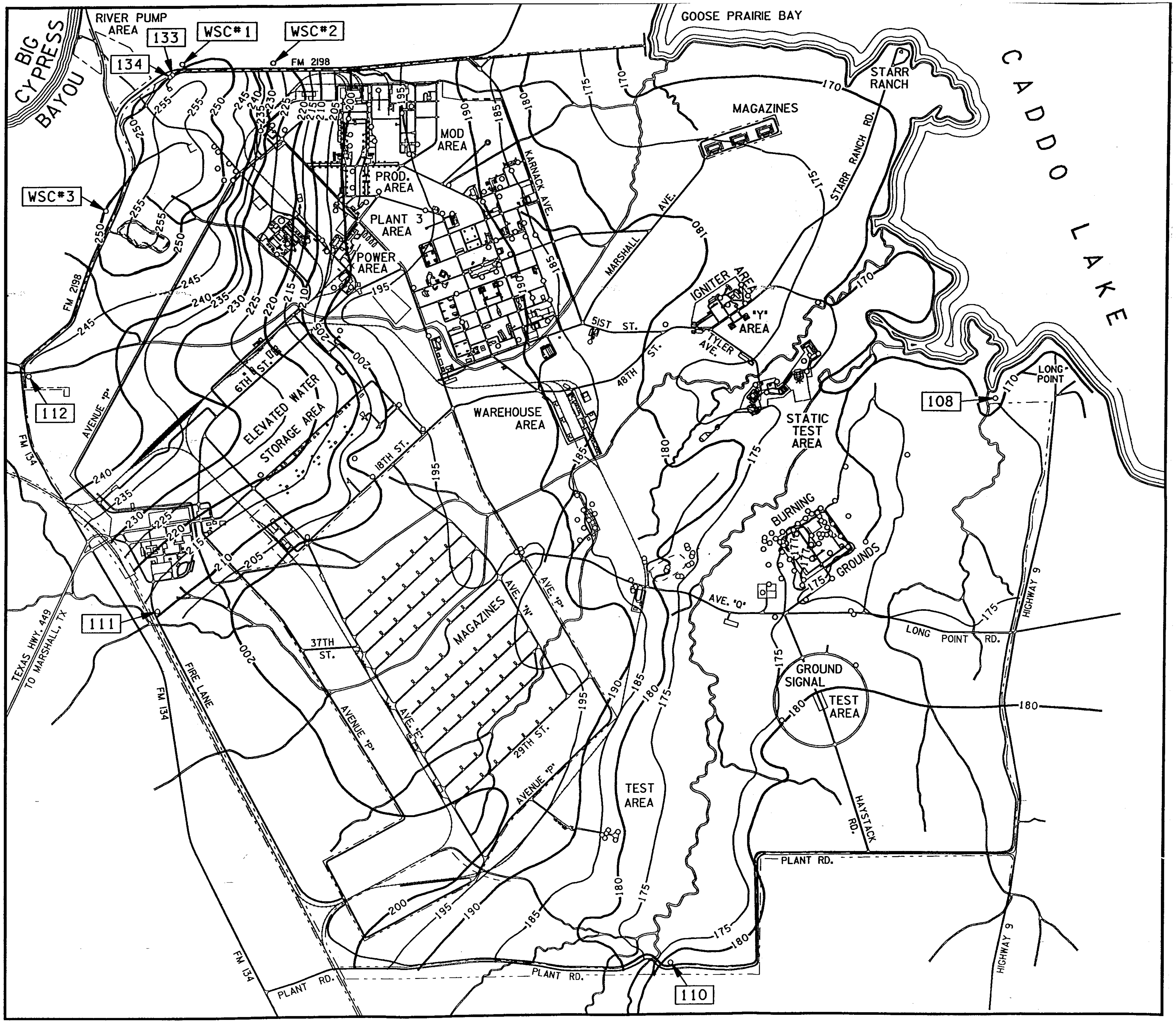
The Wilcox Group is the basal unit of the Cypress aquifer. Strata comprising the Cypress aquifer in Harrison County are, in ascending order, the Wilcox Group, Carrizo Sand, Reklaw Formation, and Queen City Sand. At LHAAP, the Cypress aquifer consists only of the Wilcox Group, except for a small area in the northwest where the lower part of the overlying Reklaw Formation is present. Therefore, the terms Cypress aquifer and Wilcox Group are essentially synonymous at LHAAP.

The Reklaw Formation overlies the Wilcox Group in the northwest corner of LHAAP. It typically consists of sand and interbedded clay and caps the top of the hills at elevations in excess of about 300 feet above sea level.

Soil types on LHAAP are generally fine-grained clays, silts and sands that occur either as a breakdown product from the weathering of Wilcox materials or as alluvial deposits associated with the drainage systems crossing the installation. Residual soils typically consist of silty or sandy clay occasionally interbedded with sand strata. Alluvial soils occur as interbedded fine-grained clays, silts and sands.

Depth to the uppermost water level at LHAAP ranges from about 1 foot to 70 feet with the depth to water being typically 12-16 feet. Groundwater flows from a condition of higher potential energy to lower potential energy, i.e. water flows downhill. The groundwater elevation map shown in Figure 2-1 illustrates the potential energy of the water table across the plant. As shown on that map, the groundwater flow direction on the plant is generally toward Caddo Lake.

Offsetting LHAAP to the north and northwest are three public water supply wells operated by the Caddo Lake Water Supply Corporation. These three wells are identified as Caddo Lake



N

MAP SYMBOL LEGEND

108 ∘ LONGHORN AAP PERIMETER MONITORING WELL, and WELL IDENTIFICATION (108, e.g.)

WSC#2 ∘ CADDO LAKE WATER SUPPLY CORPORATION WATER-WELL, and WELL IDENTIFICATION (#2, e.g.)

∘ OTHER MONITORING WELLS

U.S. ARMY CORPS OF ENGINEERS
TULSA DISTRICT

LONGHORN ARMY AMMUNITION PLANT
KARNACK, TEXAS

GROUNDWATER ELEVATION MAP 9-10 NOV, 1994

DATUM: MEAN SEA LEVEL

Date: DEC 1994 | Figure: 2-1

SCALE IN FEET
2000' 1000' 0 2000' 4000'

RBP / LHMCM2-1.DGN / 20DEC94

Water Supply Corporation Wells 1, 2 and 3 and are labeled as WSC #1, #2 and #3 on Figure 2-1. These wells are between 250 and 310 feet in depth with screened intervals being at least 170 feet below ground level. The screened intervals are within the lowermost portion of the Wilcox Group (Cypress aquifer). As shown on Figure 2-1, all three wells are hydraulically upgradient to LHAAP. Water quality data from these wells was not used in the comparison of LHAAP data, due to the uncertainty of sampling and analysis procedures. Due to the remote location of these wells from Plant operations, water removal from these wells is not expected to affect groundwater flow on Longhorn AAP.

2.0 SAMPLING METHODOLOGY

2.1 Background Sampling Locations

As stated earlier, the objective of the background sampling evaluation is to determine the naturally existing concentrations of chemicals in the groundwater. This was done by using a combination of new and existing monitoring wells. To avoid the possibility of encountering groundwater contaminated by operations at LHAAP and yet test waters that are as close as possible to the sites under investigation, the preferred locations for monitoring wells are on the border of the Plant and hydraulically upgradient from all Plant operations. By sampling monitoring wells which are hydraulically upgradient from plant operations, sampling can be performed with a reasonable degree of confidence that the analytical results will be representative of groundwaters which have not been impacted by operations at the Plant. Additionally, the presence of contaminants from off of the Plant may be detected and indicate conditions that may impact investigations performed at LHAAP.

In 1982, during the period of May through June under the auspices of the Installation Restoration Program of the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), Thiokol Corporation/Longhorn Division (Thiokol) contracted with Environmental Protection Systems, Inc. to conduct a contamination survey of LHAAP. Thirty-two monitoring wells were installed during this survey. Four of those wells were installed as boundary wells and were located on the south, west, northwest and northeast boundaries of LHAAP. Those wells are numbered 108, 110, 111 and 112 and are shown on Figure 2-1. Due to its hydraulically downgradient relation to Plant operations, the analyses from well 108 were not considered. Wells 110, 111 and 112 are 20, 21 and 22 feet deep, respectively. All three wells are completed with 15 foot screens at the bottom of the well. The boring logs and completion logs for these three wells (110, 111, and 112) are included in Appendix A.

To provide an additional background groundwater sampling location at the perimeter of the

Plant, two monitoring wells were clustered at the northwest corner of the Plant. Those wells are identified as 133 and 134 on Figure 2-1. The intent of the clustered wells is to provide a sampling point in the uppermost water bearing zone and to test a lower water bearing zone at the same location.

Well 133 was drilled to a total depth of 90 feet and was screened from 64.5' to 84.5' below ground level. Well 134 was drilled at a location approximately 10' to the southwest of well 133. It was drilled to a total depth of 151' and plugged back to a depth of 109.5' with the interval from 89' to 109' screened. Boring logs, completion logs, geophysical logs and a narrative of drilling operations for these two wells are provided in Appendix A.

2.1.1 Previous Background Well Sampling

Since 1992, Thiokol has taken samples quarterly from the four wells, 108, 110, 111, and 112, as well as many other of the wells installed during the summer of 1982. For the purposes of this background concentration study, the analytical results from wells 110, 111 and 112 were considered.

Pursuant to State and Resource Conservation and Recovery Act (RCRA) regulatory requirement, groundwater from each well is tested for the analytes listed in Table 2-1. The results for these analyses are summarized in Appendix B. No validation of this data was performed. Any suspected errors in concentration were brought to the attention of Thiokol lab personnel with the values being confirmed or corrected. A review of the volatile organics results for these wells showed no volatile organics in the samples except for the analyses of well 110 (6/30/92 and 9/11/92) and well 112 (6/29/92 and 9/11/92). Those particular detections are listed in the Table 2-2 below.

As shown in the Table 2-2 below, results of initial sampling of well 110 in June 1992 detected 1,1,1-trichloroethane (2600 μg/L), 1,1-dichloroethene (290 μg/L), and RDX (68 μg/L). In the following quarterly sampling round, performed in September 1992, only 1,1,1-trichloroethane (11 µg/L) was detected in groundwater samples. In this sampling round, 1,1,1-trichloroethane was also found in the trip blank at a concentration of 11 µg/L. Confirmatory sampling, performed one month later in October 1992, did not detect any contaminants. Since then, using consistent field sampling protocol, no organic or explosive contaminants have been detected in groundwater from this well in the last two years (eight sampling rounds) of quarterly sampling. This highly transitory nature of apparent contamination may be due to a sampling error, such as the introduction of contaminants from poorly decontaminated sampling equipment, or a short lived affect of a contaminant spill at the nearby road. Due to this apparent contamination and in particular the high concentration of 1,1,1-trichloroethane, the analytical results for the 30 June 1992 sampling round for well 110 will not be included in this statistical evaluation.

Table 2-1. Parameters Tested in Groundwater Sampled by Thiokol.

Metals		**Water Quality Parameters**	**Explosives**
Aluminum	Magnesium	pH	HMX
Arsenic	Manganese	Specific Conductance	RDX
Barium	Mercury	**Anions**	Tetryl
Cadmium	Selenium	Nitrate/Nitrite	TNT
Chromium	Silver	Sulfates	2,4-DNT
Iron	Sodium	Chlorides	2,6-DNT
Lead		**Volatile Organics**	

From the initial chemical analysis of groundwater sampled June 1992, the only contaminant detected was the explosive compound RDX (77 µg/L). In the following quarterly sampling round, performed in September 1992, RDX was again detected at a concentration of 70 µg/L. Confirmatory sampling, performed one month later in October 1992, did not detect any high explosives. Since then, using consistent field sampling protocol, no organic or explosive contaminants have been detected in groundwater from this well in the last two years (eight sampling rounds) of quarterly sampling. Because of the relatively low detections of only RDX, these detections were assumed to be anomalous results due to sampling or analytical errors. Data from well 112 was not excluded from the statistical analysis.

Table 2-2. Organic Contaminants Detected in Perimeter Wells.

Well	Sampling Date	Contaminant	Detected Concentration (μg/L)	Detection Limit (μg/L)
110	6/30/92	1,1-Dichloroethene 1,1,1-Trichloroethane RDX	290 2600 68	5.0 5.0 30
110	9/11/92	1,1,1-Trichloroethane	11	5.0
112	6/29/92	RDX	77	30
112	9/11/92	RDX	70	30

2.1.2 Groundwater Sampling 1994 Field Operations

Following the installation of monitoring wells 133 and 134, all five perimeter monitoring wells (110, 111, 112, 133 and 134) were sampled by the Corps of Engineers in late September and early October 1994 (September/October 1994) according to accepted monitor well sampling protocol. Water samples taken for analysis were unfiltered. These five wells were sampled for the parameters listed below in Table 2-3 and results summarized in Appendix B. Wells 110, 111, 112, and 133 detected no organic or explosive compounds. However, two explosive compounds consisting of 1,3-DNB (3.74 μg/L) and tetryl (5.47 μg/L) were detected in groundwater from well 134. In response to the trace level of high explosives detected in well 134, all perimeter wells, including well 108, underwent confirmatory resampling in January 1995. Well 108, a downgradient perimeter well and not part of this background study, was sampled at the request of the EPA Region VI representative.

The results of the January 1995 sampling round indicated that no high explosives or volatile organics were detected in field water samples from wells 108, 110, 111, 112, or 134. In addition, QA/QC samples for well 134 did not indicate any high explosives, suggesting that the previous results were anomalies. The only contaminant detected in well 134 was Bis (2-ethylhexyl) phthalate at a concentration of 15.4 µg/L (10 µg/L detection limit) in the QC sample. Because they are common lab contaminants, the detection of phthalates at low concentration is not unusual.

For the January 1995 sampling, the field sample for well 133 reported the detection of 27 µg/L of 4-methylphenol (10 µg/L detection limit) and 1.16 µg/L of RDX (0.60 µg/L detection), compared to all non-detects in the November 1994 sampling round. At the request of the U.S. Army Corps of Engineers (USACOE), the analyzing laboratory (NDRC Laboratories) reviewed the analysis of this sample and could find no apparent problems with their procedures. Analysis of the QA sample for well 133 indicated no explosives or organics. Due to differences between the field and QA samples, the presence of high explosive and organic compounds in the field water sample is not considered valid.

Quality assurance and quality control samples were taken for both sampling rounds (September/October 1994 and January 1995). The data was evaluated by a USCOE chemist. The reports relating those evaluation are included in Appendix B and conclude that the data is acceptable for usage in this report.

It should be noted that the detection limit reported for each analyte is adjusted for any variation in analysis such as dilution or use of smaller aliquot size. Although not specifically labeled as such, that detection limit is equivalent to the sample quantitation limit (SQL) as described in Reference 1.

Table 2-3 - Parameters Tested in Samples Taken During Summer 1994 Field Operations

Metals Tested, Chemical Abbreviations and EPA Method Used					
Aluminum (Al)	6010	Cobalt (Co)	6010	Nickel (Ni)	6010
Antimony (Sb)	6010	Copper (Cu)	6010	Potassium (K)	7610
Arsenic (As)	7060	Iron (Fe)	6010	Selenium (Se)	7740
Barium (Ba)	6010	Lead (Pb)	7421	Silver (Ag)	6010
Cadmium (Cd)	6010	Magnesium (Mg)	6010	Strontium (Sr)	6010
Calcium (Ca)	6010	Manganese (Mn)	6010	Thallium (Tl)	6010
Chromium (Cr)	6010	Mercury (Hg)	7470	Zinc (Zn)	6010
Other Chemical Analyses and EPA Method					
Explosives	8330	Volatile Organics	8240	Semivolatile Organics	8270
Nitrate/Nitrite/Sulfate/ Chloride	300.0				

3.0 METHODOLOGY FOR CALCULATING BACKGROUND CONCENTRATIONS

3.1 Rationale for Calculating LHAAP Background Values

As described in Reference 2 (*EPA document*, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities: Interim Final Guidance*, April 1989), the method of calculating background levels is dependent upon the application of the background values. To serve as a reference for the use in risk assessment and future investigations, background values representing the mean and range of concentrations will be calculated.

3.1.1 Data Distribution

Because any statistical model of actual data is an approximation of reality, all statistical tests and procedures require certain assumptions to be made for the methods to be used correctly and for proper interpretation of the results. For instance, the assumption is made that the sample set represents the total population. In order to derive the "real" upper and lower limits, mean, and other statistical parameter of a population from limited data, the distributional assumption is a key factor.

Some general rules were established for determining which type of data distribution to assume prior to calculating the various background concentrations. First, using the Shapiro-Wilk test described in Section 3.1.2, the distribution was tested for normality and lognormality. As suggested for testing groundwater in Reference 3 (pages 2,3), lognormality was assumed to be the default distribution. If the assumption of lognormality was not rejected, further statistical tests were performed on the log-transformed data. If the lognormal distribution was rejected by the Shapiro-Wilk test, the normality of the untransformed data was tested. For data sets which failed the normality test for untransformed and log transformed data, the UTL was determined using the non-parametric method and the UCL was evaluated separately. The rationale for each constituent analysis is discussed in Appendix D. Probability plots were constructed on the untransformed and log transformed data to verify the Shapiro-Wilk test.

3.1.2 Shapiro-Wilk Test of Normality

There are several ways to test for normality (Reference 2). In Reference 3 (*U.S. Environmental Protection Agency, Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities. Addendum to Interim Final Guidance, Washington, D.C., July 1992*), it was stated that the Shapiro-Wilk Test of Normality was considered to be one of the best tests of normality available. A Shapiro-Wilk Statistic was calculated, and probability values <0.05 were used to indicate non-normality/non-lognormality. The calculated Shapiro-Wilk probability values are presented in Tables 3-1. The computer software package, Statistica™ by StatSoft was used to produce the Shapiro-Wilk statistic, probability plots, and correlation graphs.

3.1.3 Outliers

The values for each constituent (water quality parameters, anions, and metals) data set were evaluated for the existence of outliers. Outliers are observations that appear to deviate markedly from other members of the sample in which it occurs. An outlier test is performed to determine whether there is statistical evidence that an observation that appears extreme does not fit the distribution of the rest of the data an outlier test. A method for determining outlier test criterion, T_n, was presented in ASTM paper E178-94 and Reference 2 (page 8-11 to 8-14). ASTM paper E178-94 is provided in Appendix C. This test criterion is used to identify suspected values as outliers. Where a value was identified to be an outlying value, it was deleted from the data set prior to statistical calculations. After removing an identified outlier, the outlier test was repeated to test for the next largest detected value. Identified outlier values were left in the probability plot in Appendix E to illustrate the variation of the value from the remainder of the data set. Outlying values are identified in the Table 4-1. For analytical data which had been collected since 1992 from wells 110, 111 and 112, plots were constructed to evaluate the data for seasonal variations and relations between wells. Those plots were also useful to identify fluctuations that may indicate lab or sampling errors or confirm outlier values.

Table 3-1. Results of Shapiro-Wilk Test for Normality

		Shapiro-Wilk p Statistic		Distribution
	Number of Detections	Untransformed p	Log Transformed p	N=Normal L=Lognormal; NN=Neither Normal or Lognormal
CHLORIDE	35	0.0003	0.0000	NN
NO2_NO3	21	0.0035	0.0055	NN
PH	37	0.0000	0.0000	NN
SPCOND	38	0.0012	0.0000	NN
SULFATE	35	0.0008	0.0001	NN
ALUMINUM	34	0.0023	0.0901	L
ANTIMONY	5	--------	--------	♦
ARSENIC	12	0.14232	0.26278	L
BARIUM	37	0.0000	0.2409	L
CADMIUM	19	0.05920	0.17038	L
CALCIUM	10	0.2698	0.0589	L
CHROMIUM	24	0.0001	0.0442	NN
COBALT	4	--------	--------	♦
COPPER	4	--------	--------	♦
IRON	37	0.0000	0.1735	L
LEAD	23	0.0158	0.0000	L
MAGNESIUM	38	0.0051	0.0000	L
MANGANESE	38	0.0136	0.0001	L
MERCURY	3	--------	--------	♦
NICKEL	10	0.2129	0.1893	L
POTASSIUM	5	0.9074	0.7379	L
SELENIUM	3	--------	--------	♦
SILVER	8	0.2872	0.6038	L
SODIUM	33	0.0035	0.0002	NN
STRONTIUM	10	0.1760	0.0423	N
THALLIUM	0	--------	--------	♦
ZINC	6	0.1364	0.5891	L

♦ Indicates analytes with insufficient quantified values to calculate distribution probability values.

3.1.4 Handling of Values Less than Detection Limit

For analytical results that were not quantified below the detection limit, six possible methods to calculate the background values were recommended by EPA representatives (EPA memorandum, 1994). The method used to calculate the background values was determined by the percentage of results which were below the detection limit with no quantified values reported. The six recommended methods are listed in Table 3-2 and discussed in more detail in the following text.

When less than or equal to fifteen percent (15%) of analytical results are reported below the SQL, values of one half of the SQL may be substituted for the non-quantified values below the detection limit.

When more than fifteen percent (15%) but less than fifty percent (50%) of analytical results are reported below the SQL and all SQL's for the non-detect results are equal, Cohen's method may be used to calculate an adjusted mean and standard deviation. The only requirements for the use of this technique are that data are normally distributed and that the detection limit (SQL) is always the same. Cohen's method is explained on page 8-7 of Reference 2 and the calculations for using Cohen's method are included in Appendix F. For the evaluation of constituents in groundwater for this study, Cohen's method was not required.

Table 3-2. Methods Used for the Treatment of Non-Detects

Percent Sample Non-Detects (ND)	Method for the Treatment of Non-Detects
0% ND	No Method Needed
≥1% ND and ≤15% ND	Simple Substitution (half SQL)
>15% ND and <50% ND (all SQLs equal)	Cohen's Method
>15% ND and <50% ND (differing SQLs)	Log Probability Regression Method
≥50% ND and <100% ND	Log Probability Regression Method
100% ND	Assign Value ≤SQL

When more than fifteen percent (15%) but less than fifty percent (50%) of analytical results are reported as being below the SQL but the SQLs for the non-detect results are not the same, the log-probability regression method may be used to estimate the population mean and standard deviation. In this method the values for the non-detect results are assumed to follow the zero-to-detection limit portion of a lognormal distribution fit to the uncensored observations by least squares regression. The log-probability regression method is discussed in detail in Reference 5 and summarized in Appendix C.

When more than fifty percent (50%) but less than one hundred percent (100%) of the analytical results are reported as being below the SQL, the log-probability regression method may be used to estimate the population mean and standard deviation. Since the log-probability regression method is based on fitting a line through the available points, this method was not used if less than four quantified points were present in a data set. In those circumstances the background value was based on the SQL. Four metals in this study-antimony, mercury, selenium, and thallium-represent this category.

When no quantified values are reported for an analyte, the background value based on the SQL may be used. Antimony and thallium had no analytical results above the SQL.

3.1.5 Background Calculations

Two calculations for the determination of background values were used. The two values calculated were the upper tolerance limit (UTL) and upper confidence limit (UCL). A tolerance interval describes the range of values that is expected to contain a certain percentage of the population with a certain degree of confidence. For background values presented in this report, the 95% UTL with 95% coverage was calculated.

The UCL of a mean is defined as a value that, when calculated repeatedly for randomly drawn subsets of facility data, equals or exceeds the true mean a desired percentage of the time. The 95% UCL was calculated and provided in this report. The explanation for calculating UTLs and UCLs is presented in Appendix C.

4.0 CALCULATIONS OF BACKGROUND CONCENTRATIONS

4.1 Summary Statistics for Parameters and Chemicals Sampled

Table 4-1 summarizes the analytical data collected for the determination of the facility-wide background values and concentrations. The calculated upper tolerance limit (UTL) and upper confidence limit (UCL) are included. A description of the contents of each column is provided below.

No. of Samples: This column contains the total number of analyses reported for the applicable analyte or parameter.

No. of Values Above Detection Limit: This column contains the total number of analyses that were reported to be above the detection limit (SQL for analyses performed September/October 1994 and January 1995) for the given analysis. This number includes all analyses above the detection limit including any possible outliers.

No. of Outliers [Outlier Value(s)]: The number of outliers that were identified using the calculation described in Section 3.1.3 are listed in this column. Additionally, the values of the identified outliers are listed in parentheses.

Mean and Standard Deviation: These descriptive statistics were calculated upon the analytical values reported above the applicable detection limit after the outliers had been excluded. Since the results which were less than the detection limit(s) are not considered in these calculations resulting in means which are biased toward the values greater than or equal to the detection limits, these values should not necessarily be considered to represent the sample population.

Maximum Detected Value: Provided in this column are the maximum values that reported for each analyte or parameter. Values that were designated to be outliers were omitted prior to determining the maximum detected value. Therefore, these values are the maximum values that are included in the calculation of the listed means and standard deviations.

Minimum Detected Value: The smallest reported value for each analyte or parameter is listed in this column. These values will be equal to or larger than the detection limit or SQL used for the particular analysis. Analytical results may have been reported as less than the applicable detection limit or SQL. Those results are assumed to be less than the detection limit or SQL but were not quantified.

Detection Limit(s): The detection limit or limits used for the analyses evaluated for this report are listed in this column to provide a reference of the limits (SQLs) applied to these evaluations.

MCL or *SMCL*: As a reference to compare the calculated background value, the maximum contaminant level or the secondary maximum contaminant level is provided for each constituents with values published in *Drinking Water Regulations and Health Advisories, Office of Water, U.S. Environmental Protection Agency, November 1994.* Underlined values are MCL values.

UTL: Provided in this column is the calculated Upper Tolerance Limit (UTL). The discussion of the rationale of the calculation of the UTL for each constituent is provided in Appendix D.

UCL: Provided in this column is the calculated Upper Confidence Limit (UTL). The discussion of the rationale of the calculation of the UCL for each constituent is provided in Appendix D.

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Table 4-1 Groundwater Summary Statistics and Background Values*

	No. of Samples	No. of Values Above Detection Limit	No. of Outliers [Outlier Value(s)]	Mean	Standard Deviation	Maximum Detected Value	Minimum Detected Value	Detection Limit(s)	MCL or *SMCL*	UTL	UCL
Water Quality Parameters											
pH	38	38	1 (10.8)	6.3	0.373	6.8	5.2		*6.5-8.5*	6.4	6.8
Specific Conductivity (umhos/cm)	38	38	0	3185	2673	8140	47		—	8140	3917
Anions (mg/L)											
Chloride	35	35	0	710	470	1416	10.2	1	*250*	1416	845
Nitrate/ nitrite	36	22	3 (1.7, 2.4, 10.5)	0.076	0.0462	0.18	0.03	0.01/0.5	10	0.27	0.06
Sulfate	35	33	0	893	825	3475	3	1.0 / 2.0	*250*	3475	1079
Metals (mg/L)											
Aluminum	38	38	4 (32.1, 47.0, 81.0, 90.0)	4.59	3.7	13.4	0.3	0.1/ 0.01/ 0.005	*0.05-0.2*	28.4	8.0
Antimony	5	0	0	---	---	---	---	0.1	0.006	0.05	0.1
Arsenic	38	12	0	0.011	0.005	0.022	0.0036	0.05/ 0.002/ 0.005	0.05	0.03	0.01
Barium	38	38	0	0.44	0.5	1.99	0.02	0.01/ 0.02	2.0	3.3	0.9
Cadmium	38	19	0	0.026	0.014	0.055	0.01	0.01	0.005	0.09	0.018
Calcium	10	10	0	139	116	320	6.8	0.1	---	478	207
Chromium	38	25	1 (0.29)	0.035	0.029	0.11	0.01	0.02/ 0.05	0.1	0.16	0.03
Cobalt	10	4	0	0.029	0.018	0.053	0.012	0.01/ 0.05	---	0.39	0.03
Copper	10	4	0	0.026	0.013	0.043	0.012	0.01	*1.0*	0.20	0.02
Iron	38	38	1 (160)	20.35	20.1	68	0.85	0.05/ 0.1	*0.3*	148	39

Table 4-1 Groundwater Summary Statistics and Background Values*

	No. of Samples	No. of Values Above Detection Limit	No. of Outliers [Outlier Value(s)]	Mean	Standard Deviation	Maximum Detected Value	Minimum Detected Value	Detection Limit(s)	MCL or *SMCL*	UTL	UCL
Lead	38	23	0	0.155	0.091	0.3	0.003	0.002/ 0.005/ 0.1	---	2.31	0.29
Magnesium	38	38	0	124.5	88.7	277	5.07	0.01/ 0.5	---	277	149
Manganese	38	38	0	3.9	2.78	11.8	0.21	0.01/ 0.02	*0.05*	11.8	4.6
Mercury	38	3	0	0.001	0	0.001	0.01	0.001	0.002	0.001	0.0005
Nickel	10	9	0	0.039	0.017	0.06	0.02	0.01	0.1	0.09	0.05
Potassium	5	5	1 (92.7)	4.45	0.968	5.5	3.2	0.2	---	9.4	5.6
Selenium	38	3	0	0.08	0.06	0.14	0.02	0.005/ 0.02	0.05	0.005	0.003
Silver	38	8	0	0.017	0.007	0.03	0.01	0.005/ 0.01	*0.1*	0.03	0.01
Sodium	33	33	0	563	455	1470	13.6	1.0	---	1470	697
Strontium	10	10	0	3.1	2.37	6.15	0.18	0.01	---	10.0	4.5
Thallium	10	0	0	---	---	---	---	0.1	0.002	0.1	0.05
Zinc	10	6	0	0.09	0.08	0.23	0.025	0.015/ 0.05	*5*	1.62	0.14

* Data to be used as guidelines to determine possible impact.

5.0 CONCLUSION

The Wilcox Group is a highly variable strata consisting of interbedded sandstones, siltstones, and shales. Background calculations for two water quality parameters, three anions, and twenty-two metals were calculated for groundwater, despite the naturally occurring variability of the groundwater quality across LHAAP. This data is intended to be used as a guideline to determine the impact that reported or suspected site activities and/or production operations may have had on groundwater in an area or areas under investigations at LHAAP. As additional information is obtained through the course of investigations, background concentrations may be reevaluated, therefore, allowing for the proper identification and delineation of any release of metals and/or anions associated with reported or suspected site activities and or production operations.

6.0 REFERENCES

1 U.S. Environmental Protection Agency, Guidance for Data Useability in Risk Assessment (Part A), Publication 9285.7-09A, Washington, D.C., July 1992.

2 U.S. Environmental Protection Agency, Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities. Interim Final Guidance, Washington, D.C., April 1989.

3 U.S. Environmental Protection Agency, Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities. Addendum to Interim Final Guidance, Washington, D.C., July 1992.

4 Gilbert, R.O., Statistical Methods For Environmental Pollution Monitoring, Van Nostrand Reinhold Company, New York, 1987.

5 Gilliom, R.J. and D.R. Helsel, Estimation Parameters for Censored Trace Level Water Quality Data 1. Estimation Techniques, Water Resources Research, February 1986, **22**:2, pp 135-146.

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Appendix A

Boring Logs and Completion Logs for Wells 110, 111 and 112.

Boring Logs, Completion Logs, Geophysical Logs and Drilling Narrative for Wells 133 and 134.

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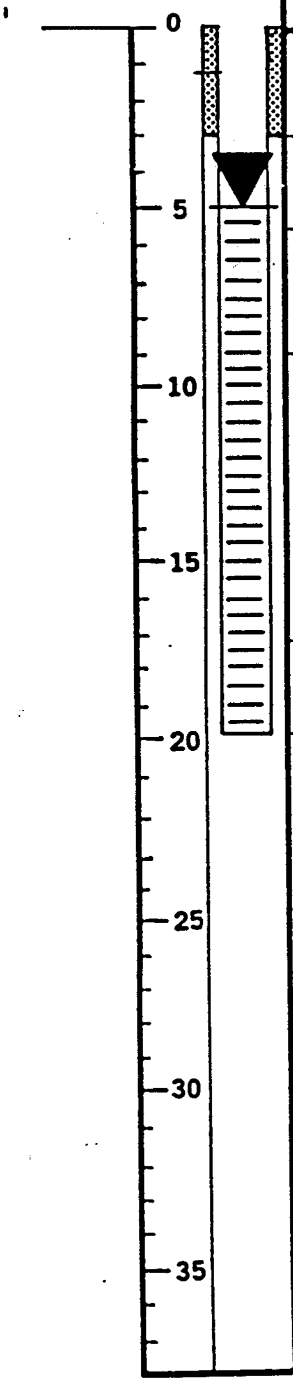


VISUAL U/S	BLOW COUNT*	MATERIAL CLASSIFICATION	% FINES	AQUIFER PERMEABILITY
SC	5/6 6/8	Clayey sand Yellowish brown	15	
SM		Slightly clayey 60% fine sand silty sand	40	
SM	1/3 4/7	Silty sand Grey mottled w/yellowish brown	30	
SM	9/9 9/9 11/9 5/5	Silty sand Grey mottled w/brownish yellow	20	
SM+CL	9/14 32/26	Silty sand & clay layers Grey to very dark grey		

*BLOWS PER 6 INCH USING 18, 24, or 36 SPLITSPOON

VERTICAL SCALE 1" = 5.0'

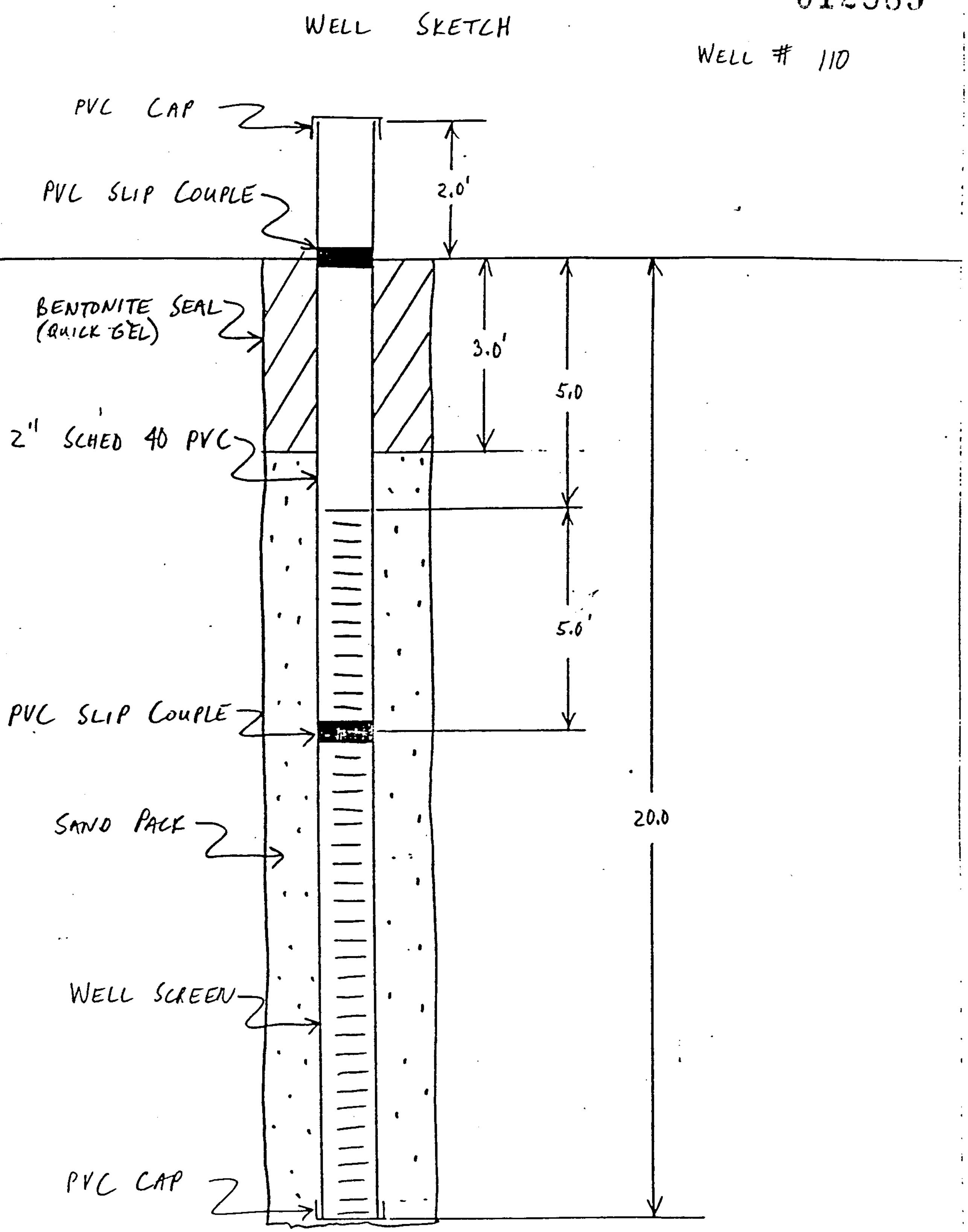
WELL 110 DATE DRILLED 7/1/82
STUDY AREA Southern Boundary
ELEVATION TOP OF STEEL CASING = 189.22 ft
ELEVATION TOP OF PVC RISER = 188.38 ft
ELEVATION OF GROUND SURFACE = 186.32 ft

SOURCE: ENVIRONMENTAL PROTECTION SYSTEMS, INC. - 198:

CONTAMINATION SURVEY
LONGHORN ARMY AMMUNITION PLANT
MARSHALL, TEXAS

U. S. ARMY TOXIC AND HAZARDOUS MATERIALS AGENCY
ABERDEEN PROVING GROUND, MARYLAND

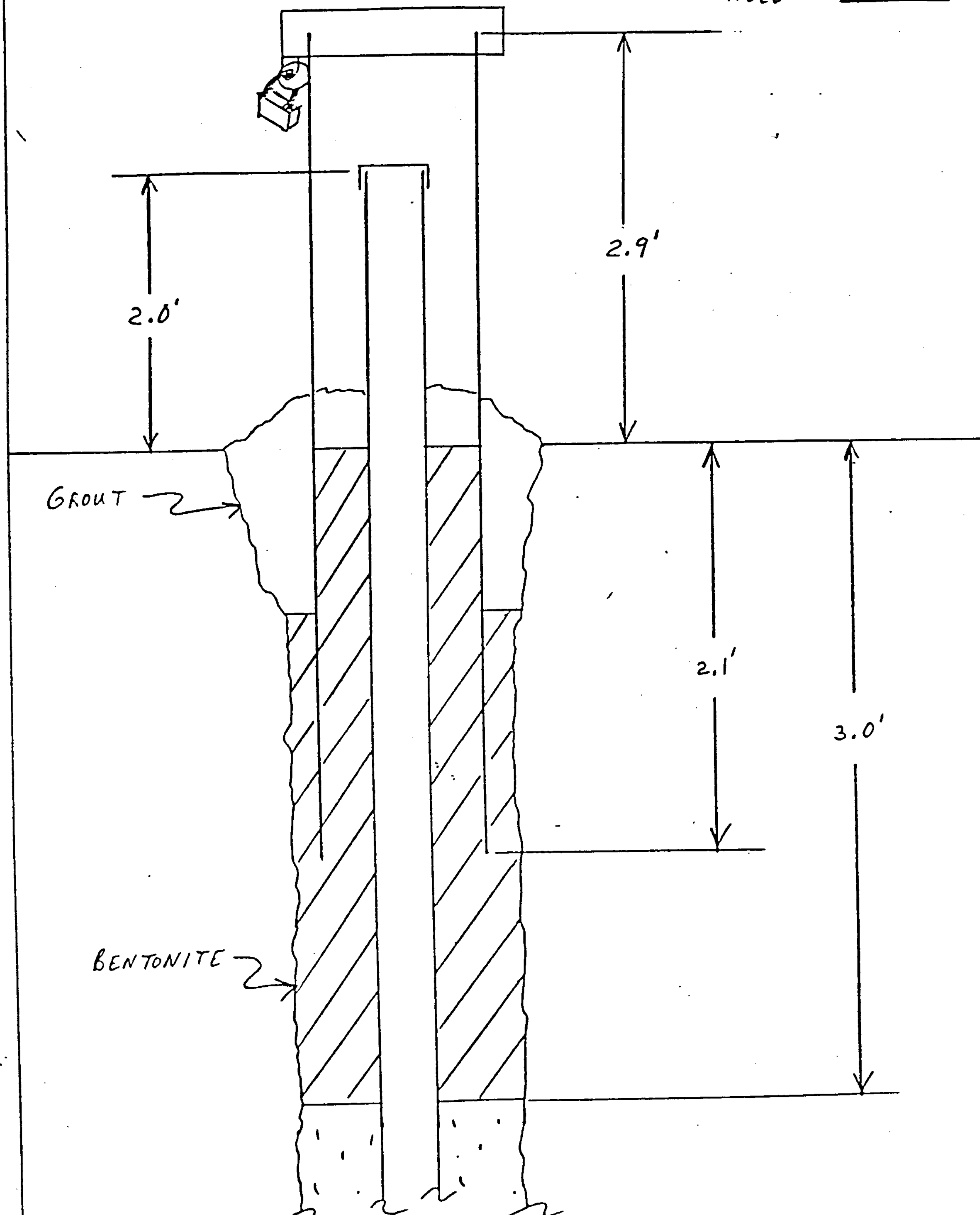
012965

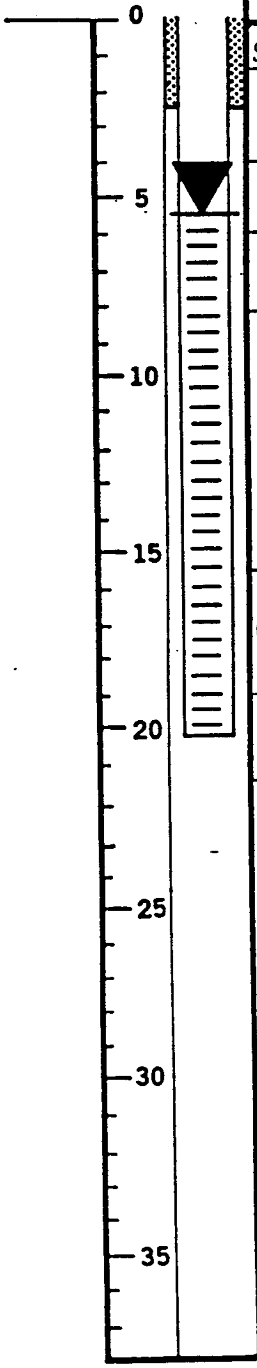

WELL SKETCH
WELL # 110
PVC CAP
PVC SLIP COUPLE
2.0'
BENTONITE SEAL (QUICK GEL)
3.0'
5.0
2" SCHED 40 PVC
5.0'
PVC SLIP COUPLE
20.0
SAND PACK
WELL SCREEN
PVC CAP

012966

PROTECTIVE CASING DETAIL

WELL # 110





VISUAL U/S	BLOW COUNT*	MATERIAL CLASSIFICATION	% FINES	AQUIFER PERMEABILITY
SM-SP	2/3 7/9	Silty sand *	10	
SM		Slightly clayey silty sand Brown	30	
ML	1/1 3/1	Sandy silt 35% fine sand Dark greyish brown		
SM		Silty sand Lt. grey mottled w/yellowish brown	15	
CL	4/6 9/11	Sandy clay 35% fine sand Pale brown mottled w/brownish yellow		
CL+SM	6/14 15/22	Thinly bedded clay & silty sand Greyish brown & yellowish brown 50% silty sand		
CL	15/19 /30	Slightly sandy silty clay Very dark grey 5% fine sand		

* Mottled pale brown & yellowish brown

*BLOWS PER 6 INCH USING 18, 24 or 36 SPLITSPOON

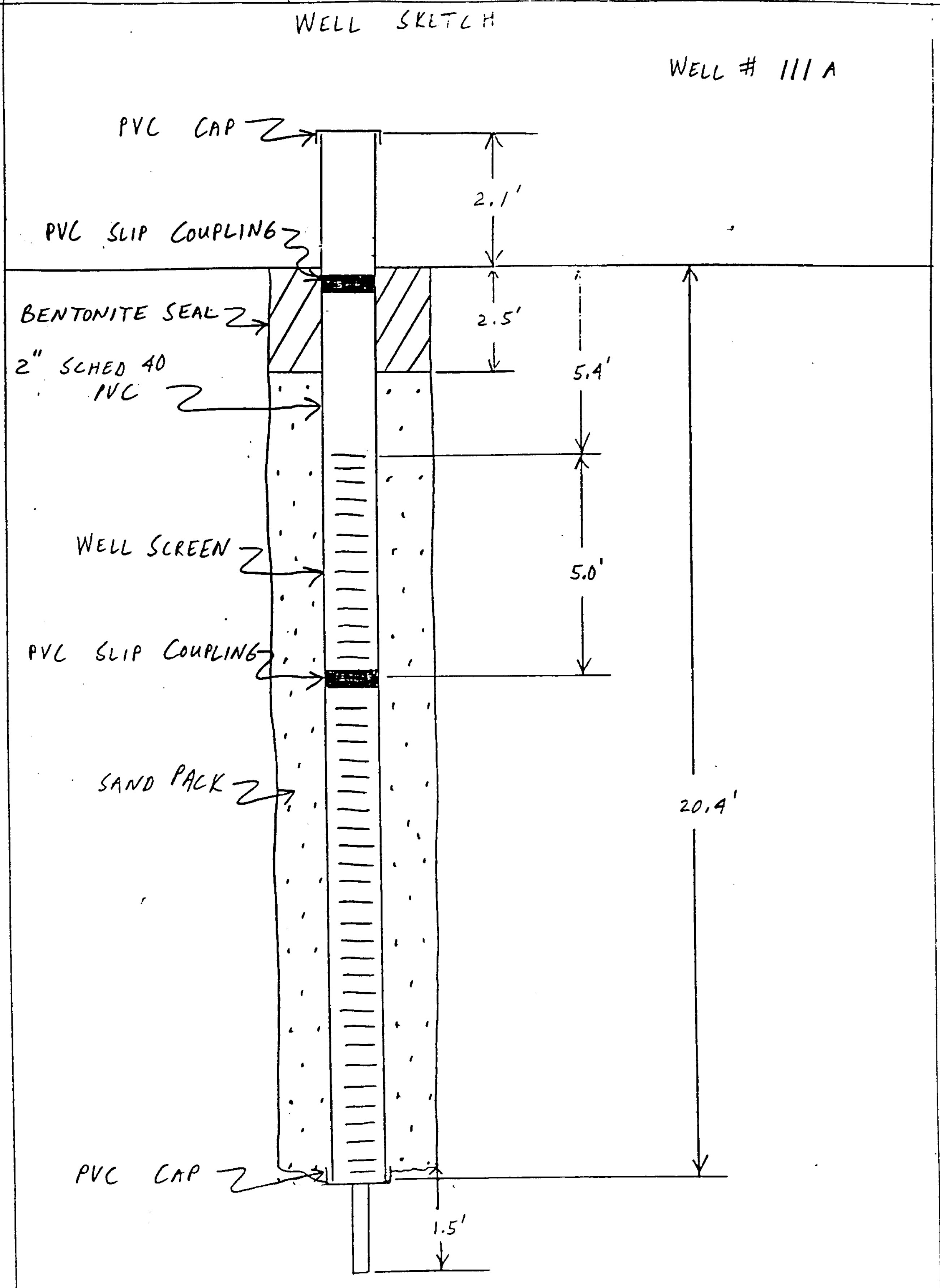
VERTICAL SCALE 1" = 5.0'

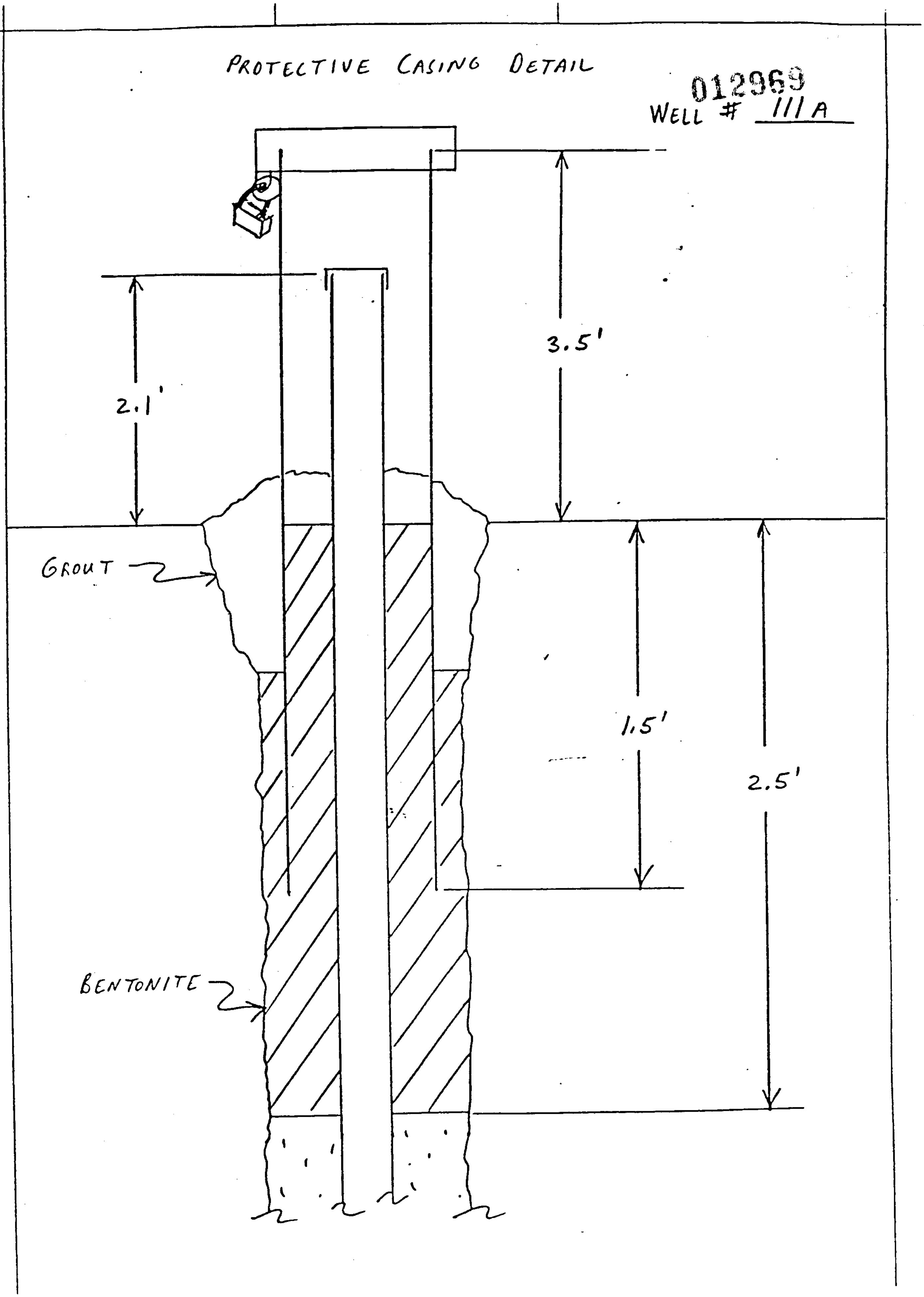
WELL 111 DATE DRILLED 7/11/82
STUDY AREA Southwestern Boundary
ELEVATION TOP OF STEEL CASING = 221.50 ft
ELEVATION TOP OF PVC RISER = 220.13 ft
ELEVATION OF GROUND SURFACE = 218.00 ft

SOURCE: ENVIRONMENTAL PROTECTION SYSTEMS, INC. - 1983

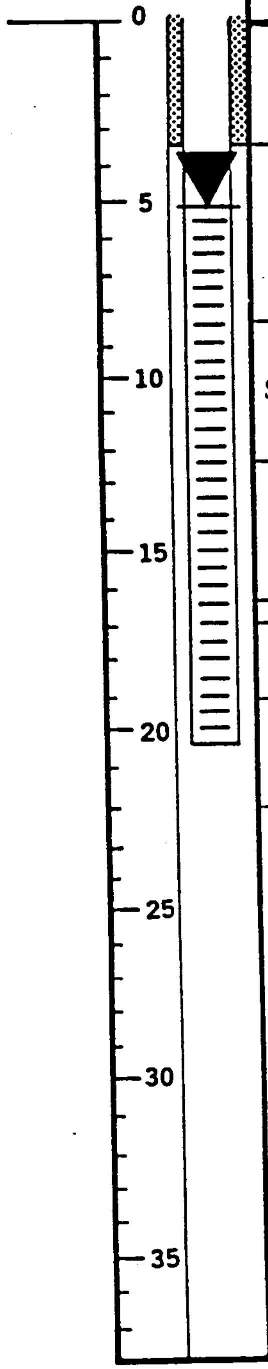
CONTAMINATION SURVEY
LONGHORN ARMY AMMUNITION PLANT
MARSHALL, TEXAS

U. S. ARMY TOXIC AND HAZARDOUS MATERIALS AGENCY
ABERDEEN PROVING GROUND, MARYLAND


WELL SKETCH
WELL # 111 A
PVC CAP
2.1'
PVC SLIP COUPLING
BENTONITE SEAL
2.5'
5.4'
2" SCHED 40 PVC
WELL SCREEN
5.0'
PVC SLIP COUPLING
SAND PACK
20.4'
PVC CAP
1.5'


PROTECTIVE CASING DETAIL
012969
WELL # 111A
3.5'
2.1'
GROUT
1.5'
2.5'
BENTONITE

012870



VISUAL U/S	BLOW COUNT*	MATERIAL CLASSIFICATION	% FINES	AQUIFER PERMEA-BILITY
SM	7/8 /9	Silty sand Pale brown & yellowish brown	15	
SM	1/1 1/1	Silty sand Brown	15	
SC+CL	4/7 10/12	Sandy clay & slightly clayey sand Grey mottled w/yellowish brown *		
CL	5/8	Slighlty sandy clay 5% fine sand Light yellowish brown mottled w/brownish yellow		
SM	11/11	Silty sand seam		
CL		Slightly sandy clay Light yellowish brown mottled w/brownish yellow		
CL-ML + SM	7/12 15/20	Thinly bedded silty sand and silty clay Light grey to brown		
		* 55% clayey sand		

*BLOWS PER 6 INCH USING 18, 24, or 36 SPLITSPOON

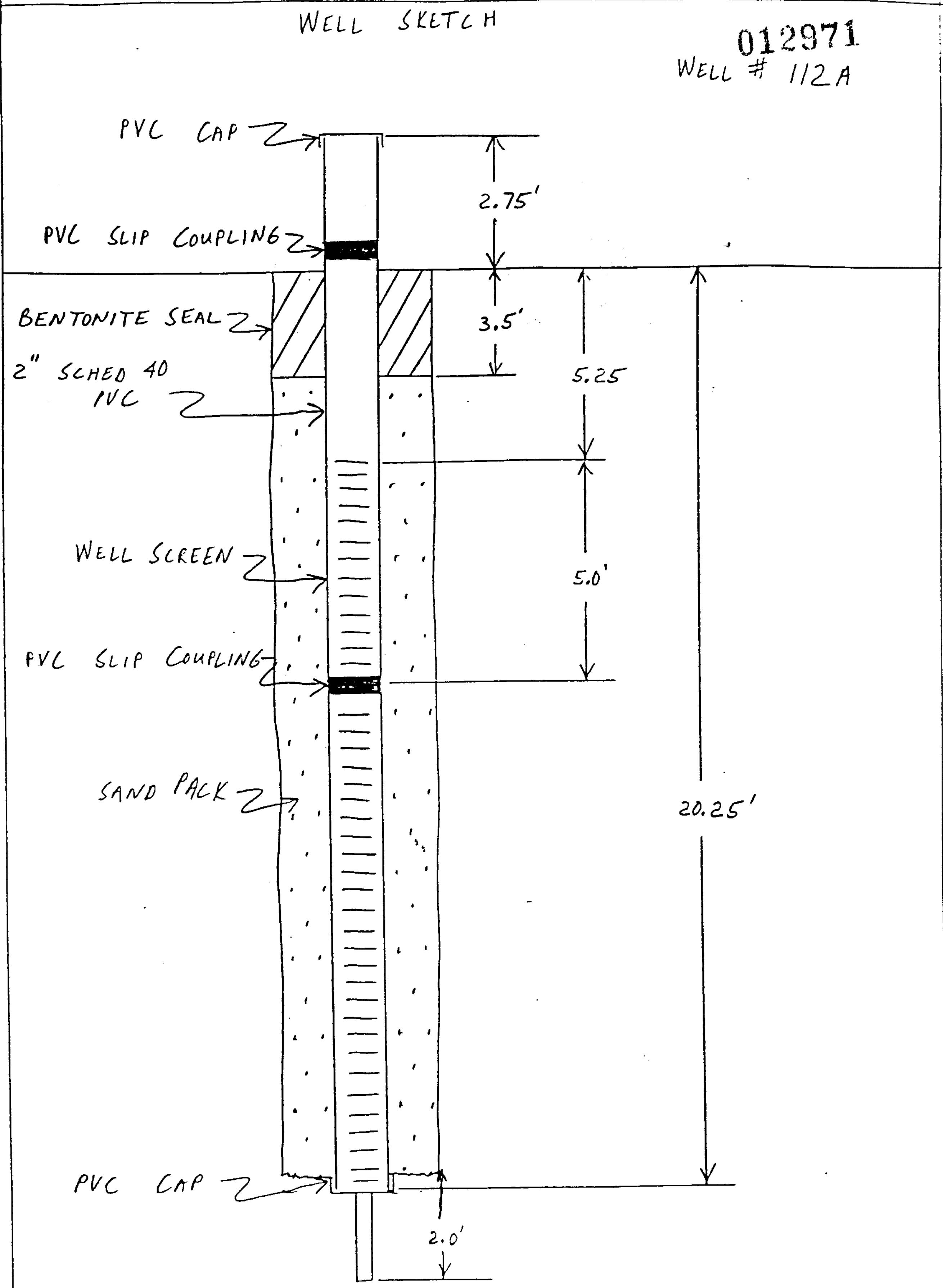
VERTICAL SCALE 1" = 5.0'

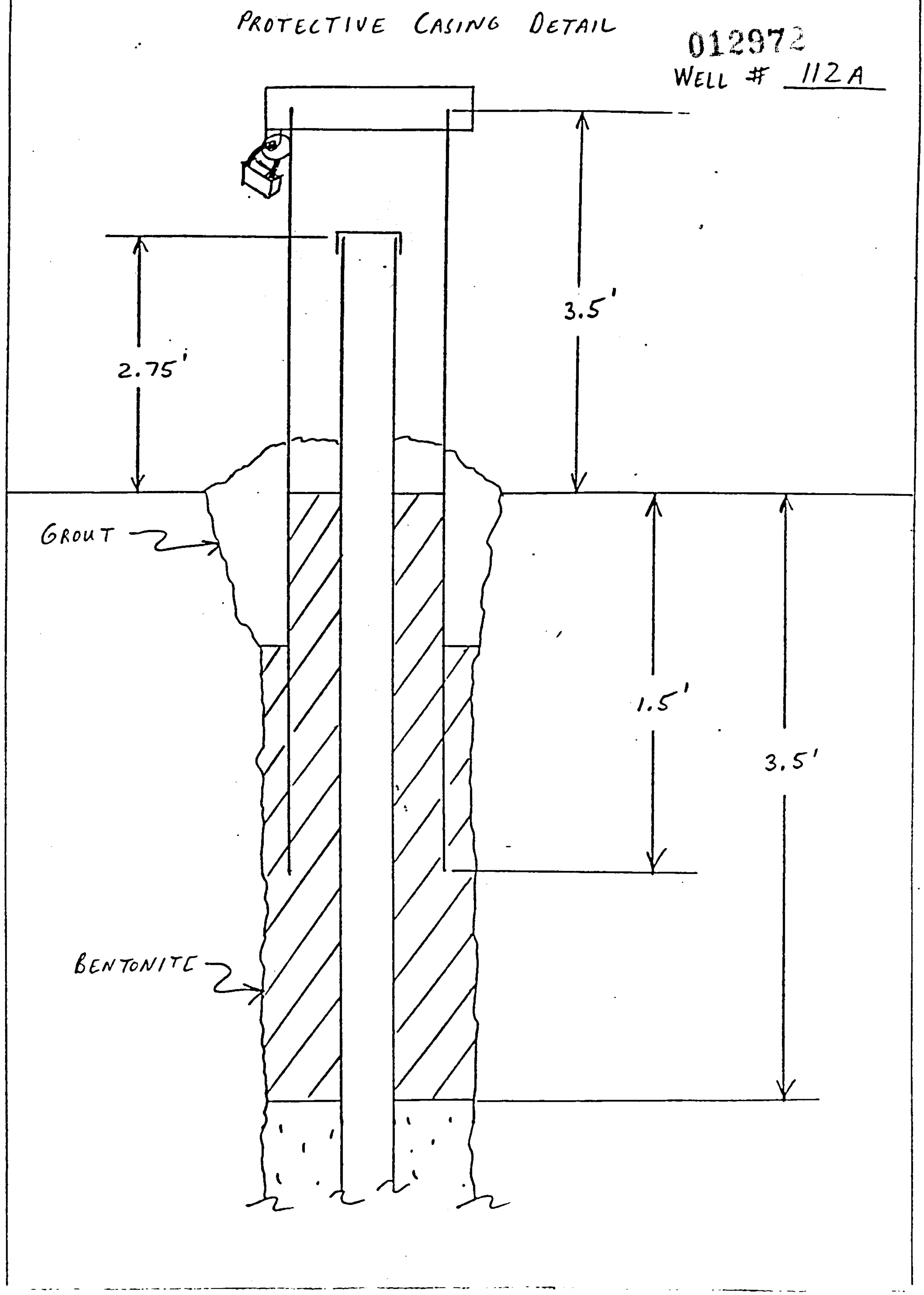
WELL 112 DATE DRILLED 7/13/82
STUDY AREA Northwestern Boundary
ELEVATION TOP OF STEEL CASING = 252.34 ft
ELEVATION TOP OF PVC RISER = 251.55 ft
ELEVATION OF GROUND SURFACE = 248.98 ft

SOURCE: ENVIRONMENTAL PROTECTION SYSTEMS, INC. - 1983

CONTAMINATION SURVEY
LONGHORN ARMY AMMUNITION PLANT
MARSHALL, TEXAS

U.S. ARMY TOXIC AND HAZARDOUS MATERIALS AGENCY
ABERDEEN PROVING GROUND, MARYLAND


WELL SKETCH
012971
WELL # 112A
PVC CAP
2.75'
PVC SLIP COUPLING
BENTONITE SEAL
3.5'
2" SCHED 40 PVC
5.25
WELL SCREEN
5.0'
PVC SLIP COUPLING
SAND PACK
20.25'
PVC CAP
2.0'


PROTECTIVE CASING DETAIL
012972
WELL # 112A
3.5'
2.75'
GROUT
1.5'
3.5'
BENTONITE

Drilling Narrative for Monitoring Wells Drilled Summer 1994

To provide additional background groundwater sampling locations at the perimeter of the Plant, two monitoring wells were clustered at the northwest corner of the Plant. Those wells are identified as 133 and 134 on Figure 2-1. The intent of the clustered wells is to provide a sampling point in the uppermost aquifer and to test a lower water bearing zone. A factor of concern in drilling the deeper monitoring well was to avoid penetration of the interval screened in the public water supply well which offsets this location by approximately 400 feet. This well is the Caddo Lake Water Supply Corporation Well # 1 which is completed in the Cypress Aquifer and was screened from 152' to 220'.

Well 133 was drilled to a total depth of 90 feet. As shown on the boring logs for this well (included in Appendix A), the soil was predominantly clay with varying amounts of sand and occasional gravel. In the interval from 70' to 75', the moisture content of the soil increased and indicated saturated soils of a perched aquifer. The sand content remained fairly constant in samples from 70' to approximately 80' with the sand content and moisture content decreasing in the interval from 80' to 85'. Due to the decreasing apparent moisture content in the samples, it was decided that the clay layer was an aquitard and most probably represents the base of the perched aquifer at this location. To verify the base of the perched aquifer, this well was drilled from 85' to 90' with the moisture content appearing to increase. Since the intent prior to drilling the well was to test the base of the aquifer without leaving a pathway through the underlying confining clay layer, the well was plugged back with a bentonite plug from 85' to 90'. A 20' screen placed from 65' to 85'. The annular volume around the screen and casing was filled with a 16/30 sand to a depth of 63'. A 3 foot thick layer of bentonite pellets was used to seal the top of the sand interval. A grout with 5% bentonite was used to seal the remainder of the open borehole as shown in the completion log included in Appendix A.

A gamma ray/resistivity log was run in the borehole prior to installing the screen and casing. That log is also included in Appendix A. A gamma ray logging tool detects the natural gamma ray radiation emitted by the materials penetrated by the borehole. In sedimentary materials, as those encountered here, gamma ray activity as measured in API-GR units increases with clay content. As shown by the highly irregular gamma ray curve for this well, the interval from about 60' to the bottom of the hole contains numerous sandy lenses one foot

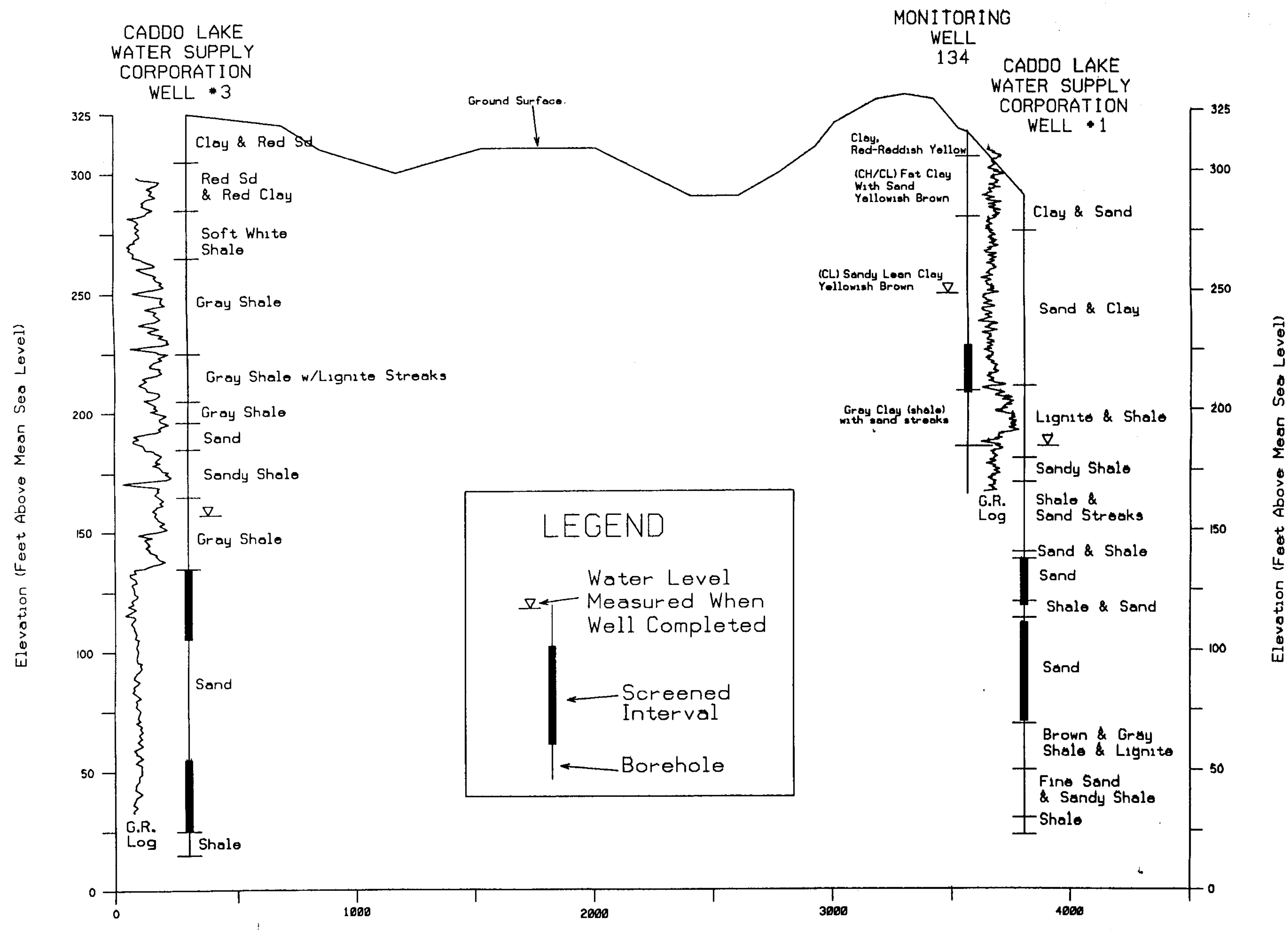


Fig. A-2: Cross Section Showing the Relationship of Screened Intervals In Monitoring Well 134 to Public Water Supply Wells.

012974

or less in thickness. It should be noted that the gamma ray log run in conjunction with a conductivity measuring instrument after the well was completed indicates clay layer from 60' to 63'. That deflection in the gamma ray curve is caused by the presence of the bentonite plug placed above the screened interval behind the casing.

Well 134 was drilled approximately 10' to the southwest of well 133. The well was drilled to a depth of 85' using a rockbit with a natural water/mud drilling fluid, at which point 8-inch casing was set to isolate the upper aquifer from subsequent drilling operations. Lithologies encountered were primarily evaluated by drill bit and drill rig behavior and confirmed by materials contained in the drilling mud circulated up the hole. Significantly sandy soils were detected in the interval from 85' to approximately 110'. The hole was drilled to a total depth of 151' with no significant sands detected. Several sandy intervals were detected in the interval from 120' to 151' but none of the intervals were deemed to have sufficient sand to yield a permeable strata that would be considered an aquifer. A gamma ray/resistivity log was run in this hole from 151' to surface. The gamma ray log showed sand development in the interval from 124' to the bottom of the hole. The gamma ray intensity was higher in the sands interval below 108'. The higher gamma ray intensity indicates a higher clay content than the upper sands which would infer poorer permeability characteristics than the upper sands. Drilling was terminated at a depth of 151' to prevent penetration of the aquifer from which water is produced from the Caddo Lake Water Supply Corporation Well #1. Figure A-2 is a cross section incorporating the sample descriptions and gamma ray logs from well 134 and CaddoLake Water Supply Corporation Well #3, and sample descriptions from Caddo Lake Water Supply Well #1. These wells are identified on Figure 2-1 of the text of this document. As shown in that cross section, monitoring well 134 is within 70 ' of the public water supply aquifer. After consulting with personnel from EPA Region VI and the Tyler office of TNRCC, it was decided to plug back the borehole and complete the wellbore in the sandy interval below the interval screened in monitoring well 133. The borehole of monitoring well 134 was filled with clean sand from 130' to 151' below ground level. Approximately twenty-one feet of bentonite pellets were used to seal the lower borehole with the top of the bentonite seal being measured at 109.5' below ground level. A twenty foot screen was placed from 109' to 89'. The annular volume around the screen and casing was filled with a 16/30 sand to a depth of 84.2'. A 3 foot thick layer of bentonite pellets was used to seal the top of the sand interval. A grout with 5% bentonite was used to seal the remainder of the open borehole as shown in the completion log included in Appendix A.

The State Plane Coordinates and elevation for well 133 and 134 are given in Table 2-1 below.

Table 2-1. State Plane Coordinates and Elevations of Monitoring Wells Installed During Summer 1994.

	State Plane Coordinates		Reference Elevation -Top of PVC Casing- (feet above Mean Sea Level)
Well	Northing	Easting	
133	390839.02	3026097.33	321.14
134	390832.00	3026089.88	322.09

012977

HOLE NO. 133

DRILLING LOG	DIVISION: SOUTHWEST	INSTALLATION: Longhorn Army Ammunition Plant	SHEET 1 of 3 SHEETS

1. PROJECT: Groundwater Background Study	10. SIZE AND TYPE OF BIT: 8" Flight
2. LOCATION (Coordinates or Station): 390844.10 3026092.10	11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
3. DRILLING AGENCY: U.S.Army COE	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number): MW133	13. OVERBURDEN SAMPLES — DISTURBED: 12 — UNDISTURBED:
5. NAME OF DRILLER: Voils, Laquement	14. TOTAL NUMBER CORE BOXES: 0
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED: 08/13/94 — COMPLETED:
7. THICKNESS OF OVERBURDEN: 0.0	17. ELEVATION TOP OF HOLE: 318.6
8. DEPTH DRILLED INTO ROCK: 0.0	18. TOTAL CORE RECOVERY FOR BORING: 0.0 %
9. TOTAL DEPTH OF HOLE: 90.0	M.W.Dean — INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0–4		(CL) (0.0 – 4.0) Est.LL 25–30, Red, Silty, Sandy, Firm, Moist.		J–1, J–2	TYPE: Flight Augr — ZONE: 0.0– 90.0
–4.0	4		(CL) (4.0 – 6.0) Est.LL 25–30, Light Tan, Silty, Slightly Sandy, Firm, Moist.			
–6.0			(CL) (6.0 – 7.0) Est.LL 25–30, Light Tan, Silty, Firm, Moist.			
–7.0	8		(CL) (7.0 – 10.0) Est.LL 25–30, Tan, Clay & Sand lenses, Moderately Firm, Moist.		J–3	
–10.0	12		(CL) (10.0 – 15.0) Est.LL 25–30, Silty, Clay & Sand lenses, Moderately Firm, Moist.		J–4	
–15.0	16, 20, 24, 28		(CL) (15.0 – 30.0) Est.LL 25–30, Light Tan, Silty, Sandy, Firm, Moist.		J–5, J–6, J–7	
–30.0	32		(CL) (30.0 – 34.5) Est.LL 25–30, Tan, Silty, Sandy, Few Gravel, Moderately Firm, Moist.		J–8	
–34.5 / 283.6			(CL) (34.5 – 35.0) Est.LL 30–35, Blue-Gray, Silty Firm, Moist.		J–9	
	36, 40		(CL) (35.0 – 50.0) Est.LL 25–30, Tan, Sandy, Slightly Firm, Moist.		J–10	
278.6	40					

Remarks:

SAMPLE	DEPTH
J–1	0.0– 0.5
J–2	1.0– 2.0
J–3	9.0– 10.0
J–4	10.0– 15.0
J–5	15.0– 20.0
J–6	20.0– 25.0
J–7	25.0– 30.0
J–8	30.0– 34.5
J–9	34.5– 35.0
J–10	35.0– 40.0
J–11	40.0– 45.0
J–12	45.0– 50.0
J–13	50.0– 55.0
J–14	55.0– 60.0
J–15	60.0– 65.0
J–16	65.0– 70.0
J–17	70.0– 75.0
J–18	80.0– 85.0

PROJECT | HOLE NO.

012978

HOLE NO. 133

DRILLING LOG	DIVISION SOUTHWEST	INSTALLATION Longhorn Army Ammunition Plant	SHEET 2 OF 3 SHEETS

1. PROJECT	Groundwater Background Study
2. LOCATION (Coordinates or Station)	390844.10 3026092.10
3. DRILLING AGENCY	U.S.Army COE
4. HOLE NO. (As shown on drawing title and file number)	MW133
5. NAME OF DRILLER	Volls, Laquement
6. DIRECTION OF HOLE	☐ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN	0.0
8. DEPTH DRILLED INTO ROCK	0.0
9. TOTAL DEPTH OF HOLE	90.0
10. SIZE AND TYPE OF BIT	8" Flight
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	MSL
12. MANUFACTURER'S DESIGNATION OF DRILL	
13. OVERBURDEN SAMPLES	DISTURBED 12 / UNDISTURBED
14. TOTAL NUMBER CORE BOXES	0
15. ELEVATION GROUND WATER	
16. DATE HOLE	STARTED 08/13/94 / COMPLETED
17. ELEVATION TOP OF HOLE	318.6
18. TOTAL CORE RECOVERY FOR BORING	0.0 %
19. SIGNATURE OF INSPECTOR	M.W.Dean INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			(CL) (35.0 – 50.0) Est.LL 25–30, Tan, Sandy, Slightly Firm, Moist.		J–10	
					J–11	
	44					
	48				J–12	
268.6			(CL) (50.0 – 60.0) Est.LL 30–35, Silty, Slightly Sandy, Some Gravel, Moderately Soft, Moist.			
	52				J–13	
	56					
					J–14	
258.6	60		(CL) (60.0 – 70.0) Est.LL 25–30, Sandy, Some Gravel, Firm, Moist.			
					J–15	
	64					
	68				J–16	
248.6			(CL) (70.0 – 80.0) Est.LL 25–30, Tan, Sandy, Slightly Wet.			
	72				J–17	
	76					
238.6	80					

PROJECT | HOLE NO.

012979

HOLE NO: MW133

DRILLING LOG	DIVISION: SOUTHWEST	INSTALLATION: Longhorn Army Ammunition Plant	SHEET 3 OF 3 SHEETS

1. PROJECT: Groundwater Background Study	10. SIZE AND TYPE OF BIT: 8" Flight
2. LOCATION (Coordinates or Station): 390844.10 3026092.10	11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
3. DRILLING AGENCY: U.S.Army COE	12. MANUFACTURER'S DESIGNATION OF DRILL:
4. HOLE NO. (As shown on drawing title and file number): MW133	13. OVERBURDEN SAMPLES: DISTURBED 12 UNDISTURBED
5. NAME OF DRILLER: Voils, Laquement	14. TOTAL NUMBER CORE BOXES: 0
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE: STARTED 08/13/94 COMPLETED
7. THICKNESS OF OVERBURDEN: 0.0	17. ELEVATION TOP OF HOLE: 318.6
8. DEPTH DRILLED INTO ROCK: 0.0	18. TOTAL CORE RECOVERY FOR BORING: 0.0 %
9. TOTAL DEPTH OF HOLE: 90.0	M.W.Dean INSPECTOR

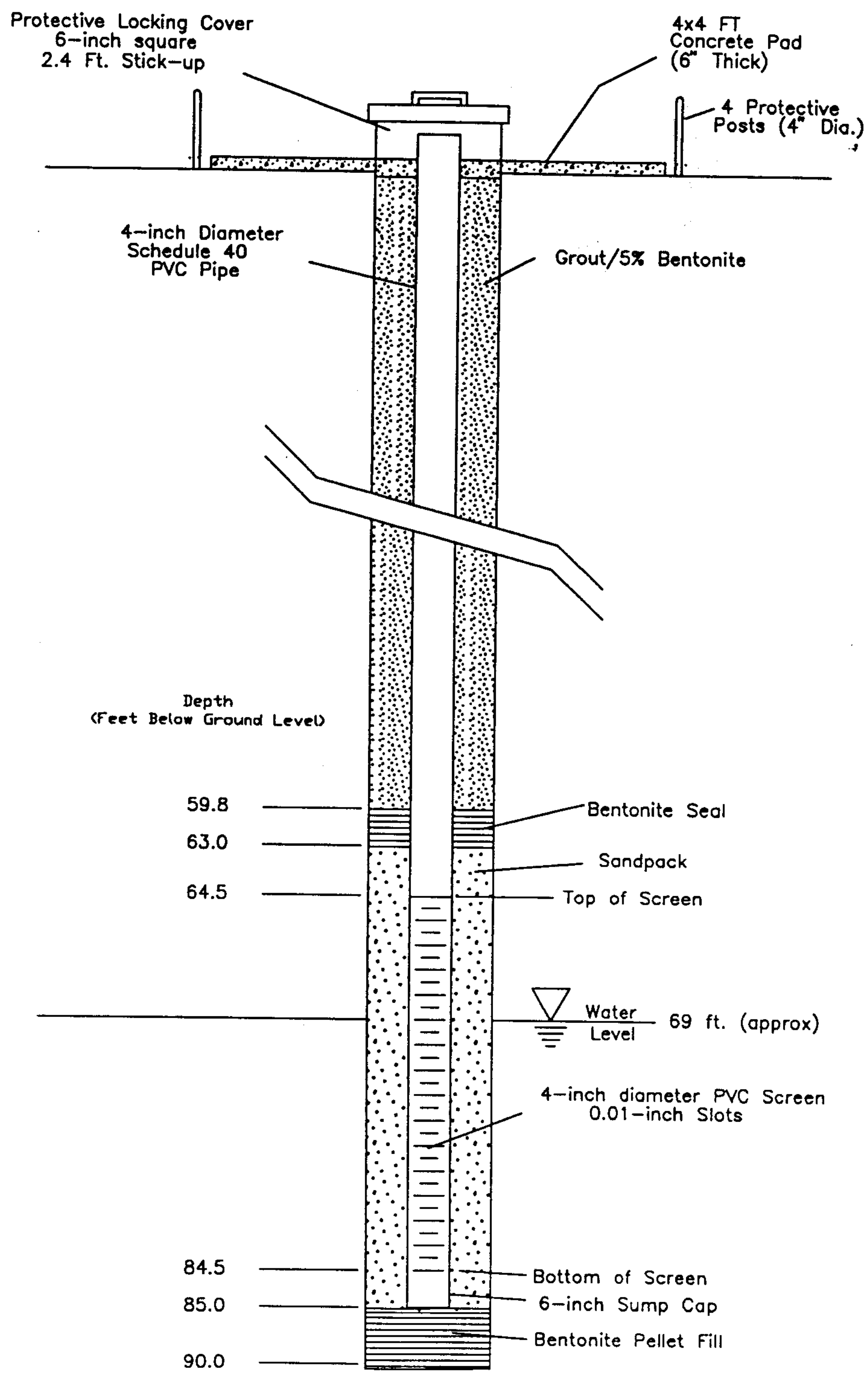
ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
238.6			(CL) (80.0 - 85.0) Est.LL 25-30, Tan, Sandy, Sandstone & Iron Oxide Gravel, Firm, Slightly Wet.		J-18	
	84					
233.6			(CL) (85.0 - 90.0) Est.LL 25-30, Tan, Very Sandy, Few Gravel, Moderately Soft, Very Moist.			
	88					
228.6						
	92					
	96					
	100					
	104					
	108					
	112					
	116					
	120					

PROJECT | HOLE NO.

Completed Well Schematic: 133

Completed 9-23-94

012980



012981

U.S. ARMY

CORPS OF ENGINEERS

TULSA DISTRICT

Monitoring Well 133

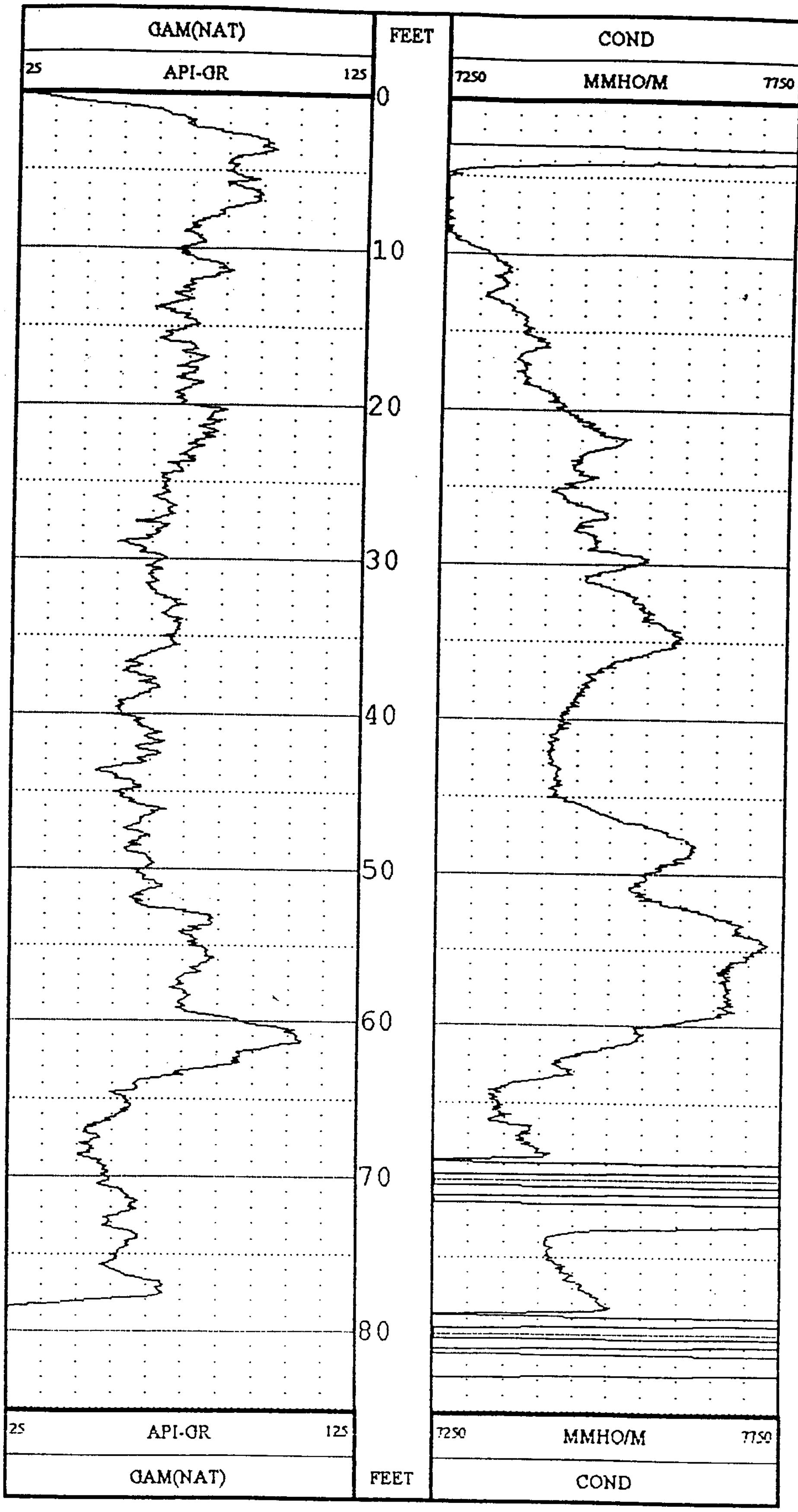
COMPANY	: U.S. Army Corps of Engineers			OTHER SERVICES:	
WELL	: Monkoring Well 133				
LOCATION/FIELD	: Longhorn Army Ammunkion Plant				
COUNTY	: Harrison				
STATE	: Texas				
SECTION	:	TOWNSHIP	:	RANGE	:
DATE	: 09/30/94	PERMANENT DATUM	:	ELEVATIONS:	
DEPTH DRILLER	:	ELEV. PERM. DATUM	:	KB	:
LOG BOTTOM	: 83.00	LOG MEASURED FROM:	T/Casing	DF	:
LOG TOP	: -1.40	DRL MEASURED FROM:	G.L.	GL	:
CASING DRILLER	:	LOGGING UNIT	:		
CASING TYPE	: 4"PVC	FIELD OFFICE	:		
CASING THICKNESS:		RECORDED BY	: M.C.Murray		
BIT SIZE	: 7" auger	BOREHOLE FLUID	:	FILE	: ORIGINAL
MAGNETIC DECL.	:	RM	:	TYPE	: 9510A
MATRIX DENSITY	:	RM TEMPERATURE	:	LOG	: 133alnd
FLUID DENSITY	:	MATRIX DELTA T	:	PLOT	: lhaeplnd.
NEUTRON MATRIX	:	FLUID DELTA T	:	THRESH:	

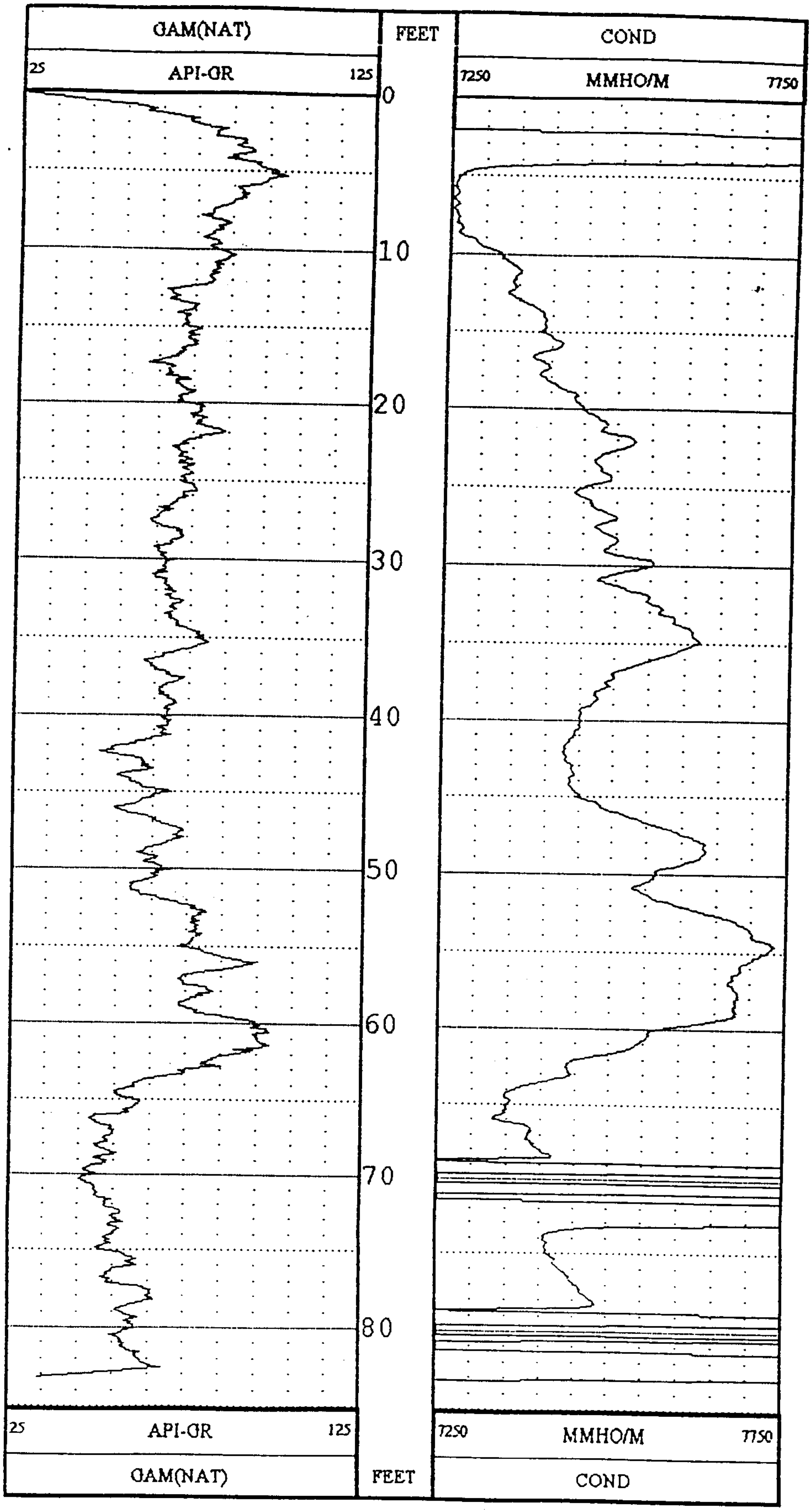
REMARKS:

Water Level at Approx. 65'.

ALL SERVICES PROVIDED SUBJECT TO STANDARD TERMS AND CONDITIONS

012982


GAM(NAT)
25
API-GR
125
FEET
COND
7250
MMHO/M
7750
0
10
20
30
40
50
60
70
80
25
API-GR
125
GAM(NAT)
FEET
7250
MMHO/M
7750
COND


GAM(NAT)
FEET
COND
25
API-GR
125
7250
MMHO/M
7750
0
10
20
30
40
50
60
70
80
25
API-GR
125
7250
MMHO/M
7750
GAM(NAT)
FEET
COND

012983

2

U.S. ARMY

CORPS OF ENGINEERS

TULSA DISTRICT

MW133

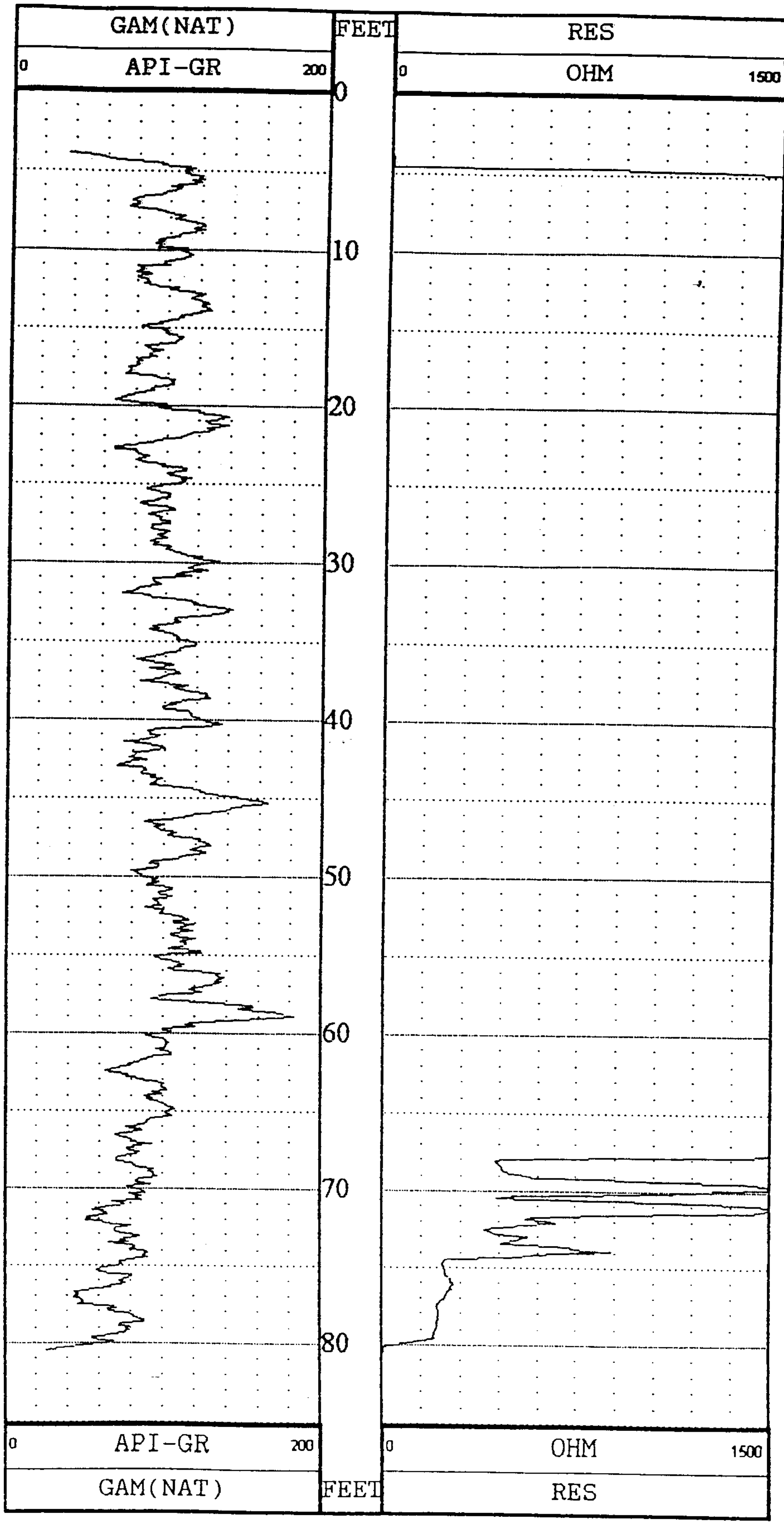
COMPANY	: U.S.ARMY CORPS OF ENGINEERS			OTHER SERVICES:	
WELL	: MW133				
LOCATION/FIELD	: TULSA				
COUNTY	: HARRISON				
STATE	: TEXAS				
SECTION	:	TOWNSHIP	:	RANGE :	
DATE	: 08/10/94	PERMANENT DATUM	:	ELEVATIONS:	
DEPTH DRILLER	: 85	ELEV. PERM. DATUM	:	KB	:
LOG BOTTOM	: 80.70	LOG MEASURED FROM:	G.L.	DF	:
LOG TOP	: 3.90	DRL MEASURED FROM :	G.L.	GL	:
CASING DRILLER	: 0	LOGGING UNIT	:		
CASING TYPE	:	FIELD OFFICE	:		
CASING THICKNESS:		RECORDED BY	: MURRAY,M.C.		
BIT SIZE	:	BOREHOLE FLUID	:	FILE	: Repeat
MAGNETIC DECL.	:	RM	:	TYPE	: 9060A
MATRIX DENSITY	:	RM TEMPERATURE	:	LOG	: mw133a
FLUID DENSITY	:	MATRIX DELTA T	:	PLOT	: lhsepres.
NEUTRON MATRIX	:	FLUID DELTA T	:	THRESH:	

REMARKS:

WTR LVL MEASURED AT 60.1 FEET BELOW G.L.

Openhole, form. wtr/air. Logged at 13:05.

ALL SERVICES PROVIDED SUBJECT TO STANDARD TERMS AND CONDITIONS


GAM(NAT)
0 API-GR 200
FEET
RES
0 OHM 1500
0
10
20
30
40
50
60
70
80
0 API-GR 200
GAM(NAT)
FEET
0 OHM 1500
RES

012985

HOLE NO. MW134

012986

DRILLING LOG	DIVISION SOUTHWEST	INSTALLATION Longhorn Army Ammunition Plant	SHEET 1 OF 2 SHEETS

1. PROJECT Groundwater Background Study	10. SIZE AND TYPE OF BIT Rockbit
2. LOCATION (Coordinates or Station) 390832.00 3026089.90	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
3. DRILLING AGENCY U.S.Army COE	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number) MW134	13. OVERBURDEN SAMPLES — DISTURBED — UNDISTURBED
5. NAME OF DRILLER Scott	14. TOTAL NUMBER CORE BOXES 0
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE STARTED 09/23/94 COMPLETED 09/28/94
7. THICKNESS OF OVERBURDEN 0.0	17. ELEVATION TOP OF HOLE 316.0
8. DEPTH DRILLED INTO ROCK 0.0	18. TOTAL CORE RECOVERY FOR BORING 0.0 %
9. TOTAL DEPTH OF HOLE 151.0	M.W.Dean INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0–10					9-23-94 Flight auger to 10' with 9.5" rockbit to 31. Mixed drilling gel
	10–20					9-24-94 9.5" rockbit to 85'. Tried to install 8" casing but hole was too tight or too crooked. Driller then changed to 9 5/8" rockbit & reamed hole.
	20					9-25-94 Reamed hole. Casing hung up @ 25'. Removed casing & reamed again with 14" rockbit to 85'. Installed 86' of 8" casing.
	30					9-26-94 7" rockbit inside casing to 95'. Split spoon 95-97.5 Split spoon 108-108.7
						9-27-94 Drilled with rockbit to 151. Occasional sand stringer.
	40					9-28-94 Backfilled hole with bentonite pellets. Bottom of screen at 109.5 20' screen.
						TYPE / ZONE Rockbit 0.0– 85.0 Rockbit 85.0–151.0
	50					
	60					
	70					
	80					
	90					
218.5	97.5	▨	(CL) (95.0 – 97.5) Tan, very sandy, moist, moderately soft.			
216.0	100					

PROJECT | HOLE NO.

HOLE NO. MW134 012987

DRILLING LOG	DIVISION SOUTHWEST	INSTALLATION Longhorn Army Ammunition Plant	SHEET 2 OF 2 SHEETS

1. PROJECT Groundwater Background Study	10. SIZE AND TYPE OF BIT Rockbit
2. LOCATION (Coordinates or Station) 390832.00 3026089.90	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
3. DRILLING AGENCY U.S.Army COE	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number) MW134	13. OVERBURDEN SAMPLES DISTURBED UNDISTURBED
5. NAME OF DRILLER Scott	14. TOTAL NUMBER CORE BOXES 0
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE STARTED 09/23/94 COMPLETED 09/28/94
7. THICKNESS OF OVERBURDEN 0.0	17. ELEVATION TOP OF HOLE 316.0
8. DEPTH DRILLED INTO ROCK 0.0	18. TOTAL CORE RECOVERY FOR BORING 0.0 %
9. TOTAL DEPTH OF HOLE 151.0	M.W.Dean INSPECTOR

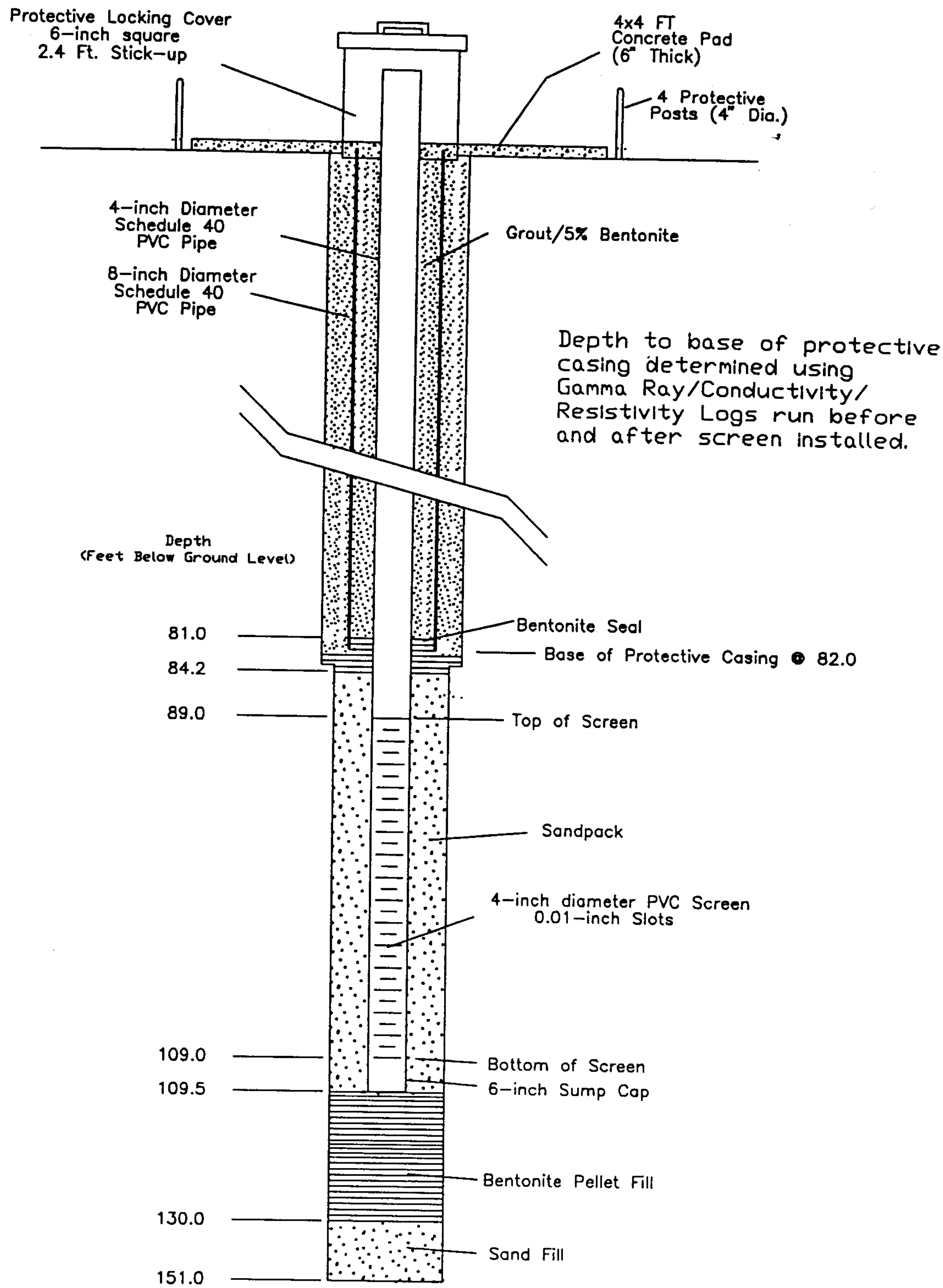
ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
208.0						
207.3	110		(CL) (108.0 - 108.7) shale(?),Black, moist, moderately soft.			
	120					
	130					
	140					
165.0	150					
	160					
	170					
	180					
	190					
	200					

PROJECT HOLE NO.

Completed Well Schematic: No. 134

Completed 9-30-94

012988



012989

U.S. ARMY

CORPS OF ENGINEERS

TULSA DISTRICT

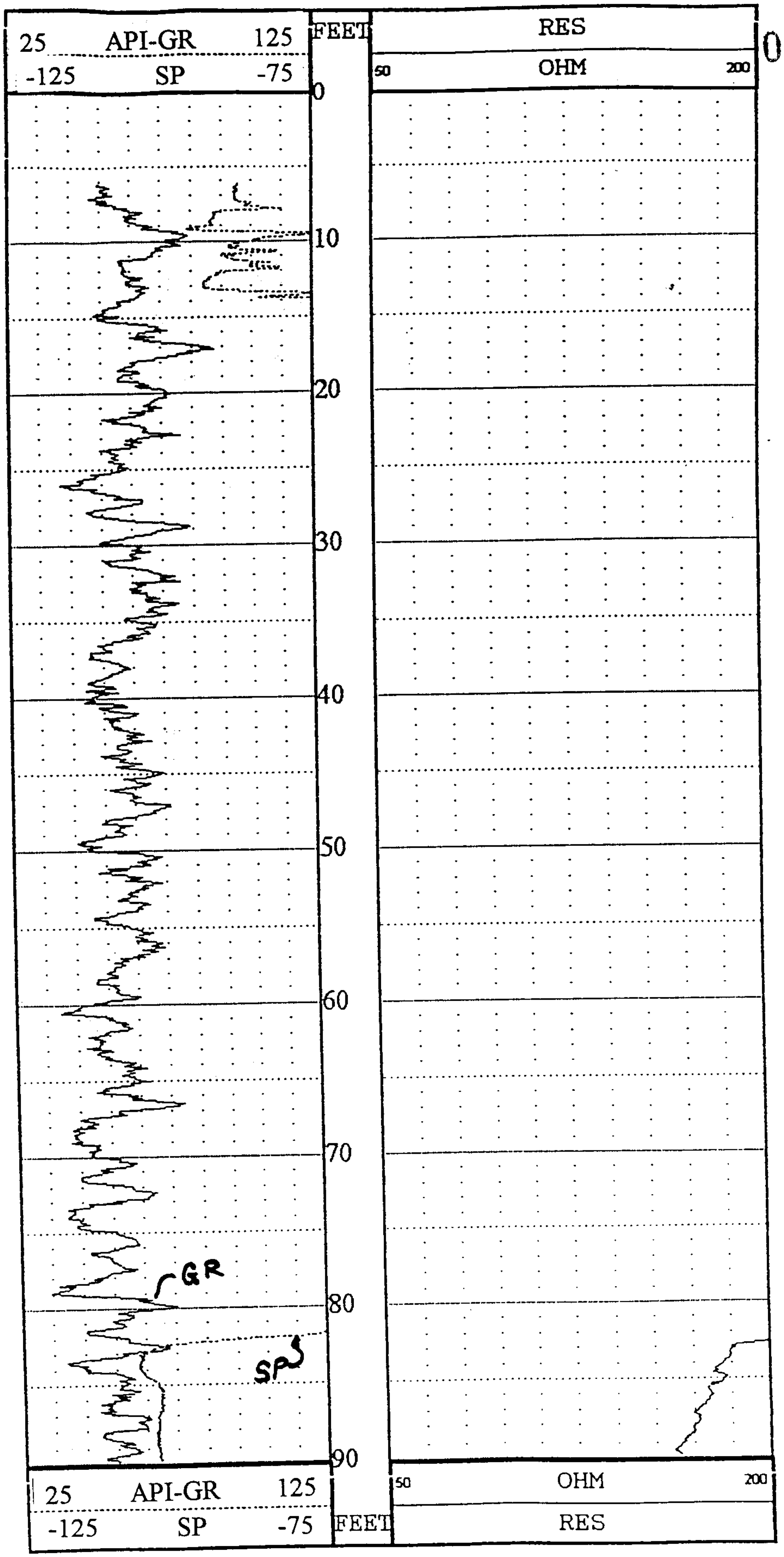
Monitoring Well 134

COMPANY	: U.S. Army COE			OTHER SERVICES:	
WELL	: Monitoring Well 134				
LOCATION/FIELD	: Longhorn AAP				
COUNTY	: Harrison				
STATE	: Texas				
SECTION	:	TOWNSHIP	:	RANGE :	
DATE	: 09/28/94	PERMANENT DATUM	:	ELEVATIONS:	
DEPTH DRILLER	:	ELEV. PERM. DATUM	:	KB	:
LOG BOTTOM	: 150.20	LOG MEASURED FROM:	G.L.	DF	:
LOG TOP	: 6.20	DRL MEASURED FROM:	G.L.	GL	:
CASING DRILLER	:	LOGGING UNIT	:		
CASING TYPE	:	FIELD OFFICE	:		
CASING THICKNESS:		RECORDED BY	:		
BIT SIZE	:	BOREHOLE FLUID	:	FILE	: REPEAT
MAGNETIC DECL.	:	RM	:	TYPE	: 9060A
MATRIX DENSITY	:	RM TEMPERATURE	:	LOG	: 0
FLUID DENSITY	:	MATRIX DELTA T	:	PLOT	: lhoepres.
NEUTRON MATRIX	:	FLUID DELTA T	:	THRESH:	

REMARKS:

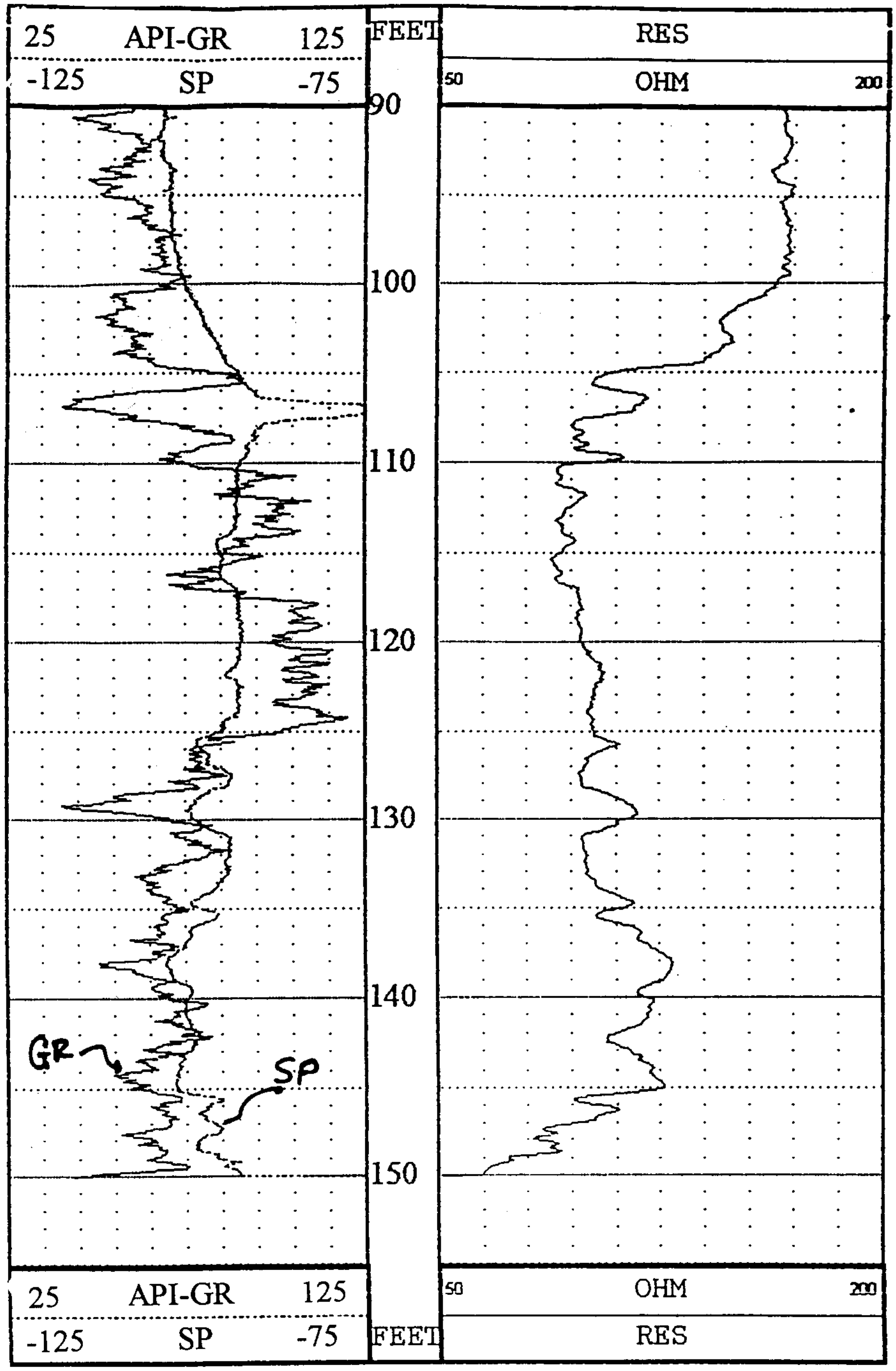
ALL SERVICES PROVIDED SUBJECT TO STANDARD TERMS AND CONDITIONS

012990



25 API-GR 125
-125 SP -75
FEET
RES
50 OHM 200
0
10
20
30
40
50
60
70
80
90
GR
SP
25 API-GR 125
-125 SP -75
FEET
50 OHM 200
RES

012991


25 API-GR 125
-125 SP -75
FEET
RES
50 OHM 200
90
100
110
120
130
140
150
GR
SP
25 API-GR 125
-125 SP -75
FEET
50 OHM 200
RES

012992

U.S. ARMY

CORPS OF ENGINEERS

TULSA DISTRICT

Monitoring Well 134

COMPANY	: U.S. Army COE			OTHER SERVICES:	
WELL	: Monitoring Well 134				
LOCATION/FIELD	: Longhorn AAP				
COUNTY	: Harrison				
STATE	: Texas				
SECTION	:	TOWNSHIP	:	RANGE	:
DATE	: 09/30/94	PERMANENT DATUM	:	ELEVATIONS:	
DEPTH DRILLER	:	ELEV. PERM. DATUM	:	KB	:
LOG BOTTOM	: 108.50	LOG MEASURED FROM	: G.L.	DF	:
LOG TOP	: -2.00	DRL MEASURED FROM	: G.L.	GL	:
CASING DRILLER	:	LOGGING UNIT	:		
CASING TYPE	:	FIELD OFFICE	:		
CASING THICKNESS	:	RECORDED BY	: M.C. Murrey		
BIT SIZE	:	BOREHOLE FLUID	:	FILE	: ORIGINAL
MAGNETIC DECL.	:	RM	:	TYPE	: 9510A
MATRIX DENSITY	:	RM TEMPERATURE	:	LOG	: 134bind
FLUID DENSITY	:	MATRIX DELTA T	:	PLOT	: lheapind.
NEUTRON MATRIX	:	FLUID DELTA T	:	THRESH:	

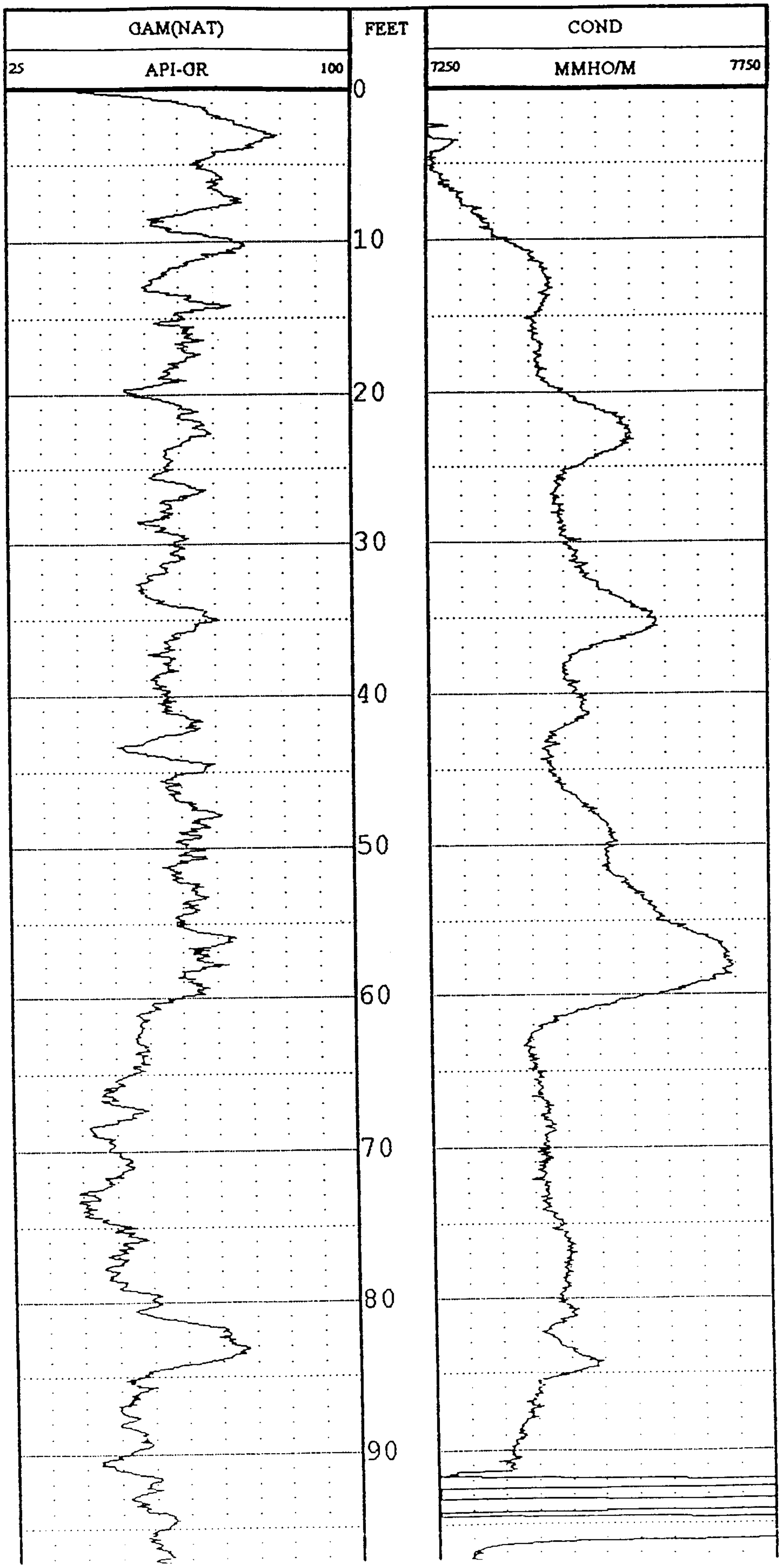
REMARKS:

Top screen at approx. 89'. GR deflection from approx. 81-84' indicate

Logged at 0734. Plugged back from total depth of 151'.

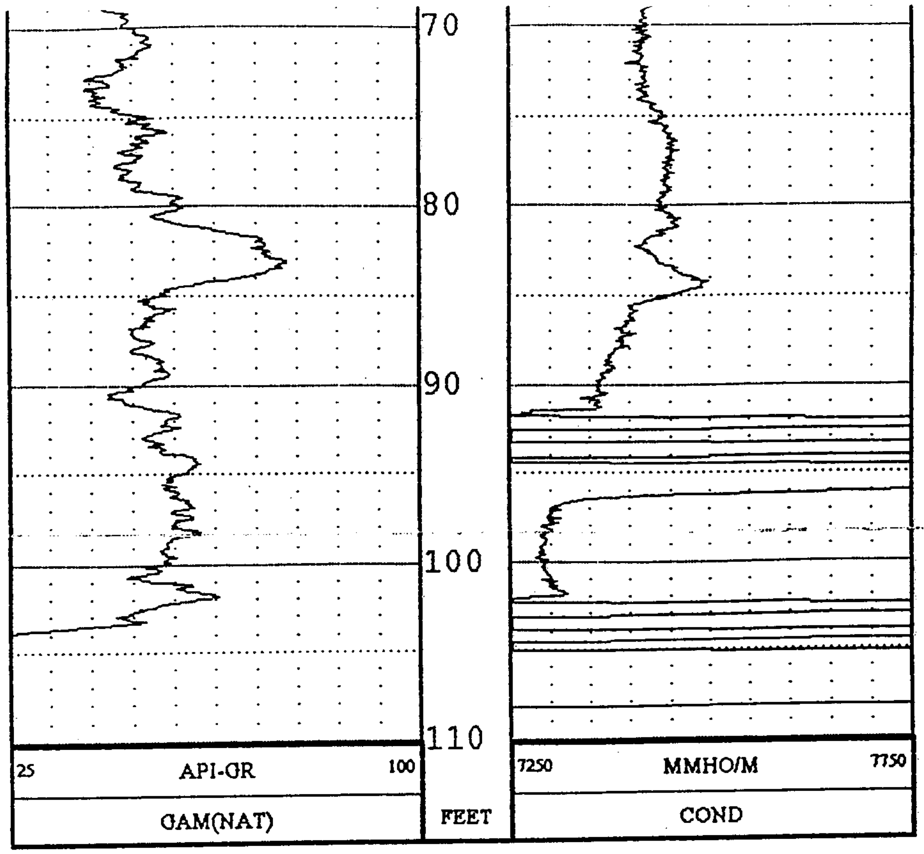
ALL SERVICES PROVIDED SUBJECT TO STANDARD TERMS AND CONDITIONS

012993



GAM(NAT)
25
API-GR
100
FEET
COND
7250
MMHO/M
7750
0
10
20
30
40
50
60
70
80
90

012994



012995

U.S. ARMY

CORPS OF ENGINEERS

TULSA DISTRICT

Monitoring Well 134

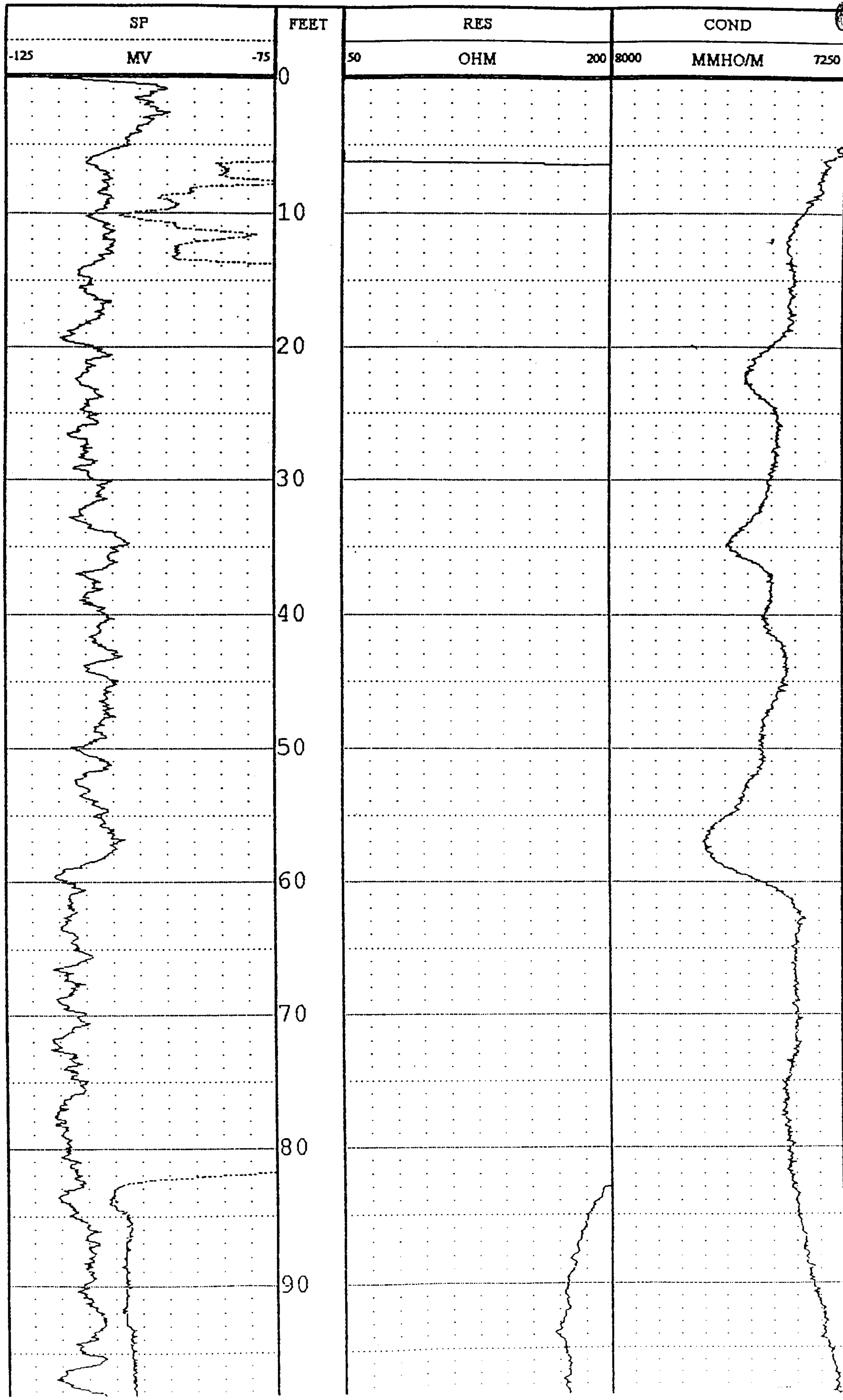
COMPANY	: U.S. Army COE			OTHER SERVICES: IND/GR Res/SP/G	
WELL	: Monitoring Well 134				
LOCATION/FIELD	: Longhorn AAP				
COUNTY	: Harrison				
STATE	: Texas				
SECTION	:	TOWNSHIP	:	RANGE	:
DATE	: 09/28/94	PERMANENT DATUM	:	ELEVATIONS:	
DEPTH DRILLER	: 151'	ELEV. PERM. DATUM	:	KB	:
LOG BOTTOM	: 145.10	LOG MEASURED FROM	: G.L.	DF	:
LOG TOP	: 0.10	DRL MEASURED FROM	: G.L.	GL	:
CASING DRILLER	:	LOGGING UNIT	:		
CASING TYPE	:	FIELD OFFICE	:		
CASING THICKNESS	:	RECORDED BY	:		
BIT SIZE	:	BOREHOLE FLUID	:	FILE	: ORIGINAL
MAGNETIC DECL.	:	RM	:	TYPE	: 9510A
MATRIX DENSITY	:	RM TEMPERATURE	:	LOG	: 134alnd
FLUID DENSITY	:	MATRIX DELTA T	:	PLOT	: combo.
NEUTRON MATRIX	:	FLUID DELTA T	:	THRESH:	

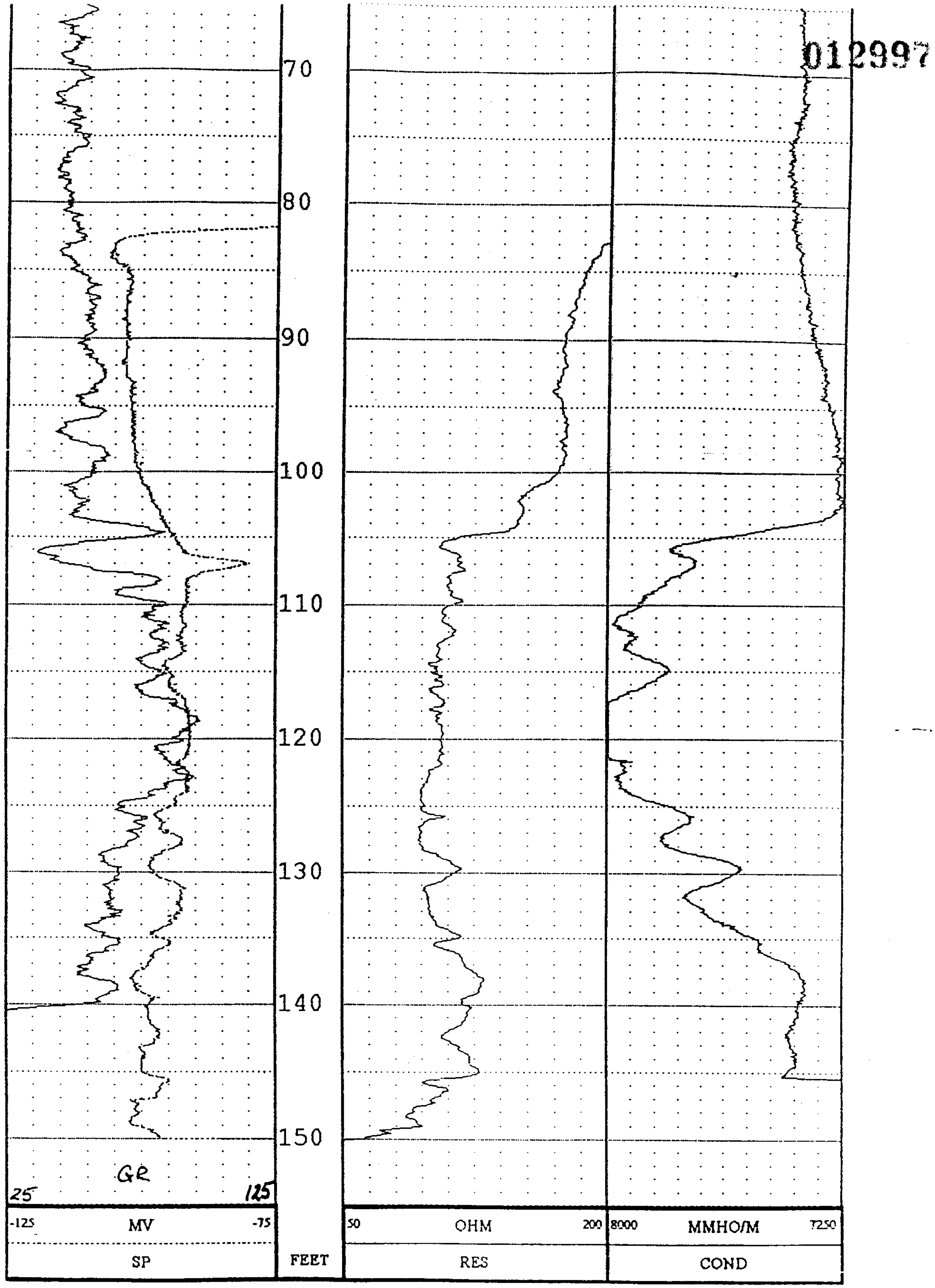
REMARKS:

Base casing set to 86' (Driller's depth).

Gamma Ray/Cond. logged in separate run from SP/Res.

ALL SERVICES PROVIDED SUBJECT TO STANDARD TERMS AND CONDITIONS


SP
-125
MV
-75
FEET
0
10
20
30
40
50
60
70
80
90
RES
50
OHM
200
COND
8000
MMHO/M
7250


012997
70
80
90
100
110
120
130
140
150
GR
25
125
-125
MV
-75
SP
FEET
50
OHM
200
RES
8000
MMHO/M
7250
COND

Appendix B

Summary of Groundwater Chemical Analyses From Background Wells

Wells :
110
111
112
133
134

012099

Groundwater Chemical Analysis Summary
Longhorn AAP

Well No.	Date	Chloride (mg/L)	pH	Spec. Cond. (umhos/cm)	Nitrite (mg/L)	Nitrate (mg/L)	NO3/ NO2 (mg/L)	Sulfate (mg/L)	Al (mg/L)	As (mg/L)	Ba (mg/L)	Ca (mg/L)	Cd (mg/L)
110	30-Jun-92	740	6.63	6900	<0.05	0.06	0.06	1500	0.47	<0.005	0.04		<0.01
110	11-Sep-92	760	6.5	5000	<0.05	0.13	0.13	1200	0.30	<0.005	0.02		<0.01
110	2-Dec-92		6.5	6190					1.09	<0.005	1.99		<0.01
110	16-Feb-93	1416	6.2	7045			<0.01	3475	6.60	0.008	1.9		<0.01
110	11-May-93	929	6.4	6179			0.1	1600	3.50	<0.005	0.3		0.01
110	14-Jul-93	816	6.4	52			0.05	1250	4.00	0.01	0.2		0.021
110	12-Oct-93	1030	6.4	4852			0.05	1900	47.00	0.01	0.08		0.05
110	22-Feb-94	1321	6.1	4636			<0.01	2050	1.32	<0.005	1		0.02
110	26-Apr-94	1180	6.6	3385			0.03	1750	1.59	<0.005	0.69		0.055
110	2-Aug-94	1162	6.6	7918			0.05	2050	4.18	0.005	0.46		0.028
110	27-Sep-94	905.5	6.3	7700	<0.5	<0.5	<0.5	1601.2	1.90	<0.005	0.04	320	<0.01
110	12-Jan-95	967	6.3	8140	<0.5	<0.5	<0.5	1618	0.33	<0.002	0.023	228	<0.01
111	1-Jun-92												
111	29-Sep-92												
111	22-Dec-92		5.5	100					6.22	<0.005	0.31		0.016
111	16-Feb-93	25	5.8	214			<0.01	<2	11.80	0.012	0.3		<0.01
111	11-May-93	271	6.2	1089			<0.01	<2	12.00	<0.005	0.7		<0.01
111	14-Jul-93	309	6.4	47			0.04	75	6.60	<0.005	0.4		0.01
111	12-Oct-93	450	6.1	1914			0.15	140	81.00	<0.005	0.56		0.04
111	22-Feb-94	35	6.8	226			0.06	22	9.60	0.01	0.4		<0.01
111	26-Apr-94	48	5.7	280			0.05	28	6.37	<0.005	0.34		0.033
111	22-Aug-94	336	6.4	1595			0.03	130	2.24	<0.005	0.39		0.019
111	27-Sep-94	379.6	6.3	1927	<0.5	<0.5	<0.5	150.8	2.30	<0.005	0.4	87.1	<0.01
111	12-Jan-95	27.3	5.2	200	<0.5	<0.5	<0.5	18.5	1.26	<0.002	0.134	6.78	<0.01
112	29-Jun-92	1200	6.4	5800	<0.05	0.13	0.13	590	2.30	0.02	0.05		0.03
112	11-Sep-92	1000	6.45	4400	<0.05	0.13	0.13	670	9.50	0.015	0.11		<0.01
112	2-Dec-92		6.3	3800		0.04	0.04		4.16	<0.005	1.36		0.02
112	16-Feb-93	1214	6.2	550		<0.01	<0.01	800	1.19	<0.005	1.5		<0.01
112	11-May-93	1198	6.3	4850			<0.01	525	4.00	<0.005	0.3		0.01
112	14-Jul-93	1085	6.4	53		0.04	0.04	1400	5.40	<0.005	0.2		0.016
112	12-Oct-93	1043	6.4	3518		0.18	0.18	275	90.00	0.01	0.16		0.04
112	22-Feb-94	991	6.8	2655			<0.01	1200	10.90	0.01	0.6		0.01
112	26-Apr-94	1128	6.5	2188			0.09	800	4.72	<0.005	0.55		0.048
112	2-Aug-94	1090	6.6	4562			0.04	1000	3.05	<0.005	0.42		0.023
112	28-Sep-94	874	6.5	5170	<0.5	<0.5	<0.5	876	4.30	<0.05	0.05	308	<0.01
112	13-Jan-95	878	6.0	5360	<0.5	<0.5	<0.5	693	0.72	<0.002	0.03	154	<0.01

Groundwater Chemical Analysis Summary
Longhorn AAP

Well No.	Date	Co (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Hg (mg/L)	K (mg/L)	Mg (mg/L)	Mn (mg/L)	Ni (mg/L)	Na (mg/L)	Pb (mg/L)	Sb (mg/L)
110	30-Jun-92		0.05		32	<0.001		110	6.8		1000	<0.1	
110	11-Sep-92		<0.02		5.6	<0.001		120	4.1		1100	<0.1	
110	2-Dec-92		<0.02		4.76	<0.001		131	4.86		1042	0.11	
110	16-Feb-93		0.025		13.3	<0.001		162	11.8		1234	0.1	
110	11-May-93		0.04		16.3	<0.001		152	5.12		990	0.2	
110	14-Jul-93		0.09		5.28	0.001		110	6.29		1270	0.1	
110	12-Oct-93		0.04		68	<0.001		56	5.12		1036	0.3	
110	22-Feb-94		<0.01		44	<0.001		205	10		1470	0.1	
110	26-Apr-94		<0.01		1.75	<0.001		151	6.73		1100	0.3	
110	2-Aug-94		0.02		8.1	<0.001		174	5.46		1180	0.2	
110	27-Sep-94	<0.05	<0.05	<0.01	2.7	<0.001	4.8	135	4.63	0.06		<0.002	<0.1
110	12-Jan-95	0.021	<0.01	<0.01	2.34	<0.0002		146	6.46	0.059	1060	<0.005	
111	1-Jun-92												
111	29-Sep-92												
111	22-Dec-92		0.013		10.66	<0.001		11	0.43		71	<0.1	
111	16-Feb-93		0.02		18.3	<0.001		5.25	0.37		15.2	<0.1	
111	11-May-93		0.02		26.2	<0.001		54	1.34		170	0.2	
111	14-Jul-93		0.04		12	<0.001		60	2		110	0.1	
111	12-Oct-93		0.04		51	<0.001		41	1.67		127	0.2	
111	22-Feb-94		0.01		16	<0.001		9	0.37		36	<0.1	
111	26-Apr-94		0.08		6.4	<0.001		8.47	0.33		20	0.3	
111	22-Aug-94		0.01		2.76	<0.001		93	0.8		216	0.1	
111	27-Sep-94	<0.05	<0.05	<0.01	2	<0.001	3.2	80.2	1.28	0.03		<0.002	<0.1
111	12-Jan-95	<0.01	<0.01	0.012	1.88	<0.09		5.07	0.213	<0.015	17.7	<0.005	
112	29-Jun-92		<0.02		160	0.001		200	5.1		600	<0.1	
112	11-Sep-92		<0.02		25	<0.001		260	3.8		560	<0.1	
112	2-Dec-92		0.01		0.85	<0.001		168	3.91		207	<0.1	
112	16-Feb-93		0.021		62.5	<0.001		6	5.61		488	0.1	
112	11-May-93		0.01		9.43	<0.001		242	3.81		460	0.2	
112	14-Jul-93		0.03		26	0.001		240	4.59		400	0.1	
112	12-Oct-93		0.02		57	<0.001		151	3.81		441	0.2	
112	22-Feb-94		0.01		57	<0.001		220	7		488	0.1	
112	26-Apr-94		0.09		25	<0.001		222	5.81		566	0.3	
112	2-Aug-94		0.02		15.5	<0.001		247	5.3		538	0.2	
112	28-Sep-94	<0.05	<0.05	<0.01	4.4	<0.001	5.5	244	1.95	0.03		<0.002	<0.1
112	13-Jan-95	0.053	<0.01	<0.01	21	<0.0002		208	5.16	0.018	482	<0.005	

013001

Groundwater Chemical Analysis Summary
Longhorn AAP

Well No.	Date	Se (mg/L)	Ag (mg/L)	Sr (mg/L)	Tl (mg/L)	Zn (mg/L)	Organics/Explosives Detected			
110	30-Jun-92	<0.005	<0.01				1,1-Dichloroethene RDX	290 ug/L 68 ug/L	1,1,1-Trichloroethane	2600 ug/L
110	11-Sep-92	<0.005	<0.01				1,1,1-Trichloroethane	11 ug/L		
110	2-Dec-92	<0.005	<0.01							
110	16-Feb-93	<0.02	0.018							
110	11-May-93	<0.02	0.03							
110	14-Jul-93	0.14	0.01							
110	12-Oct-93	<0.02	<0.01							
110	22-Feb-94	<0.02	<0.01							
110	26-Apr-94	<0.02	<0.01							
110	2-Aug-94	<0.02	<0.01							
110	27-Sep-94	<0.005	<0.01	5.02	<0.1	<0.05				
110	12-Jan-95	<0.002	<0.01	5.24	<0.09	0.025				
111	1-Jun-92									
111	29-Sep-92									
111	22-Dec-92	<0.005	<0.01							
111	16-Feb-93	<0.02	0.014							
111	11-May-93	<0.02	0.02							
111	14-Jul-93	0.02	<0.01							
111	12-Oct-93	<0.02	<0.01							
111	22-Feb-94	<0.02	<0.01							
111	26-Apr-94	<0.02	<0.01							
111	22-Aug-94	<0.02	<0.01							
111	27-Sep-94	<0.005	<0.01	2.97	<0.1	<0.05				
111	12-Jan-95	<0.002	<0.01	0.182	<0.09	0.027				
112	29-Jun-92	<0.005	<0.01				RDX	77 ug/L		
112	11-Sep-92	<0.005	<0.01				RDX	70 ug/L		
112	2-Dec-92	<0.005	<0.01							
112	16-Feb-93	<0.02	0.013							
112	11-May-93	<0.02	0.02							
112	14-Jul-93	0.08	0.01							
112	12-Oct-93	<0.02	<0.01							
112	22-Feb-94	<0.02	<0.01							
112	26-Apr-94	<0.02	<0.01							
112	2-Aug-94	<0.02	<0.01							
112	28-Sep-94	<0.005	<0.01	5.82	<0.1	<0.05				
112	13-Jan-95	<0.002	<0.01	3.47	<0.09	<0.015				

Groundwater Chemical Analysis Summary
Longhorn AAP

Well No.	Date	Chloride (mg/L)	pH	Spec. Cond. (umhos/cm)	Nitrite (mg/L)	Nitrate (mg/L)	NO3/ NO2 (mg/L)	Sulfate (mg/L)	Al (mg/L)	As (mg/L)	Ba (mg/L)	Ca (mg/L)	Cd (mg/L)
133	29-Sep-94	15.1	10.8	1715	<0.5	<0.5	<0.5	310.0	6.90	<0.005	0.14	149.0	<0.01
133	11-Jan-95	14.1	6.6	543	<0.5	2.4	2.4	9.2	32.10	0.0215	0.32	114.0	<0.01
134	4-Oct-94	15.5	5.4	126	<0.5	1.7	1.7	18.8	2.00	<0.005	0.08	13.9	<0.01
134	11-Jan-95	10.2	5.7	144	<0.5	10.5	10.5	3.0	13.40	0.0036	0.14	12.4	<0.01

013002

Groundwater Chemical Analysis Summary
Longhorn AAP

Well No.	Date	Co (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Hg (mg/L)	K (mg/L)	Mg (mg/L)	Mn (mg/L)	Ni (mg/L)	Na (mg/L)	Pb (mg/L)	Sb (mg/L)
133	29-Sep-94	<0.05	0.29	0.02	8.4	<0.001	92.7	6.2	0.51	0.02		0.003	<0.1
. 133	11-Jan-95	0.031	0.11	0.04	60.5	<0.0002		13.6	1.96	0.06	82.70	0.030	
134	4-Oct-94	<0.05	<0.05	<0.01	4.5	<0.001	4.3	277	2.34	0.03		<0.002	<0.1
134	11-Jan-95	0.012	0.02	0.028	24.7	<0.0002		7	0.40	0.04	13.60	0.02	

013003

Groundwater Chemic. ,alysis Summary
Longhorn AAP

Well No.	Date	Se (mg/L)	Ag (mg/L)	Sr (mg/L)	Tl (mg/L)	Zn (mg/L)	Organics/Explosives Detected			
133	29-Sep-94	<0.005	<0.01	1.35	<0.1	0.07	Bis (2-ethylhexyl) phthalate	13.5 ug/L		
133	11-Jan-95	<0.002	<0.01	0.70	<0.09	0.23	4-Methylphenol	27.0 ug/L	RDX	1.16 ug/L
134	4-Oct-94	<0.005	<0.01	6.15	<0.1	0.07	Di-n-butylphthalate	45 ug/L	1,3-DNB Tetryl	3.74 ug/L 5.47 ug/L
134	11-Jan-95	<0.002	<0.01	0.23	<0.09	0.12				

013004

U.S. ARMY CORPS OF ENGINEERS
SOUTHWESTERN DIVISION LABORATORY

Longhorn Army Ammunition Plant Monitoring Well Investigations

September/October 1994

Chemical Data Quality Review

Prepared by: Tulsa District Corps of Engineers
April 1995

Table of Contents

Longhorn Army Ammunition Plant
Groundwater Concentration
Background Report

1.0 Discussion.

The U.S. Army Corps of Engineers, Tulsa District, collected approximately five groundwater samples, four travel blanks, one equipment blank, one quality control (QC) duplicate sample, and one quality assurance (QA) duplicate sample in September and October of 1994.

These environmental samples were collected and analyzed in accordance with state and federal guidance documents which, at a minimum, support a level III data quality objective. These sample activities are reflective of a base-wide sampling program to assess background groundwater concentrations of various analytes conducted by the U.S. Army Corps of Engineers for LHAAP.

The Tulsa District personnel distributed their environmental samples to the U.S. Army Corps of Engineers (USACE) Southwestern Division laboratory (SWD) for distribution and analysis. Laboratories under contract to SWD include Environmental Testing and Consulting,Inc., Inchcape Environmental Services; NDRC laboratories, and Southwest Research Institute. All USACE contract laboratories were validated by the Missouri River Division USACE.

All samples were documented in SWD Reports #16124, #16124-1, and #16124-5. A data quality review has been organized in the following sections of this report.

Details of this review; reported holding times, surrogate & spike recoveries, relative percent differences (RPDs), calibration data, mass spectra, chromatograms, GC/MS performance standards, and other lab quality control information are available from the Tulsa District USACE, Chemistry and Industrial Hygiene Section, upon request.

2.0 Standards of Comparability.

The U.S. Army Corps of Engineers (USACE) assures that chemical data results generated from in-house programs and architect-engineering contracts is both accurate and reliable. This is accomplished by following the guidelines set fourth in ER 1110-1-263; Chemical Data Quality Management for Hazardous Waste Remedial Activities. Other guidance documents associated with sampling, analysis, and validation include, but are not limited to, "RCRA Groundwater Monitoring Draft Technical Guidance; EPA/530-R-93-001 (November 1992)", "Compendium of ERT Soil Sampling and Geophysics Procedures; EPA/540/P-91/006 (January 1991)", "USACE MCX-Sampling and Analysis Requirements for Measurement of Chemicals in the Environment (June 1993)", "National Functional Guidelines For Organic Data Review (June 1991)", and "National Functional Guidelines For Evaluating Inorganics Analyses (July 1988)."

The U.S. Army Corps of Engineers requires that the contractor select USACE Missouri River Division (MRD) approved laboratories. Each of the laboratories is required to have in place a laboratory quality control program which certifies that the data generated from the lab is accurate and reliable. The contractor initiates another level of review to insure that the data is accurate and reliable. Parallel to these activities, the USACE requires that the contractor collect quality assurance (QA) samples and distribute them to government laboratories. A similar review and validation process is conducted upon the QA samples.

Upon receipt of the contractor's sample data, contractor's data validation report, USACE QA sample data, and USACE QA data validation report, the USACE District office initiates another review. The District office reviews the findings of both the contractor and USACE QA data validation reports, and determines if the generated data is indeed accurate, reliable, and complete. Inconsistencies found between the field, quality control duplicate, and quality assurance duplicate samples are investigated. Guidelines previously mentioned are employed to assess the validity of the results, as well as sound professional judgement. As a District guideline, differences in field and QA duplicate sample results that are greater than a factor of two for aqueous samples and a factor of five for soil/sediment samples are considered to fall outside typical quality control ranges. Differences which cannot be analytically interpreted are noted.

When the U.S. Army Corps of Engineers elects to perform all or some of the investigation functions in-house, the procedures previously mentioned are still observed.

3.0 Chain of Custody Synopsis.

Analytical Methods					
Sample ID	8240	8270	8330	6010 7060,7470 7520,7421 7740,7610	300
Sampling Conducted on 9/27/94					
MW-110	1	1	1	1	4
MW-111	1	1	1	1	4
MW-111-TB	1				
Sampling Conducted on 9/28/94					
MW-112	1	1	1	1	4
MW-112-QA	2	2	3	2	1
MW-112-QC	1	1	1	1	4
MW-112-EB	1	1	1	1	4
MW-112-TB	1				
Sampling Conducted on 9/29/94					
MW-133	1	1	1	1	4
MW-133-TB	1				
Sampling Conducted on 10/04/94					
MW-134	1	1	1	1	4
MW-134-TB	1				

Notes: 1 - INCHAPE Testing Services, NDRC Laboratories
2 - Environmental Testing & Consulting, Inc.
3 - Southwest Research Institute
4 - Southwest Division Laboratory
* - Travel Blanks manufactured on 9/16/94

4.0 Organics.

SW-846 methods 8240 and 8270 were used to analyze the groundwater for volatile organics and semivolatile organics. All samples were reported to be analyzed within the appropriate holding times.

4.1 Accuracy. NDRC laboratories performed all of the volatile organic and semivolatle organic analyses for field samples and the quality control sample. Matrix spike (MS) and surrogate standard (SS) recoveries were typically reported as acceptable.

The QA laboratory (Environmental Testing & Consulting, Inc.) performed the volatile organic and semivolatile organic analysis for the quality assurance sample. ETC indicated that all matrix spike and surrogate recoveries fell within acceptable QC limits. However, no MS was analyzed for the semivolatile organics due to the limited amount of sample: a laboratory spike was analyzed to instead of the matrix spike for the semivolatile analyses.

4.2 Precision. NDRC laboratories performed all of the volatile organic and semivolatle organic analyses. Matrix spike duplicate (MSD) recoveries were typically reported as acceptable. Relative percent differences (RPDs) were reported to fall within acceptable QC limits.

The QA laboratory (Environmental Testing and Consulting) indicated that all MSD recoveries fell within acceptable QC limits. However, a laboratory control spike duplicate was analyzed instead of the matrix spike duplicate for the semivolatile organic analyses in which pyrene fell outside of control limits. RPD values were reported to fall within acceptable QC limits.

Quality control information was collected during the field activities. Table 4.2 lists field and quality control duplicate samples collected. Comparison of the field and quality control duplicate samples reported consistent results for volatile organic and semivolatile organic analytes.

Table 4.2
Field & QC Duplicate Samples

Field Sample	QC Duplicate Sample
MW-112	MW-112-QC

4.3 Representativeness. NDRC laboratory reported that the majority of method blanks were free of contamination. However, the semivolatile organic method blank for Batch 8270-3520-121 was contaminated with one tentatively identified compound. This compound was found in all of the associated samples.

For report #16124-1 an incorrect sampling date was given to NDRC for the travel blank. The sampling date should read 29 September 1994 instead of 16 September 1994.

The QA laboratory reported that their method blanks were free of contamination.

4.4 Comparability. Quality assurance information was collected during the field activities. Table 4.4 lists field and quality assurance duplicate samples collected. Comparison of the field and quality control duplicate samples reported consistent results for volatile organic and semivolatile organic analytes.

Table 4.4
Field & QA Duplicate Samples

Field Sample	QA Duplicate Sample
MW-112	MW-112-QA

5.0 Explosives.

Method 8330 was used to analyze the groundwater for several explosive analytes. All samples were typically reported to be analyzed within the appropriate holding time.

5.1 Accuracy. NDRC laboratories performed the explosive analyses for all field samples and the QC duplicate sample. The matrix spike and surrogate recoveries were reported to have fallen within acceptable QC limits.

The QA laboratory (Southwest Research Institute) reported that the matrix spike and liquid control spike for tetryl and nitrobenzene fell outside of control limits. All results were appropriately qualified by internal QC.

5.2. Precision. NDRC laboratories performed the explosive analyses for all field samples and the QC duplicate sample. Matrix spike duplicate recoveries were reported to have fallen within acceptable QC limits. Relative percent differences (RPDs) were reported to fall within acceptable QC limits.

The QA laboratory indicated that no matrix spike duplicate was analyzed. No explanation was given by the QA laboratory regarding this incident and the lack of requested quality control information. Any explosive analyte detected may be required to be qualified.

Quality control information was collected during the field activities. Table 5.2 lists field and quality control duplicate samples collected. Comparison of the field and quality control duplicate samples reported consistent results for the explosive analytes.

Table 5.2
Field & QC Duplicate Samples

Field Sample	QC Duplicate Sample
MW-112	MW-112-QC

5.3 Representativeness. Both NDRC and Southwest Research Institute laboratories reported that the method blanks were free of contamination.

5.4 Comparability. Quality assurance information was collected during the field activities. Table 5.4 lists field and quality control duplicate samples collected. Comparison of the field and quality assurance duplicate samples reported consistent results for the explosive analytes.

Table 5.4
Field & QA Duplicate Samples

Field Sample	QA Duplicate Sample
MW-112	MW-112-QA

6.0 Anions.

EPA method 300.0 was requested to analyze the groundwater for nitrate, nitrite, chloride and sulfate.

Chloride and Sulfate analyses for the QA duplicate sample were not performed due to an error in sample tracking.

The nitrate and nitrite analyses were performed by method 9056 instead of method 300.0 for the QA sample. The methods are similar and comparable. The nitrate QA sample was also diluted by a factor of 10.

All samples were analyzed within the appropriate holding times.

6.1. Accuracy. Southwest Division Laboratory performed all anion analyses except for the QA sample which was performed by NDRC. All matrix spike and laboratory control recoveries from SWD were within control limits with the exception that a laboratory control spike was performed instead of a matrix spike for the chloride and nitrate analyses for batch 092994.

NDRC, which performed the QA analyses, reported matrix spike and laboratory control recoveries were within control limits.

6.2. Precision. SWD reported matrix spike and laboratory control spike duplicate recoveries fell within control limits. However for batch 092994 no matrix spike duplicate was performed for chloride or nitrate; a laboratory control spike duplicate was analyzed instead. Relative percent differences (RPDs) were reported to fall within acceptable QC limits.

NDRC laboratory reported matrix spike duplicate and laboratory control spike duplicate recoveries to have fallen within acceptable QC limits. RPDs were reported to have fallen within acceptable QC limits.

Quality control information was collected during the field activities. Table 6.2 lists field and quality control duplicate samples collected. Comparison of the field and quality control duplicate samples reported consistent results for the anion analytes.

Table 6.2
Field & QC Duplicate Samples

Field Sample	QC Duplicate Sample
MW-112	MW-112-QC

6.3 Representativeness. Both SWD and NDRC laboratory reported that the method blanks were free of contamination.

6.4 Comparability. Quality assurance information was collected during the field activities. Table 6.4 lists field and quality control duplicate samples collected. Comparison of the field and quality assurance duplicate samples reported consistent results for the anion analytes.

Table 6.4
Field & QA Duplicate Samples

Field Sample	QA Duplicate Sample
MW-112	MW-112-QA

7.0 Inorganics (Total Metals).

SW-846 methods 6010 (aluminum, barium, cadmium, calcium, chromium, copper, cobalt, iron, magnesium, manganese, silver, antimony, strontium, thallium, and zinc), 7421 (lead), 7470 (mercury), 7060 (arsenic), 7610 (potassium),7740 (selenium), and 7520 (nickel) were requested to analyze the sample for a number of metals.

NDRC laboratory analyzed the field samples and the QC duplicate sample. Environmental Testing & Consulting, Inc. (ETC) analyzed the QA duplicate sample.

NDRC reported the potassium analyses was performed by method 6010A, not method 7610 as requested, for the field samples contained in report #16124. The two field samples contained in reports #16124-1 and #16124-5 as well as the QA duplicate sample analyzed by ETC were analyzed using method 7610. The lab reported that "due to the high amount of potassium in the samples, the results are comparable."

NDRC and ETC used method 7470 instead of method 6010 to analyze for mercury for all samples. Method 7470 has a lower detection limit than 6010.

The case narrative reported that both the arsenic QC and the selenium QA duplicate samples were diluted by a factor of ten before analyses.

NDRC laboratory reported the arsenic analysis for sample MW-133, report #16124-1, was diluted by a factor of five.

All samples were reported by the laboratory to have been analyzed within the appropriate holding times.

7.1 Accuracy. For all three reports NDRC laboratories matrix spike and laboratory control spike recoveries were generally reported as acceptable. However, for report #16124 matrix spike recoveries for Ca, Se, and Mg fell outside of QC limits due to "matrix interference."

For report #16124-1, NDRC reports that the matrix spike recoveries for Mg, Ca, and Sr fell outside of control limits because the concentration of the analyte was significantly greater than the spike concentration. Matrix spike concentrations for Th, Se, Pb, and Ni fell outside of control limits due to "matrix interference." All results were appropriately qualified by internal QC.

For report #16124-5, NDRC reports the matrix spike recovery for Ca was outside of control limits because the concentration of the analyte was significantly greater than the spike concentration.

ETC reported that the matrix spike recoveries for As and Se fell outside of control limits due to "matrix interference." The matrix spike for Pb also fell outside of control limits.

Results were appropriately qualified using internal laboratory QC. Specific details regarding these observations are discussed in the case narratives.

7.2 Precision. NDRC laboratories matrix spike duplicate and laboratory control spike duplicate recoveries were generally reported as acceptable for all three reports. However, for report #16124 MSD recoveries for Ca, batch 9365, and Ar, batch 9369, fell outside of QC limits due to "matrix interference." For batch 9369, Mg and Ca fell outside of control limits because the concentration of the analytes was significantly greater that the spike concentration. The RPD was reported to have fallen outside acceptable QC limits for Al, batch 9365.

For report #16124-1, NDRC reports the MSD recoveries fell outside of control limits for Mg, Ca, Sr, Se, Pb, Ni, and Tl.

For report #61124-5, NDRC reports the MSD recoveries fell outside of control limits for Ca. The RPD for As fell outside of control limits.

The QA lab , ETC, reports that the MSD recoveries for Se, As, and Pb fell outside of control limits.

All results were appropriately qualified using internal laboratory QC. Specific details regarding these observations are discussed in the SWD case narrative.

Quality control information was collected during the field activities. Table 7.2 lists field and quality control duplicate samples collected. Comparison of the field and quality control duplicate samples reported consistent results.

Table 7.2
Field & QC Duplicate Samples

Field Sample	QC Duplicate Sample
MW-112	MW-112-QC

7.3 Representativeness. NDRC laboratory reported that the majority of method blanks were free of contamination. However, potassium was detected in the equipment blank (1500 ug/L.)

ETC laboratory reported that the majority of method blanks were free of contamination with following exceptions. The inorganic method blank indicated contamination with Ca (105 ug/L), Fe (41 ug/L), and Mg (4 ug/L.)

7.4 Comparability. Quality assurance information was collected during the field activities. Table 7.4 lists field and quality assurance duplicate samples collected. Comparison of the field and quality assurance duplicate samples reported consistent results with all analytes except K and Al. Labs have been asked to recheck their calculations.

Table 7.4
Field & QA Duplicate Samples

Field Sample	QA Duplicate Sample
MW-112	MW-112-QA

8.0 Technical Summary.

Several of the requested analytical methods were changed by the analyzing laboratories. The laboratories chose to employ improved analytical methods in these cases.

Several analyses were diluted by a factor of five or ten. The results were below the adjusted detection limits.

No matrix spike duplicate or laboratory control spike duplicate was performed by Southwest Research Institute for the analyses for explosives QA sample. Any explosive analyte detected may be required to be qualified.

No chloride or sulfate analyses for the QA duplicate sample were performed due to an error in sample tracking.

Potassium was detected in the equipment blank. This contamination did not affect any of the field results.

No other problems were noted concerning the sampling and analysis of the samples from the listed sites.

9.0 Conclusion.

An overall evaluation of the Longhorn Army Ammunition Plant, September/October 1994, Monitoring Well Investigations, Reports (SWD #16124, #16124-1, and #16124-5) indicates that sampling procedures and laboratory analyses have been adequately completed and that the field data should be considered accurate and reliable.

David Jones,
Physical Scientist, Chemistry & IH Sec.

dj/CK

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CASE NARRATIVE

Three water samples, two travel blanks, one equipment blank, one quality control sample, and one quality assurance sample arrived at Southwestern Division Laboratory on 28 and 29 September 1994 from Longhorn AAP - MW-110, MW-111, and MW-112. The samples arrived in good condition and with complete chain of custodies. SWD kept the anion analyses for the field and quality control samples. The remaining analyses for the field samples and quality control sample and the anion analyses for the quality assurance sample were contracted out to a Corps of Engineers' validated laboratory, NDRC Laboratories, Inc. The explosive analysis for the quality assurance sample was contracted out to a Corps of Engineers' validated laboratory, Southwest Research Institute. The remaining analyses for the quality assurance sample were contracted out to a Corps of Engineers' validated laboratory, Environmental Testing & Consulting, Inc. Due to a tracking error, the chloride and sulfate analyses were not requested of the contract laboratory for the quality assurance sample.

The data package from Southwestern Division Laboratory was received complete with all required internal quality control information. All analyses were performed using specified methods within proper holding times. All matrix spike and laboratory control recoveries were within control limits. An LCS and LCSD were analyzed for the chloride and nitrate analyses instead of an MS and MSD for Batch 092994. All method blanks were free of contamination.

The data package from NDRC Laboratories, Inc. was received complete with all required internal quality control information. The majority of the analyses were performed using specified methods within proper holding times. The nitrate and nitrite analyses were performed by method 9056 instead of method 300.0. The methods are similar and comparable. The potassium analyses were performed using method 6010A instead of method 7610. Due to the high level of potassium in the samples, the results are comparable. The nitrite analysis for the quality assurance sample was diluted by a factor of ten. The result was below the adjusted detection limit. The arsenic analyses for samples MW-112-QC and MW-112 were diluted by a factor of ten. The results were below the adjusted detection limits. All matrix spike, surrogate and laboratory control recoveries were within control limits with the following exceptions noted.

The matrix duplicate RPD for aluminum was outside control limits for Batch 9365.

The MS and MSD recoveries for calcium were outside control limits for Batch 9365 due to matrix interference.

The MS and MSD recoveries for magnesium and calcium were outside control limits for Batch 9369 because the concentration of the analyte was significantly greater than the spike concentration.
The MSD recovery for arsenic was outside control limits for Batch 9369 due to matrix interference.

The majority of the method blanks were free of contamination. The semi-volatile method blank for Batch 8270-3520-121 was contaminated with one tentatively identified compound. This compound was found in all of the associated samples.

The data package from Environmental Testing & Consulting, Inc. was received complete with all required internal quality control information. All analyses were performed using specified methods within proper holding times. The selenium analysis for sample MW-112-QA was diluted by a factor of five. The result was below the adjusted detection limit. All matrix spike, surrogate and laboratory control recoveries were within control limits with the following exceptions noted.
The MS and MSD recoveries and the MS/MSD RPD for arsenic were outside control limits due to matrix interference.
The MS and MSD recoveries for selenium were outside control limits due to matrix interference.
The MS and MSD recoveries for lead were outside control limits.
The LCSD for pyrene, a semi-volatile compound, was outside control limits.
No MS or MSD was analyzed for the semi-volatile analysis. An LCS and LCSD were analyzed instead.

The majority of the method blanks were free of contamination. The metal method blank was contaminated with calcium (105 μg/L), iron (41 μg/L), and manganese (4 μg/L). The concentrations of these metals in the quality assurance were at least 92 times the concentration in the method blank. As a result, these contaminations are negligible.

The data package from Southwest Research Institute was received complete with all required internal quality control information. The analysis was performed using the specified method within the proper holding time. All matrix spike, surrogate and laboratory control recoveries were within control limits with the following exceptions noted.
The LCS and MS recoveries for tetryl and nitrobenzene, both explosives, were outside control limits.
No MSD was analyzed for the explosive analysis.

The method blank was free of contamination.

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Following is a synopsis of the quality assurance samples and their related QC and field samples:

Customer Sample No.: MW-112, MW-112-QC, MW-112-QA
SWD Lab Sample No.: 4-5122, 4-5120, 4-5119

Parameter	Field	QC	QA	Units	Comment
Aluminum	4,300	3,100	1,390	µg/L	Disagre
Antimony	<100	<100	< 32	µg/L	Agree
Arsenic	< 50	< 50	< 2	µg/L	Agree
Barium	50	40	73	µg/L	Agree
Cadmium	< 10	< 10	< 4	µg/L	Agree
Calcium	308,000	299,000	207,000	µg/L	Agree
Chromium	< 50	< 50	7	µg/L	Agree
Cobalt	< 50	< 50	14	µg/L	Agree
Copper	< 10	< 10	6	µg/L	Agree
Iron	4,400	3,500	3,770	µg/L	Agree
Lead	< 2	< 2	3	µg/L	Agree
Magnesium	244,000	243,000	240,000	µg/L	Agree
Manganese	1,950	2,000	1,850	µg/L	Agree
Mercury	< 1	< 1	< 1	µg/L	Agree
Nickel	30	30	30	µg/L	Agree
Potassium	5,500	5,400	2,650	µg/L	Disagre
Selenium	< 5	< 5	< 10	µg/L	Agree
Silver	< 10	< 10	< 7	µg/L	Agree
Strontium	5,820	5,860	5,120	µg/L	Agree
Thallium	<100	<100	< 40	µg/L	Agree
Zinc	< 50	< 50	26	µg/L	Agree
Chloride	874	866	NA	mg/L	Agree
Sulfate	876	869	NA	mg/L	Agree
Nitrate	< 0.5	< 0.5	0.1	mg/L	Agree
Nitrite	< 0.5	< 0.5	< 0.1	mg/L	Agree
Explosives	No Hits	No Hits	No Hits	µg/L	Agree
VOA	No Hits 0 TICs	No Hits 0 TICs	No Hits 0 TICs	µg/L	Agree
SVOA	No Hits 1 TICs	No Hits 1 TICs	No Hits 1 TICs	µg/L	Agree

NA - Not analyzed

Both laboratories have been contacted and asked to recheck their calculations. Any changes will be forwarded as soon as possible.

PROJECT: Longhorn

SAMPLES: 4-5090 to 4-5092, 4-5118 to 4-5122

REPORT DATE: October 26, 1994 **Data check time:** 2 hrs

QUALITY CONTROL CHECKLIST

Chain of Custody Check

1. Do sample ID numbers agree with the C.O.C? Yes
2. Do site and location agree with the C.O.C? Yes
3. Do sampling dates agree with the C.O.C? Yes
4. Do method numbers agree with the C.O.C? Yes
5. Are all samples and analyses accounted for? Yes

Data Check

1. Holding Times
   - (1) Metals In
   - (2) Explosives In
   - (3) Volatiles In
   - (4) Semi-volatiles In
   - (5) Nitrate/Nitrite In
   - (6) Sulfate In
   - (7) Chloride In
2. Do detection limits and dilution factors agree? Yes
3. Are units correct? Yes

QC Check

1. MS/MSD Out
2. RPD for MS/MSD In
3. LCS and/or Blank Spike In
4. Blanks Above
5. Acceptable Surrogates Yes
6. RPD for duplicates Out
7. Tuning and calibration check Yes

Comments

Data checked by: LMG

NDRC
Potassium analyzed by 6010A instead of 7610
Nitrate analyzed by 9056 instead of 300.0
Nitrite analyzed by 9056 instead of 300.0
Nitrite diluted by ten - MW-112-QA - No result
Arsenic dilute by ten - MW-112-QC - No result
Matrix duplicate RPD for aluminum out for Batch 9365
MS, MSD for calcium for Batch 9365 out due to matrix interference
MS for selenium for Batch 9365 out due to matrix interference

MS, MSD for magnesium, calcium out for Batch 9369 due to high concentration
MSD for arsenic out for Batch 9369 due to matrix interference
One TIC found in SVOA method blank for Batch 8270-3520-121 (found in all associated sample)
One TIC found in equipment blank for SVOA analysis
Potassium found in equipment blank (1,500 μg/L)

SWD
No comment

ETC
Selenium diluted by five - MW-112-QA - No result
Metal method blank contaminated - Calcium (105 μg/L), iron (41 μg/L), manganese (4 μg/L)
MS, MSD, MS/MSD RPD for arsenic out due to matrix interference
MS, MSD for selenium out due to matrix interference
MS, MSD for lead out
LCSD for pyrene out
MS, MSD not analyzed for SVOA, LCS and LCSD instead

SwRI
LCS recovery for Tetryl and nitrobenzene out
MS recovery for Tetryl and nitrobenzene out
No MSD analyzed

U.S. ARMY CORPS OF ENGINEERS
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CASE NARRATIVE

One water sample and one travel blank arrived at Southwestern Division Laboratory on 30 September 1994 from Longhorn AAP. The samples arrived in good condition and with complete chain of custodies. SWD kept the anion analyses. The remaining analyses were contracted out to a Corps of Engineers' validated laboratory, NDRC Laboratories, Inc.

The data package from Southwestern Division Laboratory was received complete with all required internal quality control information. All analyses were performed using specified methods within proper holding times. All matrix spike and laboratory control recoveries were within control limits. All method blanks were free of contamination.

The data package from NDRC Laboratories, Inc. was received complete with all required internal quality control information. Due to a tracking error, the wrong sampling date was supplied to NDRC for the travel blank. The sampling date should be 29 September 1994 instead of 16 September 1994. All analyses were performed using specified methods within proper holding times. The arsenic analysis for sample MW-133 was diluted by a factor of five. The result was below the adjusted detection limit. All matrix spike, surrogate and laboratory control recoveries were within control limits with the following exceptions noted.

The MS and MSD recoveries for magnesium, calcium, and strontium were outside control limits for Batch 9392 because the concentration of the analyte was significantly greater than the spike concentration.

The MS recovery for thallium was outside control limits for Batch 9392 due to matrix interference.

The MS and MSD recoveries for selenium, lead, and nickel were outside control limits for Batch 9392 due to matrix interference.

The majority of the method blanks were free of contamination. The semi-volatile method blank for Batch 8270-3520-121 was contaminated with one tentatively identified compound at a concentration of 38 $\mu g/L$. This compound was found in sample MW-133 at a concentration of 13 $\mu g/L$.

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PROJECT: Longhorn

SAMPLES: 4-5155 to 4-5156

REPORT DATE: October 31, 1994 **Data check time:** 1 hr

QUALITY CONTROL CHECKLIST

Chain of Custody Check

1. Do sample ID numbers agree with the C.O.C? Yes
2. Do site and location agree with the C.O.C? Yes
3. Do sampling dates agree with the C.O.C? Yes
4. Do method numbers agree with the C.O.C? Yes
5. Are all samples and analyses accounted for? Yes

Data Check

1. Holding Times
   (1) Metals In
   (2) Explosives In
   (3) Volatiles In
   (4) Semi-volatiles In
   (5) Anions In
2. Do detection limits and dilution factors agree? Yes
3. Are units correct? Yes

QC Check

1. MS/MSD Out
2. RPD for MS/MSD Out
3. LCS and/or Blank Spike Out
4. Blanks Below
5. Acceptable Surrogates Yes
6. RPD for duplicates In
7. Tuning and calibration check Yes

Comments
Data checked by: LMG

NDRC
Wrong sampling date supplied to NDRC for TB. Should be 29 September instead of 16 September.

Arsenic diluted by five. No result - MW-133 (4-5156)
SVOA method blank contaminated with one TIC.
Method blank RT - 9.09 conc - 38 µg/L
MW-133 RT - 9.08 conc - 13 µg/L
MS, MSD for magnesium for batch 9392 due to high concentration
MS for thallium for batch 9392 due to matrix interference
MS, MSD for calcium for batch 9392 due to high concentration
MS, MSD for strontium for Batch 9392 due to high concentration
MS, MSD for selenium for batch 9392 due to matrix interference
MS, MSD for lead, nickel for batch 9392 due to matrix interferen

SWD
Matrix duplicate RPD for chloride out

U.S. ARMY CORPS OF ENGINEERS
Southwestern Division Laboratory
Environmental Services Section
4815 Cass Street
Dallas, Texas 75235
214/905-9130

CASE NARRATIVE

One water sample and one travel blank arrived at Southwestern Division Laboratory on 05 October 1994 from Longhorn AAP. The samples arrived in good condition and with complete chain of custodies. One vial contained bubbles. The client authorized the method change for nickel from method 7520 to method 7521. SWD kept the anion analyses. The remaining analyses were contracted out to a Corps of Engineers' validated laboratory, NDRC Laboratories, Inc.

The data package from Southwestern Division Laboratory was received complete with all required internal quality control information. All analyses were performed using specified methods within proper holding times. All matrix spike and laboratory control recoveries were within control limits. All method blanks were free of contamination.

The data package from NDRC Laboratories, Inc. was received complete with all required internal quality control information. All analyses were performed using specified methods within proper holding times. All matrix spike, surrogate and laboratory control recoveries were within control limits with the following exceptions noted.

- The MS and MSD recoveries for calcium were outside control limits for Batch 9421 because the concentration of the analyte was significantly greater than the spike concentration.
- The matrix duplicate RPD for arsenic was outside control limits for Batch 9406.

The majority of the method blanks were free of contamination. The semi-volatile method blank was contaminated with two tentatively identified compounds at a concentration of 36 $\mu g/L$. Neither compound was found the sample.

The release of this report was delayed because a MIPR number was not identified on the chain of custodies. After contacting Tulsa District personnel on 10 November, funds were provided on 22 November 1994.

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PROJECT: Longhorn AAP

SAMPLES: 4-5180 to 4-5181

REPORT DATE: November 10, 1994 **Data check time:** 1 hr

QUALITY CONTROL CHECKLIST

Chain of Custody Check

1. Do sample ID numbers agree with the C.O.C? Yes
2. Do site and location agree with the C.O.C? Yes
3. Do sampling dates agree with the C.O.C? Yes
4. Do method numbers agree with the C.O.C? Yes
5. Are all samples and analyses accounted for? Yes

Data Check

1. Holding Times
   - (1) Metals In
   - (2) Explosives In
   - (3) Volatiles In
   - (4) Semi-volatiles In
   - (5) Nitrate/Nitrite In
   - (6) Sulfate In
   - (7) Chloride In
2. Do detection limits and dilution factors agree? Yes
3. Are units correct? Yes

QC Check

1. MS/MSD In
2. RPD for MS/MSD In
3. LCS and/or Blank Spike In
4. Blanks Above
5. Acceptable Surrogates Yes
6. RPD for duplicates In
7. Tuning and calibration check Yes

Comments

Data checked by: LMG

One vial with bubbles
Method change from 7520 to 7521

Results based on wet weight.
Semi-volatile method blank contaminated with two TICs - not found in sample
MS, MSD for calcium out for Batch 9421 due to high concentration
Matrix duplicate RPD for arsenic out for Batch 9406

013028

U.S. ARMY CORPS OF ENGINEERS
SOUTHWESTERN DIVISION LABORATORY

Longhorn Army Ammunition Plant

January 1995
Groundwater Background
Assessment

Chemical Data Quality Review

Prepared by: Tulsa District Corps of Engineers
March 1995

Table of Contents

Longhorn Army Ammunition Plant

January 1995 Groundwater Background Assessment

1.0 Discussion.

The U.S. Army Corps of Engineers, Tulsa District, collected approximately six groundwater samples, three travel blanks, one equipment blank, one quality control (QC) duplicate samples, and two quality assurance (QA) duplicate samples in January of 1995.

These environmental samples were collected and analyzed in accordance with state and federal guidance documents which, at a minimum, support a level III data quality objective.

The Tulsa District personnel distributed their environmental samples to the U.S. Army Corps of Engineers (USACE) Southwestern Division laboratory (SWD) for distribution and analysis. Laboratories under contract to SWD include Environmental Testing and Consulting,Inc., Inchcape Environmental Services; NDRC laboratories, and Southwest Research Institute. All USACE contract laboratories were validated by the Missouri River Division USACE.

All samples were documented in SWD Report #16234. A data quality review has been organized in the following sections of this report.

Details of this review; reported holding times, surrogate & spike recoveries, relative percent differences (RPDs), calibration data, mass spectra, chromatograms, GC/MS performance standards, and other lab quality control information are available from the Tulsa District USACE, Chemistry and Industrial Hygiene Section, upon request.

2.0 Standards of Comparability.

The U.S. Army Corps of Engineers (USACE) assures that chemical data results generated from in-house programs and architect-engineering contracts is both accurate and reliable. This is accomplished by following the guidelines set fourth in ER 1110-1-263; Chemical Data Quality Management for Hazardous Waste Remedial Activities. Other guidance documents associated with sampling, analysis, and validation include, but are not limited to, "RCRA Groundwater Monitoring Draft Technical Guidance; EPA/530-R-93-001 (November 1992)", "Compendium of ERT Soil Sampling and Geophysics Procedures; EPA/540/P-91/006 (January 1991)", "USACE MCX-Sampling and Analysis Requirements for Measurement of Chemicals in the Environment (June 1993)", "National Functional Guidelines For Organic Data Review (June 1991)", and "National Functional Guidelines For Evaluating Inorganics Analyses (July 1988)."

The U.S. Army Corps of Engineers requires that the contractor select USACE Missouri River Division (MRD) approved laboratories. Each of the laboratories is required to have in place a laboratory quality control program which certifies that the data generated from the lab is accurate and reliable. The contractor initiates another level of review to insure that the data is accurate and reliable. Parallel to these activities, the USACE requires that the contractor collect quality assurance (QA) samples and distribute them to government laboratories. A similar review and validation process is conducted upon the QA samples.

Upon receipt of the contractor's sample data, contractor's data validation report, USACE QA sample data, and USACE QA data validation report, the USACE District office initiates another review. The District office reviews the findings of both the contractor and USACE QA data validation reports, and determines if the generated data is indeed accurate, reliable, and complete. Inconsistencies found between the field, quality control duplicate, and quality assurance duplicate samples are investigated. Guidelines previously mentioned are employed to assess the validity of the results, as well as sound professional judgement. As a District guideline, differences in field and QA duplicate sample results that are greater than a factor of two for aqueous samples and a factor of five for soil/sediment samples are considered to fall outside typical quality control ranges. Differences which cannot be analytically interpreted are noted.

When the U.S. Army Corps of Engineers elects to perform all or some of the investigation functions in-house, the procedures previously mentioned are still observed.

3.0 Chain of Custody Synopsis.

Analytical Methods							
Sample ID	8240	8270	300.0	8330	6010,7740 7060,7421 7470/7471		
Sampling Conducted on 1/11/95							
LH MW 133 TB	2						
LH MW 111	2	2	1	2	1		
LH MW 133	2	2	1	2	1		
LH MW 133 QA	3	3	2	4	2		
LH MW 134 EB	2	2	1	2	1		
LH MW 134	2	2	1	2	1		
LH MW 134 QC	2	2	1	2	1		
LH MW 134 QA	3	3	2	4	2		
Sampling Conducted on 1/12/95							
LH MW 110 TB	2						
LH MW 110	2	2	1	2	1		
LH MW 112	2	2	1	2	1		
Sampling Conducted on 1/19/95							
LH MW 108 TB	2						
LH MW 108	2	2	1	2	1		

Notes:

1 SWD laboratory
2 Inchcape Environmental Services, NDRC Laboratories
3 Environmental Testing & Consulting, Inc.
4 Southwest Research Institute

4.0 Organics.

SW-846 methods 8240 and 8270 were used to analyze the groundwater for volatile organics and semivolatile organics. All samples were reported to be analyzed within the appropriate holding time.

4.1 Accuracy. NDRC laboratories performed the all of volatile and semivolatle organic analyses. Matrix spike and surrogate recoveries were typically reported as acceptable. However, blank spikes were analyzed for separate volatile and semivolatile organic sample batches (see NDRC case narrative for details). No explanation was given concerning the substitution for MS/MSD results, however, it is speculated by this office that not enough sample matrix was available for spiking. All recoveries were reported to have fallen within acceptable QC limits.

The QA laboratory (Environmental Testing and Consulting) indicated that all matrix spike and surrogate recoveries fell within acceptable QC limits. However, the lab reported that laboratory control spike was analyzed instead of the matrix spike for the semivolatile organic analysis.

4.2 Precision. NDRC laboratories performed the all of volatile and semivolatle organic analyses. Matrix spike duplicate recoveries were typically reported as acceptable. However, blank spike duplicates were analyzed for separate volatile and semivolatile organic sample batches (see NDRC case narrative for details). No explanation was given concerning the substitution for MS/MSD results, however, it is speculated by this office that not enough sample matrix was available for spiking. All recoveries were reported to have fallen within acceptable QC limits.

Relative percent differences (RPDs) were generally reported to fall within acceptable QC limits. However, 4-nitrophenol (semivolatile) was found to fall outside the acceptable QC limit. This result was appropriately qualified by laboratory staff.

The QA laboratory (Environmental Testing and Consulting) indicated that all matrix spike duplicate recoveries fell within acceptable QC limits. However, the lab reported that laboratory control spike duplicate was analyzed instead of the matrix spike duplicate for the semivolatile organic analysis. RPD values were also reported to fall within acceptable QC limits.

Quality control information was collected during the field activities. Table 4.2 lists field and quality control duplicate samples collected. Comparison of the field and quality control duplicate samples reported consistent results for volatile and semivolatile organic analytes. A trace amount of bis (2ethylhexyl) phthalate (15.4 ug/L) was detected in sample LH MW 134 QC and not the field sample.

Table 4.2
Field & QC Duplicate Samples

Field Sample	QC Duplicate Sample
LH MW 134	LH MW 134 QC

4.3 Representativeness. NDRC laboratory reported that the majority of method blanks were free of contamination. However, one semivolatile organic sample batch was contaminated with bis (2ethylhexyl) phthalate (14.5 ug/L). The MSD for this sample batch was also contaminated with this analyte (21.8 ug/L). A volatile organic method blank did detect a tentatively identified compound (TIC) reported to be sulfur dioxide. No other samples indicated the presence of this analyte.

The QA laboratory reported that their method blanks were free of contamination. None of the three travel blanks reported any contamination.

4.4 Comparability. Quality assurance information was collected during the field activities. Table 4.4 lists field and quality control duplicate samples collected. Comparison of the field and quality control duplicate samples reported consistent results for volatile and semivolatile organic analytes. A notable amount of bis (2ethylhexyl) phthalate (46.6 ug/L) was detected in sample LH MW 134 QA and not the field sample.

Table 4.4
Field & QA Duplicate Samples

Field Sample	QA Duplicate Sample
LH MW 133	LH MW 133 QA
LH MW 134	LH MW 134 QA

5.0 Explosives.

SW-846 method 8330 was used to analyze the groundwater for several explosive analytes. All samples were reported to be analyzed within the appropriate holding time.

5.1 Accuracy. NDRC laboratories performed the explosive analyses. Matrix spike and surrogate recoveries were reported to have fallen within acceptable QC limits.

The QA laboratory (Southwest Research Institute) indicated that all matrix spike and surrogate recoveries fell within acceptable QC limits.

5.2. Precision. NDRC laboratories performed the explosive analyses. Matrix spike duplicate recoveries were reported to have fallen within acceptable QC limits. Relative percent differences (RPDs) were reported to fall within acceptable QC limits.

The QA laboratory (Southwest Research Institute) indicated that all matrix spike duplicate recoveries fell within acceptable QC limits. All RPDs were reported to have fallen within acceptable QC limits.

Quality control information was collected during the field activities. Table 5.2 lists field and quality control duplicate samples collected. Comparison of the field and quality control duplicate samples reported consistent results for the explosive analytes.

Table 5.2
Field & QC Duplicate Samples

Field Sample	QC Duplicate Sample
LH MW 134	LH MW 134 QC

5.3 Representativeness. Both NDRC and Southwest Research Institute laboratories reported that the majority of method blanks were free of contamination. The analyzed equipment blank reported no contamination.

5.4 Comparability. Quality assurance information was collected during the field activities. Table 5.4 lists field and quality control duplicate samples collected. Comparison of the field and quality assurance duplicate samples reported consistent results for the explosive analytes. However, sample LH MW 133 detected RDX at 1.16 mg/L while no RDX was detected in the QA duplicate sample. The level at which RDX was detected is roughly equivalent to the detection level reported by the QA laboratory. No particular explanation can be given for this anomaly, however, the field results should be considered reliable.

Table 5.4
Field & QA Duplicate Samples

Field Sample	QA Duplicate Sample
LH MW 133	LH MW 133 QA
LH MW 134	LH MW 134 QA

6.0 Anions.

SW-846 method 9056 was used to analyze the groundwater for several anions, i.e. chloride, nitrate, nitrite, and sulfate. EPA method 300.0 was requested. Both of these methods are comparable.

Southwestern Division laboratory reported that nitrite, chloride, and sulfate samples were analyzed within the appropriate holding time.

The QA laboratory (NDRC) reported that the nitrate QA samples were analyzed outside of the holding time by approximately five days. Further investigation revealed that a tracking error had occurred, delaying the analysis of the samples. The laboratory has taken steps to eliminate this error.

The QA nitrite samples were diluted by a factor of ten. The results were less than the adjusted detection limits as reported in the SWD case narrative.

6.1 Accuracy. Southwestern Division Laboratory reported matrix spike and laboratory spike recoveries to have fallen within acceptable QC limits.

The QA laboratory (NDRC) reported that all matrix spike and laboratory control spike recoveries fell within acceptable QC limits.

6.2. Precision. Southwestern Division Laboratory reported matrix spike duplicate and laboratory spike duplicate recoveries to have fallen within acceptable QC limits. Relative percent differences (RPDs) were reported to fall within acceptable QC limits.

The QA laboratory (NDRC) reported that all matrix spike duplicate and laboratory spike duplicate recoveries fell within acceptable QC limits. All RPDs were reported to have fallen within acceptable QC limits.

Quality control information was collected during the field activities. Table 6.2 lists field and quality control duplicate samples collected. Comparison of the field and quality control duplicate samples generally reported consistent results for the anion analytes. However, field sample LH MW 134 indicated 10.5 mg/L of nitrate while the QC duplicate sample indicated 3.9 mg/L. No explanation was provided for this discrepancy. It was noted that the QC and QA duplicate results appear consistent. The field sample should be considered to be reliable.

Table 6.2
Field & QC Duplicate Samples

Field Sample	QC Duplicate Sample
LH MW 134	LH MW 134 QC

6.3 Representativeness. NDRC laboratory reported that the majority of method blanks were free of contamination.

6.4 Comparability. Quality assurance information was collected during the field activities. Table 6.4 lists field and quality control duplicate samples collected. Comparison of the field and quality assurance duplicate samples generally reported consistent results for the anion analytes. However, field sample LH MW 134 indicated 10.5 mg/L of nitrate while the QA duplicate sample indicated 3.5 mg/L. The field sample result should be considered to be reliable.

Table 6.4
Field & QA Duplicate Samples

Field Sample	QA Duplicate Sample
LH MW 133	LH MW 133 QA
LH MW 134	LH MW 134 QA

7.0 Inorganics (Total Metals).

SW-846 methods 7740 (selenium), 6010 (aluminum, barium, cadmium, chromium, copper, cobalt, iron, magnesium, manganese, silver, nickel, antimony, strontium, sodium, thallium, and zinc), 7421 (lead), 7470 (mercury), and 7060 (arsenic) were requested to analyze the sample for a number of metals.

All samples were reported by the laboratory to have been analyzed within the appropriate holding times.

The QA laboratory (Environmental Testing and Consulting) indicated that the selenium concentration for the QA duplicate sample LH MW 133 QA was diluted by a factor of five. The result was less than the adjusted detection limit.

7.1 Accuracy. SWD Matrix spike and laboratory control spike recoveries were generally reported as acceptable. However, the MS recovery for Fe was reported to have fallen outside of the QC limit reported for one of the sample batches. Fe concentrations were reported to be significantly higher in the sample than in the spike concentration. Details pertaining to this observation are discussed in the SWD case narrative.

The quality assurance laboratory (Environmental Testing and Consulting Inc.), reported that matrix spike and laboratory control spike recoveries were generally reported as acceptable. However, the MS recoveries for Na, Ca, and Se fell outside of the QC limits reported for different sample batches. The Na and Ca recoveries were effected by the presence of Na and Ca at concentrations greater than the spiked concentrations. The Se recovery was effected by a matrix interference. Details pertaining to each sample batch are discussed in the SWD case narrative.

7.2 Precision. SWD Matrix spike duplicate and laboratory control spike duplicate recoveries were generally reported as acceptable. However, the MSD recovery for Fe was reported to have fallen outside of the QC limit reported for one of the sample batches. Fe concentrations were reported to be significantly higher in the sample than in the spike concentration. No matrix spike duplicate was analyzed for Na for one sample batch. Details pertaining to this observation are discussed in the SWD case narrative. All RPDs were reported to have fallen within acceptable QC limits.

The quality assurance laboratory (Environmental Testing and Consulting Inc.), reported that matrix spike duplicate and laboratory control spike duplicate recoveries were generally reported as acceptable. However, the MSD recoveries for Na, Ca, and Se fell outside of the QC limits reported for different sample batches. The Na and Ca recoveries were effected by the presence of Na and Ca at concentrations greater than the spiked concentrations. The Se recovery was effected by a matrix interference. Details pertaining to each sample batch are discussed in the SWD case narrative. All RPDs were reported to have fallen within acceptable QC limits.

Quality control information was collected during the field activities. Table 7.2 lists field and quality control duplicate samples collected. Comparison of the field and quality control duplicate samples reported consistent results.

Table 7.2
Field & QC Duplicate Samples

Field Sample	QC Duplicate Sample
LH MW 134	LH MW 134 QC

7.3 Representativeness. SWD laboratory reported that the majority of method blanks were free of contamination. However, sodium was detected at 421 ug/L in one of the sample batches. The QA laboratory also reported that their method blanks were free of contamination.

The equipment blank sample LH MW 134 EB was found to have detected 220 ug/L of calcium, 65 ug/L of iron, and 2250 ug/L of sodium. Disposable bailers were used to sample the wells. No cross contamination should have occurred between each well. It is highly probable that the filtering system employed by the sampling crew was not functioning properly and had created a batch of unfiltered water. Since this sampling episode, a new filtering system has been installed and has been closely monitored. Analysis of the equipment blank should indicate if the bailer contributed to any contamination of the sample. Bailers are individually wrapped and sealed by the manufacturer and are not opened until just prior to sampling. No other analytes were reported to have been detected in the equipment blank. The results of the equipment blank do not negatively impact the field results.

7.4 Comparability. Quality assurance information was collected during the field activities. Table 7.4 lists field and quality assurance duplicate samples collected. Comparison of the field and quality assurance duplicate samples reported consistent results.

Table 7.4
Field & QA Duplicate Samples

Field Sample	QA Duplicate Sample
LH MW 133	LH MW 133 QA
LH MW 134	LH MW 134 QA

8.0 Technical Summary.

SWD laboratory reported that samples arrived in good condition and with complete chain of custody forms. SWD had noted that the sample LH MW 108 (which arrived on 1/19/95) did not have the COC forms properly filled out. Copies of the original document were checked by the District staff and found to be in order.

Two QA nitrate samples were analyzed five days outside of holding time. Field results are considered reliable.

As documented in section 7.3, the equipment blank reported three metals, Fe, Ca, and Na. The results of the equipment blank did not negatively impact the field results.

No other problems were noted concerning the sampling and analysis of the samples from the listed sites.

9.0 Conclusion.

An overall evaluation of the Longhorn Army Ammunition Plant, Remedial Investigation, Hydrogeologic Assessment Report (SWD #16234) indicates that sampling procedures and laboratory analyses have been adequately completed and that the field data should be considered accurate and reliable.

Chris Kennedy,
Chemist, CIH Section

ck/CK

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CASE NARRATIVE

Six water samples, three travel blanks, one equipment blank, one quality control samples, and two quality assurance samples arrived at Southwestern Division Laboratory on 12, 13, and 19 January 1995 from Longhorn AAP - Hydrogeologic Assessment. The samples arrived in good condition and with relatively complete chain of custodies. The COC for sample LHMW-108 was not properly relinquished. The signature and time of relinquishment were not indicated. One vial contained bubbles in the 12 January shipment. SWD kept the anion and metal analyses for the field and quality control samples. The remaining analyses for the field and quality control samples were contracted out to a Corps of Engineers' validated laboratory, NDRC Laboratories. The analyses for the quality assurance samples were contracted out to a Corps of Engineers' validated laboratory, Environmental Testing & Consulting, Inc. Preliminary results were faxed to the client on 30 January and 03 February 1995. Preliminary results for samples arriving on 12 January were Federal Expressed on 01 February 1995.

The data package from Southwestern Division Laboratory was received complete with all required internal quality control information. All analyses were performed using specified methods within proper holding times. All matrix spike, surrogate and laboratory control recoveries were within control limits with the following exceptions noted.

The MS and MSD recoveries for iron were outside control limits for Batch i01W95 because the concentration of the analyte was significantly greater than the spike concentration.

The MS and MSD recoveries for chloride were outside control limits for Batch 011395 because the concentration of the analyte was significantly greater than the spike concentration.

No matrix duplicate was analyzed for sodium for Batch i07W95.

The majority of the method blanks were free of contamination. The metal method blank for Batch i01W95 was contaminated with 421 $\mu g/L$ sodium.

The data package from NDRC Laboratories, Inc. was received complete with all required internal quality control information. The majority of the analyses were performed using specified methods within proper holding times. The nitrite analyses for LHMW-133-QA and LHMW-134-QA were analyzed outside the proper holding time. Nitrate, nitrite, chloride, and sulfate were analyzed using method 9056 instead of method 300.0 as requested. The methods are similar and comparable. The nitrite analyses for LHMW-133-QA and LHMW-134-QA were diluted by a factor of ten. The results were less the adjusted detection limits. A BS and BSD were analyzed for the semi

-volatile analyses for Batches AA745-24 and AA745-41 instead of an MS and MSD. A BS and BSD were analyzed for the explosive analyses for Batches AB544-38 and AA544-40 instead of an MS and MSD. A BS and BSD were analyzed for the volatile analyses for Batches ITS7-528 and ITS7-535 instead of an MS and MSD. All matrix spike, surrogate and laboratory control recoveries were within control limits with the following exceptions noted.

The MS/MSD RPD for 4-nitrophenol, a semi-volatile compound, was outside control limits for Batch AA745-18.

The majority of the method blanks were free of contamination. The semi-volatile method blank for Batch AA745-41 was contaminated with 14.5 μg/L Bis(2-ethylhexyl)phthalate. The MSD for this batch was contaminated with 21.8 μg/L Bis(2-ethylhexyl)phthalate. The associated sample was not contaminated. The volatile method blank for Batch ITS7-535 was contaminated with a tentatively identified compound (sulfur dioxide). This compound was not found in the associated samples.

The data package from Environmental Testing & Consulting, Inc. was received complete with all required internal quality control information. ETC subcontracted out the explosive analyses to a Corps of Engineers' validated laboratory, Southwest Research Institute. All analyses were performed using specified methods within proper holding times. The selenium analysis was diluted by a factor of five for LHMW-133-QA. The result was less than the adjusted detection limit. A LCS and LCSD were analyzed for the semi-volatile analyses instead of an MS and MSD. All matrix spike, surrogate and laboratory control recoveries were within control limits with the following exceptions noted.

The MS and MSD recoveries for sodium and calcium were outside control limits on 1/17/95 because the concentration of the analyte was significantly greater than the spike concentration.

The MS and MSD recoveries for selenium were outside control limits on 1/17/95 due to matrix interference.

All method blanks were free of contamination.

The data package from Southwest Research Institute was received complete with all required internal quality control information. All analyses were performed using specified methods within proper holding times. All matrix spike, surrogate and laboratory control recoveries were within control limits with the following exceptions noted.

No MSD was reported for the explosive analyses.

All method blanks were free of contamination.

The equipment blank (LHMW-134EB) was contaminated with 220 μg/L calcium, 65 μg/L iron, and 2250 μg/L sodium. The following table shows the level of these metals in the associated samples:

Sample Identification	Calcium	Iron	Sodium
LHMW-111 (5-0081)	6780	1880	17700

Sample Identification	Calcium	Iron	Sodium
LHMW-133 (5-0082)	114000	60500	82700
LHMW-134EB (5-0083)	220	65	2250
LHMW-134 (5-0084)	12400	24700	13600
LHMW-134QC (5-0085)	12000	22300	13600

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Following is a synopsis of the quality assurance samples and their related QC and field samples:

Customer Sample No.: LHMW-133, LHMW-133 QA
SWD Lab Sample No.: 5-0082, 4-0086

Parameter	Field	QA	Units	Comment
Aluminum	32100	2380	µg/L	Disagre
Arsenic	21.5	9	µg/L	Disagre
Barium	316	89	µg/L	Disagre
Cadmium	< 10	< 4	µg/L	Agree
Calcium	114000	33300	µg/L	Disagre
Chromium	114	25	µg/L	Disagre
Cobalt	31	9	µg/L	Disagre
Copper	43	11	µg/L	Disagre
Iron	60500	12900	µg/L	Disagre
Lead	29.8	9	µg/L	Disagre
Magnesium	13600	6650	µg/L	Disagre
Manganese	1960	1250	µg/L	Agree
Mercury	< 0.2	< 1	µg/L	Agree
Nickel	64	< 15	µg/L	Agree
Selenium	< 2.0	< 10	µg/L	Disagre
Silver	< 10	< 7	µg/L	Agree
Sodium	82700	85800	µg/L	Agree
Strontium	699	291	µg/L	Disagre
Thallium	< 90	< 40	µg/L	Agree
Zinc	231	109	µg/L	Disagre
Chloride	14.1	14.2	mg/L	Agree
Sulfate	9.2	11.0	mg/L	Agree
Nitrate	2.4	2.7	mg/L	Agree
Nitrite	< 0.5	< 0.1	mg/L	Agree
Explosives				
RDX	1.16	< 0.84	µg/L	Agree
VOA	No Hits 0 TICs	No Hits 0 TICs	µg/L	Agree
SVOA				
4-Methylphenol	27	< 10	µg/L	Disagre
Bis(2-ethylhexyl) phthalate	< 10	10.4	µg/L	Agree
	3 TICs	13 TICs		

Following is a synopsis of the quality assurance samples and their related QC and field samples:

Customer Sample No.: LHMW-134, LHMW-134 QC, LHMW-134 QA
SWD Lab Sample No.: 5-0084, 5-0085, 4-0087

Parameter	Field	QC	QA	Units	Comment
Aluminum	13400	10900	13300	µg/L	Agree
Arsenic	3.6	3.8	2	µg/L	Agree
Barium	142	130	148	µg/L	Agree
Cadmium	< 10	< 10	< 4	µg/L	Agree
Calcium	12400	12000	11700	µg/L	Agree
Chromium	23	26	27	µg/L	Agree
Cobalt	12	12	12	µg/L	Agree
Copper	28	27	29	µg/L	Agree
Iron	24700	22300	22100	µg/L	Agree
Lead	18.8	16.4	25	µg/L	Agree
Magnesium	6950	6470	6780	µg/L	Agree
Manganese	397	377	421	µg/L	Agree
Mercury	< 0.2	< 0.2	< 1	µg/L	Agree
Nickel	39	35	39	µg/L	Agree
Selenium	< 2.0	< 2.0	< 10	µg/L	Agree
Silver	< 10	< 10	< 7	µg/L	Agree
Sodium	13600	13600	13900	µg/L	Agree
Strontium	225	218	205	µg/L	Agree
Thallium	< 90	< 90	< 40	µg/L	Agree
Zinc	124	105	179	µg/L	Agree
Chloride	10.2	10.1	10.5	mg/L	Agree
Sulfate	3.0	4.3	4.2	mg/L	Agree
Nitrate	10.5	3.9	3.5	mg/L	Disagree
Nitrite	< 0.5	< 0.5	< 0.1	mg/L	Agree
Explosives	No Hits	No Hits	No Hits	µg/L	Agree
VOA	No Hits 0 TICs	No Hits 0 TICs	No Hits 0 TICs	µg/L	Agree
SVOA					
Bis(2-ethylhexyl) phthalate	< 10 0 TICs	15.4 0 TICs	46.6 1 TICs	µg/L	Agree

Both laboratories have been contacted and asked to recheck their calculations for the analysis which did not agree. SWD has verified its results.

Appendix C

Statistical Calculations:
Supporting Articles and Tables

Contents:

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Designation: E 178 – 94

AMERICAN SOCIETY FOR TESTING AND MATERIALS
1916 Race St. Philadelphia, Pa 19103
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If not listed in the current combined index, will appear in the next edition.

An American National Standard

Standard Practice for Dealing With Outlying Observations[1]

This standard is issued under the fixed designation E 178; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers outlying observations in samples and how to test the statistical significance of them. An outlying observation, or "outlier," is one that appears to deviate markedly from other members of the sample in which it occurs. In this connection, the following two alternatives are of interest:

1.1.1 An outlying observation may be merely an extreme manifestation of the random variability inherent in the data. If this is true, the value should be retained and processed in the same manner as the other observations in the sample.

1.1.2 On the other hand, an outlying observation may be the result of gross deviation from prescribed experimental procedure or an error in calculating or recording the numerical value. In such cases, it may be desirable to institute an investigation to ascertain the reason for the aberrant value. The observation may even actually be rejected as a result of the investigation, though not necessarily so. At any rate, in subsequent data analysis the outlier or outliers will be recognized as probably being from a different population than that of the other sample values.

1.2 It is our purpose here to provide statistical rules that will lead the experimenter almost unerringly to look for causes of outliers when they really exist, and hence to decide whether alternative 1.1.1 above, is not the more plausible hypothesis to accept, as compared to alternative 1.1.2, in order that the most appropriate action in further data analysis may be taken. The procedures covered herein apply primarily to the simplest kind of experimental data, that is, replicate measurements of some property of a given material, or observations in a supposedly single random sample. Nevertheless, the tests suggested do cover a wide enough range of cases in practice to have broad utility.

2. General

2.1 When the experimenter is clearly aware that a gross deviation from prescribed experimental procedure has taken place, the resultant observation should be discarded, whether or not it agrees with the rest of the data and without recourse to statistical tests for outliers. If a reliable correction procedure, for example, for temperature, is available, the observation may sometimes be corrected and retained.

2.2 In many cases evidence for deviation from prescribed procedure will consist primarily of the discordant value itself. In such cases it is advisable to adopt a cautious attitude. Use of one of the criteria discussed below will sometimes permit a clear-cut decision to be made. In doubtful cases the experimenter's judgment will have considerable influence. When the experimenter cannot identify abnormal conditions, he should at least report the discordant values and indicate to what extent they have been used in the analysis of the data.

2.3 Thus, for purposes of orientation relative to the over-all problem of experimentation, our position on the matter of screening samples for outlying observations is precisely the following:

2.3.1 *Physical Reason Known or Discovered for Outlier(s)*:

2.3.1.1 Reject observation(s).

2.3.1.2 Correct observation(s) on physical grounds.

2.3.1.3 Reject it (them) and possibly take additional observation(s).

2.3.2 *Physical Reason Unknown—Use Statistical Test*:

2.3.2.1 Reject observation(s).

2.3.2.2 Correct observation(s) statistically.

2.3.2.3 Reject it (them) and possibly take additional observation(s).

2.3.2.4 Employ truncated-sample theory for censored observations.

2.4 The statistical test may always be used to support a judgment that a physical reason does actually exist for an outlier, or the statistical criterion may be used routinely as a basis to initiate action to find a physical cause.

3. Basis of Statistical Criteria for Outliers

3.1 There are a number of criteria for testing outliers. In all of these, the doubtful observation is included in the calculation of the numerical value of a sample criterion (or statistic), which is then compared with a critical value based on the theory of random sampling to determine whether the doubtful observation is to be retained or rejected. The critical value is that value of the sample criterion which would be exceeded by chance with some specified (small) probability on the assumption that all the observations did indeed constitute a random sample from a common system of causes, a single parent population, distribution or universe. The specified small probability is called the "significance level" or "percentage point" and can be thought of as the risk of erroneously rejecting a good observation. It becomes clear, therefore, that if there exists a real shift or change in the value of an observation that arises from nonrandom causes (human error, loss of calibration of instrument, change of measuring instrument, or even change of time of measurements, etc.), then the observed value of the sample criterion used would exceed the "critical value" based on random-sampling theory. Tables of critical values are usually given for several different significance levels, for example, 5 %, 1 %. For statistical tests of outlying observations, it is

[1] This practice is under the jurisdiction of ASTM Committee E-11 on Statistical Methods and is the direct responsibility of Subcommittee E11.03 on Statistical Analysis and Control Techniques.

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generally recommended that a low significance level, such as 1 %, be used and that significance levels greater than 5 % should not be common practice.

NOTE 1—In this practice, we will usually illustrate the use of the 5 % significance level. Proper choice of level in probability depends on the particular problem and just what may be involved, along with the risk that one is willing to take in rejecting a good observation, that is, if the null-hypothesis stating "all observations in the sample come from the same normal population" may be assumed correct.

3.2 It should be pointed out that almost all criteria for outliers are based on an assumed underlying normal (Gaussian) population or distribution. When the data are not normally or approximately normally distributed, the probabilities associated with these tests will be different. Until such time as criteria not sensitive to the normality assumption are developed, the experimenter is cautioned against interpreting the probabilities too literally.

3.3 Although our primary interest here is that of detecting outlying observations, we remark that some of the statistical criteria presented may also be used to test the hypothesis of normality or that the random sample taken did come from a normal or Gaussian population. The end result is for all practical purposes the same, that is, we really wish to know whether we ought to proceed as if we have in hand a sample of homogeneous normal observations.

4. Recommended Criteria for Single Samples

4.1 Let the sample of n observations be denoted in order of increasing magnitude by $x_1 \leq x_2 \leq x_3 \leq \ldots \leq x_n$. Let x_n be the doubtful value, that is the largest value. The test criterion, T_n, recommended here for a single outlier is as follows:

$$T_n = (x_n - \bar{x})/s$$

where:

$\bar{x}$ = arithmetic average of all n values, and

s = estimate of the population standard deviation based on the sample data, calculated as follows:

$$s = \left\{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{(n-1)}\right\}^{1/2} = \left\{\frac{n\Sigma x_i^2 - (\Sigma x_i)^2}{n(n-1)}\right\}^{1/2}$$

If x_1 rather than x_n is the doubtful value, the criterion is as follows:

$$T_1 = (\bar{x} - x_1)/s$$

The critical values for either case, for the 1 and 5 % levels of significance, are given in Table 1. Table 1 and the following tables give the "one-sided" significance levels. In the previous tentative recommended practice (1961), the tables listed values of significance levels double those in the present practice, since it was considered that the experimenter would test either the lowest or the highest observation (or both) for statistical significance. However, to be consistent with actual practice and in an attempt to avoid further misunderstanding, single-sided significance levels are tabulated here so that both viewpoints can be represented.

4.2 The hypothesis that we are testing in every case is that all observations in the sample come from the same normal population. Let us adopt, for example, a significance level of 0.05. If we are interested *only* in outliers that occur on the *high side*, we should always use the statistic $T_n = (x_n - \bar{x})/s$ and take as critical value the 0.05 point of Table 1. On the other hand, if we are interested *only* in outliers occurring on the *low side*, we would always use the statistic $T_1 = (\bar{x} - x_1)/s$ and again take as a critical value the 0.05 point of Table 1. Suppose, however, that we are interested in outliers occurring on *either side*, but do not believe that outliers can occur on both sides simultaneously. We might, for example, believe that at some time during the experiment something possibly happened to cause an extraneous variation on the high side or on the low side, but that it was very unlikely that two or more such events could have occurred, one being an extraneous variation on the high side *and* the other an extraneous variation on the low side. With this point of view we should use the statistic $T_n = (x_n - \bar{x})/s$ or the statistic $T_1 = (\bar{x} - x_1)/s$ whichever is larger. If in this instance we use the 0.05 point of Table 1 as our critical value, the true significance level would be twice 0.05 or 0.10. If we wish a significance level of 0.05 and not 0.10, we must in this case use as a critical value the 0.025 point of Table 1. Similar considerations apply to the other tests given below.

4.2.1 *Example 1*—As an illustration of the use of T_n and Table 1, consider the following ten observations on breaking strength (in pounds) of 0.104-in. hard-drawn copper wire: 568, 570, 570, 570, 572, 572, 572, 578, 584, 596. The doubtful observation is the high value, $x_{10} = 596$. Is the value of 596 significantly high? The mean is $\bar{x} = 575.2$ and the estimated standard deviation is $s = 8.70$. We compute

$$T_{10} = (596 - 575.2)/8.70 = 2.39$$

From Table 1, for $n = 10$, note that a T_{10} as large as 2.39 would occur by chance with probability less than 0.05. In fact, so large a value would occur by chance not much more often than 1 % of the time. Thus, the weight of the evidence is against the doubtful value having come from the same population as the others (assuming the population is normally distributed). Investigation of the doubtful value is therefore indicated.

4.3 An alternative system, the Dixon criteria, based entirely on ratios of differences between the observations is described in the literature (**1**)[2] and may be used in cases where it is desirable to avoid calculation of s or where quick judgment is called for. For the Dixon test, the sample criterion or statistic changes with sample size. Table 2 gives the appropriate statistic to calculate and also gives the critical values of the statistic for the 1, 5, and 10 % levels of significance.

4.3.1 *Example 2*—As an illustration of the use of Dixon's test, consider again the observations on breaking strength given in Example 1, and suppose that a large number of such samples had to be screened quickly for outliers and it was judged too time-consuming to compute s. Table 2 indicates use of

$$r_{11} = (x_n - x_{n-1})/(x_n - x_2)$$

Thus, for $n = 10$,

$$r_{11} = (x_{10} - x_9)/(x_{10} - x_2)$$

For the measurements of breaking strength above,

$$r_{11} = (596 - 584)/(596 - 570) = 0.462$$

[2] The boldface numbers in parentheses refer to the list of references at the end of this practice.

TABLE 1 Critical Values for *T* (One-Sided Test) When Standard Deviation is Calculated from the Same Sample[A]

Number of Observations, *n*	Upper 0.1 % Significance Level	Upper 0.5 % Significance Level	Upper 1 % Significance Level	Upper 2.5 % Significance Level	Upper 5 % Significance Level	Upper 10 % Significance Level
3	1.155	1.155	1.155	1.155	1.153	1.148
4	1.499	1.496	1.492	1.481	1.463	1.425
5	1.780	1.764	1.749	1.715	1.672	1.602
6	2.011	1.973	1.944	1.887	1.822	1.729
7	2.201	2.139	2.097	2.020	1.938	1.828
8	2.358	2.274	2.221	2.126	2.032	1.909
9	2.492	2.387	2.323	2.215	2.110	1.977
10	2.606	2.482	2.410	2.290	2.176	2.036
11	2.705	2.564	2.485	2.355	2.234	2.088
12	2.791	2.636	2.550	2.412	2.285	2.134
13	2.867	2.699	2.607	2.462	2.331	2.175
14	2.935	2.755	2.659	2.507	2.371	2.213
15	2.997	2.806	2.705	2.549	2.409	2.247
16	3.052	2.852	2.747	2.585	2.443	2.279
17	3.103	2.894	2.785	2.620	2.475	2.309
18	3.149	2.932	2.821	2.651	2.504	2.335
19	3.191	2.968	2.854	2.681	2.532	2.361
20	3.230	3.001	2.884	2.709	2.557	2.385
21	3.266	3.031	2.912	2.733	2.580	2.408
22	3.300	3.060	2.939	2.758	2.603	2.429
23	3.332	3.087	2.963	2.781	2.624	2.448
24	3.362	3.112	2.987	2.802	2.644	2.467
25	3.389	3.135	3.009	2.822	2.663	2.486
26	3.415	3.157	3.029	2.841	2.681	2.502
27	3.440	3.178	3.049	2.859	2.698	2.519
28	3.464	3.199	3.068	2.876	2.714	2.534
29	3.486	3.218	3.085	2.893	2.730	2.549
30	3.507	3.236	3.103	2.908	2.745	2.563
31	3.528	3.253	3.119	2.924	2.759	2.577
32	3.546	3.270	3.135	2.938	2.773	2.591
33	3.565	3.286	3.150	2.952	2.786	2.604
34	3.582	3.301	3.164	2.965	2.799	2.616
35	3.599	3.316	3.178	2.979	2.811	2.628
36	3.616	3.330	3.191	2.991	2.823	2.639
37	3.631	3.343	3.204	3.003	2.835	2.650
38	3.646	3.356	3.216	3.014	2.846	2.661
39	3.660	3.369	3.228	3.025	2.857	2.671
40	3.673	3.381	3.240	3.036	2.866	2.682
41	3.687	3.393	3.251	3.046	2.877	2.692
42	3.700	3.404	3.261	3.057	2.887	2.700
43	3.712	3.415	3.271	3.067	2.896	2.710
44	3.724	3.425	3.282	3.075	2.905	2.719
45	3.736	3.435	3.292	3.085	2.914	2.727
46	3.747	3.445	3.302	3.094	2.923	2.736
47	3.757	3.455	3.310	3.103	2.931	2.744
48	3.768	3.464	3.319	3.111	2.940	2.753
49	3.779	3.474	3.329	3.120	2.948	2.760
50	3.789	3.483	3.336	3.128	2.956	2.768
51	3.798	3.491	3.345	3.136	2.964	2.775
52	3.808	3.500	3.353	3.143	2.971	2.783
53	3.816	3.507	3.361	3.151	2.978	2.790
54	3.825	3.516	3.368	3.158	2.986	2.798
55	3.834	3.524	3.376	3.166	2.992	2.804
56	3.842	3.531	3.383	3.172	3.000	2.811
57	3.851	3.539	3.391	3.180	3.006	2.818
58	3.858	3.546	3.397	3.186	3.013	2.824
59	3.867	3.553	3.405	3.193	3.019	2.831
60	3.874	3.560	3.411	3.199	3.025	2.837
61	3.882	3.566	3.418	3.205	3.032	2.842
62	3.889	3.573	3.424	3.212	3.037	2.849
63	3.896	3.579	3.430	3.218	3.044	2.854

TABLE 1 *Continued*

Number of Observations, *n*	Upper 0.1 % Significance Level	Upper 0.5 % Significance Level	Upper 1 % Significance Level	Upper 2.5 % Significance Level	Upper 5 % Significance Level	Upper 10 % Significance Level
64	3.903	3.586	3.437	3.224	3.049	2.860
65	3.910	3.592	3.442	3.230	3.055	2.866
66	3.917	3.598	3.449	3.235	3.061	2.871
67	3.923	3.605	3.454	3.241	3.066	2.877
68	3.930	3.610	3.460	3.246	3.071	2.883
69	3.936	3.617	3.466	3.252	3.076	2.888
70	3.942	3.622	3.471	3.257	3.082	2.893
71	3.948	3.627	3.476	3.262	3.087	2.897
72	3.954	3.633	3.482	3.267	3.092	2.903
73	3.960	3.638	3.487	3.272	3.098	2.908
74	3.965	3.643	3.492	3.278	3.102	2.912
75	3.971	3.648	3.496	3.282	3.107	2.917
76	3.977	3.654	3.502	3.287	3.111	2.922
77	3.982	3.658	3.507	3.291	3.117	2.927
78	3.987	3.663	3.511	3.297	3.121	2.931
79	3.992	3.669	3.516	3.301	3.125	2.935
80	3.998	3.673	3.521	3.305	3.130	2.940
81	4.002	3.677	3.525	3.309	3.134	2.945
82	4.007	3.682	3.529	3.315	3.139	2.949
83	4.012	3.687	3.534	3.319	3.143	2.953
84	4.017	3.691	3.539	3.323	3.147	2.957
85	4.021	3.695	3.543	3.327	3.151	2.961
86	4.026	3.699	3.547	3.331	3.155	2.966
87	4.031	3.704	3.551	3.335	3.160	2.970
88	4.035	3.708	3.555	3.339	3.163	2.973
89	4.039	3.712	3.559	3.343	3.167	2.977
90	4.044	3.716	3.563	3.347	3.171	2.981
91	4.049	3.720	3.567	3.350	3.174	2.984
92	4.053	3.725	3.570	3.355	3.179	2.989
93	4.057	3.728	3.575	3.358	3.182	2.993
94	4.060	3.732	3.579	3.362	3.186	2.996
95	4.064	3.736	3.582	3.365	3.189	3.000
96	4.069	3.739	3.586	3.369	3.193	3.003
97	4.073	3.744	3.589	3.372	3.196	3.006
98	4.076	3.747	3.593	3.377	3.201	3.011
99	4.080	3.750	3.597	3.380	3.204	3.014
100	4.084	3.754	3.600	3.383	3.207	3.017
101	4.088	3.757	3.603	3.386	3.210	3.021
102	4.092	3.760	3.607	3.390	3.214	3.024
103	4.095	3.765	3.610	3.393	3.217	3.027
104	4.098	3.768	3.614	3.397	3.220	3.030
105	4.102	3.771	3.617	3.400	3.224	3.033
106	4.105	3.774	3.620	3.403	3.227	3.037
107	4.109	3.777	3.623	3.406	3.230	3.040
108	4.112	3.780	3.626	3.409	3.233	3.043
109	4.116	3.784	3.629	3.412	3.236	3.046
110	4.119	3.787	3.632	3.415	3.239	3.049
111	4.122	3.790	3.636	3.418	3.242	3.052
112	4.125	3.793	3.639	3.422	3.245	3.056
113	4.129	3.796	3.642	3.424	3.248	3.058
114	4.132	3.799	3.645	3.427	3.251	3.061
115	4.135	3.802	3.647	3.430	3.254	3.064
116	4.138	3.805	3.650	3.433	3.257	3.067
117	4.141	3.808	3.653	3.435	3.259	3.070
118	4.144	3.811	3.656	3.438	3.262	3.073
119	4.146	3.814	3.659	3.441	3.265	3.075
120	4.150	3.817	3.662	3.444	3.267	3.078
121	4.153	3.819	3.665	3.447	3.270	3.081
122	4.156	3.822	3.667	3.450	3.274	3.083
123	4.159	3.824	3.670	3.452	3.276	3.086
124	4.161	3.827	3.672	3.455	3.279	3.089
125	4.164	3.831	3.675	3.457	3.281	3.092

TABLE 1 *Continued*

Number of Observations, n	Upper 0.1 % Significance Level	Upper 0.5 % Significance Level	Upper 1 % Significance Level	Upper 2.5 % Significance Level	Upper 5 % Significance Level	Upper 10 % Significance Level
126	4.166	3.833	3.677	3.460	3.284	3.095
127	4.169	3.836	3.680	3.462	3.286	3.097
128	4.173	3.838	3.683	3.465	3.289	3.100
129	4.175	3.840	3.686	3.467	3.291	3.102
130	4.178	3.843	3.688	3.470	3.294	3.104
131	4.180	3.845	3.690	3.473	3.296	3.107
132	4.183	3.848	3.693	3.475	3.298	3.109
133	4.185	3.850	3.695	3.478	3.302	3.112
134	4.188	3.853	3.697	3.480	3.304	3.114
135	4.190	3.856	3.700	3.482	3.306	3.116
136	4.193	3.858	3.702	3.484	3.309	3.119
137	4.196	3.860	3.704	3.487	3.311	3.122
138	4.198	3.863	3.707	3.489	3.313	3.124
139	4.200	3.865	3.710	3.491	3.315	3.126
140	4.203	3.867	3.712	3.493	3.318	3.129
141	4.205	3.869	3.714	3.497	3.320	3.131
142	4.207	3.871	3.716	3.499	3.322	3.133
143	4.209	3.874	3.719	3.501	3.324	3.135
144	4.212	3.876	3.721	3.503	3.326	3.138
145	4.214	3.879	3.723	3.505	3.328	3.140
146	4.216	3.881	3.725	3.507	3.331	3.142
147	4.219	3.883	3.727	3.509	3.334	3.144

$T_n = (x_n - \bar{x})/s$

$$s = [\Sigma (x_i - \bar{x})^2/(n-1)]^{1/2}$$
$$= [(n \Sigma x_i^2 - (\Sigma x_i)^2)/(n(n-1))]^{1/2}$$
$$T_1 = [(\bar{x} - x_1)/s], x_1 \le x_2 \le \ldots \le x_n$$

[A] Values of T are taken from Ref (2). All values have been adjusted for division by $n - 1$ instead of n in calculating s.

which is a little less than 0.477, the 5 % critical value for $n = 10$. Under the Dixon criterion, we should therefore *not* consider this observation as an outlier at the 5 % level of significance. These results illustrate how borderline cases may be accepted under one test but rejected under another. It should be remembered, however, that the T-statistic discussed above is the best one to use for the single-outlier case, and final statistical judgment should be based on it. See Ferguson (3,4).

4.3.2 Further examination of the sample observations on breaking strength of hand-drawn copper wire indicates that none of the other values need testing.

NOTE 2—With experience we may usually just look at the sample values to observe if an outlier is present. However, strictly speaking the statistical test should be applied to all samples to guarantee the significance levels used. Concerning "multiple" tests on a single sample, we comment on this below.

4.4 A test equivalent to T_n (or T_1) based on the sample sum of squared deviations from the mean for all the observations and the sum of squared deviations omitting the "outlier" is given by Grubbs (5).

4.5 The next type of problem to consider is the case where we have the possibility of two outlying observations, the least and the greatest observation in a sample. (The problem of testing the two highest or the two lowest observations is considered below.) In testing the least and the greatest observations simultaneously as probable outliers in a sample, we use the ratio of sample range to sample standard deviation test of David, Hartley, and Pearson (6). The significance levels for this sample criterion are given in Table 3. Alternatively, the largest residuals test of Tietjen and Moore (7) could be used. An example in astronomy follows.

4.5.1 *Example 3*—There is one rather famous set of observations that a number of writers on the subject of outlying observations have referred to in applying their various tests for "outliers". This classic set consists of a sample of 15 observations of the vertical semidiameters of Venus made by Lieutenant Herndon in 1846 (8). In the reduction of the observations, Prof. Pierce assumed two unknown quantities and found the following residuals which have been arranged in ascending order of magnitude:

−1.40 in.	−0.24	−0.05	0.18	0.48
−0.44	−0.22	0.06	0.20	0.63
−0.30	−0.13	0.10	0.39	1.01

The deviations −1.40 and 1.01 appear to be outliers. Here the suspected observations lie at each end of the sample. Much less work has been accomplished for the case of outliers at both ends of the sample than for the case of one or more outliers at only one end of the sample. This is not necessarily because the "one-sided" case occurs more frequently in practice but because "two-sided" tests are much more difficult to deal with. For a high and a low outlier in a single sample, we give two procedures below, the first being a combination of tests, and the second a single test of Tietjen and Moore (7) which may have nearly optimum properties. For optimum procedures when there is an independent estimate at hand, s^2 or σ^2, see (9).

4.6 For the observations on the semi-diameter of Venus given above, all the information on the measurement error is

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TABLE 2 Dixon Criteria for Testing of Extreme Observation (Single Sample)[A]

n	Criterion	Significance Level: 10 percent	5 percent	1 percent
3	$r_{10} = (x_2 - x_1)/(x_n - x_1)$ if smallest value is suspected;	0.886	0.941	0.988
4	$= (x_n - x_{n-1})/(x_n - x_1)$ if largest value is suspected	0.679	0.765	0.889
5		0.557	0.642	0.780
6		0.482	0.560	0.698
7		0.434	0.507	0.637
8	$r_{11} = (x_2 - x_1)/(x_{n-1} - x_1)$ if smallest value is suspected;	0.479	0.554	0.683
9	$= (x_n - x_{n-1})/(x_n - x_2)$ if largest value is suspected.	0.441	0.512	0.635
10		0.409	0.477	0.597
11	$r_{21} = (x_3 - x_1)/(x_{n-1} - x_1)$ if smallest value is suspected;	0.517	0.576	0.679
12	$= (x_n - x_{n-2})/(x_n - x_2)$ if largest value is suspected.	0.490	0.546	0.642
13		0.467	0.521	0.615
14	$r_{22} = (x_3 - x_1)/(x_{n-2} - x_1)$ if smallest value is suspected;	0.492	0.546	0.641
15	$= (x_n - x_{n-2})/(x_n - x_3)$ if largest value is suspected.	0.472	0.525	0.616
16		0.454	0.507	0.595
17		0.438	0.490	0.577
18		0.424	0.475	0.561
19		0.412	0.462	0.547
20		0.401	0.450	0.535
21		0.391	0.440	0.524
22		0.382	0.430	0.514
23		0.374	0.421	0.505
24		0.367	0.413	0.497
25		0.360	0.406	0.489
26		0.354	0.399	0.486
27		0.348	0.393	0.475
28		0.342	0.387	0.469
29		0.337	0.381	0.463
30		0.332	0.376	0.457

[A] $x_1 \leq x_2 \leq \ldots \leq x_n$. (See Ref (1), Appendix.)

contained in the sample of 15 residuals. In cases like this, where no independent estimate of variance is available (that is, we still have the single sample case), a useful statistic is the ratio of the range of the observations to the sample standard deviation:

$$w/s = (x_n - x_1)/s$$

where:

$$s = \sqrt{\Sigma[(x_i - \bar{x})^2/(n-1)]}$$

If x_n is about as far above the mean, $\bar{x}$, as x_1 is below $\bar{x}$, and if w/s exceeds some chosen critical value, then one would conclude that *both* the doubtful values are outliers. If, however, x_1 and x_n are displaced from the mean by different amounts, some further test would have to be made to decide whether to reject as outlying only the lowest value or only the highest value or both the lowest and highest values.

4.7 For this example the mean of the deviations is $\bar{x} = 0.018$, $s = 0.551$, and

$$w/s = [1.01 - (-1.40)]/0.551 = 2.41/0.551 = 4.374$$

From Table 3 for $n = 15$, we see that the value of $w/s = 4.374$ falls between the critical values for the 1 and 5 % levels, so if the test were being run at the 5 % level of significance, we would conclude that this sample contains one or more outliers. The lowest measurement, −1.40 in., is 1.418 below the sample mean, and the highest measurement, 1.01 in., is 0.992 above the mean. Since these extremes are not symmetric about the mean, either *both* extremes are outliers, or else only −1.40 is an outlier. That −1.40 is an outlier can be verified by use of the T_1 statistic. We have

$$T_1 = (\bar{x} - x_1)/s = [0.018 - (-1.40)]/0.551 = 2.574$$

This value is greater than the critical value for the 5 % level,

TABLE 3 Critical Values for *w/s* (Ratio of Range to Sample Standard Deviation)[A]

Number of Observations, n	5 Percent Significance Level	1 Percent Significance Level	0.5 Percent Significance Level
3	2.00	2.00	2.00
4	2.43	2.44	2.45
5	2.75	2.80	2.81
6	3.01	3.10	3.12
7	3.22	3.34	3.37
8	3.40	3.54	3.58
9	3.55	3.72	3.77
10	3.68	3.88	3.94
11	3.80	4.01	4.08
12	3.91	4.13	4.21
13	4.00	4.24	4.32
14	4.09	4.34	4.43
15	4.17	4.43	4.53
16	4.24	4.51	4.62
17	4.31	4.59	4.69
18	4.38	4.66	4.77
19	4.43	4.73	4.84
20	4.49	4.79	4.91
30	4.89	5.25	5.39
40	5.15	5.54	5.69
50	5.35	5.77	5.91
60	5.50	5.93	6.09
80	5.73	6.18	6.35
100	5.90	6.36	6.54
150	6.18	6.64	6.84
200	6.38	6.85	7.03
500	6.94	7.42	7.60
1000	7.33	7.80	7.99

[A] See Ref (6), where:

$$w = x_n - x_1$$

$$x_1 \leq x_2 \leq \ldots \leq x_n$$

$$s = \sqrt{[\Sigma(x_i - \bar{x})^2]/(n-1)}$$

2.409 from Table 1, so we reject −1.40. Since we have decided that −1.40 should be rejected, we use the remaining 14 observations and test the upper extreme 1.01, either with the criterion

$$T_n = (x_n - \bar{x})/s$$

or with Dixon's r_{22}. Omitting −1.40 and renumbering the observations, we compute

$$\bar{x} = 1.67/14 = 0.119, s = 0.401,$$

and

$$T_{14} = (1.01 - 0.119)/0.401 = 2.22$$

From Table 1, for $n = 14$, we find that a value as large as 2.22 would occur by chance more than 5 % of the time, so we should retain the value 1.01 in further calculations. We next calculate

$$r_{22} = (x_{14} - x_{12})/x_{14} - x_3) = (1.01 - 0.48)/(1.01 + 0.24) = 0.53/1.25 = 0.424$$

From Table 2 for $n = 14$, we see that the 5 % critical value for r_{22} is 0.546. Since our calculated value (0.424) is less than the critical value, we also retain 1.01 by Dixon's test, and no further values would be tested in this sample.

NOTE 3—It should be noted that in repeated application of outlier tests to a sample, the overall significance level changes. If we apply k tests, an acceptable rule would be to use a significance level of α/k for each test so that the overall significance level will be approximately α.

4.8 For suspected observations on both the high and low sides in the sample, and to deal with the situation in which some of $k \geq 2$ suspected outliers are larger and some smaller than the remaining values in the sample, Tietjen and Moore (7) suggest the following statistic. Let the sample values be $x_1, x_2, x_3, \ldots x_n$ and compute the sample mean, $\bar{x}$. Then compute the n absolute residuals

$$r_1 = |x_1 - \bar{x}|, r_2 = |x_2 - \bar{x}|, \ldots r_n = |x_n - \bar{x}|$$

Now relabel the original observations $x_1, x_2, \ldots, x_n$ as z's in such a manner that z_i is that x whose r_i is the ith largest absolute residual above. This now means that z_1 is that observation x which is closest to the mean and that z_n is the observation x which is farthest from the mean. The Tietjen-Moore statistic for testing the significance of the k largest residuals is then

$$E_k = \left[\sum_{i=1}^{n-k} (z_i - \bar{z}_k)^2 \Big/ \sum_{i=1}^{n} (z_i - \bar{z})^2 \right]$$

where:

$$\bar{z}_k = \sum_{i=1}^{n-k} z_i/(n-k)$$

is the mean of the $(n-k)$ least extreme observations and z is the mean of the full sample.

4.8.1 Applying this test to the above data, we find that the total sum of squares of deviations for the entire sample is 4.24964. Omitting —1.40 and 1.01, the suspected two outliers, we find that the sum of squares of deviations for the reduced sample of 13 observations is 1.24089. Then E_2 = 1.24089/4.24964 = 0.292, and by using Table 4, we find that this observed E_2 is slightly smaller than the 5 % critical value of 0.317, so that the E_2 test would reject both of the observations, —1.40 and 1.01. We would probably take this latter recommendation, since the level of significance for the E_2 test is precisely 0.05 whereas that for the double application of a test for a single outlier cannot be guaranteed to be smaller than $1 - (0.95)^2 = 0.0975$. The table of percentage points of E_k was computed by Monte Carlo methods on a high-speed electronic calculator.

4.9 We next turn to the case where we may have the two largest or the two smallest observations as probable outliers. Here, we employ a test provided by Grubbs (5, 10) which is based on the ratio of the sample sum of squares when the two doubtful values are omitted to the sample sum of squares when the two doubtful values are included. If simplicity in calculation is the prime requirement, then the Dixon type of test (actually omitting one observation in the sample) might be used for this case. In illustrating the test procedure, we give the following Examples 4 and 5.

4.9.1 *Example 4*—In a comparison of strength of various plastic materials, one characteristic studied was the percentage elongation at break. Before comparison of the average elongation of the several materials, it was desirable to isolate for further study any pieces of a given material which gave very small elongation at breakage compared with the rest of the pieces in the sample. In this example, one might have primary interest only in outliers to the left of the mean for study, since very high readings indicate exceeding plasticity, a desirable characteristic.

4.9.1.1 Ten measurements of percentage elongation at break made on material No. 23 follow: 3.73, 3.59, 3.94, 4.13, 3.04, 2.22, 3.23, 4.05, 4.11, and 2.02. Arranged in ascending order of magnitude, these measurements are: 2.02, 2.22, 3.04, 3.23, 3.59, 3.73, 3.94,. 4.05, 4.11, 4.13. The questionable readings are the two lowest, 2.02 and 2.22. We can test these two low readings simultaneously by using the following criterion of Table 5:

$$S_{1,2}^2/S^2$$

For the above measurements:

$$S^2 = \sum_{i=1} (x_i - \bar{x})^2 = [n \sum x_i^2 - (\sum x_i)^2]/n = [10(121.3594) - (34.06)^2]/10 = 5.351,$$

and

$$S_{1,2}^2 = \sum_{i=3}^{n} (x_i - \bar{x}_{1,2})^2 = \left[(n-2)\sum_{i=3}^{n} x_i^2 - \left(\sum_{i=3}^{n} x_i\right)^2\right] \Big/ (n-2) = [8(112.3506) - (29.82)^2]/8 = 9.5724/8 = 1.197$$

[where $\bar{x}_{1,2} = \sum_{i=3}^{n} x_i/(n-2)$]

We find:

$$S_{1,2}^2/S^2 = 1.197/5.351 = 0.224$$

From Table 5 for $n = 10$, the 5 % significance level for $S_{1,2}^2/S^2$ is 0.2305. Since the calculated value is less than the critical value, we should conclude that both 2.02 and 2.22 are outliers. In a situation such as the one described in this example, where the outliers are to be isolated for further analysis, a significance level as high as 5 % or perhaps even 10 % would probably be used in order to get a reasonable size of sample for additional study. The problem may really be one of economics, and we use probability as a sensible basis for action.

4.9.2 *Example 5*—The following ranges (horizontal distances in yards from gun muzzle to point of impact of a projectile) were obtained in firings from a weapon at a

TABLE 4 1000 X Tietjen-Moore Critical Values for E_k

k	n: α	50	45	40	35	30	25	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3
1[A]	0.01	748	728	704	669	624	571	499	484	459	440	422	404	374	337	311	274	235	197	156	110	68	29	4	...
	0.05	796	776	756	732	698	654	594	579	562	544	525	503	479	453	423	390	353	310	262	207	145	81	25	1
	0.10	820	802	784	762	730	692	638	624	610	593	576	556	534	510	482	451	415	374	326	270	203	127	49	3
2	0.01	636	607	574	533	482	418	339	323	306	290	263	238	207	181	159	134	101	78	50	28	12	2	...	...
	0.05	684	658	629	596	549	493	416	398	382	362	340	317	293	262	234	204	172	137	99	65	34	10	1	...
	0.10	708	684	657	624	582	528	460	442	424	406	384	360	337	309	278	250	214	175	137	94	56	22	2	...
3	0.01	550	518	480	435	386	320	236	219	206	188	166	146	123	103	83	64	44	26	14	6	1	...	...	...
	0.05	599	567	534	495	443	381	302	287	267	248	227	206	179	156	133	107	83	57	34	16	4	...	...	...
	0.10	622	593	562	523	475	417	338	322	304	284	263	240	216	189	162	138	108	80	53	27	9	...	...	...
4	0.01	482	446	408	364	308	245	170	156	141	122	107	90	72	56	42	30	18	9	4	...	...	...	...	...
	0.05	529	492	458	417	364	298	221	203	187	170	153	134	112	92	73	55	37	21	10	...	...	...	...	...
	0.10	552	522	486	443	391	331	252	234	217	198	182	160	138	116	94	73	52	32	16	...	...	...	...	...
5	0.01	424	386	347	299	250	188	121	108	94	79	68	54	42	31	20	12	6	...	...	...	...	...	...	...
	0.05	468	433	395	351	298	236	163	146	132	116	102	84	68	53	39	26	14	...	...	...	...	...	...	...
	0.10	492	459	422	379	325	264	188	172	156	140	122	105	86	68	52	36	22	...	...	...	...	...	...	...
6	0.01	376	336	298	252	204	146	86	74	62	52	40	32	22	14	8	...	...	...	...	...	...	...	...	...
	0.05	417	381	343	298	246	186	119	105	91	78	67	52	39	28	18	...	...	...	...	...	...	...	...	...
	0.10	440	406	367	324	270	210	138	124	110	95	82	67	52	38	26	...	...	...	...	...	...	...	...	...
7	0.01	334	294	258	211	166	110	58	50	41	32	24	18	12	...	...	...	...	...	...	...	...	...	...	...
	0.05	373	337	297	254	203	146	85	74	62	50	41	30	21	...	...	...	...	...	...	...	...	...	...	...
	0.10	396	360	320	276	224	168	102	89	76	64	53	40	29	...	...	...	...	...	...	...	...	...	...	...
8	0.01	297	258	220	177	132	87	40	32	26	18	14	...	...	...	...	...	...	...	...	...	...	...	...	...
	0.05	334	299	259	214	166	114	59	50	41	32	24	...	...	...	...	...	...	...	...	...	...	...	...	...
	0.10	355	320	278	236	186	132	72	62	51	42	32	...	...	...	...	...	...	...	...	...	...	...	...	...
9	0.01	264	228	190	149	108	66	26	20	14	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	0.05	299	263	223	181	137	89	41	33	26	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	0.10	319	284	243	202	154	103	51	42	34	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
10	0.01	235	200	164	124	87	50	17	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	0.05	268	233	195	164	112	68	28	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	0.10	287	252	212	172	126	80	35	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

[A] From Grubbs (1950, Table 1) for $n \le 25$.

constant angle of elevation and at the same weight of charge of propellant powder.

Distances in Yards

4782	4420
4838	4803
4765	4730
4549	4833

4.9.2.1 It is desired to make a judgment on whether the projectiles exhibit uniformity in ballistic behavior or if some of the ranges are inconsistent with the others. The doubtful values are the two smallest ranges, 4420 and 4549. For testing these two suspected outliers, the statistic $S_{1,2}^2/S^2$ of Table 5 is probably the best to use.

NOTE 4—Kudo (11) indicates that if the two outliers are due to a shift in location or level, as compared to the scale σ, then the optimum sample criterion for testing should be of the type:

$$\min (2\bar{x} - x_i - x_j)/s = (2\bar{x} - x_1 - x_2)/s \text{ in our Example 5.}$$

4.9.2.2 The distances arranged in increasing order of magnitude are:

4420	4782
4549	4803
4730	4833
4765	4838

The value of S^2 is 158 592. Omission of the two shortest ranges, 4420 and 4549, and recalculation, gives $S_{1,2}^2$ equal to 8590.8. Thus,

$$S_{1,2}^2/S^2 = 8590.8/158\ 592 = 0.054$$

which is significant at the 0.01 level (See Table 5). It is thus highly unlikely that the two shortest ranges (occurring actually from excessive yaw) could have come from the same population as that represented by the other six ranges. It should be noted that the critical values in Table 5 for the 1 % level of significance are smaller than those for the 5 % level. So for this particular test, the calculated value is significant if it is *less* than the chosen critical value.

4.10 By Monte Carlo methods using an electronic calculator, Tietjen and Moore (7) have recently extended the tables of percentage points for the two highest or the two lowest observations to $k > 2$ highest or lowest sample values. Their results are given in Table 6 where

$$L_k = \sum_{i=1}^{n-k} (x_i - \bar{x}_k)^2 / \sum_{i=1}^{n} (x_i - \bar{x})^2 \quad \text{and} \quad \bar{x}_k = \sum_{i=1}^{n-k} x_i/(n-k).$$

Note that their L_2 equals our $S_{n,n-1}^2/S^2$. For $k = 1$, their critical values agreed with exact values calculated by Grubbs (1950). This new table may be used to advantage in many practical problems of interest.

4.11 If simplicity in calculation is very important, or if a large number of samples must be examined individually for outliers, the questionable observations may be tested with the application of Dixon's criteria. Disregarding the lowest range, 4420, we test if the next lowest range, 4549, is outlying. With $n = 7$, we see from Table 2 that r_{10} is the appropriate statistic. Renumbering the ranges as x_i to x_7, beginning with 4549, we find:

$$r_{10} = (x_2 - x_1)/(x_7 - x_1) = (4730 - 4549)/(4838 - 4549) = 181/289 = 0.626$$

TABLE 5 Critical Values for $S^2_{n-1,n}/S^2$, or $S^2_{1,2}/S^2$ for Simultaneously Testing the Two Largest or Two Smallest Observations[A]

Number of Observations, *n*	Lower 0.1 % Significance Level	Lower 0.5 % Significance Level	Lower 1 % Significance Level	Lower 2.5 % Significance Level	Lower 5 % Significance Level	Lower 10 % Significance Level
4	0.0000	0.0000	0.0000	0.0002	0.0008	0.0031
5	0.0003	0.0018	0.0035	0.0090	0.0183	0.0376
6	0.0039	0.0116	0.0186	0.0349	0.0564	0.0920
7	0.0135	0.0308	0.0440	0.0708	0.1020	0.1479
8	0.0290	0.0563	0.0750	0.1101	0.1478	0.1994
9	0.0489	0.0851	0.1082	0.1492	0.1909	0.2454
10	0.0714	0.1150	0.1414	0.1864	0.2305	0.2863
11	0.0953	0.1448	0.1736	0.2213	0.2667	0.3227
12	0.1198	0.1738	0.2043	0.2537	0.2996	0.3552
13	0.1441	0.2016	0.2333	0.2836	0.3295	0.3843
14	0.1680	0.2280	0.2605	0.3112	0.3568	0.4106
15	0.1912	0.2530	0.2859	0.3367	0.3818	0.4345
16	0.2136	0.2767	0.3098	0.3603	0.4048	0.4562
17	0.2350	0.2990	0.3321	0.3822	0.4259	0.4761
18	0.2556	0.3200	0.3530	0.4025	0.4455	0.4944
19	0.2752	0.3398	0.3725	0.4214	0.4636	0.5113
20	0.2939	0.3585	0.3909	0.4391	0.4804	0.5270
21	0.3118	0.3761	0.4082	0.4556	0.4961	0.5415
22	0.3288	0.3927	0.4245	0.4711	0.5107	0.5550
23	0.3450	0.4085	0.4398	0.4857	0.5244	0.5677
24	0.3605	0.4234	0.4543	0.4994	0.5373	0.5795
25	0.3752	0.4376	0.4680	0.5123	0.5495	0.5906
26	0.3893	0.4510	0.4810	0.5245	0.5609	0.6011
27	0.4027	0.4638	0.4933	0.5360	0.5717	0.6110
28	0.4156	0.4759	0.5050	0.5470	0.5819	0.6203
29	0.4279	0.4875	0.5162	0.5574	0.5916	0.6292
30	0.4397	0.4985	0.5268	0.5672	0.6008	0.6375
31	0.4510	0.5091	0.5369	0.5766	0.6095	0.6455
32	0.4618	0.5192	0.5465	0.5856	0.6178	0.6530
33	0.4722	0.5288	0.5557	0.5941	0.6257	0.6602
34	0.4821	0.5381	0.5646	0.6023	0.6333	0.6671
35	0.4917	0.5469	0.5730	0.6101	0.6405	0.6737
36	0.5009	0.5554	0.5811	0.6175	0.6474	0.6800
37	0.5098	0.5636	0.5889	0.6247	0.6541	0.6860
38	0.5184	0.5714	0.5963	0.6316	0.6604	0.6917
39	0.5266	0.5789	0.6035	0.6382	0.6665	0.6972
40	0.5345	0.5862	0.6104	0.6445	0.6724	0.7025
41	0.5422	0.5932	0.6170	0.6506	0.6780	0.7076
42	0.5496	0.5999	0.6234	0.6565	0.6834	0.7125
43	0.5568	0.6064	0.6296	0.6621	0.6886	0.7172
44	0.5637	0.6127	0.6355	0.6676	0.6936	0.7218
45	0.5704	0.6188	0.6412	0.6728	0.6985	0.7261
46	0.5768	0.6246	0.6468	0.6779	0.7032	0.7304
47	0.5831	0.6303	0.6521	0.6828	0.7077	0.7345
48	0.5892	0.6358	0.6573	0.6876	0.7120	0.7384
49	0.5951	0.6411	0.6623	0.6921	0.7163	0.7422
50	0.6008	0.6462	0.6672	0.6966	0.7203	0.7459
51	0.6063	0.6512	0.6719	0.7009	0.7243	0.7495
52	0.6117	0.6560	0.6765	0.7051	0.7281	0.7529
53	0.6169	0.6607	0.6809	0.7091	0.7319	0.7563
54	0.6220	0.6653	0.6852	0.7130	0.7355	0.7595
55	0.6269	0.6697	0.6894	0.7168	0.7390	0.7627
56	0.6317	0.6740	0.6934	0.7205	0.7424	0.7658
57	0.6364	0.6782	0.6974	0.7241	0.7456	0.7687
58	0.6410	0.6823	0.7012	0.7276	0.7489	0.7716
59	0.6454	0.6862	0.7049	0.7310	0.7520	0.7744
60	0.6497	0.6901	0.7086	0.7343	0.7550	0.7772
61	0.6539	0.6938	0.7121	0.7375	0.7580	0.7798
62	0.6580	0.6975	0.7155	0.7406	0.7608	0.7824
63	0.6620	0.7010	0.7189	0.7437	0.7636	0.7850
64	0.6658	0.7045	0.7221	0.7467	0.7664	0.7874
65	0.6696	0.7079	0.7253	0.7496	0.7690	0.7898

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TABLE 5 *Continued*

Number of Observations, *n*	Lower 0.1 % Significance Level	Lower 0.5 % Significance Level	Lower 1 % Significance Level	Lower 2.5 % Significance Level	Lower 5 % Significance Level	Lower 10 % Significance Level
66	0.6733	0.7112	0.7284	0.7524	0.7716	0.7921
67	0.6770	0.7144	0.7314	0.7551	0.7741	0.7944
68	0.6805	0.7175	0.7344	0.7578	0.7766	0.7966
69	0.6839	0.7206	0.7373	0.7604	0.7790	0.7988
70	0.6873	0.7236	0.7401	0.7630	0.7813	0.8009
71	0.6906	0.7265	0.7429	0.7655	0.7836	0.8030
72	0.6938	0.7294	0.7455	0.7679	0.7859	0.8050
73	0.6970	0.7322	0.7482	0.7703	0.7881	0.8070
74	0.7000	0.7349	0.7507	0.7727	0.7902	0.8089
75	0.7031	0.7376	0.7532	0.7749	0.7923	0.8108
76	0.7060	0.7402	0.7557	0.7772	0.7944	0.8127
77	0.7089	0.7427	0.7581	0.7794	0.7964	0.8145
78	0.7117	0.7453	0.7605	0.7815	0.7983	0.8162
79	0.7145	0.7477	0.7628	0.7836	0.8002	0.8180
80	0.7172	0.7501	0.7650	0.7856	0.8021	0.8197
81	0.7199	0.7525	0.7672	0.7876	0.8040	0.8213
82	0.7225	0.7548	0.7694	0.7896	0.8058	0.8230
83	0.7250	0.7570	0.7715	0.7915	0.8075	0.8245
84	0.7275	0.7592	0.7736	0.7934	0.8093	0.8261
85	0.7300	0.7614	0.7756	0.7953	0.8109	0.8276
86	0.7324	0.7635	0.7776	0.7971	0.8126	0.8291
87	0.7348	0.7656	0.7796	0.7989	0.8142	0.8306
88	0.7371	0.7677	0.7815	0.8006	0.8158	0.8321
89	0.7394	0.7697	0.7834	0.8023	0.8174	0.8335
90	0.7416	0.7717	0.7853	0.8040	0.8190	0.8349
91	0.7438	0.7736	0.7871	0.8057	0.8205	0.8362
92	0.7459	0.7755	0.7889	0.8073	0.8220	0.8376
93	0.7481	0.7774	0.7906	0.8089	0.8234	0.8389
94	0.7501	0.7792	0.7923	0.8104	0.8248	0.8402
95	0.7522	0.7810	0.7940	0.8120	0.8263	0.8414
96	0.7542	0.7828	0.7957	0.8135	0.8276	0.8427
97	0.7562	0.7845	0.7973	0.8149	0.8290	0.8439
98	0.7581	0.7862	0.7989	0.8164	0.8303	0.8451
99	0.7600	0.7879	0.8005	0.8178	0.8316	0.8463
100	0.7619	0.7896	0.8020	0.8192	0.8329	0.8475
101	0.7637	0.7912	0.8036	0.8206	0.8342	0.8486
102	0.7655	0.7928	0.8051	0.8220	0.8354	0.8497
103	0.7673	0.7944	0.8065	0.8233	0.8367	0.8508
104	0.7691	0.7959	0.8080	0.8246	0.8379	0.8519
105	0.7708	0.7974	0.8094	0.8259	0.8391	0.8530
106	0.7725	0.7989	0.8108	0.8272	0.8402	0.8541
107	0.7742	0.8004	0.8122	0.8284	0.8414	0.8551
108	0.7758	0.8018	0.8136	0.8297	0.8425	0.8563
109	0.7774	0.8033	0.8149	0.8309	0.8436	0.8571
110	0.7790	0.8047	0.8162	0.8321	0.8447	0.8581
111	0.7806	0.8061	0.8175	0.8333	0.8458	0.8591
112	0.7821	0.8074	0.8188	0.8344	0.8469	0.8600
113	0.7837	0.8088	0.8200	0.8356	0.8479	0.8610
114	0.7852	0.8101	0.8213	0.8367	0.8489	0.8619
115	0.7866	0.8114	0.8225	0.8378	0.8500	0.8628
116	0.7881	0.8127	0.8237	0.8389	0.8510	0.8637
117	0.7895	0.8139	0.8249	0.8400	0.8519	0.8646
118	0.7909	0.8152	0.8261	0.8410	0.8529	0.8655
119	0.7923	0.8164	0.8272	0.8421	0.8539	0.8664
120	0.7937	0.8176	0.8284	0.8431	0.8548	0.8672
121	0.7951	0.8188	0.8295	0.8441	0.8557	0.8681
122	0.7964	0.8200	0.8306	0.8451	0.8567	0.8689
123	0.7977	0.8211	0.8317	0.8461	0.8576	0.8697
124	0.7990	0.8223	0.8327	0.8471	0.8585	0.8705
125	0.8003	0.8234	0.8338	0.8480	0.8593	0.8713
126	0.8016	0.8245	0.8348	0.8490	0.8602	0.8721
127	0.8028	0.8256	0.8359	0.8499	0.8611	0.8729

TABLE 5 *Continued*

Number of Observations, n	Lower 0.1 % Significance Level	Lower 0.5 % Significance Level	Lower 1 % Significance Level	Lower 2.5 % Significance Level	Lower 5 % Significance Level	Lower 10 % Significance Level
128	0.8041	0.8267	0.8369	0.8508	0.8619	0.8737
129	0.8053	0.8278	0.8379	0.8517	0.8627	0.8744
130	0.8065	0.8288	0.8389	0.8526	0.8636	0.8752
131	0.8077	0.8299	0.8398	0.8535	0.8644	0.8759
132	0.8088	0.8309	0.8408	0.8544	0.8652	0.8766
133	0.8100	0.8319	0.8418	0.8553	0.8660	0.8773
134	0.8111	0.8329	0.8427	0.8561	0.8668	0.8780
135	0.8122	0.8339	0.8436	0.8570	0.8675	0.8787
136	0.8134	0.8349	0.8445	0.8578	0.8683	0.8794
137	0.8145	0.8358	0.8454	0.8586	0.8690	0.8801
138	0.8155	0.8368	0.8463	0.8594	0.8698	0.8808
139	0.8166	0.8377	0.8472	0.8602	0.8705	0.8814
140	0.8176	0.8387	0.8481	0.8610	0.8712	0.8821
141	0.8187	0.8396	0.8489	0.8618	0.8720	0.8827
142	0.8197	0.8405	0.8498	0.8625	0.8727	0.8834
143	0.8207	0.8414	0.8506	0.8633	0.8734	0.8840
144	0.8218	0.8423	0.8515	0.8641	0.8741	0.8846
145	0.8227	0.8431	0.8523	0.8648	0.8747	0.8853
146	0.8237	0.8440	0.8531	0.8655	0.8754	0.8859
147	0.8247	0.8449	0.8539	0.8663	0.8761	0.8865
148	0.8256	0.8457	0.8547	0.8670	0.8767	0.8871
149	0.8266	0.8465	0.8555	0.8677	0.8774	0.8877

$$S^2 = \sum_{i=1}^{n} (x_i - \bar{x})^2$$

$$\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i$$

$$x_1 \leq x_2 \leq \ldots \leq x_n$$

$$S^2_{1,2} = \sum_{i=1}^{n} (x_i - \bar{x}_{1,2})^2$$

$$\bar{x}_{1,2} = \frac{1}{n-2} \sum_{i=3}^{n} x_i$$

$$S^2_{n-1,n} = \sum_{i=1}^{n-2} (x_i - \bar{x}_{n-1,n})^2$$

$$\bar{x}_{n-1,n} = \frac{1}{n-2} \sum_{i=1}^{n-2} x_i$$

[A] These significance levels are taken from Table 11, Ref (2). An observed ratio less than the appropriate critical ratio in this table calls for rejection of the null hypothesis.

which is only a little less than the 1 % critical value, 0.637, for $n = 7$. So, if the test is being conducted at any significance level greater than a 1 % level, we would conclude that 4549 is an outlier. Since the lowest of the original set of ranges, 4420, is even more outlying than the one we have just tested, it can be classified as an outlier without further testing. We note here, however, that this test did not use all of the sample observations.

4.12 *Rejection of Several Outliers*—So far we have discussed procedures for detecting one or two outliers in the same sample, but these techniques are not generally recommended for repeated rejection, since if several outliers are present in the sample the detection of one or two spurious values may be "masked" by the presence of other anomalous observations. Outlying observations occur due to a shift in level (or mean), or a change in scale (that is, change in variance of the observations), or both. Ferguson (3,4) has studied the power of the various rejection rules relative to changes in level or scale. For several outliers and repeated rejection of observations, Ferguson points out that the sample coefficient of skewness,

$$\sqrt{b_1} = \sqrt{n} \sum_{i=1}^{n} (x_i - \bar{x})^3/(n-1)^{3/2}s^3$$
$$= \sqrt{n} \sum_{i=1}^{n} (x_i - \bar{x})^3/[\Sigma(x_i - \bar{x})^2]^{3/2}$$

should be used for "one-sided" tests (change in level of several observations in the same direction), and the sample coefficient of kurtosis,

$$b_2 = n \sum_{i=1}^{n} (x_i - \bar{x})^4/(n-1)^2s^4$$
$$= n \sum_{i=1}^{n} (x_i - \bar{x})^4/[\Sigma(x_i - \bar{x})^2]^2$$

is recommended for "two-sided" tests (change in level to higher and lower values) and also for changes in scale (variance) (see Note 5). In applying the above tests, the $\sqrt{b_1}$ or the b_2, or both, are computed and if their observed values exceed those for significance levels given in Tables 7 and 8, then the observation farthest from the mean is rejected and the same procedure repeated until no further sample values are judged as outliers. (As is well-known $\sqrt{b_1}$ and b_2 are also used as tests of normality.)

TABLE 6 1000 X Tietjen-Moore Critical Values for L_k

k	α	n = 50	45	40	35	30	25	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3
1[A]	0.01	768	745	722	690	650	607	539	522	504	486	463	440	414	386	355	321	283	241	195	145	93	44	10	...
	0.025	796	776	756	732	699	654	594	579	562	544	525	503	479	453	423	390	353	310	262	207	145	81	25	1
	0.05	820	802	784	762	730	692	638	624	610	593	576	556	534	510	482	451	415	374	326	270	203	127	49	3
	0.10	840	826	812	792	766	732	685	673	660	646	631	613	594	573	548	520	488	450	405	350	283	199	98	11
2[B]	0.01	667	641	610	573	527	468	391	373	353	332	310	286	261	233	204	174	141	108	75	44	19	4	...	...
	0.025	697	667	644	610	567	512	439	421	403	382	360	337	311	284	254	221	186	149	110	71	35	9	...	...
	0.05	720	698	673	641	601	550	480	464	446	426	405	382	357	330	300	267	230	191	148	102	56	18	1	...
	0.10	746	726	702	674	637	591	527	511	494	476	456	435	411	384	355	323	286	245	199	148	92	38	3	...
3	0.01	592	558	522	484	434	377	300	272	260	237	219	194	172	147	120	98	70	48	28	10	2	...	...	...
	0.025	622	592	561	527	479	417	341	321	299	282	261	239	214	184	162	129	100	73	45	21	5	...	...	...
	0.05	646	618	588	554	506	450	377	354	337	322	300	276	250	224	196	162	129	99	64	32	10	...	...	...
	0.10	673	648	622	586	523	489	420	398	384	364	342	322	298	270	240	208	170	134	95	56	20	...	...	...
4	0.01	531	498	460	418	369	308	231	211	192	171	151	132	113	94	70	52	32	18	8	...	...	...	...	...
	0.025	559	529	491	455	408	342	265	243	226	208	185	167	145	122	96	74	52	30	13	...	...	...	...	...
	0.05	588	556	523	482	434	374	299	277	259	240	219	197	174	150	125	98	70	45	22	...	...	...	...	...
	0.10	614	586	554	516	472	412	339	316	302	282	260	236	212	186	159	128	98	68	38	...	...	...	...	...
5	0.01	483	444	406	364	312	246	175	154	140	126	108	90	72	56	38	26	12	...	...	...	...	...	...	...
	0.025	510	473	433	398	352	282	209	189	171	151	135	113	95	77	57	40	23	...	...	...	...	...	...	...
	0.05	535	502	468	424	376	312	238	217	200	181	159	140	122	98	76	54	34	...	...	...	...	...	...	...
	0.10	562	533	499	458	411	350	273	251	236	216	194	172	150	126	103	74	51	...	...	...	...	...	...	...
6	0.01	438	399	364	321	268	204	136	118	104	91	72	57	46	33	19	...	...	...	...	...	...	...	...	...
	0.025	466	430	387	348	302	233	165	145	129	117	96	78	63	47	31	...	...	...	...	...	...	...	...	...
	0.05	490	456	421	376	327	262	188	168	154	136	115	97	79	60	42	...	...	...	...	...	...	...	...	...
	0.10	518	488	451	410	359	296	220	199	184	165	144	124	104	82	62	...	...	...	...	...	...	...	...	...
7	0.01	400	361	324	282	229	168	104	88	76	64	49	37	27	...	...	...	...	...	...	...	...	...	...	...
	0.025	428	391	348	308	261	192	128	108	95	82	65	51	38	...	...	...	...	...	...	...	...	...	...	...
	0.05	450	417	378	334	283	222	150	130	116	100	82	66	50	...	...	...	...	...	...	...	...	...	...	...
	0.10	477	447	408	365	316	251	176	158	142	125	104	86	68	...	...	...	...	...		...	...	...	...	...
8	0.01	368	328	292	250	196	144	78	64	53	44	30	...	...	...	...	...	...	...	...	...	...	...	...	...
	0.025	392	356	314	274	226	159	98	80	68	58	45	...	...	...	...	...	...	...	...	...	...	...	...	...
	0.05	414	382	342	297	245	184	115	99	86	72	55	...	...	...	...	...	...	...	...	...	...	...	...	...
	0.10	442	410	372	328	276	213	140	124	108	92	73	...	...	...	...	...	...	...	...	...	...	...	...	...
9	0.01	336	296	262	220	166	112	68	46	36	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	0.025	363	325	283	242	193	132	73	59	48	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	0.05	383	350	310	264	212	154	88	74	62	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	0.10	410	378	338	294	240	180	110	94	80	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
10	0.01	308	270	234	194	142	92	42	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	0.025	334	295	257	213	165	108	54	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	0.05	356	320	280	235	183	126	66	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	0.10	380	348	307	262	210	152	85	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

[A] From Grubbs (1950, Table I) for $n \leq 25$.

[B] From Grubbs (1972, Table II).

NOTE 5—In the above equations for $\sqrt{b_1}$ and b_2, s is defined as used in this standard:

$$s = \sqrt{\sum_{i=1}^{n} (x_i - \bar{x})^2/(n-1)}$$

4.12.1 The significance levels in Tables 7 and 8 for sample sizes of 5, 10, 15, and 20 (and 25 for b_2) were obtained by Ferguson on an IBM 704 computer using a sampling experiment or "Monte Carlo" procedure. The significance levels for the other sample sizes are from Pearson, E. S. "Table of Percentage Points of $\sqrt{b_1}$ and b_2 in Normal Samples; a Rounding Off," *Biometrika*, Vol 52, 1965, pp. 282–285.

4.12.2 The $\sqrt{b_1}$ and b_2 statistics have the optimum property of being "locally" best against one-sided and two-sided alternatives, respectively. The $\sqrt{b_1}$ test is good for up to 50 % spurious observations in the sample for the one-sided case, and the b_2 test is optimum in the two-sided alternatives case for up to 21 % "contamination" of sample values. For only one or two outliers the sample statistics of the previous paragraphs are recommended, and Ferguson (3) discusses in detail their optimum properties of *pointing out* one or two outliers.

TABLE 7 Significance Levels for $\sqrt{b_1}$

Significance Level, percent	n = 5[A]	10[A]	15[A]	20[A]	25	30	35	40	50	60
1	1.34	1.31	1.20	1.11	1.06	0.98	0.92	0.87	0.79	0.72
5	1.05	0.92	0.84	0.79	0.71	0.66	0.62	0.59	0.53	0.49

[A] These values were obtained by Ferguson, using a Monte Carlo procedure.

TABLE 8 Significance Levels for b_2

Significance Level, percent	n = 5[A]	10[A]	15[A]	20[A]	25[A]	50	75	100
1	3.11	4.83	5.08	5.23	5.00	4.88	4.59	4.39
5	2.89	3.85	4.07	4.15	4.00	3.99	3.87	3.77

[A] These values were obtained by Ferguson, using a Monte Carlo procedure. For $n = 25$; Ferguson's Monte Carlo values of b_2 agree with Pearson's computed values.

4.12.2.1 Instead of the more complicated $\sqrt{b_1}$ and b_2 statistics, one can use Tables 4 and 6 (7) for sample sizes and percentage points given.

5. Recommended Criterion Using Independent Standard Deviation

5.1 Suppose that an independent estimate of the standard deviation is available from previous data. This estimate may be from a single sample of previous similar data or may be the result of combining estimates from several such previous sets of data. In any event, each estimate is said to have degrees of freedom equal to one less than the sample size that it is based on. The proper combined estimate is a weighted average of the several values of s^2, the weights being proportional to the respective degrees of freedom. The total degrees of freedom in the combined estimate is then the sum of the individual degrees of freedom. When one uses an independent estimate of the standard deviation, s_v, the test criterion recommended here for an outlier is as follows:

$$T'_1 = (\bar{x} - x_1)/s$$

or:

$$T'_n = (x_n - \bar{x})/s_v$$

where:

v = total number of degrees of freedom.

5.2 The critical values for T'_1 and T'_n for the 5 % and 1 % significance levels are due to David (12) and are given in Table 9. In Table 9 the subscript v = df indicates the total number of degrees of freedom associated with the independent estimate of standard deviation σ and n indicates the number of observations in the sample under study. We illustrate with an example on interlaboratory testing.

5.3 *Example 6—Interlaboratory Testing*—In an analysis of interlaboratory test procedures, data representing normalities of sodium hydroxide solutions were determined by twelve different laboratories. In all the standardizations, a 0.1 *N* sodium hydroxide solution was prepared by the Standard Methods Committee using carbon-dioxide-free distilled

TABLE 9 Critical Values for T' When Standard Deviation s_v Is Independent of Present Sample[A]

$$T' = \frac{x_n - \bar{x}}{s_v}, \text{ or } \frac{\bar{x} - x_1}{s_v}$$

v = d.f.	n: 3	4	5	6	7	8	9	10	12
				1 percentage point					
10	2.78	3.10	3.32	3.48	3.62	3.73	3.82	3.90	4.04
11	2.72	3.02	3.24	3.39	3.52	3.63	3.72	3.79	3.93
12	2.67	2.96	3.17	3.32	3.45	3.55	3.64	3.71	3.84
13	2.63	2.92	3.12	3.27	3.38	3.48	3.57	3.64	3.76
14	2.60	2.88	3.07	3.22	3.33	3.43	3.51	3.58	3.70
15	2.57	2.84	3.03	3.17	3.29	3.38	3.46	3.53	3.65
16	2.54	2.81	3.00	3.14	3.25	3.34	3.42	3.49	3.60
17	2.52	2.79	2.97	3.11	3.22	3.31	3.38	3.45	3.56
18	2.50	2.77	2.95	3.08	3.19	3.28	3.35	3.42	3.53
19	2.49	2.75	2.93	3.06	3.16	3.25	3.33	3.39	3.50
20	2.47	2.73	2.91	3.04	3.14	3.23	3.30	3.37	3.47
24	2.42	2.68	2.84	2.97	3.07	3.16	3.23	3.29	3.38
30	2.38	2.62	2.79	2.91	3.01	3.08	3.15	3.21	3.30
40	2.34	2.57	2.73	2.85	2.94	3.02	3.08	3.13	3.22
60	2.29	2.52	2.68	2.79	2.88	2.95	3.01	3.06	3.15
120	2.25	2.48	2.62	2.73	2.82	2.89	2.95	3.00	3.08
∞	2.22	2.43	2.57	2.68	2.76	2.83	2.88	2.93	3.01
				5 percentage points					
10	2.01	2.27	2.46	2.60	2.72	2.81	2.89	2.96	3.08
11	1.98	2.24	2.42	2.56	2.67	2.76	2.84	2.91	3.03
12	1.96	2.21	2.39	2.52	2.63	2.72	2.80	2.87	2.98
13	1.94	2.19	2.36	2.50	2.60	2.69	2.76	2.83	2.94
14	1.93	2.17	2.34	2.47	2.57	2.66	2.74	2.80	2.91
15	1.91	2.15	2.32	2.45	2.55	2.64	2.71	2.77	2.88
16	1.90	2.14	2.31	2.43	2.53	2.62	2.69	2.75	2.86
17	1.89	2.13	2.29	2.42	2.52	2.60	2.67	2.73	2.84
18	1.88	2.11	2.28	2.40	2.50	2.58	2.65	2.71	2.82
19	1.87	2.11	2.27	2.39	2.49	2.57	2.64	2.70	2.80
20	1.87	2.10	2.26	2.38	2.47	2.56	2.63	2.68	2.78
24	1.84	2.07	2.23	2.34	2.44	2.52	2.58	2.64	2.74
30	1.82	2.04	2.20	2.31	2.40	2.48	2.54	2.60	2.69
40	1.80	2.02	2.17	2.28	2.37	2.44	2.50	2.56	2.65
60	1.78	1.99	2.14	2.25	2.33	2.41	2.47	2.52	2.61
120	1.76	1.96	2.11	2.22	2.30	2.37	2.43	2.48	2.57
∞	1.74	1.94	2.08	2.18	2.27	2.33	2.39	2.44	2.52

[A] The percentage points are reproduced from Ref (12).

water. Potassium acid phthalate (P.A.P.), obtained from the National Institute of Standards and Technology, was used as the test standard.

5.3.1 Test data by the twelve laboratories are given in Table 10. The P.A.P. readings have been coded to simplify the calculations. The variances between the three readings within all laboratories were found to be homogeneous. A one-way classification in the analysis of variance was first analyzed to determine if the variation in laboratory results (averages) was statistically significant. This variation was significant and indicated a need for action, so tests for outliers were then applied to isolate the particular laboratories whose results gave rise to the significant variation.

5.3.2 Table 11 shows that the variation between laboratories is highly significant. To test if this (very significant) variation is due to one (or perhaps two) laboratories that obtained "outlying" results (that is, perhaps showing non-standard technique), we can test the laboratory averages for outliers. From the analysis of variance, we have an estimate of the variance of an individual reading as 0.008793, based on 24 degrees of freedom. The estimated standard deviation of an individual measurement is $\sqrt{0.008793} = 0.094$ and the estimated standard deviation of the average of three readings is therefore $0.094/\sqrt{3} = 0.054$.

5.3.3 Since the estimate of within-laboratory variation is independent of any difference between laboratories, we can use the statistic T'_1 of 5.1 to test for outliers. An examination of the deviations of the laboratory averages from the grand average indicates that Laboratory 10 obtained an average reading much lower than the grand average, and that Laboratory 12 obtained a high average compared to the over-all average. To first test if Laboratory 10 is an outlier, we compute

$$T' = (1.871 - 0.745)/0.054 = 20.9$$

5.3.4 This value of T' is obviously significant at a very low level of probability ($P \ll 0.01$—Refer to Table 9 with $n = 12$ and $\nu = 24$ degrees of freedom). We conclude, therefore, that the test methods of Laboratory 10 should be investigated.

5.3.5 Excluding Laboratory 10, we compute a new grand average of 1.973 and test if the results of Laboratory 12 are outlying. We have

$$T' = (2.327 - 1.973)/0.054 = 6.56$$

and this value of T' is significant at $P \ll 0.01$ (Refer to Table 7 with $n = 11$ and $\nu = 24$ degrees of freedom). We conclude that the procedures of Laboratory 12 should also be investigated.

5.3.6 To verify that the remaining laboratories did indeed obtain homogeneous results, we might repeat the analysis of variance omitting Laboratories 10 and 12. The calculations give the results shown in Table 12.

5.3.6.1 For this analysis, the variation between laboratories is not significant at the 5 % level and we conclude that all the laboratories except No. 10 and No. 12 exhibit the same capability in testing procedure.

5.3.6.2 In conclusion, there should be a systematic investigation of test methods for Laboratories No. 10 and No. 12 to determine why their test procedures are apparently different from the other ten laboratories. (In this type of

TABLE 10 Standardization of Sodium Hydroxide Solutions as Determined by Plant Laboratories
Standard used: Potassium Acid Phthalate (P.A.P.)

Laboratory	(P.A.P. − 0.096000 × 10⁵)	Sums	Averages	Deviation of Average from Grand Average
1	1.893 1.972 1.876	5.741	1.914	+0.043
2	2.046 1.851 1.949	5.846	1.949	+0.078
3	1.874 1.792 1.829	5.495	1.832	−0.039
4	1.861 1.998 1.983	5.842	1.947	+0.076
5	1.922 1.881 1.850	5.653	1.884	+0.013
6	2.082 1.958 2.029	6.069	2.023	+0.152
7	1.992 1.980 2.066	6.038	2.013	+0.142
8	2.050 2.181 1.903	6.134	2.045	+0.174
9	1.831 1.883 1.855	5.569	1.856	−0.015
10	0.735 0.722 0.777	2.234	0.745	−1.126
11	2.064 1.794 1.891	5.749	1.916	+0.045
12	2.475 2.403 2.102	6.980	2.327	+0.456
Grand sum		67.350		
Grand average			1.871	

TABLE 11 Analysis of Variance

Source of Variation	Degrees of Freedom (d.f.)	Sum of Squares (SS)	Mean Square (MS)	F-ratio
Between laboratories	11	4.70180	0.4274	F = 48.61
Within laboratories	24	0.21103	0.008793	(highly significant)
Total	35	4.91283		

TABLE 12 Analysis of Variance
(Omitting Labs 10 and 12)

Source of Variation	d.f.	SS	MS	F-ratio
Between laboratories	9	0.13889	0.01543	F = 2.36
Within laboratories	20	0.13107	0.00655	$F_{0.05}(9, 20)$ = 2.40 $F_{0.01}(9, 20)$ = 3.45
Total	29	0.26996		

problem, the tables of Greenhouse, Halperin, and Cornfield (13) could also be used for testing outlying laboratory averages.)

5.3.7 *Cautionary Remarks*—In the use of the tests for outliers as given above, our interest was to direct the statistical tests of significance toward picking out those laboratories which have different levels of measurement than the others. Thus, we have assumed that there should not exist any component of variance among the laboratory true means of measurement. On the other hand, it is well known that in practically all interlaboratory tests one does indeed find a nonzero component of variance among the laboratory levels. Often the variance among the laboratory means may be several times that within individual laboratories. Thus, if we knew the size of the actual component of variance among laboratories we must live with—or guard against—then the observed F ratio could be multiplied by the within variance of a sample mean and divided by this quantity plus the among laboratory variance, in order to adjust the F test to detect the undesirable deviations of those laboratories which departed in average level from measurements of the common or acceptable level of the closely agreeing laboratories. Also, a somewhat similar adjustment, if desired, could be applied to the tests for isolated outliers. In our particular example, however, we desired to detect those particular laboratories which departed in average level from that of the closely agreeing laboratories. In fact, this should be the aim of many interlaboratory testing programs, if we are to seek high precision and accuracy of measurement.

6. Recommended Criteria for Known Standard Deviation

6.1 Frequently the population standard deviation σ may be known accurately. In such cases, Table 13 may be used for single outliers and we illustrate with the following example:

6.2 *Example 7* (σ *known*)—Passage of the Echo I (Balloon) Satellite was recorded on star-plates when it was visible. Photographs were made by means of a camera with shutter automatically timed to obtain a series of points for the Echo path. Since the stars were also photographed at the same times as the Satellite, all the pictures show star-trails and are thus called "star-plates."

6.2.1 The x- and y-coordinate of each point on the Echo path are read from a photograph, using a stereo-comparator. To eliminate bias of the reader, the photograph is placed in one position and the coordinates are read; then the photograph is rotated 180 deg and the coordinates reread. The average of the two readings is taken as the final reading. Before any further calculations are made, the readings must be "screened" for gross reading or tabulation errors. This is done by examining the difference in the readings taken at the two positions of the photograph.

6.2.2 Table 14 records a sample of six readings made at the two positions and the differences in these readings. On the third reading, the differences are rather large. Has the operator made an error in placing the cross hair on the point?

6.2.3 For this example, an independent estimate of σ is available since extensive tests on the stereo-comparator have shown that the standard deviation in reader's error is about 4 µm. The determination of this standard error was based on such a large sample that we can assume σ = 4 µm. The standard deviation of the difference in two readings is therefore

$$\sqrt{4^2 + 4^2} = \sqrt{32} \text{ or } 5.7\ \mu m$$

6.2.4 For the six readings above, the mean difference in the x-coordinates is $\overline{\Delta x} = 3.5$ and the mean difference in the y-coordinates is $\overline{\Delta y} = 1.8$. For the questionable third reading, we have

$$T'_x = (24 - 3.5)/5.7 = 3.60$$

$$T'_y = (22 - 1.8)/5.7 = 3.54$$

From Table 13 we see that for $n = 6$, values of $T'_{n\infty}$ as large as the calculated values would occur by chance less than 1 % of the time so that a significant reading error seems to have been made on the third point.

6.3 A great number of points are read and automatically tabulated on star-plates. Here we have chosen a very small sample of these points. In actual practice, the tabulations would probably be scanned quickly for very large errors such as tabulator errors; then some rule-of-thumb such as ±3 standard deviations of reader's error might be used to scan for outliers due to operator error (Note 6). In other words,

TABLE 13 Critical Values of $T'_{1\infty}$ and $T'_{n\infty}$ When the Population Standard Deviation σ Is Known[A]

Number of Observations, n	5 Percent Significance Level	1 Percent Significance Level	0.5 Percent Significance Level
2	1.39	1.82	1.99
3	1.74	2.22	2.40
4	1.94	2.43	2.62
5	2.08	2.57	2.76
6	2.18	2.68	2.87
7	2.27	2.76	2.95
8	2.33	2.83	3.02
9	2.39	2.88	3.07
10	2.44	2.93	3.12
11	2.48	2.97	3.16
12	2.52	3.01	3.20
13	2.56	3.04	3.23
14	2.59	3.07	3.26
15	2.62	3.10	3.29
16	2.64	3.12	3.31
17	2.67	3.15	3.33
18	2.69	3.17	3.36
19	2.71	3.19	3.38
20	2.73	3.21	3.39
21	2.75	3.22	3.41
22	2.77	3.24	3.42
23	2.78	3.26	3.44
24	2.80	3.27	3.45
25	2.81	3.28	3.46

$$x_1 \le x_2 \le x_3 \le \ldots \le x_n$$
$$T'_1 = (\bar{x} - x_1)/\sigma;\ T'_n = (x_n - \bar{x})/\sigma$$

[A] This table is taken from Ref (13).

TABLE 14 Measurements, µm

x-Coordinate			y-Coordinate		
Position 1	Position 1 + 180 deg	Δx	Position 1	Position 1 + 180 deg	Δy
−53011	−53004	−7	70263	70258	+5
−38112	−38103	−9	−39739	−39729	−8
−2804	−2828	+24	81162	81140	+22
18473	18467	+6	41477	41485	−8
25507	25497	+10	1082	1076	+6
87736	87739	−3	−7442	−7434	−8

the data are probably too extensive to allow repeated use of precise tests like those described above (especially for varying sample size), but this example does illustrate the case where σ is assumed known. If gross disagreement is found in the two readings of a coordinate, then the reading could be omitted or reread before further computations are made.

NOTE 6—Note that the values of Table 13 vary between about 1.4σ and 3.5σ.

7. Additional Comments

7.1 In the above, we have covered only that part of screening samples to detect outliers statistically. However, a large area remains after the decision has been reached that outliers are present in data. Once some of the sample observations are branded as "outliers," then a thorough investigation should be initiated to determine the cause. In particular, one should look for gross errors, personal errors, errors of measurement, errors in calibration, etc. If reasons are found for aberrant observations, then one should act accordingly and perhaps scrutinize also the other observations. Finally, if one reaches the point that some observations are to be discarded or treated in a special manner based solely on statistical judgment, then it must be decided what action should be taken in the further analysis of the data. We do not propose to cover this problem here, since in many cases it will depend greatly on the particular case in hand. However, we do remark that there could be the outright rejection of aberrant observations once and for all on physical grounds (and preferably not on statistical grounds generally) and only the remaining observations would be used in further analyses or in estimation problems. On the other hand, some may want to replace aberrant values with newly taken observations and others may want to "Winsorize" the outliers, that is, replace them with the next closest values in the sample. Also with outliers in a sample, some may wish to use the median instead of the mean, and so on. Finally, we remark that perhaps a fair or appropriate practice might be that of using truncated-sample theory **(11)** for cases of samples where we have "censored" or rejected some of the observations. We cannot go further into these problems here. For additional reading on outliers, see Refs **(12,14,15,16,17,18,19)**.

7.2 A sample test criterion for non-normality, and hence possibly for outliers, not covered above is the Wilk-Shapiro W statistic for a sample of size n given by

$$W = \frac{\left[\sum_{i=1}^{[n/2]} a_{n-i+1}(x_{n-i+1} - x_i)\right]^2}{\sum_{i=1}^{n} (x_i - \bar{x})^2}$$

where:

$x_1 \leq x_2 \leq x_3 \leq \ldots \leq x_n$

$\bar{x} = \sum_{i=1}^{n} x_i/n,$

$[n/2]$ is the greatest integer in $n/2$, and the coefficients a_{n-i+1} are the order statistics for $n = 2(1)50$ given in Ref **(20)**. The Wilk-Shapiro W statistic has been found to be quite sensitive to departures from normality and generally may compare most favorably with the $\sqrt{b_1}$ and b_2 tests discussed above. In addition, therefore, the W statistic may also be used as a test for outliers, or otherwise as a general test for heterogeneity of sample values. Our significance tests given above have been selected and recommended since they specifically point out particular suspected outliers in the sample. We therefore are inclined to favor the above tests for specific outliers in samples for the case where they will be used routinely, for example, by engineers.

8. Keywords

8.1 dixon test; gross deviation; Grubbs test; outlier

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Cohen's Method

Where the percentage of analytical results reported below the detection limit is greater than 15% and less than 50%, a technique (Cohen's Method) described in reference 2 (page 8-7) can be used to adjust the sample mean and sample standard deviation to account for data below the detection limit. The only requirements for this use of this technique is that data are normally distributed and that the detection limit always be the same. The table on the following pages is used to calculate the adjusted mean and standard deviation as follows.

$$\bar{x} = \bar{x}_d - \lambda (\bar{x}_d - DL) \quad ; \quad \delta = \sqrt{\delta_d^2 + \lambda (\bar{x}_d - DL)^2}$$

where:

$\bar{x}$ = adjusted mean

$\bar{x}_d$ = sample mean of data above the detection limit

λ = value taken from the table on the following pages , where

$$\gamma = \frac{\delta_d^2}{(\bar{x} - DL)^2}$$

DL = detection limit

δ_d^2 = sample variance of data above the detection limit

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VALUES OF LAMBDA FOR COHEN'S METHOD

	Percentage of Non-detects										
γ	.01	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50
.01	.0102	.0530	.1111	.1747	.2443	.3205	.4043	.4967	.5989	.7128	.8403
.05	.0105	.0547	.1143	.1793	.2503	.3279	.4130	.5066	.6101	.7252	.8540
.10	.0110	.0566	.1180	.1848	.2574	.3366	.4233	.5184	.6234	.7400	.8703
.15	.0113	.0584	.1215	.1898	.2640	.3448	.4330	.5296	.6361	.7542	.8860
.20	.0116	.0600	.1247	.1946	.2703	.3525	.4422	.5403	.6483	.7678	.9012
.25	.0120	.0615	.1277	.1991	.2763	.3599	.4510	.5506	.6600	.7810	.9158
.30	.0122	.0630	.1306	.2034	.2819	.3670	.4595	.5604	.6713	.7937	.9300
.35	.0125	.0643	.1333	.2075	.2874	.3738	.4676	.5699	.6821	.8060	.9437
.40	.0128	.0657	.1360	.2114	.2926	.3803	.4755	.5791	.6927	.8179	.9570
.45	.0130	.0669	.1385	.2152	.2976	.3866	.4831	.5880	.7029	.8295	.9700
.50	.0133	.0681	.1409	.2188	.3025	.3928	.4904	.5967	.7129	.8408	.9826
.55	.0135	.0693	.1432	.2224	.3073	.3987	.4976	.6051	.7225	.8517	.9950
.60	.0137	.0704	.1455	.2258	.3118	.4045	.5046	.6133	.7320	.8625	1.0070
.65	.0140	.0715	.1477	.2291	.3163	.4101	.5114	.6213	.7412	.8729	1.0188
.70	.0142	.0726	.1499	.2323	.3206	.4156	.5180	.6291	.7502	.8832	1.0303
.75	.0144	.0736	.1520	.2355	.3249	.4209	.5245	.6367	.7590	.8932	1.0416
.80	.0146	.0747	.1540	.2386	.3290	.4261	.5308	.6441	.7676	.9031	1.0527
.85	.0148	.0756	.1560	.2416	.3331	.4312	.5370	.6515	.7761	.9127	1.0636
.90	.0150	.0766	.1579	.2445	.3370	.4362	.5430	.6586	.7844	.9222	1.0743
.95	.0152	.0775	.1598	.2474	.3409	.4411	.5490	.6656	.7925	.9314	1.0847
1.00	.0153	.0785	.1617	.2502	.3447	.4459	.5548	.6725	.8005	.9406	1.0951
1.05	.0155	.0794	.1635	.2530	.3484	.4506	.5605	.6793	.8084	.9496	1.1052
1.10	.0157	.0803	.1653	.2557	.3521	.4553	.5662	.6860	.8161	.9584	1.1152
1.15	.0159	.0811	.1671	.2584	.3557	.4598	.5717	.6925	.8237	.9671	1.1250
1.20	.0160	.0820	.1688	.2610	.3592	.4643	.5771	.6990	.8312	.9756	1.1347
1.25	.0162	.0828	.1705	.2636	.3627	.4687	.5825	.7053	.8385	.9841	1.1443
1.30	.0164	.0836	.1722	.2661	.3661	.4730	.5878	.7115	.8458	.9924	1.1537
1.35	.0165	.0845	.1738	.2686	.3695	.4773	.5930	.7177	.8529	1.0006	1.1629
1.40	.0167	.0853	.1754	.2710	.3728	.4815	.5981	.7238	.8600	1.0087	1.1721
1.45	.0168	.0860	.1770	.2735	.3761	.4856	.6031	.7298	.8670	1.0166	1.1812
1.50	.0170	.0868	.1786	.2758	.3793	.4897	.6081	.7357	.8738	1.0245	1.1901
1.55	.0171	.0876	.1801	.2782	.3825	.4938	.6130	.7415	.8806	1.0323	1.1989
1.60	.0173	.0883	.1817	.2805	.3856	.4977	.6179	.7472	.8873	1.0400	1.2076
1.65	.0174	.0891	.1832	.2828	.3887	.5017	.6227	.7529	.8939	1.0476	1.2162
1.70	.0176	.0898	.1846	.2851	.3918	.5055	.6274	.7585	.9005	1.0551	1.2248
1.75	.0177	.0905	.1861	.2873	.3948	.5094	.6321	.7641	.9069	1.0625	1.2332
1.80	.0179	.0913	.1876	.2895	.3978	.5132	.6367	.7696	.9133	1.0698	1.2415
1.85	.0180	.0920	.1890	.2917	.4007	.5169	.6413	.7750	.9196	1.0771	1.2497
1.90	.0181	.0927	.1904	.2938	.4036	.5206	.6458	.7804	.9259	1.0842	1.2579
1.95	.0183	.0933	.1918	.2960	.4065	.5243	.6502	.7857	.9321	1.0913	1.2660

Source: U.S. Environmental Protection Agency, Statistical Analysis of Ground-Water Monitoring at RCRA FAcilities, Addendum to Interim Final Guidance, July 1992

VALUES OF LAMBDA FOR COHEN'S METHOD

γ	Percentage of Non-detects										
	.01	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50
2.00	.0184	.0940	.1932	.2981	.4093	.5279	.6547	.7909	.9382	1.0984	1.2739
2.05	.0186	.0947	.1945	.3001	.4122	.5315	.6590	.7961	.9442	1.1053	1.2819
2.10	.0187	.0954	.1959	.3022	.4149	.5350	.6634	.8013	.9502	1.1122	1.2897
2.15	.0188	.0960	.1972	.3042	.4177	.5385	.6676	.8063	.9562	1.1190	1.2974
2.20	.0189	.0967	.1986	.3062	.4204	.5420	.6719	.8114	.9620	1.1258	1.3051
2.25	.0191	.0973	.1999	.3082	.4231	.5454	.6761	.8164	.9679	1.1325	1.3127
2.30	.0192	.0980	.2012	.3102	.4258	.5488	.6802	.8213	.9736	1.1391	1.3203
2.35	.0193	.0986	.2025	.3122	.4285	.5522	.6844	.8262	.9794	1.1457	1.3278
2.40	.0194	.0992	.2037	.3141	.4311	.5555	.6884	.8311	.9850	1.1522	1.3352
2.45	.0196	.0998	.2050	.3160	.4337	.5588	.6925	.8359	.9906	1.1587	1.3425
2.50	.0197	.1005	.2062	.3179	.4363	.5621	.6965	.8407	.9962	1.1651	1.3498
2.55	.0198	.1011	.2075	.3198	.4388	.5654	.7005	.8454	1.0017	1.1714	1.3571
2.60	.0199	.1017	.2087	.3217	.4414	.5686	.7044	.8501	1.0072	1.1777	1.3642
2.65	.0201	.1023	.2099	.3236	.4439	.5718	.7083	.8548	1.0126	1.1840	1.3714
2.70	.0202	.1029	.2111	.3254	.4464	.5750	.7122	.8594	1.0180	1.1902	1.3784
2.75	.0203	.1035	.2123	.3272	.4489	.5781	.7161	.8639	1.0234	1.1963	1.3854
2.80	.0204	.1040	.2135	.3290	.4513	.5812	.7199	.8685	1.0287	1.2024	1.3924
2.85	.0205	.1046	.2147	.3308	.4537	.5843	.7237	.8730	1.0339	1.2085	1.3993
2.90	.0206	.1052	.2158	.3326	.4562	.5874	.7274	.8775	1.0392	1.2145	1.4061
2.95	.0207	.1058	.2170	.3344	.4585	.5905	.7311	.8819	1.0443	1.2205	1.4129
3.00	.0209	.1063	.2182	.3361	.4609	.5935	.7348	.8863	1.0495	1.2264	1.4197
3.05	.0210	.1069	.2193	.3378	.4633	.5965	.7385	.8907	1.0546	1.2323	1.4264
3.10	.0211	.1074	.2204	.3396	.4656	.5995	.7422	.8950	1.0597	1.2381	1.4330
3.15	.0212	.1080	.2216	.3413	.4679	.6024	.7458	.8993	1.0647	1.2439	1.4396
3.20	.0213	.1085	.2227	.3430	.4703	.6054	.7494	.9036	1.0697	1.2497	1.4462
3.25	.0214	.1091	.2238	.3447	.4725	.6083	.7529	.9079	1.0747	1.2554	1.4527
3.30	.0215	.1096	.2249	.3464	.4748	.6112	.7565	.9121	1.0796	1.2611	1.4592
3.35	.0216	.1102	.2260	.3480	.4771	.6141	.76	.9163	1.0845	1.2668	1.4657
3.40	.0217	.1107	.2270	.3497	.4793	.6169	.7635	.9205	1.0894	1.2724	1.4720
3.45	.0218	.1112	.2281	.3513	.4816	.6197	.7670	.9246	1.0942	1.2779	1.4784
3.50	.0219	.1118	.2292	.3529	.4838	.6226	.7704	.9287	1.0990	1.2835	1.4847
3.55	.0220	.1123	.2303	.3546	.4860	.6254	.7739	.9328	1.1038	1.2890	1.4910
3.60	.0221	.1128	.2313	.3562	.4882	.6282	.7773	.9369	1.1086	1.2945	1.4972
3.65	.0222	.1133	.2324	.3578	.4903	.6309	.7807	.9409	1.1133	1.2999	1.5034
3.70	.0223	.1138	.2334	.3594	.4925	.6337	.7840	.9449	1.1180	1.3053	1.5096
3.75	.0224	.1143	.2344	.3609	.4946	.6364	.7874	.9489	1.1226	1.3107	1.5157
3.80	.0225	.1148	.2355	.3625	.4968	.6391	.7907	.9529	1.1273	1.3160	1.5218
3.85	.0226	.1153	.2365	.3641	.4989	.6418	.7940	.9568	1.1319	1.3213	1.5279
3.90	.0227	.1158	.2375	.3656	.5010	.6445	.7973	.9607	1.1364	1.3266	1.5339
3.95	.0228	.1163	.2385	.3672	.5031	.6472	.8006	.9646	1.1410	1.3318	1.5399

Source: U.S. Environmental Protection Agency, Statistical Analysis of Ground-Water Monitoring at RCRA FAcilities, Addendum to Interim Final Guidance, July 1992

VALUES OF LAMBDA FOR COHEN'S METHOD

γ	Percentage of Non-detects										
	.01	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50
4.00	.0229	.1168	.2395	.3687	.5052	.6498	.8038	.9685	1.1455	1.3371	1.5458
4.05	.0230	.1173	.2405	.3702	.5072	.6525	.8070	.9723	1.1500	1.3423	1.5518
4.10	.0231	.1178	.2415	.3717	.5093	.6551	.8102	.9762	1.1545	1.3474	1.5577
4.15	.0232	.1183	.2425	.3732	.5113	.6577	.8134	.9800	1.1590	1.3526	1.5635
4.20	.0233	.1188	.2435	.3747	.5134	.6603	.8166	.9837	1.1634	1.3577	1.5693
4.25	.0234	.1193	.2444	.3762	.5154	.6629	.8198	.9875	1.1678	1.3627	1.5751
4.30	.0235	.1197	.2454	.3777	.5174	.6654	.8229	.9913	1.1722	1.3678	1.5809
4.35	.0236	.1202	.2464	.3792	.5194	.6680	.8260	.9950	1.1765	1.3728	1.5866
4.40	.0237	.1207	.2473	.3806	.5214	.6705	.8291	.9987	1.1809	1.3778	1.5924
4.45	.0238	.1212	.2483	.3821	.5234	.6730	.8322	1.0024	1.1852	1.3828	1.5980
4.50	.0239	.1216	.2492	.3836	.5253	.6755	.8353	1.0060	1.1895	1.3878	1.6037
4.55	.0240	.1221	.2502	.3850	.5273	.6780	.8384	1.0097	1.1937	1.3927	1.6093
4.60	.0241	.1225	.2511	.3864	.5292	.6805	.8414	1.0133	1.1980	1.3976	1.6149
4.65	.0241	.1230	.2521	.3879	.5312	.6830	.8445	1.0169	1.2022	1.4024	1.6205
4.70	.0242	.1235	.2530	.3893	.5331	.6855	.8475	1.0205	1.2064	1.4073	1.6260
4.75	.0243	.1239	.2539	.3907	.5350	.6879	.8505	1.0241	1.2106	1.4121	1.6315
4.80	.0244	.1244	.2548	.3921	.5370	.6903	.8535	1.0277	1.2148	1.4169	1.6370
4.85	.0245	.1248	.2558	.3935	.5389	.6928	.8564	1.0312	1.2189	1.4217	1.6425
4.90	.0246	.1253	.2567	.3949	.5407	.6952	.8594	1.0348	1.2230	1.4265	1.6479
4.95	.0247	.1257	.2576	.3963	.5426	.6976	.8623	1.0383	1.2272	1.4312	1.6533
5.00	.0248	.1262	.2585	.3977	.5445	.7000	.8653	1.0418	1.2312	1.4359	1.6587
5.05	.0249	.1266	.2594	.3990	.5464	.7024	.8682	1.0452	1.2353	1.4406	1.6641
5.10	.0249	.1270	.2603	.4004	.5482	.7047	.8711	1.0487	1.2394	1.4453	1.6694
5.15	.0250	.1275	.2612	.4018	.5501	.7071	.8740	1.0521	1.2434	1.4500	1.6747
5.20	.0251	.1279	.2621	.4031	.5519	.7094	.8768	1.0556	1.2474	1.4546	1.6800
5.25	.0252	.1284	.2629	.4045	.5537	.7118	.8797	1.0590	1.2514	1.4592	1.6853
5.30	.0253	.1288	.2638	.4058	.5556	.7141	.8825	1.0624	1.2554	1.4638	1.6905
5.35	.0254	.1292	.2647	.4071	.5574	.7164	.8854	1.0658	1.2594	1.4684	1.6958
5.40	.0255	.1296	.2656	.4085	.5592	.7187	.8882	1.0691	1.2633	1.4729	1.7010
5.45	.0255	.1301	.2664	.4098	.5610	.7210	.8910	1.0725	1.2672	1.4775	1.7061
5.50	.0256	.1305	.2673	.4111	.5628	.7233	.8938	1.0758	1.2711	1.4820	1.7113
5.55	.0257	.1309	.2682	.4124	.5646	.7256	.8966	1.0792	1.2750	1.4865	1.7164
5.60	.0258	.1313	.2690	.4137	.5663	.7278	.8994	1.0825	1.2789	1.4910	1.7215
5.65	.0259	.1318	.2699	.4150	.5681	.7301	.9022	1.0858	1.2828	1.4954	1.7266
5.70	.0260	.1322	.2707	.4163	.5699	.7323	.9049	1.0891	1.2866	1.4999	1.7317
5.75	.0260	.1326	.2716	.4176	.5716	.7346	.9077	1.0924	1.2905	1.5043	1.7368
5.80	.0261	.1330	.2724	.4189	.5734	.7368	.9104	1.0956	1.2943	1.5087	1.7418
5.85	.0262	.1334	.2732	.4202	.5751	.7390	.9131	1.0989	1.2981	1.5131	1.7468
5.90	.0263	.1338	.2741	.4215	.5769	.7412	.9158	1.1021	1.3019	1.5175	1.7518
5.95	.0264	.1342	.2749	.4227	.5786	.7434	.9185	1.1053	1.3057	1.5218	1.7568
6.00	.0264	.1346	.2757	.4240	.5803	.7456	.9212	1.1085	1.3094	1.5262	1.7617

Source: U.S. Environmental Protection Agency, Statistical Analysis of Ground-Water Monitoring at RCRA FAcilities, Addendum to Interim Final Guidance, July 1992

Upper Tolerance Limits

To determine background values for the comparison of discrete samples, 95% upper tolerance limits (UTLs) are calculated as the background values for the naturally occurring inorganics (metals). A tolerance interval describes the range of values expected to contain a certain percentage of the population with a certain degree of confidence. The 95% UTL with 95% coverage was recommended in Reference 2 (page 5-21) as the value that defines a great enough proportion of the population (% coverage) with a generally accepted degree of confidence. That is, there is a 95% confidence that approximately 95% of the individual population measurements fall below this upper limit. A graph representing a normal distribution with mean and upper tolerance limit is shown in Figure F-1.

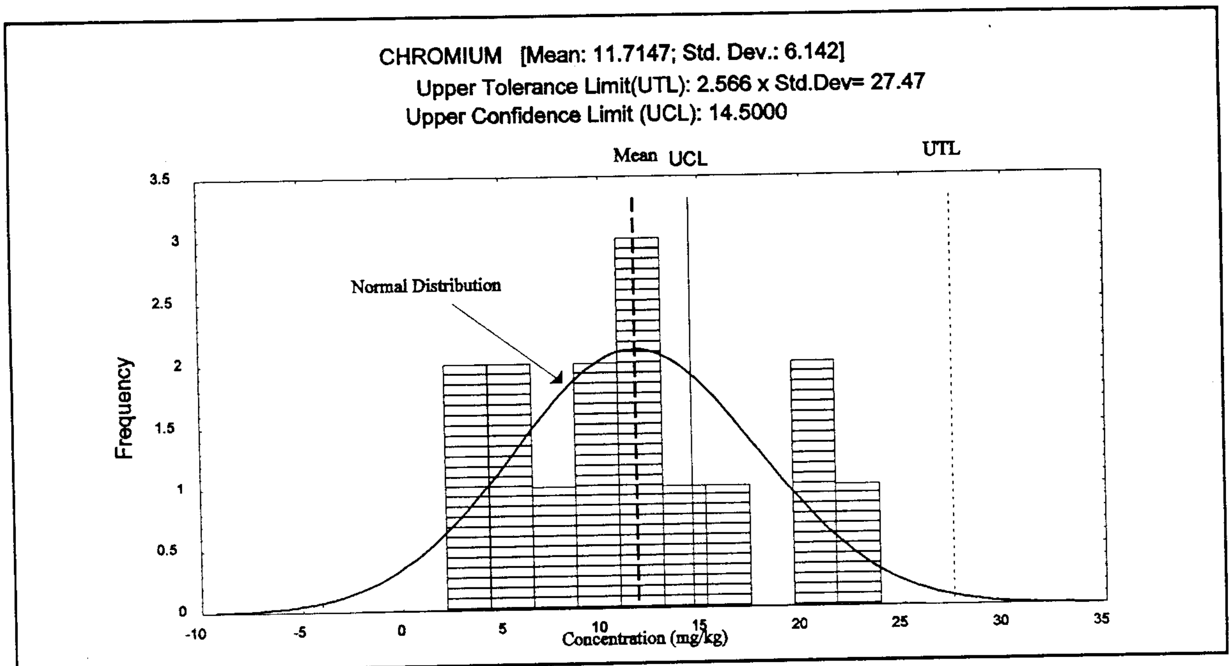

Figure F-1. Distribution curve and histogram with Upper Tolerance Limit (UTL) and Upper Confidence Limit (UCL) indicated.

The normal distribution UTL is calculated using the following equation:

$$95\%\ UTL = \bar{x} + sK$$

where:

$\bar{x}$ = population mean

s = sample standard deviation

K = K-factor for the 95% confidence level and 95% coverage (Reference 2, table reprinted on the following page).

For data to be distributed lognormally, the logarithms of the data must be normally distributed. The typical lognormal distribution curve is similar to the normal distribution curve with the peak moved to the left and the right side stretched out. The lognormal UTL is calculated using the same equation as that for the normal UTL except the mean ($\bar{x}$) and the sample standard deviation are calculated using the natural logarithms of the background sample concentrations. The lognormal UTL is transformed back to the concentration units using the following equation:

$$95\%\ UTL = \exp^{(\text{UTL of logged values})}.$$

When the assumptions of normality and lognormality cannot be justified, especially when a significant portion of the samples are nondetect, the use of non-parametric tolerance intervals were considered. The upper tolerance limit in a nonparametric setting is usually chosen as a order statistic of the sample data, in the case of this background evalution, the maximum detected value will be used.

For those constituents which have a limited number of results above the detection limit, the SQL will be used as the UTL.

TOLERANCE FACTORS (K) FOR ONE-SIDED NORMAL TOLERANCE INTERVALS WITH PROBABILITY LEVEL (CONFIDENCE FACTOR) Y = 0.95 AND COVERAGE P = 95%

n	K
3	7.655
4	5.145
5	4.202
6	3.707
7	3.399
8	3.188
9	3.031
10	2.911
11	2.815
12	2.736
13	2.670
14	2.614
15	2.566
16	2.523
17	2.486
18	2.543
19	2.423
20	2.396
21	2.371
22	2.350
23	2.329
24	2.309
25	2.292
30	2.220
35	2.166
40	2.125
45	2.092
50	2.065
55	2.036
60	2.017
65	2.000
70	1.986

n	K
75	1.972
100	1.924
125	1.891
150	1.868
175	1.850
200	1.836
225	1.824
250	1.814
275	1.806
300	1.799
325	1.792
350	1.787
375	1.782
400	1.777
425	1.773
450	1.769
475	1.766
500	1.763
525	1.760
550	1.757
575	1.754
600	1.752
625	1.750
650	1.748
675	1.746
700	1.744
725	1.742
750	1.740
775	1.739
800	1.737
825	0.736
850	1.734
875	1.733
900	1.732
925	1.731
950	1.729
975	1.728
1000	1.727

Source: Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities: Interim Final Guidance, U.S. Environmental Protection Agency, April 1989

Upper Confidence Limits

When the mean concentration of a sample population is compared to the background value, the upper confidence limit (UCL) is calculated. The 95% UCL of a mean is defined as a value that, when calculated repeatedly for randomly drawn subsets of facility data, equals or exceeds the true mean 95% of the time. The 95% UCL of the arithmetic mean concentration is used as the average concentration because it is not possible to know the true mean. The 95% UCL therefore accounts for uncertainties due to limited sampling.

The UCL of the arithmetic mean for a normal distribution is calculated using the following equation (Ref. 4):
where:

$$UCL = \bar{x} + t\left(\frac{s}{\sqrt{n}}\right)$$

UCL = upper confidence limit
$\bar{x}$ = mean of the untransformed data
s = standard deviation of the untransformed data
t = Student t-statistic (Reference 3,table reprinted on the following page)
n = number of samples

For the calculation of the lognormal UCL, the mean and standard deviation are calculated using the natural logarithms of the background sample concentrations. The lognormal UCL is calculated using the following equation (Ref 4):

$$UCL = e^{\left(\bar{x} + 0.5\, s^2 + \frac{sH}{\sqrt{n-1}}\right)}$$

where:
UCL = upper confidence limit
e = constant (base of the natural log, equal to 2.718)
$\bar{x}$ = mean of the transformed data
s = standard deviation of the transformed data
H = H-statistic (Reference 3, table reprinted on the second page following this page)
n = number of samples

Quantiles of the t Distribution (Values of t Such That $100p\%$ of the Distribution Is Less Than t_p)

Degrees of Freedom	$t_{0.60}$	$t_{0.70}$	$t_{0.80}$	$t_{0.90}$	$t_{0.95}$	$t_{0.975}$	$t_{0.990}$	$t_{0.995}$
1	.325	.727	1.376	3.078	6.314	12.706	31.821	63.657
2	.289	.617	1.061	1.886	2.920	4.303	6.965	9.925
3	.277	.584	.978	1.638	2.353	3.182	4.541	5.841
4	.271	.569	.941	1.533	2.132	2.776	3.747	4.604
5	.267	.559	.920	1.476	2.015	2.571	3.365	4.032
6	.265	.553	.906	1.440	1.943	2.447	3.143	3.707
7	.263	.549	.896	1.415	1.895	2.365	2.998	3.499
8	.262	.546	.889	1.397	1.860	2.306	2.896	3.355
9	.261	.543	.883	1.383	1.833	2.262	2.821	3.250
10	.260	.542	.879	1.372	1.812	2.228	2.764	3.169
11	.260	.540	.876	1.363	1.796	2.201	2.718	3.106
12	.259	.539	.873	1.356	1.782	2.179	2.681	3.055
13	.259	.538	.870	1.350	1.771	2.160	2.650	3.012
14	.258	.537	.868	1.345	1.761	2.145	2.624	2.977
15	.258	.536	.866	1.341	1.753	2.131	2.602	2.947
16	.258	.535	.865	1.337	1.746	2.120	2.583	2.921
17	.257	.534	.863	1.333	1.740	2.110	2.567	2.898
18	.257	.534	.862	1.330	1.734	2.101	2.552	2.878
19	.257	.533	.861	1.328	1.729	2.093	2.539	2.861
20	.257	.533	.860	1.325	1.725	2.086	2.528	2.845
21	.257	.532	.859	1.323	1.721	2.080	2.518	2.831
22	.256	.532	.858	1.321	1.717	2.074	2.508	2.819
23	.256	.532	.858	1.319	1.714	2.069	2.500	2.807
24	.256	.531	.857	1.318	1.711	2.064	2.492	2.797
25	.256	.531	.856	1.316	1.708	2.060	2.485	2.787
26	.256	.531	.856	1.315	1.706	2.056	2.479	2.779
27	.256	.531	.855	1.314	1.703	2.052	2.473	2.771
28	.256	.530	.855	1.313	1.701	2.048	2.467	2.763
29	.256	.530	.854	1.311	1.699	2.045	2.462	2.756
30	.256	.530	.854	1.310	1.697	2.042	2.457	2.750
40	.255	.529	.851	1.303	1.684	2.021	2.423	2.704
60	.254	.527	.848	1.296	1.671	2.000	2.390	2.660
120	.254	.526	.845	1.289	1.658	1.980	2.358	2.617
∞	.253	.524	.842	1.282	1.645	1.960	2.326	2.576

Source: Statistical Methods for Environmental Pollution Monitoring, Richard O. Gilbert, Van Nostrand Reinhbold Company, 1987

Values of $H_{1-\alpha} = H_{0.95}$ for Computing a One-Sided Upper 95% Confidence Limit on a Lognormal Mean

	n									
s_y	3	5	7	10	12	15	21	31	51	101
0.10	2.750	2.035	1.886	1.802	1.775	1.749	1.722	1.701	1.684	1.670
0.20	3.295	2.198	1.992	1.881	1.843	1.809	1.771	1.742	1.718	1.697
0.30	4.109	2.402	2.125	1.977	1.927	1.882	1.833	1.793	1.761	1.733
0.40	5.220	2.651	2.282	2.089	2.026	1.968	1.905	1.856	1.813	1.777
0.50	6.495	2.947	2.465	2.220	2.141	2.068	1.989	1.928	1.876	1.830
0.60	7.807	3.287	2.673	2.368	2.271	2.181	2.085	2.010	1.946	1.891
0.70	9.120	3.662	2.904	2.532	2.414	2.306	2.191	2.102	2.025	1.960
0.80	10.43	4.062	3.155	2.710	2.570	2.443	2.307	2.202	2.112	2.035
0.90	11.74	4.478	3.420	2.902	2.738	2.589	2.432	2.310	2.206	2.117
1.00	13.05	4.905	3.698	3.103	2.915	2.744	2.564	2.423	2.306	2.205
1.25	16.33	6.001	4.426	3.639	3.389	3.163	2.923	2.737	2.580	2.447
1.50	19.60	7.120	5.184	4.207	3.896	3.612	3.311	3.077	2.881	2.713
1.75	22.87	8.250	5.960	4.795	4.422	4.081	3.719	3.437	3.200	2.997
2.00	26.14	9.387	6.747	5.396	4.962	4.564	4.141	3.812	3.533	3.295
2.50	32.69	11.67	8.339	6.621	6.067	5.557	5.013	4.588	4.228	3.920
3.00	39.23	13.97	9.945	7.864	7.191	6.570	5.907	5.388	4.947	4.569
3.50	45.77	16.27	11.56	9.118	8.326	7.596	6.815	6.201	5.681	5.233
4.00	52.31	18.58	13.18	10.38	9.469	8.630	7.731	7.024	6.424	5.908
4.50	58.85	20.88	14.80	11.64	10.62	9.669	8.652	7.854	7.174	6.590
5.00	65.39	23.19	16.43	12.91	11.77	10.71	9.579	8.688	7.929	7.277
6.00	78.47	27.81	19.68	15.45	14.08	12.81	11.44	10.36	9.449	8.661
7.00	91.55	32.43	22.94	18.00	16.39	14.90	13.31	12.05	10.98	10.05
8.00	104.6	37.06	26.20	20.55	18.71	17.01	15.18	13.74	12.51	11.45
9.00	117.7	41.68	29.46	23.10	21.03	19.11	17.05	15.43	14.05	12.85
10.00	130.8	46.31	32.73	25.66	23.35	21.22	18.93	17.13	15.59	14.26

Source: Statistical Methods for Environmental Pollution Monitoring, Richard O. Gilbert, Van Nostrand Reinhbold Company, 1987

Log-probability Regression Method

A recurring difficulty encountered in investigations of many metals is that a substantial portion of the sample concentrations are below limits of detection established by analytical laboratories. Gilliom and Helsel (1986) identified the log-probability regression method as the most robust method for minimizing error in censored-sample estimates.

In the log-probability regression method, the censored observations are assumed to follow the zero-to-detection limit portion of a lognorma distribution fit to the uncensored observations by least squares regression. Using log-transformed data, "normal scores," z, were computed for each uncensored observation using

$$z = \Phi^{-1}\left(\frac{r}{n + 1}\right)$$

where Φ^{-1} is the inverse cumulative distribution function; r is the observation rank (r=nc + 1,..., n), nc=number of data censored; and n is the sample size for the entire data set. A least squares regression of concentration on normal scores for all data above the detection limit was extrapolated to estimate censored observations (ranks r=1, ..., nc).

Gilliom, R.J. and Helsel, D.R., 1986, Estimation of Distributional Parameters for Censored Trace Level Water Quality Data 1. Estimation Techniques, Water Resources Research, Vol. 22, No. 2, pp. 135-146.

Calculated UTLs and UCLs for Groundwater
at LHAAP

5/7/95
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	Chemical/ Constituent	n	Adjusted Mean	Adjusted Standard Deviation		K value	UTL		H-value	UCL
	Nitrate/Nitrite	32	-3.342	0.9170		2.198	0.266		2.4107	0.058
	Arsenic	37	-5.886	1.1488		2.150	0.033		2.3239	0.006
	Cadmium	37	-4.573	0.9943		2.150	0.088		2.3817	0.018
	Chromium	36	-4.252	1.1257		2.158	0.162		2.5466	0.029
	Cobalt	9	-4.849	1.2926		3.031	0.394		3.3016	0.031
	Copper	9	-4.661	1.0125		3.031	0.204		3.3314	0.024
	Lead	37	-3.493	2.0133		2.150	2.306		3.7483	0.285
	Silver	37	-5.422	0.9421		2.150	0.034		2.3248	0.007
	Zinc	9	-3.387	1.2764		3.031	1.619		3.9681	0.144

Nitrate/Nitrite Adjusted Mean and Standard Deviation

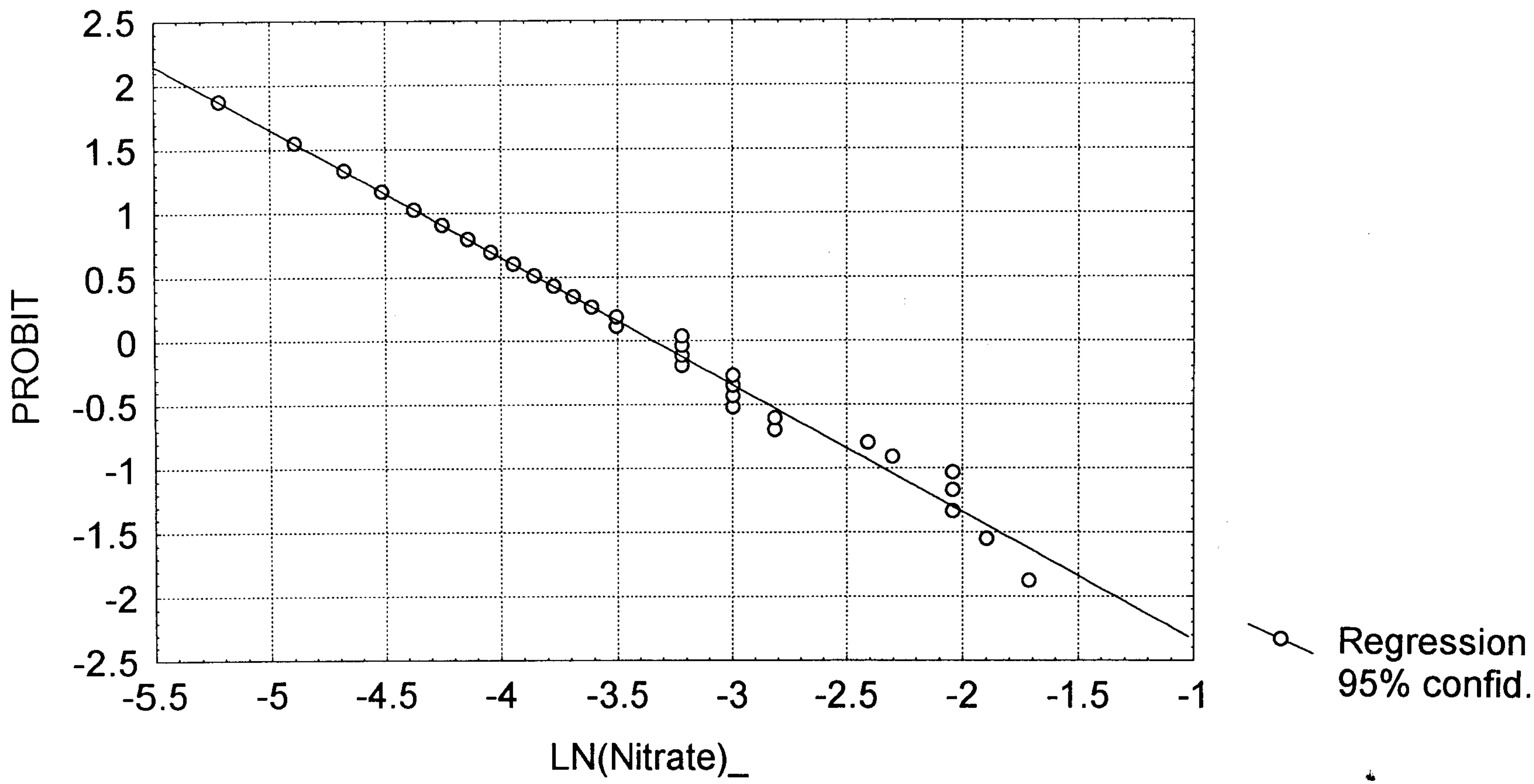
5/6/95

	Rank	x	lnX	r/(n1+1)	Probit	Ln(X) using linefit	COMBINED ACTUAL AND PROJECTED LnX	
	33	0.18	-1.7148	0.9706	-1.87636		-1.715	
	32	0.15	-1.89712	0.9412	-1.54971		-1.897	
	31	0.13	-2.04022	0.9118	-1.33518		-2.040	
	30	0.13	-2.04022	0.8824	-1.16895		-2.040	
	29	0.13	-2.04022	0.8529	-1.02996		-2.040	
	28	0.1	-2.30259	0.8235	-0.90846		-2.303	
	27	0.09	-2.40795	0.7941	-0.79908		-2.408	
	26	0.06	-2.81341	0.7647	-0.69853		-2.813	
	25	0.06	-2.81341	0.7353	-0.60459		-2.813	
	24	0.05	-2.99573	0.7059	-0.5157		-2.996	
	23	0.05	-2.99573	0.6765	-0.43073		-2.996	
	22	0.05	-2.99573	0.6471	-0.34876		-2.996	
	21	0.05	-2.99573	0.6176	-0.26907		-2.996	
	20	0.04	-3.21888	0.5882	-0.19105		-3.219	
	19	0.04	-3.21888	0.5588	-0.11419		-3.219	
	18	0.04	-3.21888	0.5294	-0.03799		-3.219	
	17	0.04	-3.21888	0.5000	0.037988		-3.219	
	16	0.03	-3.50656	0.4706	0.114185		-3.507	
	15	0.03	-3.50656	0.4412	0.191052		-3.507	
	14	<0.5	#VALUE!	0.4118	0.269066	-3.612	-3.612	
	13	<0.5	#VALUE!	0.3824	0.348756	-3.691	-3.691	
	12	<0.5	#VALUE!	0.3529	0.430727	-3.774	-3.774	
	11	<0.5	#VALUE!	0.3235	0.515705	-3.859	-3.859	
	10	<0.5	#VALUE!	0.2941	0.604585	-3.948	-3.948	
	9	<0.5	#VALUE!	0.2647	0.698526	-4.042	-4.042	
	8	<0.5	#VALUE!	0.2353	0.799083	-4.143	-4.143	
	7	<0.01	#VALUE!	0.2059	0.908458	-4.252	-4.252	
	6	<0.01	#VALUE!	0.1765	1.029957	-4.374	-4.374	
	5	<0.01	#VALUE!	0.1471	1.168949	-4.513	-4.513	
	4	<0.01	#VALUE!	0.1176	1.335178	-4.680	-4.680	
	3	<0.01	#VALUE!	0.0882	1.549706	-4.895	-4.895	
	2	<0.01	#VALUE!	0.0588	1.876359	-5.222	-5.222	
	1	<0.01	#VALUE!	0.0294				
							Standard Dev. (LN(x))	**0.9170**
							Mean (LN(x))	**-3.3420**

LN (Nitrate) vs. PROBIT

PROBIT = -3.336 - .9982 * LN(Nitrate)_

Correlation: r = -.9939



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Arsenic Adjusted Mean and Standard Deviation

5/6/95
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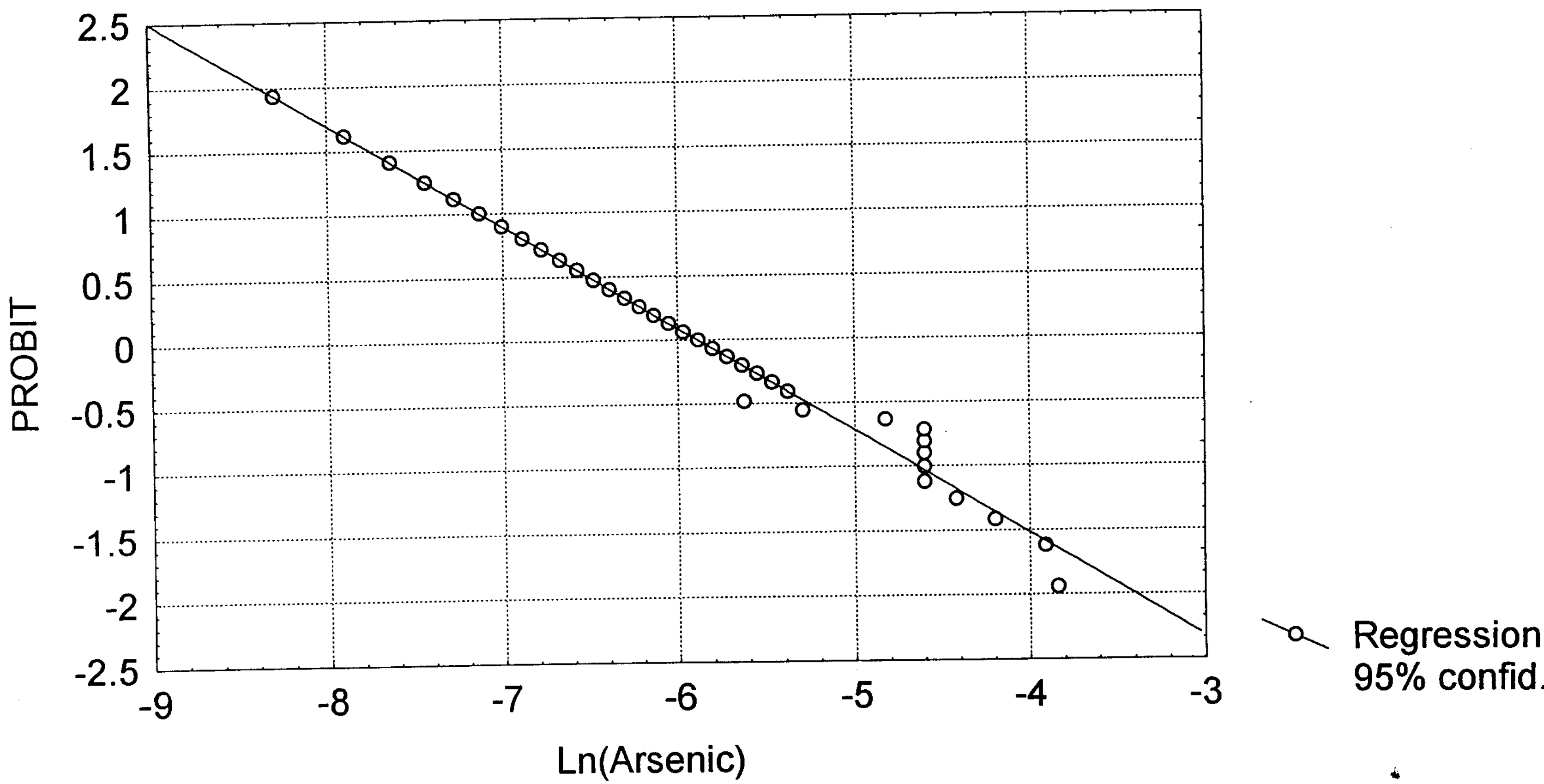
Rank	Arsenic Results	Ln (X)	r/(n+1)	Probit	Ln(X) Using linefit	Combined Actual and Projected LnX
38	0.0215	-3.840	0.9744	-1.9379		-3.8397
37	0.02	-3.912	0.9487	-1.6199		-3.91202
36	0.015	-4.200	0.9231	-1.4122		-4.19971
35	0.012	-4.423	0.8974	-1.2521		-4.42285
34	0.01	-4.605	0.8718	-1.1190		-4.60517
33	0.01	-4.605	0.8462	-1.0031		-4.60517
32	0.01	-4.605	0.8205	-0.8994		-4.60517
31	0.01	-4.605	0.7949	-0.8046		-4.60517
30	0.01	-4.605	0.7692	-0.7165		-4.60517
29	0.008	-4.828	0.7436	-0.6336		-4.82831
28	0.005	-5.298	0.7179	-0.5549		-5.29832
27	0.0036	-5.627	0.6923	-0.4795		-5.62682
26	<0.05		0.6667	-0.4067	-5.380	-5.38007
25	<0.005		0.6410	-0.3360	-5.468	-5.46808
24	<0.005		0.6154	-0.2670	-5.554	-5.55404
23	<0.005		0.5897	-0.1992	-5.638	-5.63844
22	<0.005		0.5641	-0.1323	-5.722	-5.72172
21	<0.005		0.5385	-0.0660	-5.804	-5.80427
20	<0.005		0.5128	0.0000	-5.886	-5.88645
19	<0.005		0.4872	0.0660	-5.969	-5.96864
18	<0.005		0.4615	0.1323	-6.051	-6.05119
17	<0.005		0.4359	0.1992	-6.134	-6.13446
16	<0.005		0.4103	0.2670	-6.219	-6.21887
15	<0.005		0.3846	0.3360	-6.305	-6.30483
14	<0.005		0.3590	0.4067	-6.393	-6.39283
13	<0.005		0.3333	0.4795	-6.483	-6.48345
12	<0.005		0.3077	0.5549	-6.577	-6.57734
11	<0.005		0.2821	0.6336	-6.675	-6.67535
10	<0.005		0.2564	0.7165	-6.779	-6.77851
9	<0.005		0.2308	0.8046	-6.888	-6.88819
8	<0.005		0.2051	0.8994	-7.006	-7.00627
7	<0.005		0.1795	1.0031	-7.135	-7.13539
6	<0.005		0.1538	1.1190	-7.280	-7.27958
5	<0.005		0.1282	1.2521	-7.445	-7.44537
4	<0.005		0.1026	1.4122	-7.645	-7.64466
3	<0.002		0.0769	1.6199	-7.903	-7.90321
2	<0.002		0.0513	1.9379	-8.299	-8.29922
1	<0.002		0.0256			
					Standard Deviation	**1.14881**
					Mean	**-5.88632**

Ln(Arsenic) vs. PROBIT

PROBIT = -4.727 - .8031 * Ln(Arsenic)

Correlation: r = -.9936



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Cadmium Adjusted Mean and Standard Deviation
Log Probability Regression Method

5/6/95
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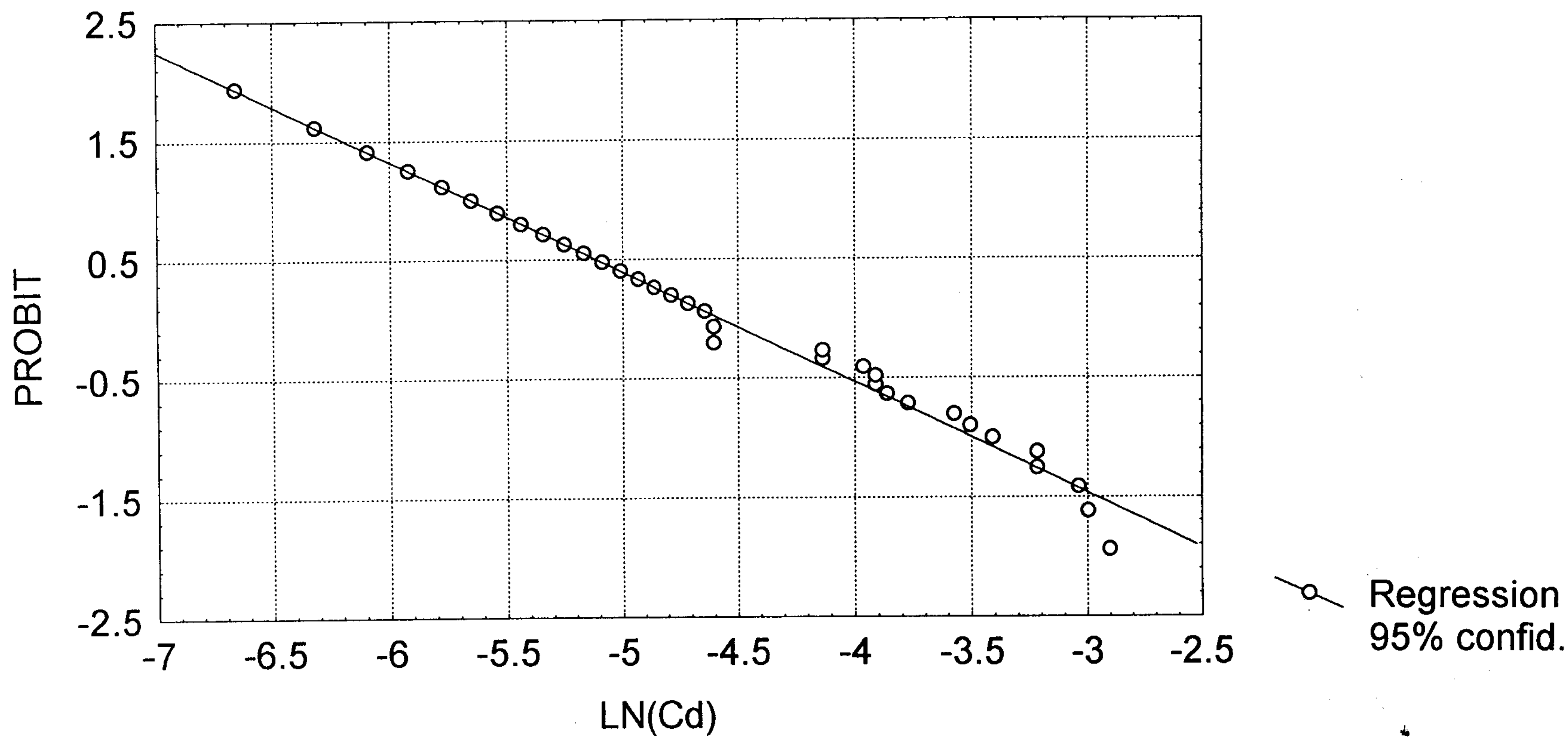
Rank	Cadmium conc.	LnX	r/(n+1)	Probit	Ln(X) Using Linefit	Combined Actual and Projected LnX
38	0.055	-2.90042	0.974359	-1.93793		-2.9004
37	0.05	-2.99573	0.948718	-1.61986		-2.9957
36	0.048	-3.03655	0.923077	-1.41219		-3.0366
35	0.04	-3.21888	0.897436	-1.25212		-3.2189
34	0.04	-3.21888	0.871795	-1.11896		-3.2189
33	0.033	-3.41125	0.846154	-1.00315		-3.4112
32	0.03	-3.50656	0.820513	-0.89943		-3.5066
31	0.028	-3.57555	0.794872	-0.8046		-3.5756
30	0.023	-3.77226	0.769231	-0.7165		-3.7723
29	0.021	-3.86323	0.74359	-0.63364		-3.8632
28	0.02	-3.91202	0.717949	-0.55492		-3.9120
27	0.02	-3.91202	0.692308	-0.47951		-3.9120
26	0.019	-3.96332	0.666667	-0.40672		-3.9633
25	0.016	-4.13517	0.641026	-0.33604		-4.1352
24	0.016	-4.13517	0.615385	-0.26699		-4.1352
23	0.01	-4.60517	0.589744	-0.1992		-4.6052
22	0.01	-4.60517	0.564103	-0.13231		-4.6052
21	0.01	-4.60517	0.538462	-0.06601		-4.6052
20	0.01	-4.60517	0.512821	0		-4.6052
19	<0.01	#VALUE!	0.487179	0.066012	-4.64383	-4.6438
18	<0.01	#VALUE!	0.461538	0.132313	-4.71528	-4.7153
17	<0.01	#VALUE!	0.435897	0.199201	-4.78737	-4.7874
16	<0.01	#VALUE!	0.410256	0.266994	-4.86043	-4.8604
15	<0.01	#VALUE!	0.384615	0.336038	-4.93484	-4.9348
14	<0.01	#VALUE!	0.358974	0.406724	-5.01102	-5.0110
13	<0.01	#VALUE!	0.333333	0.479506	-5.08946	-5.0895
12	<0.01	#VALUE!	0.307692	0.554923	-5.17073	-5.1707
11	<0.01	#VALUE!	0.282051	0.63364	-5.25557	-5.2556
10	<0.01	#VALUE!	0.25641	0.716498	-5.34486	-5.3449
9	<0.01	#VALUE!	0.230769	0.804596	-5.43981	-5.4398
8	<0.01	#VALUE!	0.205128	0.899435	-5.54201	-5.5420
7	<0.01	#VALUE!	0.179487	1.003148	-5.65379	-5.6538
6	<0.01	#VALUE!	0.153846	1.118958	-5.7786	-5.7786
5	<0.01	#VALUE!	0.128205	1.25212	-5.9221	-5.9221
4	<0.01	#VALUE!	0.102564	1.412188	-6.09461	-6.0946
3	<0.01	#VALUE!	0.076923	1.619856	-6.31841	-6.3184
2	<0.01	#VALUE!	0.051282	1.937932	-6.6612	-6.6612
1	<0.01	#VALUE!	0.025641			
					Mean	**-4.5730**
					Standard Deviation	**0.99429**

LN(Cadmium) vs. PROBIT

PROBIT = -4.244 - .9281 * PROJ_LNX

Correlation: r = -.9938

(Cadmium values include projected values)



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Chromium Adjusted Mean and Standard Deviation
Log Probability Regression Method

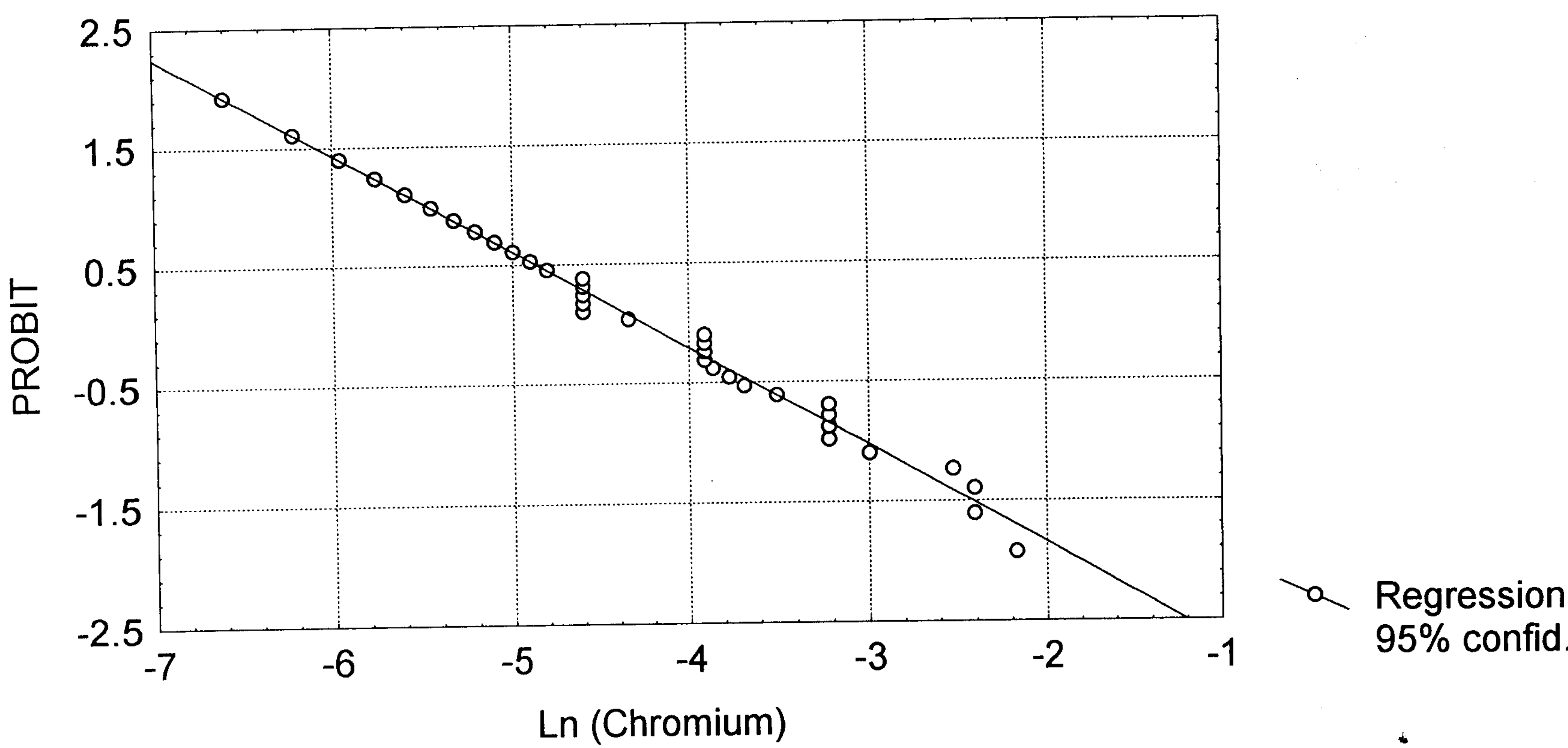
Rank	Chromium Conc.	LnX	r/(n+1)	Probit	Ln(X) Using Linefit	Combined Actual and projected LnX
37	0.11	-2.1716	0.948718	-1.9264		-2.1716
36	0.09	-2.4079	0.923077	-1.60676		-2.4079
35	0.09	-2.4079	0.897436	-1.39784		-2.4079
34	0.08	-2.5257	0.871795	-1.23665		-2.5257
33	0.05	-2.9957	0.846154	-1.10244		-2.9957
32	0.04	-3.2189	0.820513	-0.98561		-3.2189
31	0.04	-3.2189	0.794872	-0.88089		-3.2189
30	0.04	-3.2189	0.769231	-0.78504		-3.2189
29	0.04	-3.2189	0.74359	-0.69591		-3.2189
28	0.03	-3.5066	0.717949	-0.612		-3.5066
27	0.025	-3.6889	0.692308	-0.53219		-3.6889
26	0.02	-3.7723	0.666667	-0.45564		-3.7723
25	0.021	-3.8632	0.641026	-0.38167		-3.8632
24	0.02	-3.9120	0.615385	-0.30974		-3.9120
23	0.02	-3.9120	0.589744	-0.23938		-3.9120
22	0.02	-3.9120	0.564103	-0.17018		-3.9120
21	0.02	-3.9120	0.538462	-0.1018		-3.9120
20	0.02	-3.9120	0.512821	-0.03388		-3.9120
19	0.013	-4.3428	0.487179	0.03388		-4.3428
18	0.01	-4.6052	0.461538	0.101796		-4.6052
17	0.01	-4.6052	0.435897	0.170185		-4.6052
16	0.01	-4.6052	0.410256	0.23938		-4.6052
15	0.01	-4.6052	0.384615	0.309743		-4.6052
14	0.01	-4.6052	0.358974	0.381675		-4.6052
13	<0.05		0.333333	0.45564	-4.80845	-4.80845
12	<0.05		0.307692	0.53219	-4.90193	-4.90193
11	<0.05		0.282051	0.611996	-4.99938	-4.99938
10	<0.05		0.25641	0.695908	-5.10185	-5.10185
9	<0.02		0.230769	0.785036	-5.21069	-5.21069
8	<0.02		0.205128	0.880888	-5.32774	-5.32774
7	<0.02		0.179487	0.98561	-5.45562	-5.45562
6	<0.02		0.153846	1.10244	-5.59829	-5.59829
5	<0.01		0.128205	1.236652	-5.76218	-5.76218
4	<0.01		0.102564	1.397837	-5.95901	-5.95901
3	<0.01		0.076923	1.606755	-6.21413	-6.21413
2	<0.01		0.051282	1.926403	-6.60447	-6.60447
1	<0.01		0.025641			
					Mean	**-4.25244**
					Standard Deviation	**1.125673**

Ln (Chromium) vs. PROBIT

PROBIT = -3.483 - .8191 * PROJ_LNX

Correlation: r = -.9944

(Chromium values include projected values)



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Cobalt Adjusted Mean and Standard Deviation
Log Probability Regression Method

5/6/95
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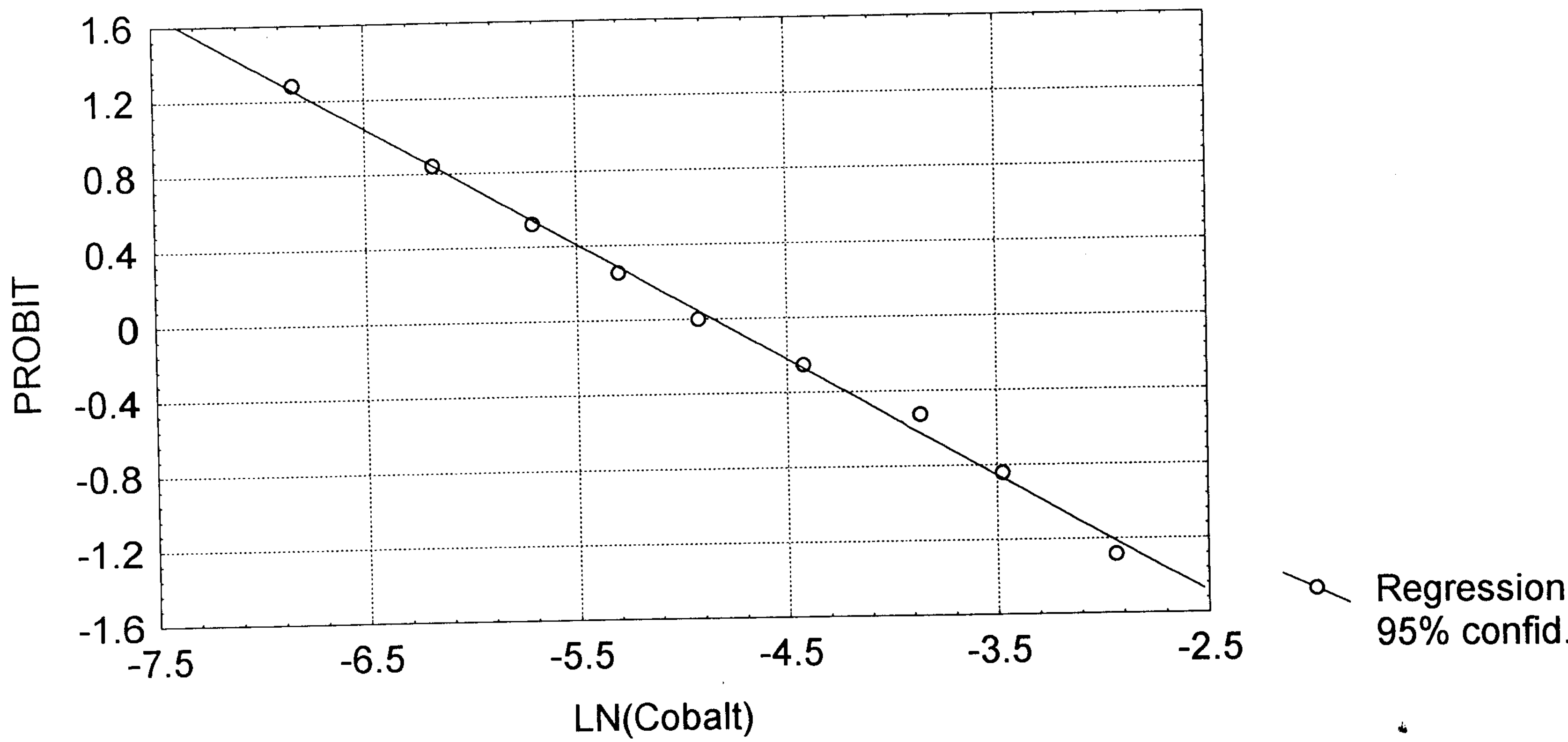
	Rank	Cobalt Conc.	LnX	r/(n+1)	Probit	Ln(x) Using Linefit	Combined Actual and Projected LnX		
	10	0.053	-2.93746	0.9091	-1.28155		-2.93746		
	9	0.031	-3.47377	0.8182	-0.84162		-3.47377		
	8	0.021	-3.86323	0.7273	-0.5244		-3.86323		
	7	0.012	-4.42285	0.6364	-0.25335		-4.42285		
	6	<0.05		0.5455	0	-4.9223	-4.9223		
	5	<0.05		0.4545	0.253347	-5.30088	-5.30088		
	4	<0.05		0.3636	0.524401	-5.70592	-5.70592		
	3	<0.05		0.2727	0.841621	-6.17995	-6.17995		
	2	<0.05		0.1818	1.281552	-6.83735	-6.83735		
	1	<0.01		0.0909					
						Mean	**-4.8493**		
						Standard Deviation	**1.292642**		

Ln (Cobalt) vs. PROBIT

PROBIT = -3.071 - .6332 * PROJ_LNX

Correlation: r = -.9981

(Cobalt Values include Projected Values)



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Copper Adjusted Mean and Standard Deviation
Log Probability Regression Method

5/6/95
7:06 PM

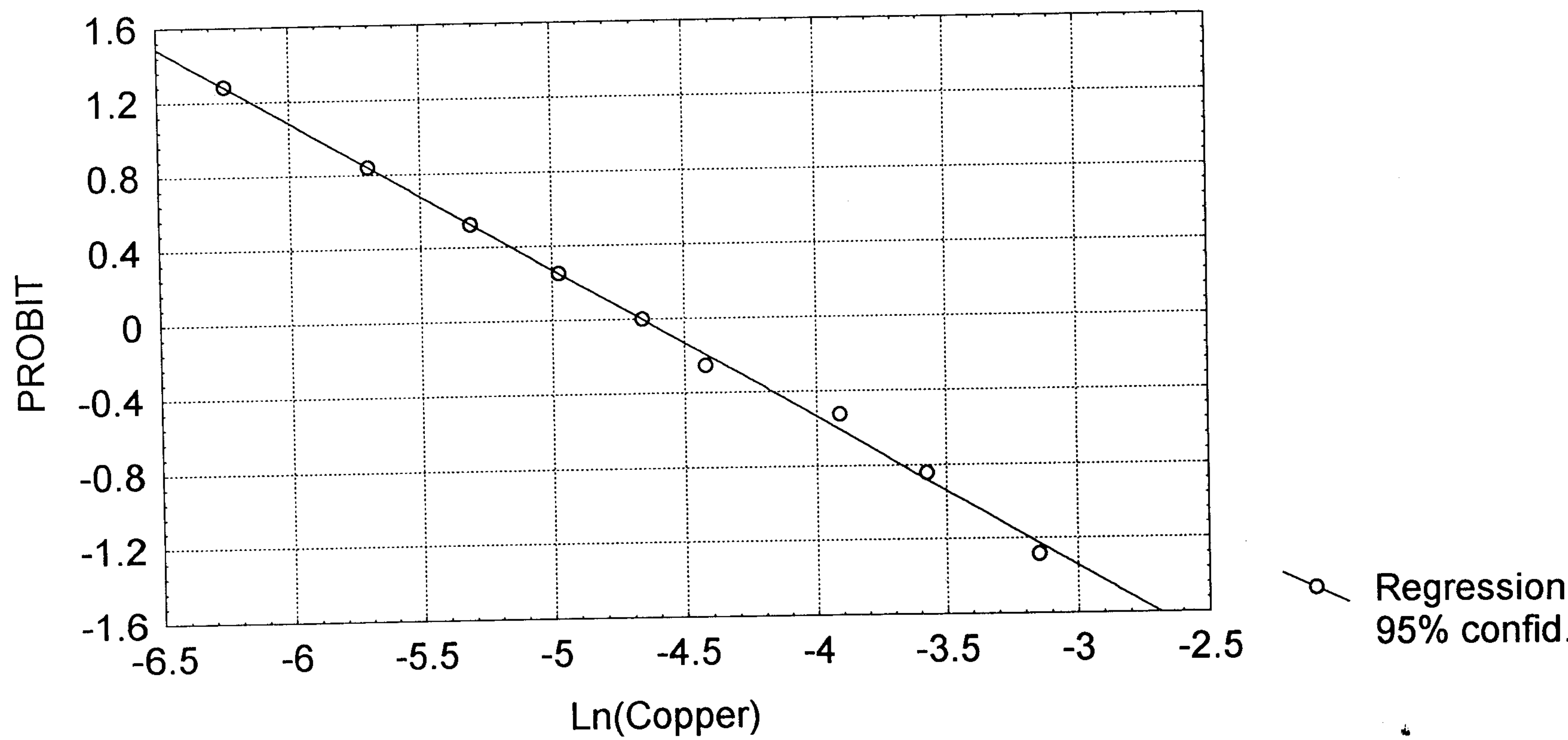
Rank	Copper Conc.	LnX	r/(n+1)	Probit	Ln(x) Using Linefit	Combined Actual and Projected LnX
10	0.04	-3.14656	0.909091	-1.28155		-3.14656
9	0.028	-3.57555	0.818182	-0.84162		-3.57555
8	0.02	-3.91202	0.727273	-0.5244		-3.91202
7	0.012	-4.42285	0.636364	-0.25335		-4.42285
6	<0.01		0.545455	0	-4.66131	-4.66131
5	<0.01		0.454545	0.253347	-4.97447	-4.97447
4	<0.01		0.363636	0.524401	-5.30952	-5.30952
3	<0.01		0.272727	0.841621	-5.70163	-5.70163
2	<0.01		0.181818	1.281552	-6.24543	-6.24543
1	<0.01		0.090909			
					Mean	**-4.66104**
					Standard Deviation	**1.012521**

Ln (Copper) vs. PROBIT

PROBIT = -3.770 - .8088 * PROJ_LNX

Correlation: r = -.9986

(Copper Values Include Projected Values)



Lead Adjusted Mean and Standard Deviation
Log Probability Regression Method

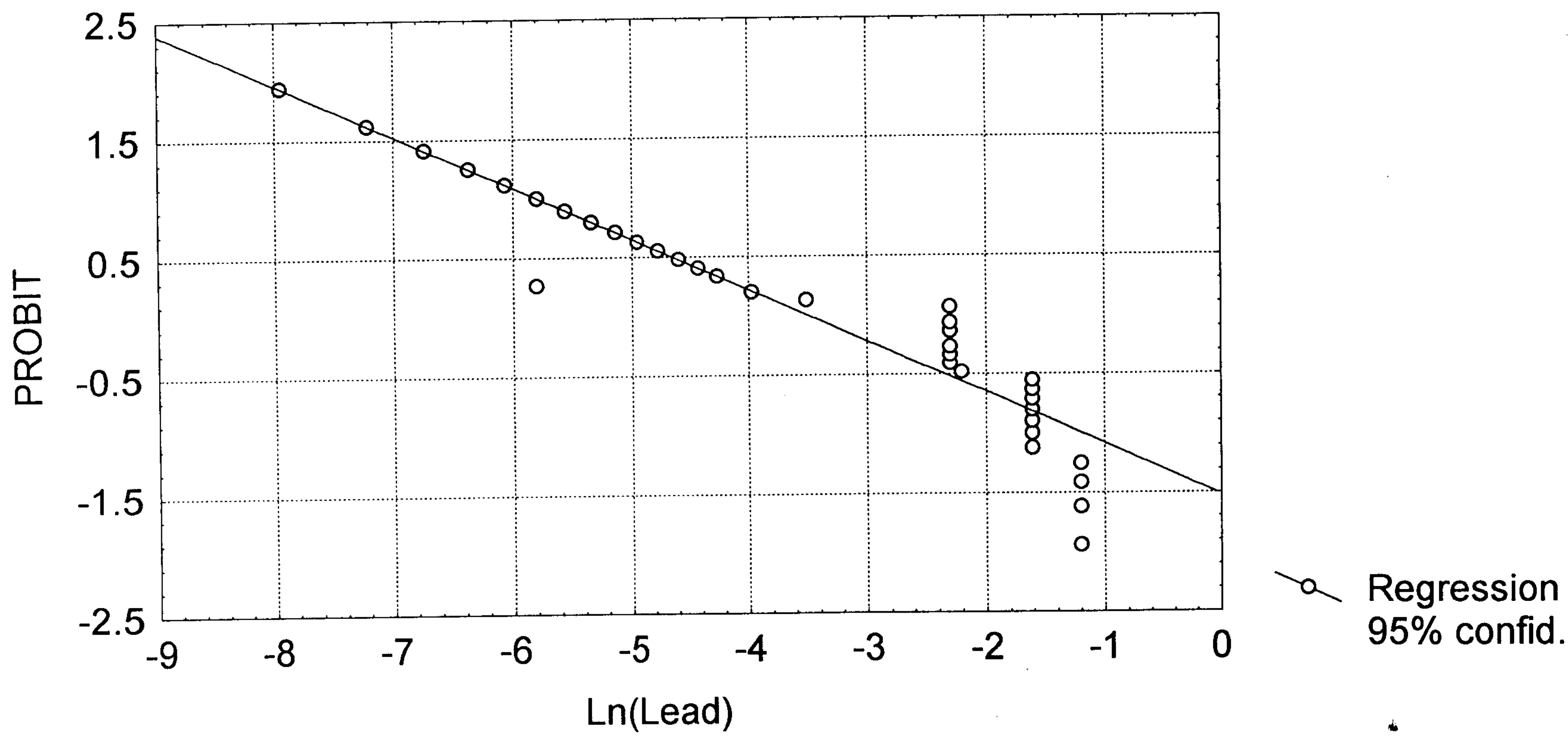
Rank	Lead Conc.	LnX	r/(n+1)	Probit	Ln(X) Using Linefit	Combined Actual and Projected LnX
38	0.3	-1.20397	0.9744	-1.93793		-1.20397
37	0.3	-1.20397	0.9487	-1.61986		-1.20397
36	0.3	-1.20397	0.9231	-1.41219		-1.20397
35	0.3	-1.20397	0.8974	-1.25212		-1.20397
34	0.2	-1.60944	0.8718	-1.11896		-1.60944
33	0.2	-1.60944	0.8462	-1.00315		-1.60944
32	0.2	-1.60944	0.8205	-0.89943		-1.60944
31	0.2	-1.60944	0.7949	-0.8046		-1.60944
30	0.2	-1.60944	0.7692	-0.7165		-1.60944
29	0.2	-1.60944	0.7436	-0.63364		-1.60944
28	0.2	-1.60944	0.7179	-0.55492		-1.60944
27	0.11	-2.20727	0.6923	-0.47951		-2.20727
26	0.1	-2.30259	0.6667	-0.40672		-2.30259
25	0.1	-2.30259	0.6410	-0.33604		-2.30259
24	0.1	-2.30259	0.6154	-0.26699		-2.30259
23	0.1	-2.30259	0.5897	-0.1992		-2.30259
22	0.1	-2.30259	0.5641	-0.13231		-2.30259
21	0.1	-2.30259	0.5385	-0.06601		-2.30259
20	0.1	-2.30259	0.5128	0		-2.30259
19	0.1	-2.30259	0.4872	0.066012		-2.30259
18	0.030	-3.51325	0.4615	0.132313		-3.51325
17	0.02	-3.9739	0.4359	0.199201		-3.9739
16	0.003	-5.80914	0.4103	0.266994		-5.80914
15	<0.1		0.3846	0.336038	-4.26706	-4.26706
14	<0.1		0.3590	0.406724	-4.42975	-4.42975
13	<0.1		0.3333	0.479506	-4.59725	-4.59725
12	<0.1		0.3077	0.554923	-4.77082	-4.77082
11	<0.1		0.2821	0.63364	-4.95199	-4.95199
10	<0.1		0.2564	0.716498	-5.14269	-5.14269
9	<0.1		0.2308	0.804596	-5.34545	-5.34545
8	<0.1		0.2051	0.899435	-5.56372	-5.56372
7	<0.005		0.1795	1.003148	-5.80241	-5.80241
6	<0.005		0.1538	1.118958	-6.06895	-6.06895
5	<0.005		0.1282	1.25212	-6.37542	-6.37542
4	<0.002		0.1026	1.412188	-6.74381	-6.74381
3	<0.002		0.0769	1.619856	-7.22176	-7.22176
2	<0.002		0.0513	1.937932	-7.95381	-7.95381
1	<0.002		0.0256			
					Mean	**-3.493**
					Standard Deviation	**2.013325**

Ln (Lead)vs. PROBIT

PROBIT = -1.517 - .4344 * PROJ_LNX

Correlation: r = -.9419

(Lead Values Include Projected Values)



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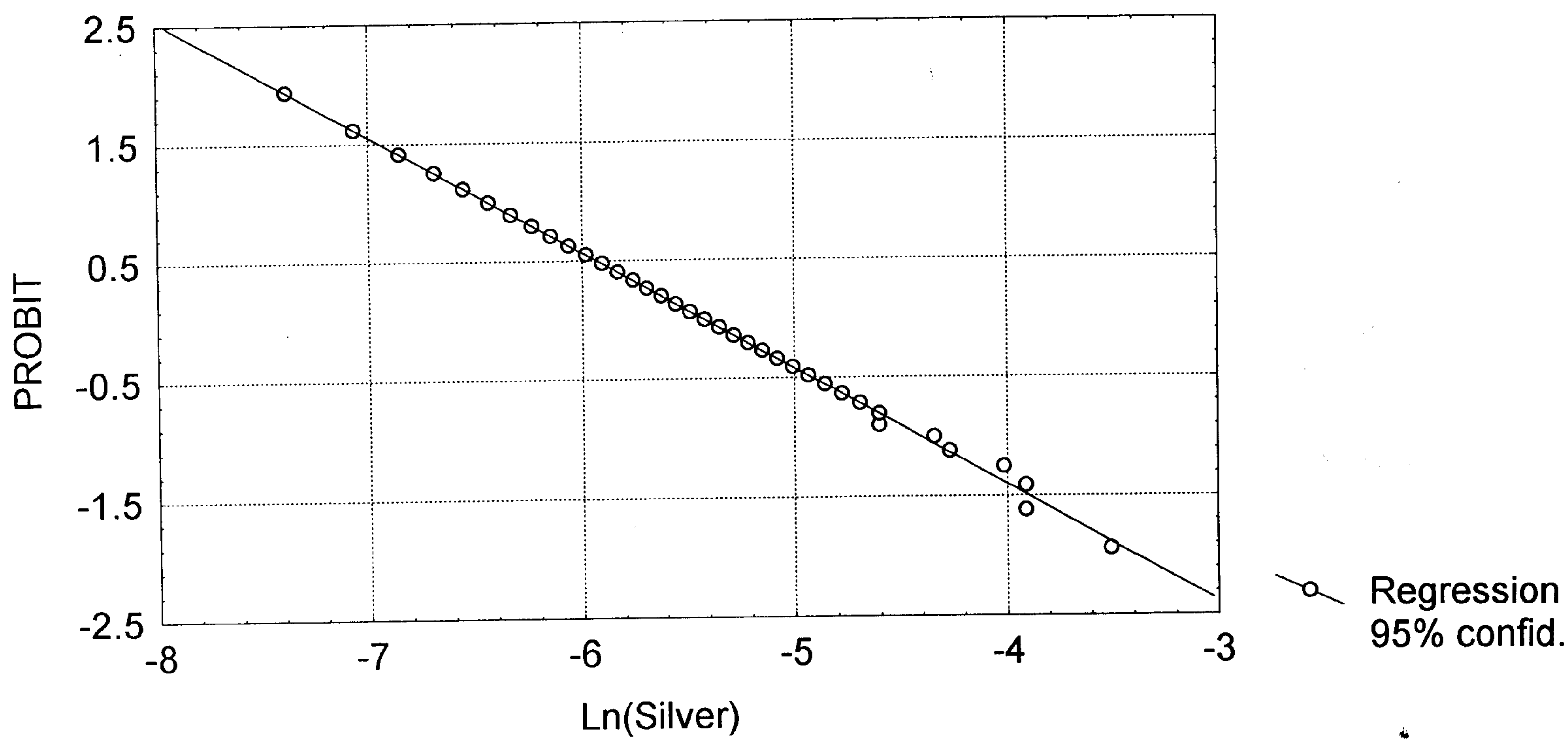
Silver Adjusted Mean and Standard Deviation
Log Probability Regression Method

Rank	Silver Conc.	LnX	r/(n+1)	Probit	Ln(X) Using Linefit	Combined Actual and Projected LnX
38	0.03	-3.50656	0.974359	-1.93793		-3.506558
37	0.02	-3.91202	0.948718	-1.61986		-3.912023
36	0.02	-3.91202	0.923077	-1.41219		-3.912023
35	0.018	-4.01738	0.897436	-1.25212		-4.017384
34	0.014	-4.2687	0.871795	-1.11896		-4.268698
33	0.013	-4.34281	0.846154	-1.00315		-4.342806
32	0.01	-4.60517	0.820513	-0.89943		-4.60517
31	0.01	-4.60517	0.794872	-0.8046		-4.60517
30	<0.01		0.769231	-0.7165	-4.69379	-4.693787
29	<0.01		0.74359	-0.63364	-4.77794	-4.77794
28	<0.01		0.717949	-0.55492	-4.85789	-4.857889
27	<0.01		0.692308	-0.47951	-4.93449	-4.934485
26	<0.01		0.666667	-0.40672	-5.00841	-5.008405
25	<0.01		0.641026	-0.33604	-5.0802	-5.080197
24	<0.01		0.615385	-0.26699	-5.15032	-5.150321
23	<0.01		0.589744	-0.1992	-5.21917	-5.219174
22	<0.01		0.564103	-0.13231	-5.28711	-5.287109
21	<0.01		0.538462	-0.06601	-5.35445	-5.354447
20	<0.01		0.512821	0	-5.42149	-5.421491
19	<0.01		0.487179	0.066012	-5.48854	-5.488535
18	<0.01		0.461538	0.132313	-5.55587	-5.555873
17	<0.01		0.435897	0.199201	-5.62381	-5.623808
16	<0.01		0.410256	0.266994	-5.69266	-5.692661
15	<0.01		0.384615	0.336038	-5.76279	-5.762785
14	<0.01		0.358974	0.406724	-5.83458	-5.834577
13	<0.01		0.333333	0.479506	-5.9085	-5.908496
12	<0.01		0.307692	0.554923	-5.98509	-5.985093
11	<0.01		0.282051	0.63364	-6.06504	-6.065042
10	<0.01		0.25641	0.716498	-6.1492	-6.149195
9	<0.01		0.230769	0.804596	-6.23867	-6.238672
8	<0.01		0.205128	0.899435	-6.33499	-6.334994
7	<0.01		0.179487	1.003148	-6.44033	-6.440329
6	<0.01		0.153846	1.118958	-6.55795	-6.557951
5	<0.01		0.128205	1.25212	-6.69319	-6.693195
4	<0.01		0.102564	1.412188	-6.85577	-6.855766
3	<0.01		0.076923	1.619856	-7.06668	-7.066683
2	<0.01		0.051282	1.937932	-7.38973	-7.389733
1	<0.01		0.025641			
					Mean	**-5.42158**
					Standard Deviation	**0.9421154**

Ln (Silver) vs. PROBIT
PROBIT = -5.339 - .9847 * PROJ_LNX
Correlation: r = -.9991
(Silver Values included Projected Values)



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Zinc Adjusted Mean and Standard Deviation
Log Probability Regression Method

5/7/95
2:33 PM

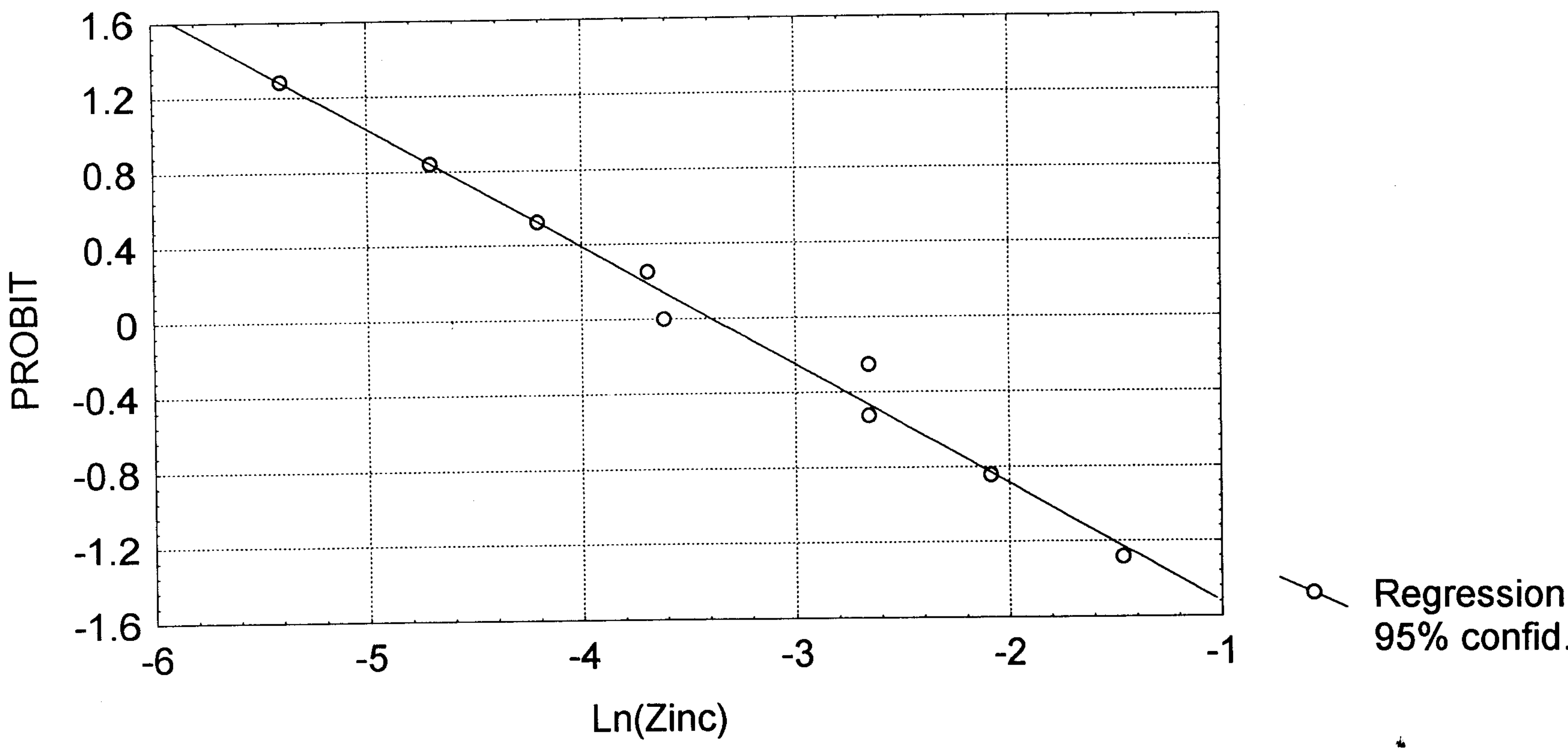
Rank	Zinc Conc.	LnX	r/(n+1)	Probit	Ln(X) Using Linefit	Combined Actual and Projected Ln(X)
10	0.23	-1.46534	0.909091	-1.28155		-1.46534
9	0.12	-2.08747	0.818182	-0.84162		-2.08747
8	0.07	-2.65926	0.727273	-0.5244		-2.65926
7	0.07	-2.65926	0.636364	-0.25335		-2.65926
6	0.027	-3.61192	0.545455	0		-3.61192
5	0.025	-3.68888	0.454545	0.253347		-3.68888
4	<0.05		0.363636	0.524401	-4.20884	-4.20884
3	<0.05		0.272727	0.841621	-4.70621	-4.70621
2	<0.05		0.181818	1.281552	-5.39597	-5.39597
1	<0.015		0.090909			
					Mean	**-3.38702**
					Standard Deviation	**1.276431**

Ln(Zinc) vs. PROBIT

PROBIT = -2.161 - .6379 * PROJ_LNX

Correlation: r = -.9929

(Zinc Value include projected values)



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Appendix D

Discussion of Statistical Evaluation of Groundwater Parameters and Chemicals

Discussion of Individual Constituents

In the following sections, the statistical analysis of each constituent will be presented. The different constituents are listed in alphabetical order, divided by group - water quality parameter, anions, and metals.. For each constituent, the distribution will be evaluated with the Shapiro-Wilk statistic presented in tabular form. The probability plots for the normal and log-transformed data sets are provided in Appendix E. Also included in tabular form will be the statistics (valid sample count used, arithmetic mean, standard deviation, and maximum and minimum values). Following the discussion of the preliminary statistics, the upper tolerance limit(UTL) and upper confidence limit (UCL).

WATER QUALITY PARAMETERS

pH

Thirty-eight values for pH were used for this evaluation. No pH values were reported for well 111 for the June and September 1992 sampling rounds. One data point was considered as an outlier for this evaluation. That point was for well 133 which recorded a value of 10.8 when sampled on 29 September 1994. Sampling field notes indicate the well was grouted immediately prior to the development and sampling of that well. The higher pH is indicative of contamination of the sampled water by the alkaline grout. Sampling conducted on 11 January 1995 resulted in a pH value of 6.6 which indicates that the conditions around the monitoring well have stabilized. This outlier was deleted from the data set prior to statistical evaluations being performed upon the remaining 37 values.

The summary statistics for each distribution test are given in the table below. The constructed probability plots presented in Appendix E show very little difference in the distributions of the transformed data sets. The Shapiro-Wilk probability value is less than 0.05 for both distributions.

pH Summary Statistics							
						Shapiro-Wilk Test	
	Valid N	**Mean**	Std.Dev.	Minimum	Maximum	W	p
Untransformed	37	6.268	0.373	5.2	6.8	0.876	0.0005
Log-Transformed	37	1.834	0.062	1.649	1.917	0.857	0.0001

Since neither normal or lognormal distribution are indicated by the Shapiro-Wilk statistics, the non-parametric treatment for calculating a UTL was selected. As detailed in section UTL, the non-parametric UTL used for the evaluation of groundwater is the maximum detected concentration, exclusive of outliers. That value is included in the table below.

With no normal distribution apparent for either transformed or log-transformed data, a UCL was calculated using the log-transformed data. The assumption was made that the distribution would be lognormal if a greater sample population were used. The calculated UCL is provided in the table below. Also included in the table below is the Secondary Maximum Contaminant Level (SMCL) taken from the Drinking Water Regulations and Health Advisories by the Office of Water, U.S. Environmental Protection Agency, November 1994. The lower bound of the range defined as SMCL is higher than the calculated UCL although the variation is only one-tenth of a pH unit.

Background Limit	Distribution used for Calculation	Calculated Value
UTL	non-parametric	6.8
UCL	lognormal	6.4
SMCL		6.5-8.5

Specific Conductivity

A wide but fairly consistent range of values is represented by the samples in this data set. As can be seen on the graph of specific conductivity plotted per well (Appendix F) the three wells (110, 111 and 112) each represent a certain interval of the range of data. The two measurements each for 133 and 134 (1715 and 543 umhos/cm and 126 and 144 umhos/cm, respectively) would fall in the lower portion of the range.

The summary statistics for specific conductivity using the 38 values are provided below. No clear distribution exists as evidenced by the Shapiro-Wilk statistic.

Specific Conductivity Summary Statistics							
		Units - umhos/cm				Shapiro-Wilk W Test	
	Valid N	Mean	Std.Dev.	Minimum	Maximum	W	p
Untransformed	38	3184.8	2673.2	47	8140	0.892	0.0012
Log-Transformed	38	7.268	1.665	3.850	9.005	0.837	0.0000

Since neither normal nor lognormal distribution are indicated by the Shapiro-Wilk statistics, the non-parametric treatment for calculating a UTL for specific conductivity was selected. As detailed in section UTL, the non-parametric UTL used for the evaluation of groundwater is the maximum detected concentration, exclusive of outliers. That value is included in the table below.

With no normal distribution for specific conductivity apparent for either transformed or log-transformed data, the UCL was calculated using the log-transformed data. The assumption was made that the distribution would be lognormal if a greater sample population were used. The calculated UCL was 13,890 umhos/cm which is higher than the UTL value. This disparity can be explained by the large standard deviation upon which the H-statistic is based. The UCL was then calculated using the untransformed data. The calculated UCL using the untransformed data was 3917 umhos/cm. Specific conductivity is an indicator parameter and is not a direct component of groundwater, therefore, no MCL or SMCL exists for this parameter.

Background Limit	Distribution used for Calculation	Calculated Value (umhos/cm)
UTL	non-parametric	8140
UCL	normal	3,917

ANIONS

Chlorides

Thirty-five values for chlorides were collected from the 5 wells tested. As shown in the plot of chloride values for each well over time in Appendix F, the three wells with historical data (110, 111 and 112) fall in two different ranges as defined by chloride concentrations with 110 and 112 contained in the higher chloride concentration range. The two newer wells, 133 and 134, both fall in the lower portion of the range represented by well 111.

Chloride Summary Statistics

		Values in mg/L				Shapiro-Wilk W Test	
	Valid N	Mean	Std.Dev.	Minimum	Maximum	W	p
Untransformed	35	710.4	470.5	10.2	1416	0.866	0.00035
Log-Transformed	35	5.890	1.640	2.322	7.256	0.723	0.00000

Since all wells have been defined as background wells and are located on the perimeter of the plant with no extended organic concentrations detected, these wells can be assumed to represent the range of naturally occurring background chloride concentrations and all values were included for the calculation of the upper tolerance limit (UTL) and upper confidence limit (UCL). With the range of concentrations that are present, it is evident that some chance for false negative or false positive indications exists and site specific evaluations may be required.

Neither normal nor lognormal distribution are indicated by the Shapiro-Wilk statistics, therefore the non-parametric treatment for calculating a UTL for chloride concentrations was selected. As detailed in section UTL, the non-parametric UTL used for the evaluation of groundwater is the maximum detected concentration, exclusive of outliers. That value is included in the table below.

With no normal distribution for chloride concentration apparent for either transformed or log-transformed data, a UCL was calculated using the log-transformed data. The assumption was made that the distribution would be lognormal if a greater sample population were used. The calculated UCL was 3441 mg/L which is higher than the non-parametric UTL value. This disparity can be explained by the large standard deviation upon which the H-statistic is based. To provide a more useable value, the UCL was calculated using the untransformed data. The resulting UCL was 845, which more closely brackets the mean value and is included in the table below. The SMCL for chloride is included for comparison. As shown by the table below, the UTL exceeds the SMCL indicating that the SMCL is not a viable indicator of unimpacted groundwater at LHAAP.

Background Limit	Distribution used for Calculation	Calculated Value (mg/L)
UTL	non-parametric	1416
UCL	normal	845
SMCL		250

Nitrate/Nitrite

Thirty-six sample results were reported with analytical results for nitrates and nitrites as nitrogen or nitrate/nitrite as nitrogen. This mixture of reported values complicates the analysis. A portion of the results from Thiokol's sampling procedures showed the same concentration for nitrate and the combination of nitrate/nitrite. Since no quantified values were reported in thirty results for nitrite, the assumption was made that the nitrite concentration was insignificant. Therefore, for this evaluation, sample results which had nitrate reported separately will assume that nitrate is the dominant species and the nitrate concentration will be used as the nitrate/nitrogen concentration. Twenty-two values were reported above the applicable detection limits which ranged from 0.01 to 0.5 mg/L.

For the calculation of background concentrations, three values were identified as outliers. Those values are 1.7, 2.4, and 10.5 mg/L from wells 133 and 134. These values were omitted from the calculations of the summary statistics presented below except for the calculation of Shapiro-Wilk W test for testing for normal or lognormal distribution. As shown by the Shapiro-Wilk statistics, the data passed the test for log-normal distribution.

Nitrate/Nitrite Summary Statistic (prior to adjustment to account for nondetect values)

		Values in mg/L				Shapiro-Wilk W Test	
	Valid N	Mean	Std.Dev.	Minimum	Maximum	W	p
Untransformed	19	0.076	0.046	0.03	0.18	0.838	0.003
Log-transformed	19	-2.734	0.572	-3.507	-1.715	0.903	0.055

With approximately forty percent (38%) of the analytical results being below the applicable detection limits and the detection limits were not the same, the mean and standard deviation require adjustment using the log probability regression method. The spreadsheet calculations and associated plot are included at the end of Appendix C. The log-transformed adjusted mean and standard deviation are shown below with the calculated UCL and UTL. The MCL is included for reference.

Nitrate/Nitrite Adjusted Mean and Standard Deviation with Calculated UTL and UCL Adjusted using Log Probability Regression Method					
Log-transformed Mean	Log-transformed Standard Deviation	n	UCL (mg/L)	UTL (mg/L)	MCL (mg/L)
-3.342	0.9170	32	0.06	0.27	10

Sulfate

Thirty five values for sulfate were collected from the five wells. Two values were below the detection limit of 2 mg/L. The three wells with historical analytical data (wells 110, 111 and 112) represent a range of sulfate concentrations with each well roughly occupying one part of the range as shown on the graph in Appendix F. Well 111 represents the lowest portion of the range with well 110 representing the upper portion of the range. The results from wells 133 and 134 (310 mg/L and 18.8 mg/L, respectively) are more closely associated with the lower portion of the range represented by well 111.

The summary statistics shown below were calculated after substituting one-half of the detection limit of 2 mg/L for the two results that were reported as being below the detection limit.

Sulfate							
		Values in mg/L				Shapiro-Wilk W Test	
	Valid N	Mean	Std.Dev.	Minimum	Maximum	W	p
Untransformed	35	842.4	828.15	1.0	3475	0.878	0.0008
Log-transformed	35	5.564	2.267	0.000	8.153	0.840	0.0001

Neither normal nor lognormal distribution are indicated by the Shapiro-Wilk statistics, therefore the non-parametric treatment for calculating a UTL for sulfate concentrations was selected. As detailed in section UTL, the non-parametric UTL used for the evaluation of groundwater is the maximum detected concentration, exclusive of outliers. That value is included in the table below.

With no normal distribution for chloride concentration apparent for either untransformed or log-transformed data, a UCL was calculated using the log-transformed data. The assumption was made that the distribution would be lognormal if a greater sample population were used. The calculated UCL was 19,806 mg/L which is higher than the non-parametric UTL value. This disparity can be explained by the large standard deviation upon which the H-statistic is based. The UCL was calculated using the untransformed data. The resulting UCL was 1079 mg/L which more closely brackets the mean value. The SMCL for sulfate is included in the table below for comparison. As shown in the table below, the SMCL for sulfate is significantly smaller than either the UCL or UTL.

Background Limit	Distribution used for Calculation	Calculated Value (mg/L)
UTL	non-parametric	3475
UCL	normal	1,079
SMCL		250

METALS

Aluminum

Thirty-eight analytical values for aluminum were collected. The values for aluminum from the December 1993 sampling round were anomalously high as shown in the graph in Appendix F. Those values were identified as outliers by the outlier test described in Section 3 of the text of this report. No explanation was identified for these values so those values were omitted from the calculations of summary statistics. No apparent seasonal trend was evidenced in the graph provided in Appendix F. The summary statistics are presented in the table below

Distribution tests of the aluminum analytical data indicated a lognormal distribution of the data. The summary statistics and Shapiro-Wilk statistics are provided in the table below.

Aluminum Summary Statistics

		Values in mg/L				Shapiro-Wilk W Test	
	Valid N	Mean	Std.Dev.	Minimum	Maximum	W	p
Untransformed	34	4.594	3.698	0.3	13.4	0.890	0.002
Log-Transformed	34	1.123	1.022	-1.204	2.595	0.942	0.090

With the lognormal distribution of aluminum concentration values indicated, the UTL and UCL were calculated. There is no MCL or SMCL established for aluminum. Although the UTL is over three times the UCL and is larger than the maximum detected value that wasn't identified as an outlier, the calculated UTL is considered to be a valid representation of the upper 95% Tolerance Limit due to the identification of a good fit for the lognormal distribution.

Background Limit	Distribution used for Calculation	Calculated Value (mg/L)
UTL	Lognormal	28.4
UCL	Lognormal	8.0
SMCL		0.05-0.2

Antimony

Analytical sampling performed by Thiokol had not tested for antimony. Therefore the only antimony analyses available for determination of background concentrations were those performed on samples from the five background wells which were sampled October 1994. The threshold value for this background determination was decided by the nonparametric method, which uses the detection limit of 0.1 mg/L, since all of the results were below the detection limit of 0.1 mg/L and there were no quantified values for statistical evaluation. As is evidenced by the table below, the detection limit of 0.1 mg/L and corresponding UCL of 0.05 mg/L is greater than the applicable MCL of 0.006 mg/L.

Background Limit	Distribution used for Calculation	Calculated Value (mg/L)
UTL	Lognormal	0.1
UCL	Lognormal	0.05
MCL		0.006

Arsenic

The results of thirty-eight sample analyses were considered for the determination of the background concentration for arsenic. Twelve (12) quantified results were reported with the remainder (26) or 68% being below the specified detection limit. Of the results reported below the detection limit, a detection limit of 0.005 mg/L (5 µg/L) was used in 22 cases, 0.002 mg/L (2 µg/L) in 3 cases, and 0.05 mg/L (50 µg/L) in one case (October 1994 sample from well 112). Analysis of that sample required a ten-fold dilution which caused the sample quantitation limit (detection limit) to be changed from 0.005 mg/L to 0.05 mg/L.

As stated in reference 2 (page 8-7) and reference 3 (page 28), Cohen's adjustment is not recommended when the number of nondetects exceeds 50%. Therefore, the mean and standard deviation were adjusted using the log-probability regression method. The log-transformed adjusted mean and standard deviation are presented in the table below with the calculated UTL and UCL. The MCL is included in the table below to be used as a reference.

Arsenic - Adjusted Mean and Standard Deviation with Calculated UTL and UCL Adjusted using Log Probability Regression Method+					
Log-transformed Mean	Log-transformed Standard Deviation	n	UCL (mg/L)	UTL (mg/L)	MCL* (mg/L)
-5.886	1.1488	37	0.01	0.03	0.05

Barium

Thirty-eight values for barium were collected for this evaluation. With the omission of the data from well 110 for the 30 June 1992 sampling round (as described in Section 2.1.1), thirty-seven barium data points were used for the background evaluation. No analyses were reported to be below the detection limit. Fluctuations over time were evidenced on the graph in Appendix F but there was no clear correlation. The increase in barium concentrations in wells 110 and 112 in December 1992 and March 1993 and to a lesser extent March 94 are assumed to be a natural variation due to regional factors, such as rainfall, and those values are honored in this evaluation. Due to the large spatial separation between these two well, there is no reason to suspect related anthropogenic sources of contamination. The summary statistics are listed in the table below.

Barium Summary Statistics							
		Values in mg/L				Shapiro-Wilk W Test	
	Valid N	Mean	Std.Dev.	Minimum	Maximum	W	p
Untransformed	37	0.450	0.498	0.02	1.99	0.7534	0.0000
Log-Transformed	37	-1.388	1.203	-3.912	0.6881	0.9585	0.2409

As shown by the p-value in the table above as well as the probability plots in Appendix E, the log transformed values (lognormal distribution test) show the best fit of a normal distribution. Therefore, the UTL and UCL are calculated from the mean and standard deviation of the lognormal distribution. As indicated by the MCL for barium included in the table below, the UCL representing the mean value of the sample population is well below the MCL, however the calculated UTL is above the MCL. Due to the good distribution indicator (p-value) for the lognormal distribution, the calculated UTL is believed to accurately represent the upper bound of the expected population.

Background Limit	Distribution used for Calculation	Calculated Value (mg/L)
UTL	Lognormal	3.3
UCL	Lognormal	0.9
MCL		2.0

Cadmium

The results of thirty-eight sampling points were considered for the determination of the background concentration for cadmium. Nineteen (19) quantified results were reported with the remainder (19) or 50% being below the specified detection limit. A detection limit of 0.01 mg/L (10 µg/L) was used in all analyses. As indicated in Section 3.1.2 for data sets of 50% or more, the log-probability regression method is recommended for the calculation of the adjusted mean and standard deviation. The log-transformed adjusted mean and standard deviation, as well as the calculated UCL and UTL, are presented in the table below. The applicable MCL is included for reference. The caluclated UCL and UTL values are larger than the MCL of 0.005 mg/L. Due to the detection limit of 0.1, the adjusted mean and standard deviation may contain inherent error which is reflected in the UCL and UTL being higher that the MCL.

Cadmium - Adjusted Mean and Standard Deviation with Calculated UTL and UCL Adjusted using Log Probability Regression Method					
Log-transformed Mean	Log-transformed Standard Deviation	n	UCL (mg/L)	UTL (mg/L)	MCL (mg/L)
-4.573	0.9943	37	0.018	0.088	0.005

Calcium

Analytical tests performed by Thiokol had not tested for calcium. Therefore the only calcium concentrations available for determination of background concentrations were the ten samples taken from the five background wells sampled September/October 1994 and January 1995. The summary statistics for those analyses are presented in the table below.

Calcium Summary Statistics							
		Values in mg/L				Shapiro-Wilk W Test	
	Valid N	Mean	Std.Dev.	Minimum	Maximum	W	p
Untransformed	10	139.3	116.45	6.78	320	0.910	0.270
Log-Transformed	10	4.324	1.43	1.914	5.768	0.852	0.059

As shown by the Shapiro-Wilk statistic above, the data meets the test for both normal and lognormal distribution. The data was first evaluated for lognormal distribution. Since the p-value for the log-transformed data was greater that 0.05, a lognormal distribution was assumed. The UCL and UTL for the log-transformed data were calculated. From the log-transformed data, the calculated UCL and UTL were 1439 and 4835 mg/L, respectively. With the maximum detected concentration being only 320 mg/L, these values for UCL and UTL appear unreasonably large.

Therefore, the UCL and UTL using the untransformed data were calculated. From the untransformed data, the calculated UCL and UTL were 207 and 478 mg/L, respectively. These values bracket the analytically derived values much closer than do those calculated from the log-transformed data. No MCL or SMCL exist for calcium.

Background Limit	Distribution used for Calculation	Calculated Value (mg/L)
UTL	Lognormal	478
UCL	Lognormal	207

Chromium

The results of thirty-eight sample analyses were considered for the determination of the background concentration for chromium. Twenty-five (25) quantified results were reported with the remainding 13 (34%) being below the specified detection limit. The detection limit ranged from 0.01 mg/L to 0.05 mg/L. Five samples were reported below a detection limit of 0.01 mg/L, four samples were reported below a detection limit of 0.02 mg/L and four samples were reported below a detection limit of 0.05 mg/L.

One point, well 133 for October 1994, had a value judged to be extreme. That value was 0.29 mg/L which was over three times the next largest value. The T_n value, as described on pages 8-11 to 8-13 of Reference 2, was calculated with the resulting value of 4.2 which exceeded the value in Table 8 of Appendix B in Reference 2. This indicated that the value was an outlier. The following statistics were calculated on the data with the outlier omitted.

Chromium Summary Statistics (Unadjusted)							
		Values in mg/L				Shapiro-Wilk W Test	
	Valid N	Mean	Std.Dev.	Minimum	Maximum	W	p
Untransformed	24	0.035	0.029	0.01	0.11	0.7862	0.0001
Log-Transformed	24	-3.638	0.755	-4.605	-2.207	0.9146	0.0442

Since various detection limits were used, the Cohen adjustment was judged not to be applicable, so the log-probability regression method was used to calculate an adjusted mean and standard deviation. The spreadsheet calculations and associated plot are included at the end of Appendix C. The log-transformed adjusted mean and standard deviation, as well as the calculated UCL and UTL are presented in the table below. As shown in that UCL is less than the MCL, yet the UTL exceeds the MCL.

Chromium - Adjusted Mean and Standard Deviation with Calculated UTL and UCL Adjusted using Log Probability Regression Method					
Log-transformed Mean	Log-transformed Standard Deviation	n	UCL (mg/L)	UTL (mg/L)	MCL (mg/L)
-4.252	1.1257	36	0.03	0.16	0.1

Cobalt

Analytical tests performed by Thiokol had not tested for cobalt. Therefore the only cobalt concentrations available for determination of background concentrations were those determined from the five background wells sampled September/October 1994 and January 1995. Of the ten samples tested for cobalt, only four samples resulted in values greater than the detection limit. The summary statistics were not calculated. Due to the high percentage of non-detect results, the log-probability regression method was used to determine an adjusted mean and standard deviation. The log-transformed adjusted mean and standard deviation are presented in the table below. The calculated UCL and UTL are also included. No MCL or SMCL have been established for cobalt.

Cobalt - Adjusted Mean and Standard Deviation with Calculated UTL and UCL
Adjusted using Log Probability Regression Method

Log-transformed Mean	Log-transformed Standard Deviation	n	UCL (mg/L)	UTL (mg/L)	MCL (mg/L)
-4.849	1.2926	9	0.03	0.39	---

Copper

Analytical tests performed by Thiokol had not tested for copper. Therefore the only copper concentrations available for the determination of background concentrations were those determined from the five background wells sampled September/October 1994 and January 1995. Of the ten samples tested for cobalt, only four samples resulted in values greater than the detection limit. Due to the high percentage of non-detect results, the log-probability regression method was used to determine an adjusted mean and standard deviation. The log-transformed adjusted mean and standard deviation, as well as the calculated UCL and UTL, are presented in the table below. The SMCL is also included as a reference.

Copper - Adjusted Mean and Standard Deviation with Calculated UTL and UCL Adjusted using Log Probability Regression Method					
Log-transformed Mean	Log-transformed Standard Deviation	n	UCL (mg/L)	UTL (mg/L)	SMCL* (mg/L)
-4.661	1.0125	9	0.02	0.20	1.0

Iron

Thirty-eight values for iron were utilized for the determination of background concentrations. Fluctuations over time were evidenced on the graph in Appendix F but there was no clear correlation by season or well. As seen on the plots in Appendix F and Appendix E, the iron concentration (160 mg/L) reported for well 112 for the June 1992 sample period was over twice the value of any other reported value for the sampled wells. The T_n (T_{38}) value, as described on pages 8-11 to 8-13 of Reference 2, was calculated with the resulting value of 4.5 which exceeded the value in Table 8 of Appendix B in Reference 2. This indicated that the value was an outlier. The Shapiro-Wilk statistics were calculated on the data with the outlier omitted. Since that value is the only value reported to that extreme, it was considered to be an outlier and will be omitted from the determination of background concentrations. The summary statistics and distribution statistics are given in the table below.

Iron Summary Statistics								
		Values in mg/L					Shapiro-Wilk W Test	
	Valid N	Mean	Std.Dev.	Minimum	Maximum		W	p
Untransformed	37	20.354	20.093	0.85	68		0.820	0.000
Log-Transformed	37	2.444	1.187	-0.163	4.220		0.954	0.174

As illustrated by the p-value of the Shapiro-Wilk statistics, the data for iron are best represented by a lognormal distribution. The calculated UTL and UCL for the lognormal distribution for iron with the outlier omitted are presented in the table below. Also listed in the table below is the listed SMCL for iron which is significantly smaller than the minimum detected concentration.

Background Limit	Distribution used for Calculation	Calculated Value (mg/L)
UTL	Lognormal	148
UCL	Lognormal	39
SMCL		0.3

Lead

Thirty-eight analyses for lead were utilized from the five wells for the determination of background concentrations. Twenty-three results were above the detection limits and fifteen analyses (39%) were below the detection limit. The detection limit for samples collected by Thiokol was 0.1 mg/L. Eight results were reported below this detection limit. The detection limit for samples collected by the Corps of Engineers during September/October 1994 was 0.002 mg/L. Four results were reported below this detection limit. The detection limit for samples collected by the Corps of Engineers during January 1995 was 0.005 mg/L. Three results were reported below this detection limit. No seasonal trend is evident in the plot of concentration versus time presented in Appendix F.

Lead Summary Statistics -Unadjusted Mean and Standard Deviation							
		Values in mg/L				Shapiro-Wilk W Test	
	Valid N	Mean	Std.Dev.	Minimum	Maximum	W	p
Untransformed	23	0.155	0.091	0.003	0.3	0.892	0.016
Log-Transformed	23	-2.151	1.049	-5.809	-1.204	0.739	0.000

Due to the wide range of detection limits used, the Cohen method of adjustment was not used. The log-probability regression method was used to adjust the mean and standard deviation of the sample population. The spreadsheet calculations and associated plot are included at the end of Appendix C. The log-transformed adjusted mean and standard deviation, as well as the calculated UCL and UTL, are included in the table below. No MCL or SMCL have been established for lead.

Lead - Adjusted Mean and Standard Deviation with Calculated UTL and UCL Adjusted using Log Probability Regression Method					
Log-transformed Mean	Log-transformed Standard Deviation	n	UCL (mg/L)	UTL (mg/L)	MCL (mg/L)
-3.493	2.0.133	37	0.29	2.31	---

Magnesium

Thirty-eight values for magnesium were utilized from the five wells for the determination of background concentrations. The three wells with historical analytical data (wells 110, 111 and 112) represent the range of magnesium concentrations with each well occupying a more or less distinct portion of the range as shown on the graph in Appendix F. Well 111 represents the lowest portion of the range with well 112 representing the upper portion of the range. The September/October 1994 results from wells 133 and 134 (6.2 mg/L and 277 mg/L, respectively) bracket the entire range of values detected in the other 3 wells.

The summary statistics and distribution statistics for magnesium are presented in the table below.

Magnesium Summary Statistics							
		Values in mg/L				Shapiro-Wilk W Test	
	Valid N	Mean	Std.Dev.	Minimum	Maximum	W	p
Untransformed	38	124.5	88.7	5.07	277	0.910	0.0051
Log-Transformed	38	4.27	1.36	1.623	5.624	0.794	0.0000

As shown by the Shapiro-Wilk p-value above, neither the untransformed or log-transformed data set met the criteria for normal distribution. Therefore, the nonparametric UTL method was chosen due to the lack of normality in either of the data sets with the selected UTL being 277 mg/L, which is the maximum detected concentration.

For the calculation of the UCL, a log-normal distribution was assumed and the UCL was calculated using the mean and standard deviation. Due to the large standard deviation, the UCL calculated using the log-normal distribution was seemingly large at 337 mg/L. Due to this large calculated value, the UCL was calculated using the untransformed data. That calculated UCL was 149 mg/L and is presented below as the recommended UCL. No MCL or SMCL has been established for magnesium.

Background Limit	Distribution used for Calculation	Calculated Value (mg/L)
UTL	non-parametric	277
UCL	normal	149

Manganese

Thirty-eight values for manganese were utilized for this evaluation. As with magnesium, wells 110, 111 and 112 each represent a portion of the detected range of manganese values. This is illustrated in the plot in Appendix F. Well 111 represents the lower portion of the range and well 110 represents the upper portion of the range. Well 110 reported elevated peaks in the manganese levels for the first quarter sampling rounds of 1993 and 1994. Those peaks are not more than twice the other values for well 110 and were not identified as outliers using the outlier test so these peaks are interpreted to be seasonal variations and will be used in this evaluation. This is similar to the temporal distribution of barium concentrations which also had seasonal spikes in the first quarter of 1993 and 1994.

The summary statistics and distribution statistics for manganese are presented in the table below.

Manganese Summary Statistics							
		Values in mg/L				Shapiro-Wilk W Test	
	Valid N	Mean	Std.Dev.	Minimum	Maximum	W	p
Untransformed	38	3.875	2.778	0.213	11.8	0.922	0.014
Log-Transformed	38	0.939	1.100	-1.546	2.468	0.861	0.000

As shown by the Shapiro-Wilk p-value above, neither the untransformed or log-transformed data set met the criteria for normal distribution. Therefore, the nonparametric UTL method was chosen due to the lack of normality in either of the data sets with the selected UTL being 11.8 mg/L, which is the maximum detected concentration.

For the calculation of the UCL, a log-normal distribution was assumed and the UCL was calculated using the mean and standard deviation. Due to the large standard deviation, the UCL calculated using the log-normal distribution was seemingly large at 7.4 mg/L. Due to this large calculated value, the UCL was calculated using the untransformed data. That calculated UCL was 4.6 mg/L and is presented below as the recommended UCL. The SMCL for manganese is included in the table below. The SMCL exceeds even the minimum detected value of all 38 samples of the background population.

Background Limit	Distribution used for Calculation	Calculated Value (mg/L)
UTL	Non-parametric	11.8
UCL	Lognormal	4.6
SMCL		0.05

Mercury

The results of thirty-eight analyses were used for the mercury background determination. Three quantified values were provided from these analyses with the remainder (35) or 92% being reported as being below the applicable detection limit. Thirty results were below a detection limit of 0.001 mg/L (1 µg/L), four results were below a detection limit of 0.002 mg/L (2 µg/L), and one result was below a detection limit of 0.09 mg/L. The three quantified values were 0.001 mg/L which is the same as the detection limit for those analyses. The recommended UTL by virtue of the nonparametric solution is the maximum detected value (0.001 mg/L).

For the assignment of a UCL value for mercury, one-half the value of the detection limit (0.0005 mg/L) will be used.

The MCL of mercury is included in the table below.

Background Limit	Distribution used for Calculation	Calculated Value (mg/L)
UTL	Non-parametric	0.001
UCL	Lognormal	0.0005
MCL		0.002

Nickel

Analytical tests performed by Thiokol had not tested for nickel. Therefore the only nickel concentrations available for the determination of background concentrations were the ten samples taken from the five background wells sampled October 1994 and January 1995. Only one sample result was less than the detection limit of 0.015 mg/L. The summary statistics which for those analyses are presented in the table below. These statistics include the value of 0.0075 mg/L (one-half of the detection limit) substituted for the result below the detection limit.

Nickel Summary Statistics								
		Values in mg/L					Shapiro-Wilk W Test	
	Valid N	Mean	Std.Dev.	Minimum	Maximum	W	p
Untransformed	10	0.035	0.0188	0.008	0.06	0.901	0.213
Log-Transformed	10	-3.502	0.6539	-4.893	-2.813	0.896	0.189

As shown in the table above, both distributions meet the criteria of normal distribution for untransformed and log-transformed data as seen by the p-values which are greater than 0.05. Under the assumption that the distribution is log-normal, the UCL and UTL were calculated. The UCL and UTL calculated using the log-normal formula are 0.064 and 0.20 mg/L, respectively. Since the calculated UCL using the log-normal formula is greater than the maximum detected value, the UCL and UTL were calculated assuming a normal distribution. The UCL and UTL calculated using the normal formula are 0.05 and 0.09 mg/L, respectively. These calculated UCL more closely bounds the sample mean so the values calculated using the normal distribution formula are recommended as the UCL and UTL values. For reference, the MCL value is included in the table below.

Background Limit	Distribution used for Calculation	Calculated Value (mg/L)
UTL	Non-parametric	0.09
UCL	Lognormal	0.05
MCL		0.1

Potassium

Analytical tests performed by Thiokol had not tested for potassium and the confirmation sampling performed in January 1995 also did not test for potassium. Therefore the only potassium concentrations available for the determination of background concentrations were the five samples taken from the five background wells sampled October 1994. The summary statistics for those analyses are presented in the table below. The potassium concentration from well 133 (92.7 mg/L) was nearly twenty times the next largest reported concentration (5.5 mg/L in well 112). Since the pH in well 133 was considered as an outlier and indicative of influences of the mixture used to grout the well, it is assumed that the elevated potassium is also a result of the completion procedure. As such, the value for well 133 will be omitted from the background determination.

Potassium Summary Statistics							
		Values in mg/L				Shapiro-Wilk W Test	
	Valid N	Mean	Std.Dev.	Minimum	Maximum	W	p
Untransformed	4	4.45	0.968	3.2	5.5	0.9851	0.907
Log-Transformed	4	1.474	0.230	1.163	1.705	0.9586	0.738

Due to the small number of valid sample points, the calculation of background values for potassium has less certainty than constituents with larger sample populations. Since the p-values for both datasets (untransformed and log-transformed) were significantly larger than 0.05, the UCL and UTL for both datasets were calculated. With only four values available for the calculation of potassium background concentration level, the value of the computed values must be used with caution. UCL and UTL values were calculated on both distributions with the resulting values compared for reasonableness. For the log-transformed values, the calculated UCL and UTL were 6.6 and 2.7 mg/L, respectively. Since the UTL was calculated as being smaller than the UCL, an assumption, such as the assumption of log-normality, may be in error. The UCL and UTL values calculated on the untransformed data were 5.6 and 9.4 mg/L, respectively. These values are more reasonable and will be submitted as background values for this report. No values exist for the MCL or SMCL of potassium.

Background Limit	Distribution used for Calculation	Calculated Value (mg/L)
UTL	Non-parametric	9.4
UCL	Lognormal	5.6

Selenium

Thirty-eight analyses for selenium were utilized in these evaluations. Three quantified values were reported with the remaining 35 results being reported below detection limits of either 0.02 mg/L, 0.005 mg/L, or 0.002 mg/L. The quantified results are somewhat suspect since all three values were reported in the 3rd quarter 1993 sampling round. The quantified results for wells 110, 111 and 112 for the 3rd quarter 1993 were 0.14 mg/L, 0.02 mg/L and 0.08 mg/L, respectively. The detection limit of 0.005 mg/L was used in a total of twelve analyses performed in 1992 and October 1994. A detection limit of 0.02 mg/L was used in 17 cases and a detection limit of 0.002 was used in the analysis of the five sample taken January 1995. The three quantified results appear to be due to an error which occurred during the process of analysis of a large portion of the samples. The detection limit of 0.005 mg/L is recommended to be used as the UTL with the recommended UCL being equal to one-half of the detection limit or 0.003 mg/L which is one-half of the detection limit. The MCL for selenium is 0.05 mg/L. The MCL for selenium and the recommended UCL and UTL are listed in the table below.

Background Limit	Distribution used for Calculation	Calculated Value (mg/L)
UTL	Non-parametric	0.005
UCL	Non-parametric	0.003
MCL		0.05

Silver

Thirty-eight analyses were utilized in the evaluation of silver background concentration. Of the thirty-eight analyses, eight quantified results were reported. The detection limit for all analyses was 0.01 mg/L.

The Cohen adjustment was not used for this evaluation because the percentage of values below the detection limit is 79%. The Cohen method is not recommended when the percentage of values less than the detection limit is greater than 50%. Therefore, the log-probability regression method for calculating an adjusted mean and standard deviation was utilized. The log-transformed values for the adjusted mean and standard deviation, as well asthe calculated UCL and UTL, are included in the table below. The listed SMCL is also included in the table below.

Silver - Adjusted Mean and Standard Deviation with Calculated UTL and UCL Adjusted using Log Probability Regression Method					
Log-transformed Mean	Log-transformed Standard Deviation	n	UCL (mg/L)	UTL (mg/L)	SMCL (mg/L)
-5.422	0.9421	37	0.01	0.034	0.1

Sodium

Thirty-three sodium concentration values were utilized in these evaluations. Sodium was not tested in the 5 wells sampled in October 1994. The plot of sodium concentrations by well versus time is presented in Appendix F. As with the anions (chloride and sulfate) and cations (magnesium and manganese), each well represented a distinct portion of the range of sodium detected with well 110 representing the upper portion and well 112 representing the lower portion of the range.

Sodium Summary Statistics							
		Values in mg/L				Shapiro-Wilk W Test	
	Valid N	Mean	Std.Dev.	Minimum	Maximum	W	p
Untransformed	33	563.4	454.7	13.6	1470	0.894	0.004
Log-transformed	33	5.705	1.442	2.61	7.29	0.851	0.000

As shown by the Shapiro-Wilk p-value above, neither the untransformed or log-transformed data set met the criteria for normal distribution. Therefore, the nonparametric UTL method was chosen due to the lack of normality in either of the data sets with the selected UTL being 1470 mg/L, which is the maximum detected concentration.

For the calculation of the UCL, a log-normal distribution was assumed and the UCL was calculated using the mean and standard deviation. Due to the large standard deviation, the UCL calculated using the log-normal distribution was seemingly large at 1814 mg/L which is larger than the maximum detected concentration. Due to this large calculated value, the UCL was calculated using the untransformed data. That calculated UCL was 697 mg/L and is presented below as the recommended UCL. There is no MCL or SMCL for sodium.

Background Limit	Distribution used for Calculation	Calculated Value (mg/L)
UTL	Non-parametric	1470
UCL	Normal	697

Strontium

Analytical tests performed by Thiokol had not tested for strontium. Therefore the only strontium concentrations available for determination of background concentrations were the ten samples taken from the five background wells sampled October 1994 and January 1995. The summary statistics for those analyses are presented in the table below.

Strontium Summary Statistics							
		Values in mg/L				Shapiro-Wilk W Test	
	Valid N	Mean	Std.Dev.	Minimum	Maximum	W	p
Untransformed	10	3.113	2.373	0.182	6.15	0.893	0.176
Log-Transformed	10	0.595	1.342	-1.704	1.816	0.839	0.042

As shown in the table above, the untransformed data most closely represents a normal distribution. Therefore, both UCL and UTL were calculated using the untransformed data. Both values are presented in the table below. There is no MCL or SMCL listed for strontium.

Background Limit	Distribution used for Calculation	Calculated Value (mg/L)
UTL	Normal	10.0
UCL	Normal	4.5

Thallium

Analytical tests performed by Thiokol had not tested for thallium. Therefore the only thallium concentrations available for determination of background concentrations were the ten samples taken from the five background wells sampled October 1994 and January 1995. The recommended UTL for this background determination as determined by the nonparametric method is the detection limit of 0.1 mg/L, since all of the results were below the detection limit of 0.1 mg/L and there were no quantified values for statistical evaluation.

Similarly, the recommended UCL is 0.05 mg/L which is one-half of the detection limit. The MCL for thallium is 0.002 mg/L.

Background Limit	Distribution used for Calculation	Calculated Value (mg/L)
UTL	Normal	0.1
UCL	Normal	0.05
MCL		0.002

Zinc

Analytical tests performed by Thiokol had not tested for zinc. Therefore the only zinc concentrations available for determination of background concentrations were the ten samples taken from the five background wells sampled October 1994. Six of the ten samples had results greater than the applicable detection limit. Of the four results below the detection limit, three were less than the detection limit of 0.05 mg/L and one was less than a detection limit of 0.015 mg/L.

With the inconsistent detection limits, the log-probability method was used to calculate the adjusted mean and standard deviation. The table below includes the log-transformed values of the adjusted mean and standard deviation, as well as the calculated UCL and UTL. The SMCL is included for reference.

Zinc - Adjusted Mean and Standard Deviation with Calculated UTL and UCL
Adjusted using Log Probability Regression Method

Log-transformed Mean	Log-transformed Standard Deviation	n	UCL (mg/L)	UTL (mg/L)	SMCL (mg/L)
-3.387	1.2764	9	0.14	1.62	5.0

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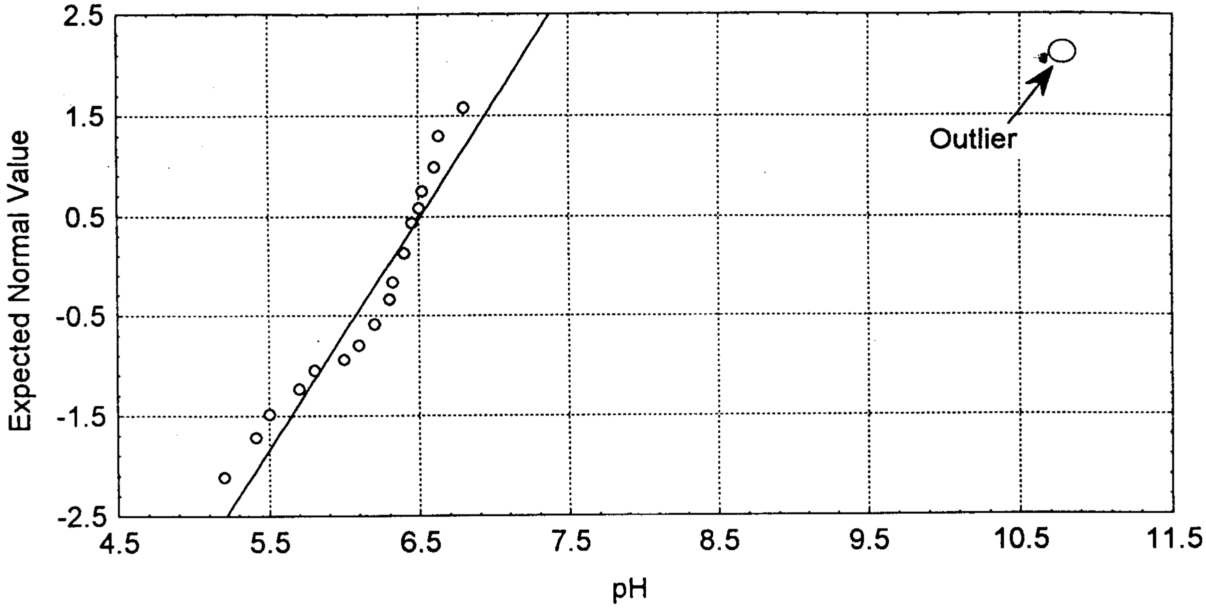
Appendix E

Probability Plots of Groundwater Chemical Parameters.

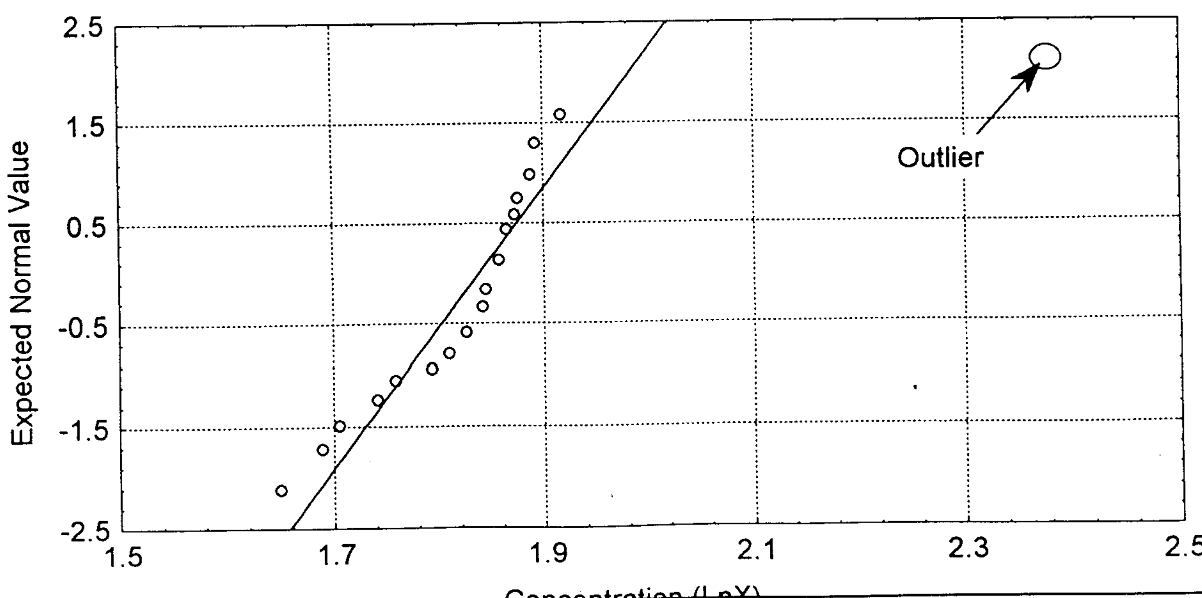
Plots Provided Alphabetically in the Following Categories:

Water Quality Parameters
Anions
Metals

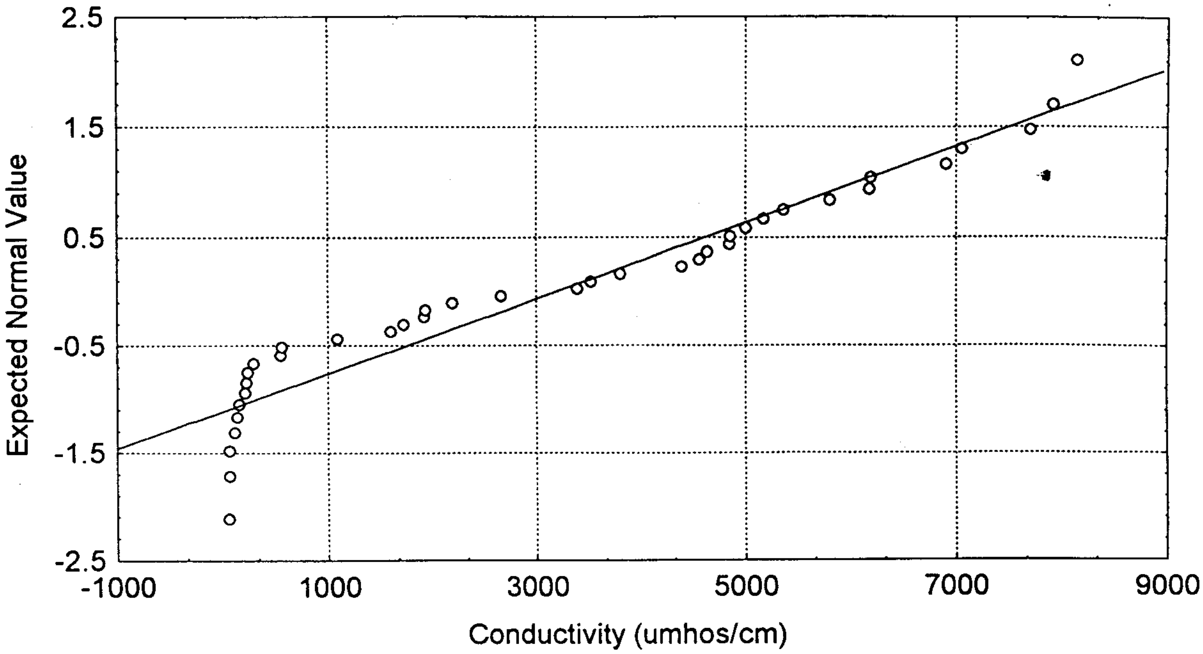
Normal Probability Plot
pH - Untransformed Data
Outlier Not Considered in Line Fit



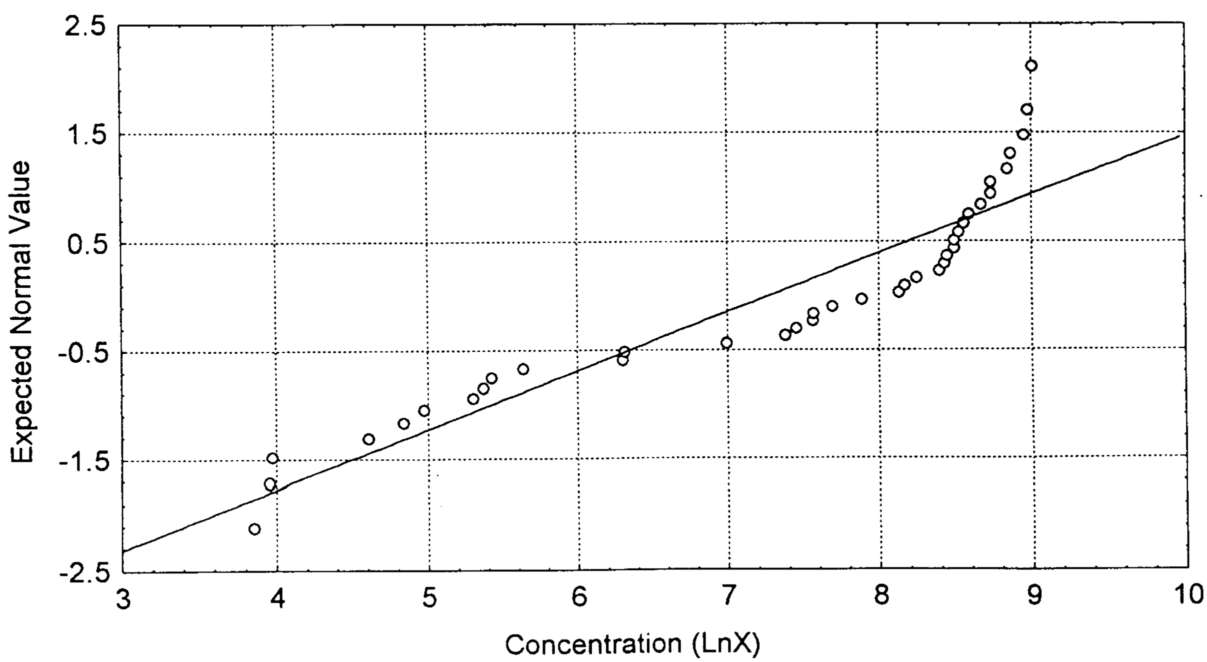
Normal Probability Plot
pH - Log Transformed Data
Outlier Not Considered For Line Fit



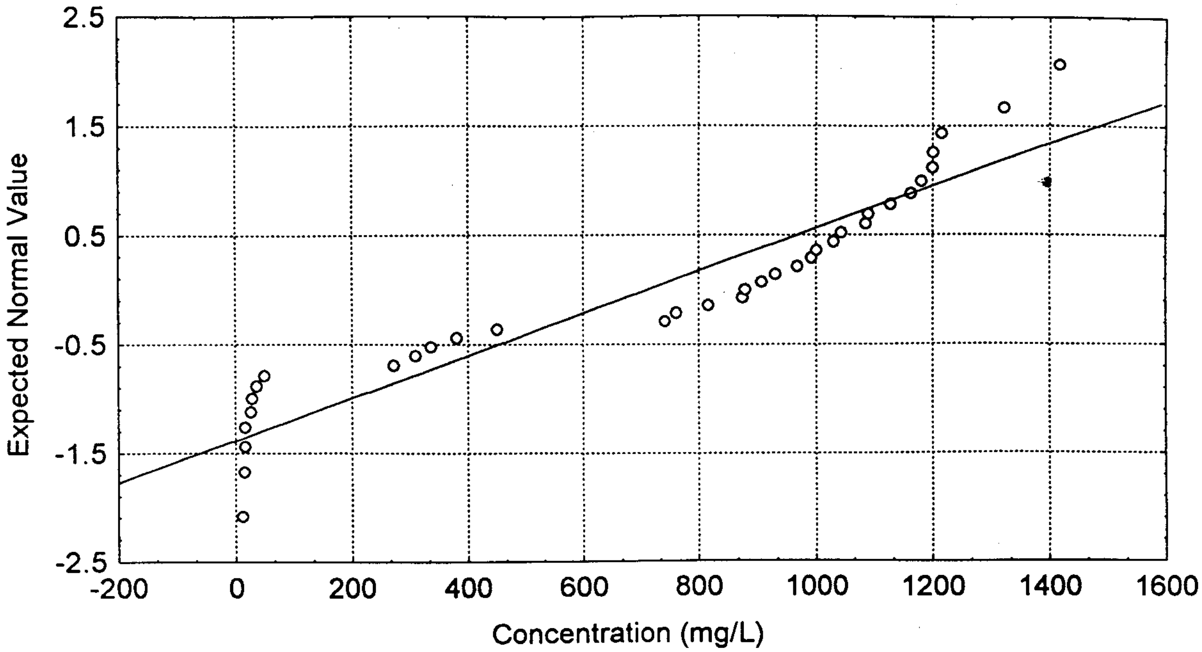
Normal Probability Plot
Specific Conductivity - Untransformed Data



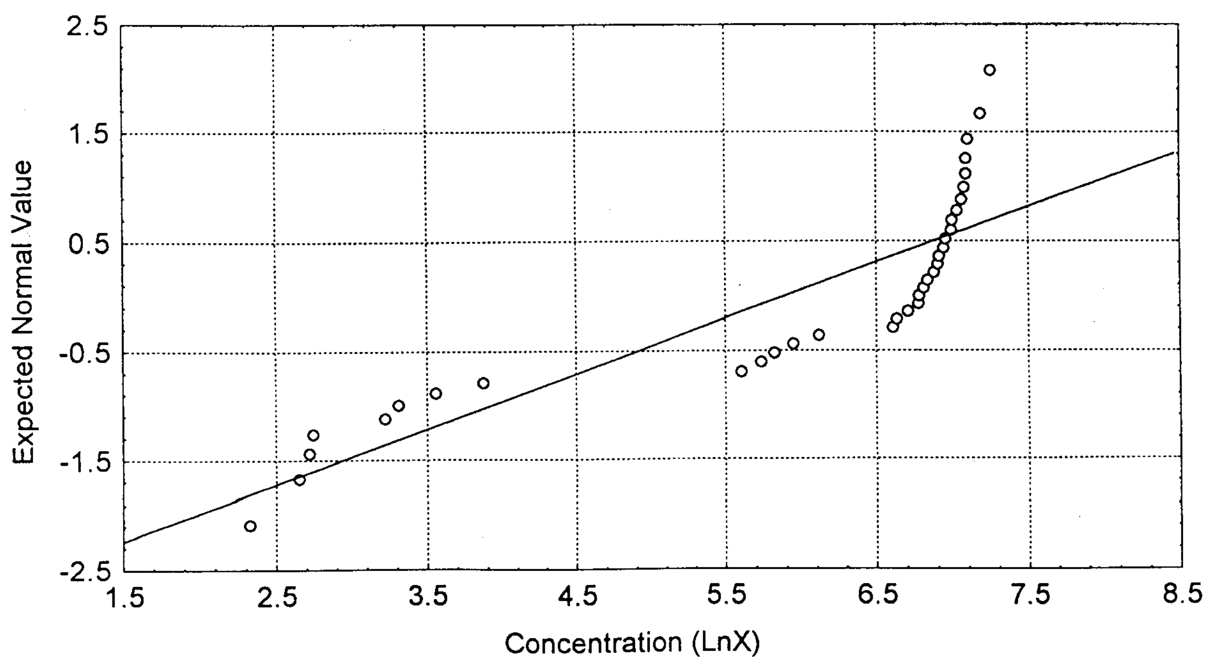
Normal Probability Plot
Specific Conductivity - Log Transformed Data

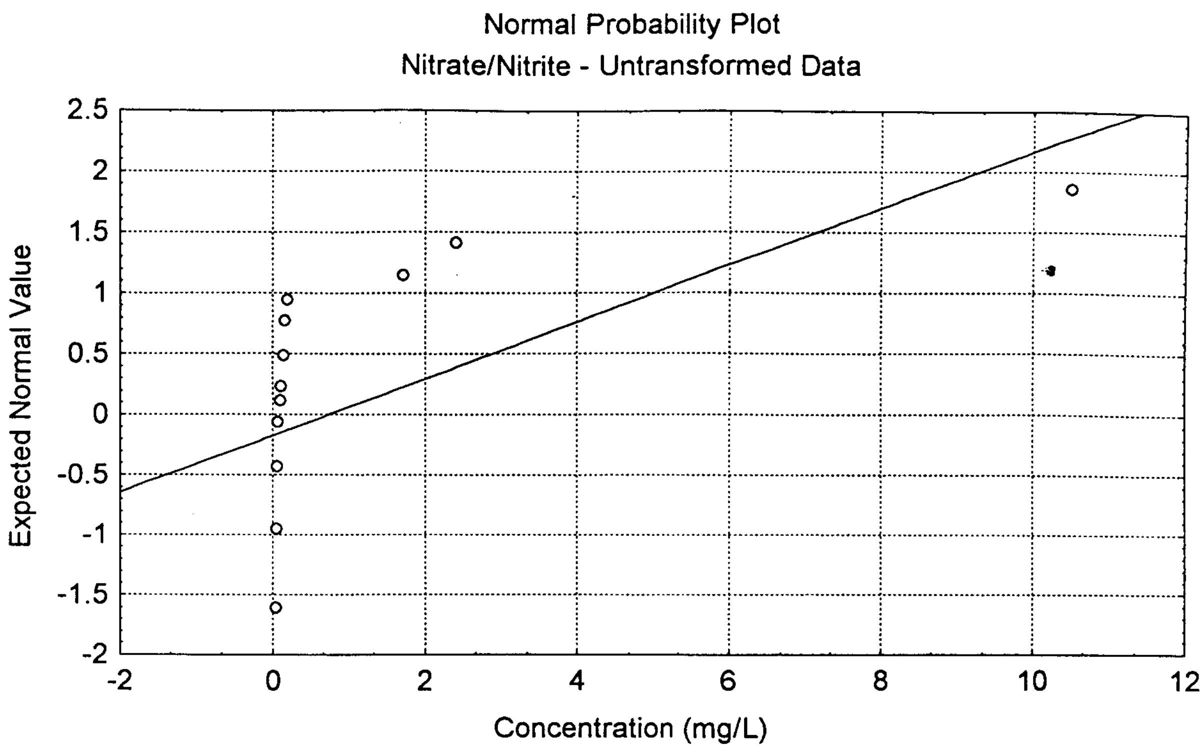


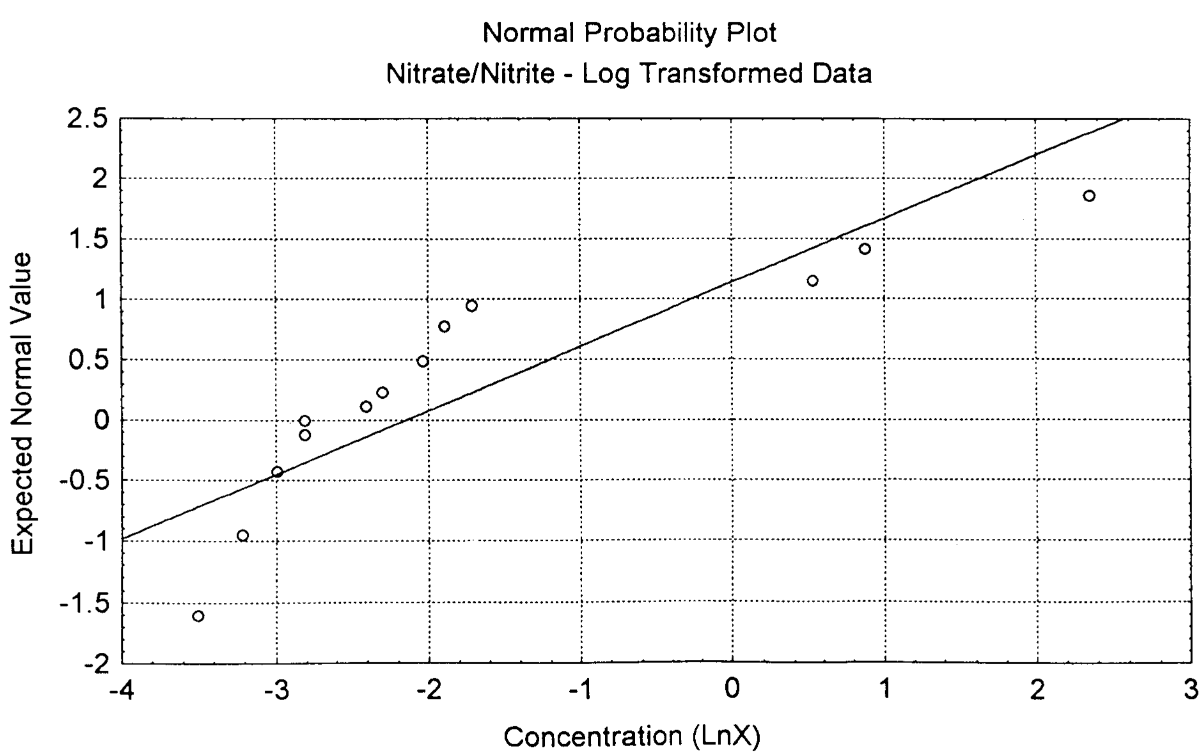
Normal Probability Plot
Chloride -Untransformed Data

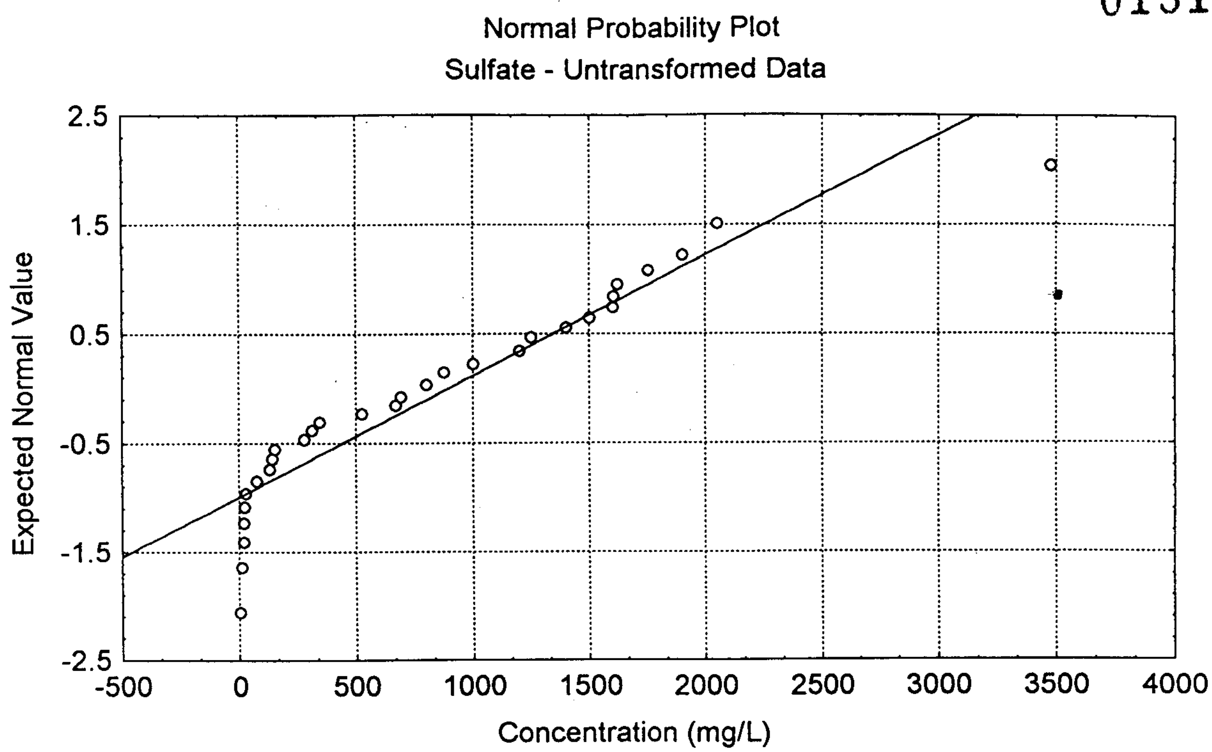


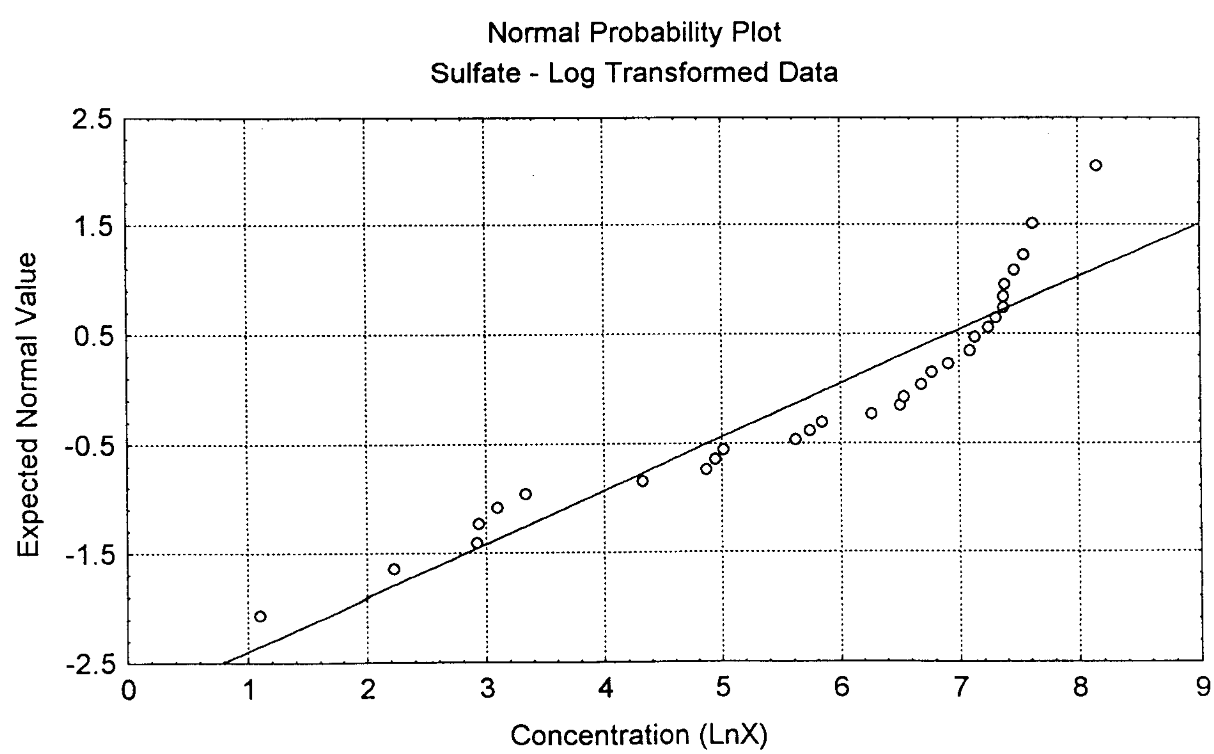
Normal Probability Plot
Chloride - Log Transformed Data



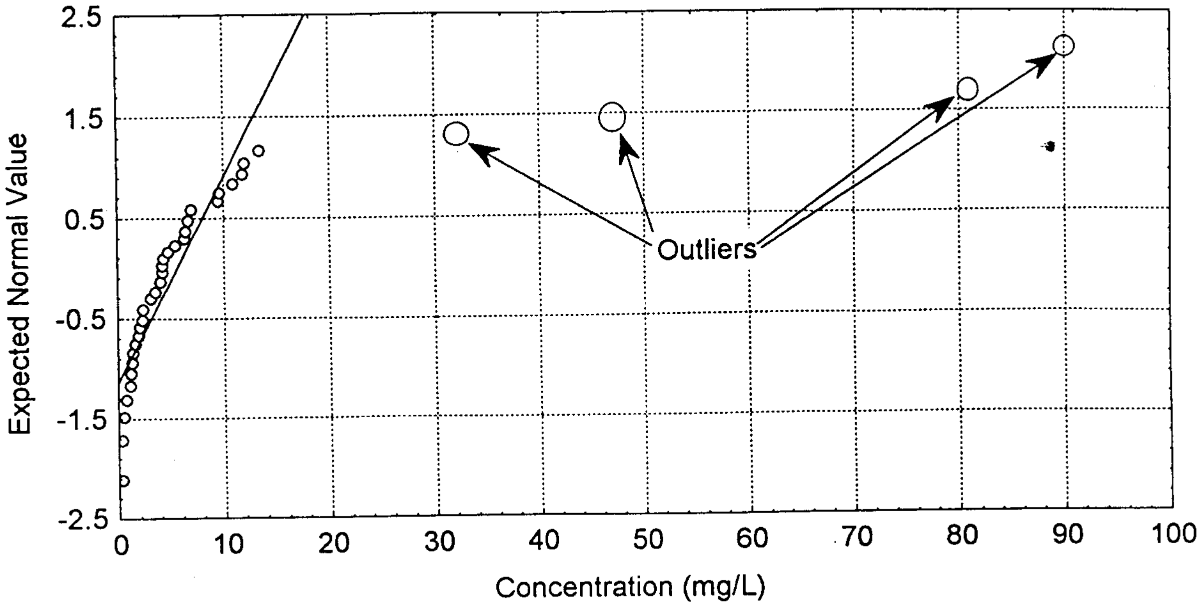

Normal Probability Plot
Nitrate/Nitrite - Untransformed Data
Expected Normal Value
Concentration (mg/L)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2
0
2
4
6
8
10
12


Normal Probability Plot
Nitrate/Nitrite - Log Transformed Data
Expected Normal Value
Concentration (LnX)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-4
-3
-2
-1
0
1
2
3

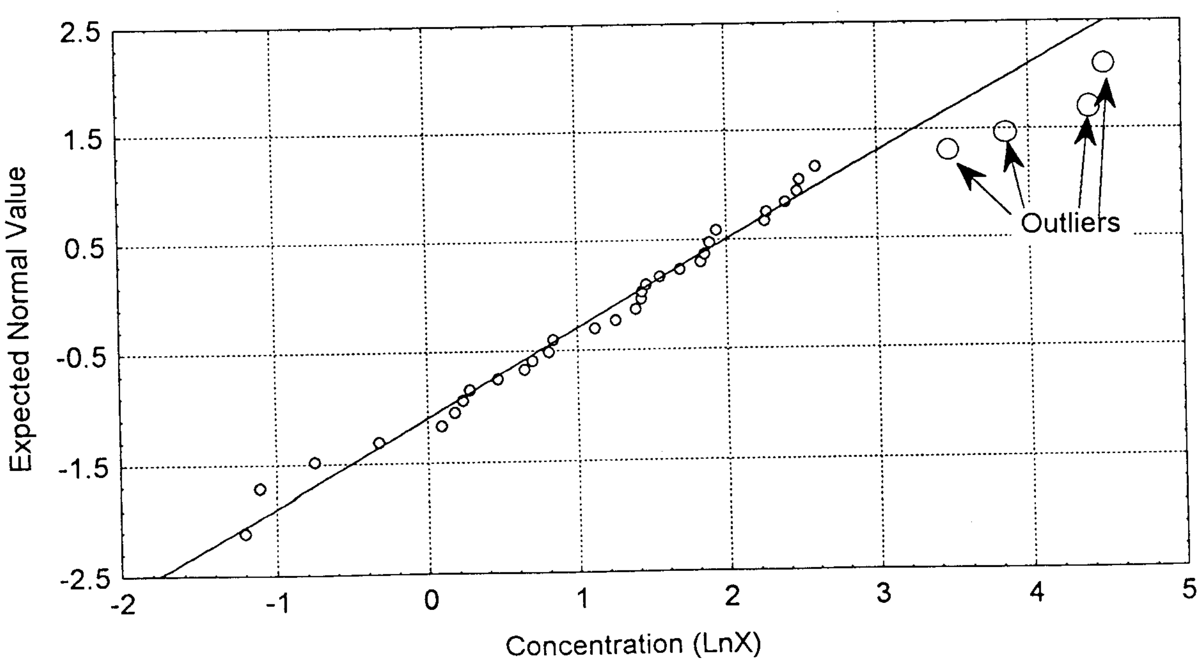

Normal Probability Plot
Sulfate - Untransformed Data
Expected Normal Value
2.5
1.5
0.5
-0.5
-1.5
-2.5
-500
0
500
1000
1500
2000
2500
3000
3500
4000
Concentration (mg/L)

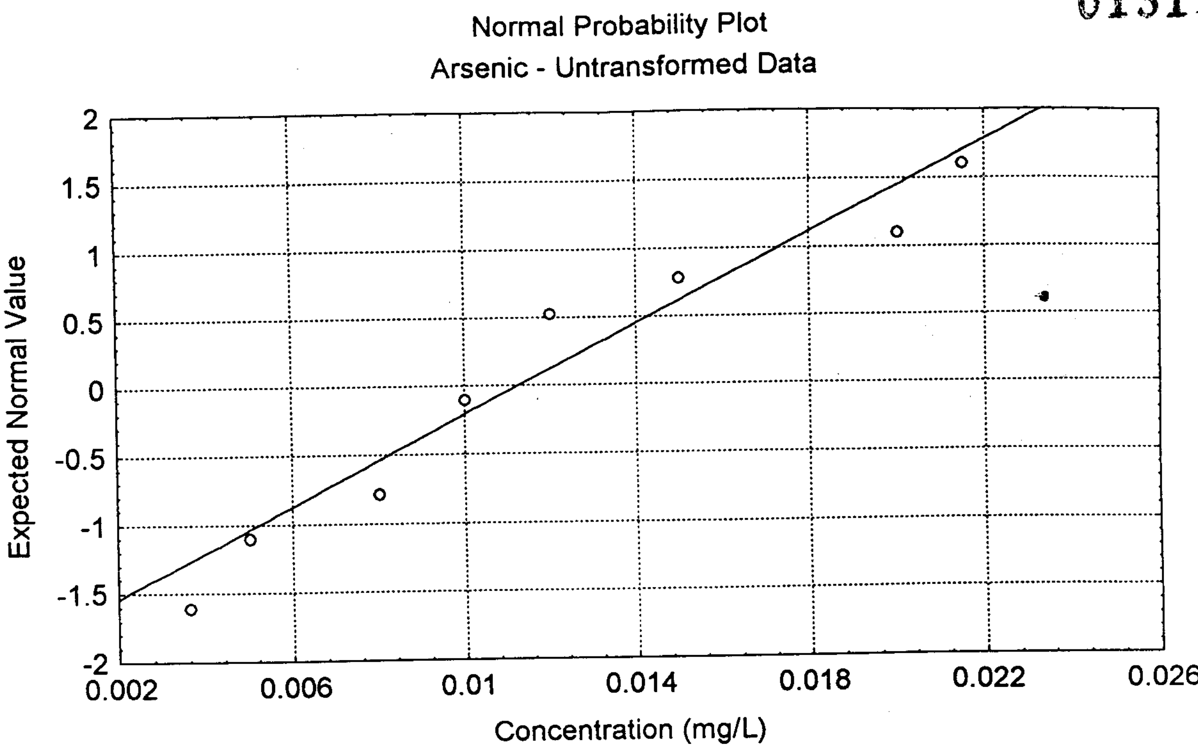

Normal Probability Plot
Sulfate - Log Transformed Data
Expected Normal Value
2.5
1.5
0.5
-0.5
-1.5
-2.5
0
1
2
3
4
5
6
7
8
9
Concentration (LnX)

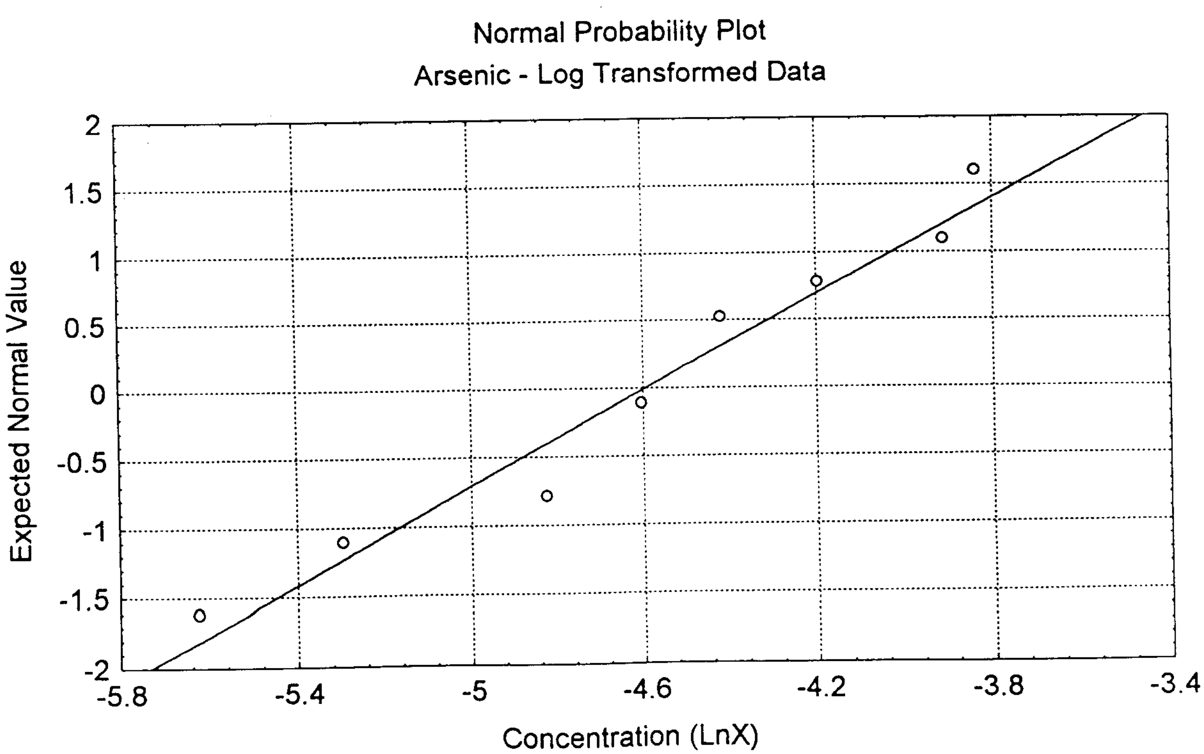
Normal Probability Plot
Aluminum - Untransformed Data
Possible Outliers Included

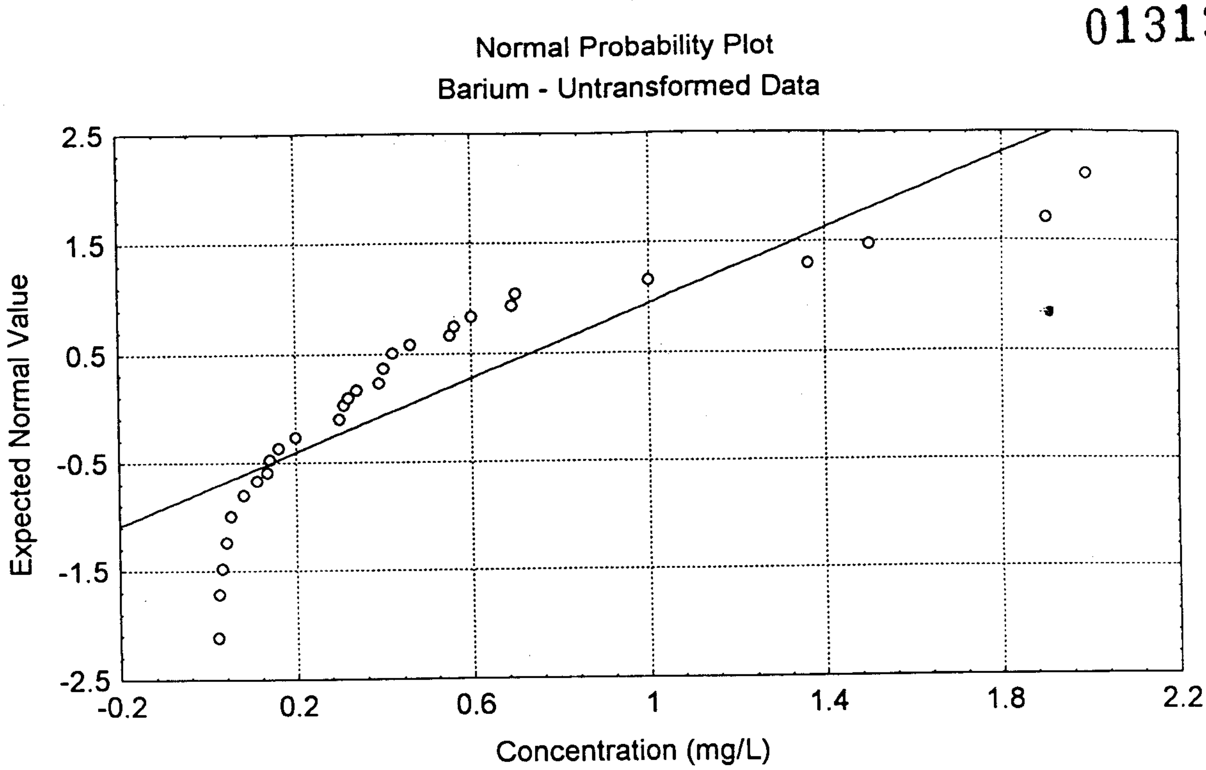


Normal Probability Plot
Aluminum - Log Transformed Data

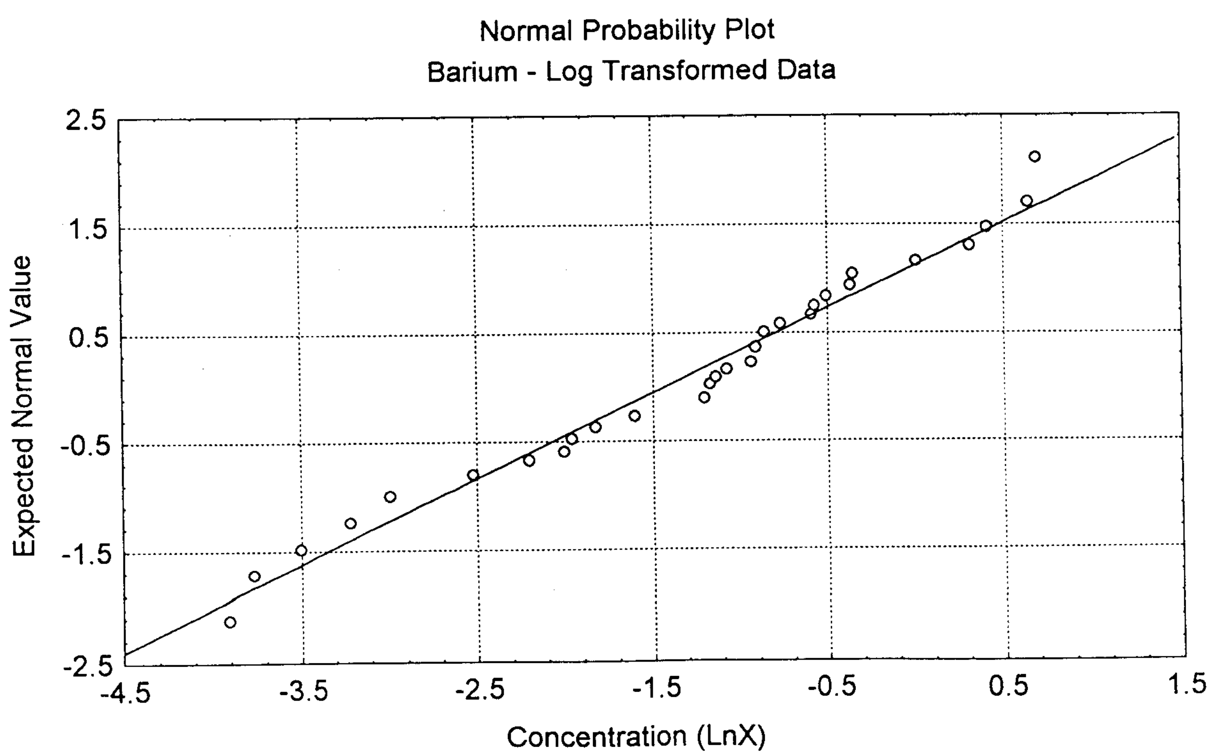



Normal Probability Plot
Arsenic - Untransformed Data
Expected Normal Value
Concentration (mg/L)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0.002
0.006
0.01
0.014
0.018
0.022
0.026

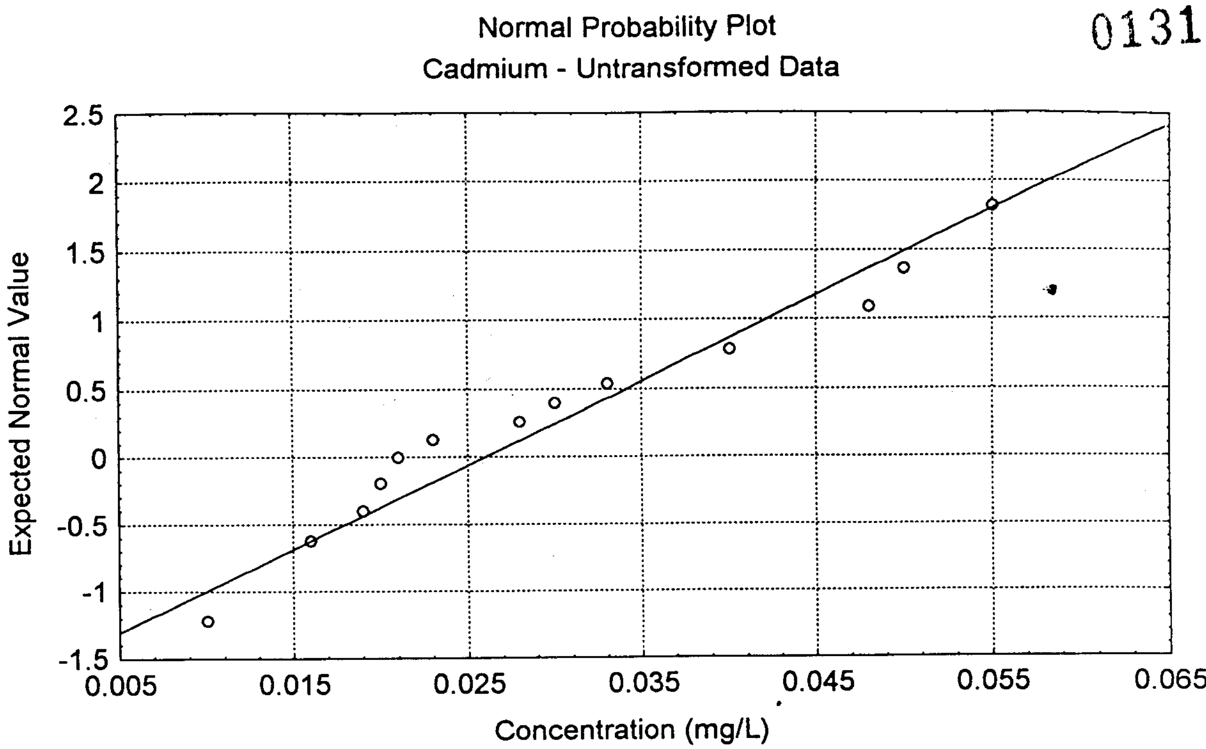

Normal Probability Plot
Arsenic - Log Transformed Data
Expected Normal Value
Concentration (LnX)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-5.8
-5.4
-5
-4.6
-4.2
-3.8
-3.4

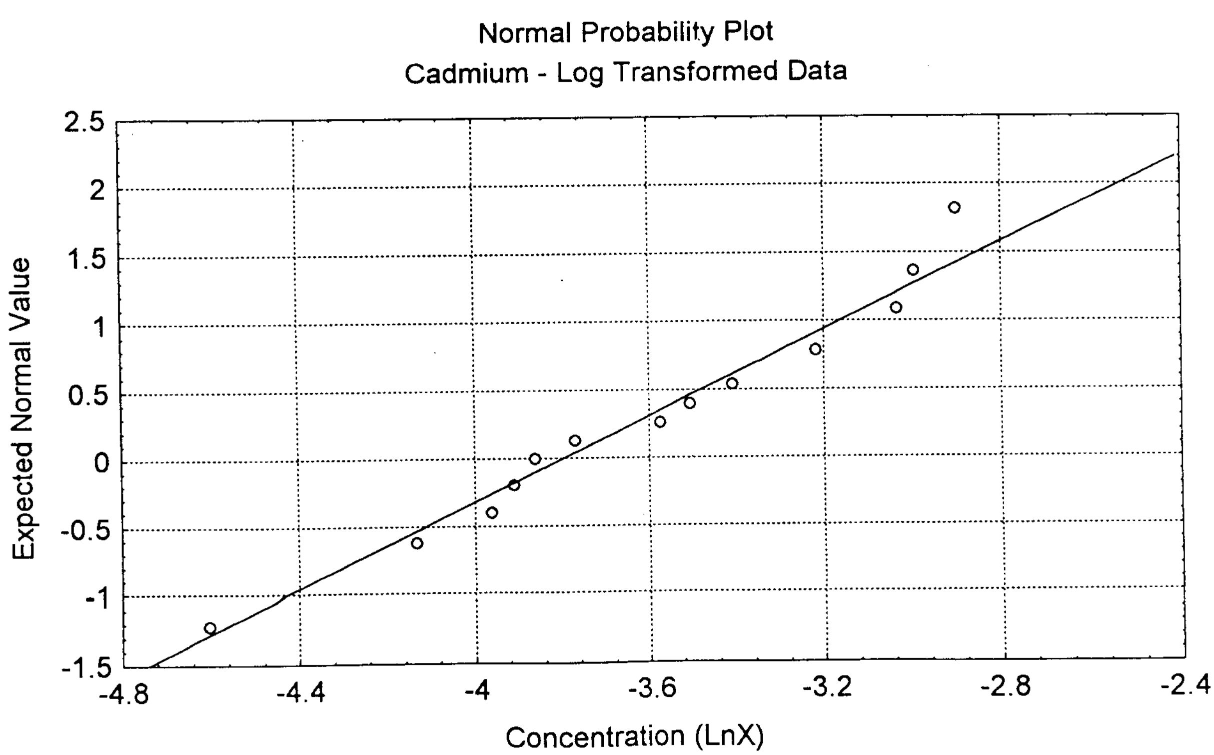


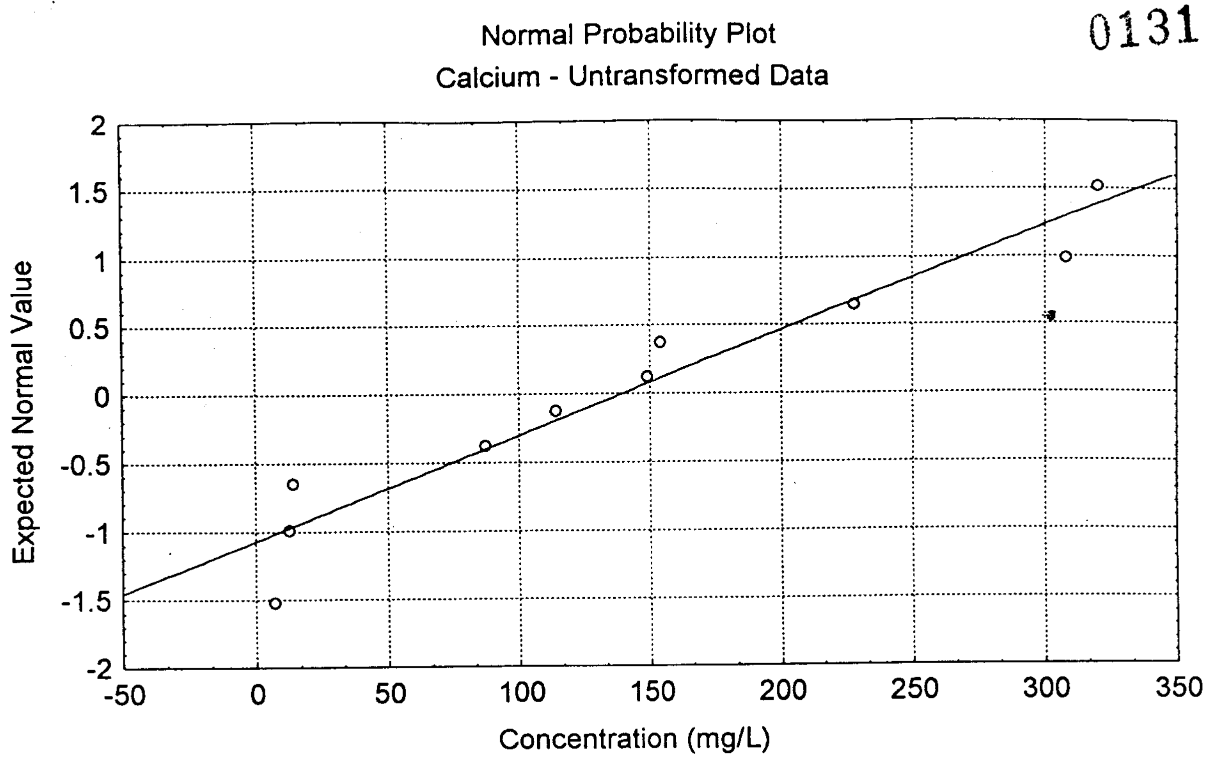
Normal Probability Plot
Barium - Untransformed Data
Expected Normal Value
Concentration (mg/L)
2.5
1.5
0.5
-0.5
-1.5
-2.5
-0.2
0.2
0.6
1
1.4
1.8
2.2

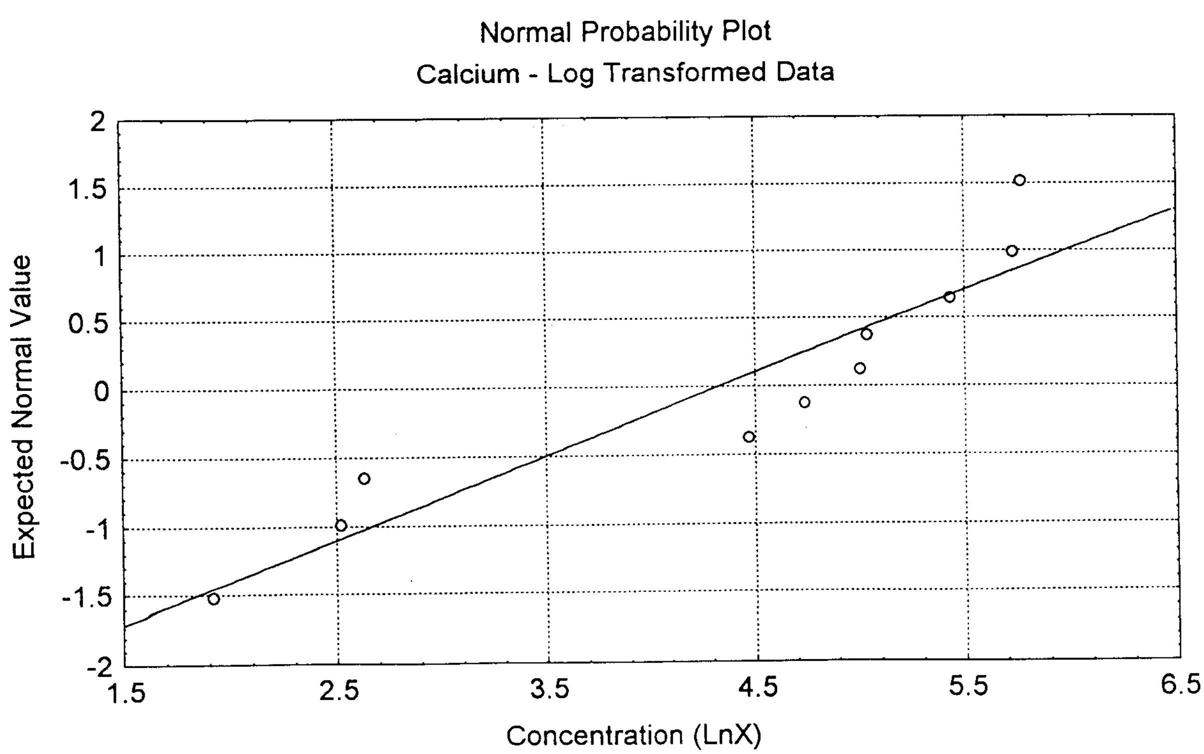


Normal Probability Plot
Barium - Log Transformed Data
Expected Normal Value
Concentration (LnX)
2.5
1.5
0.5
-0.5
-1.5
-2.5
-4.5
-3.5
-2.5
-1.5
-0.5
0.5
1.5

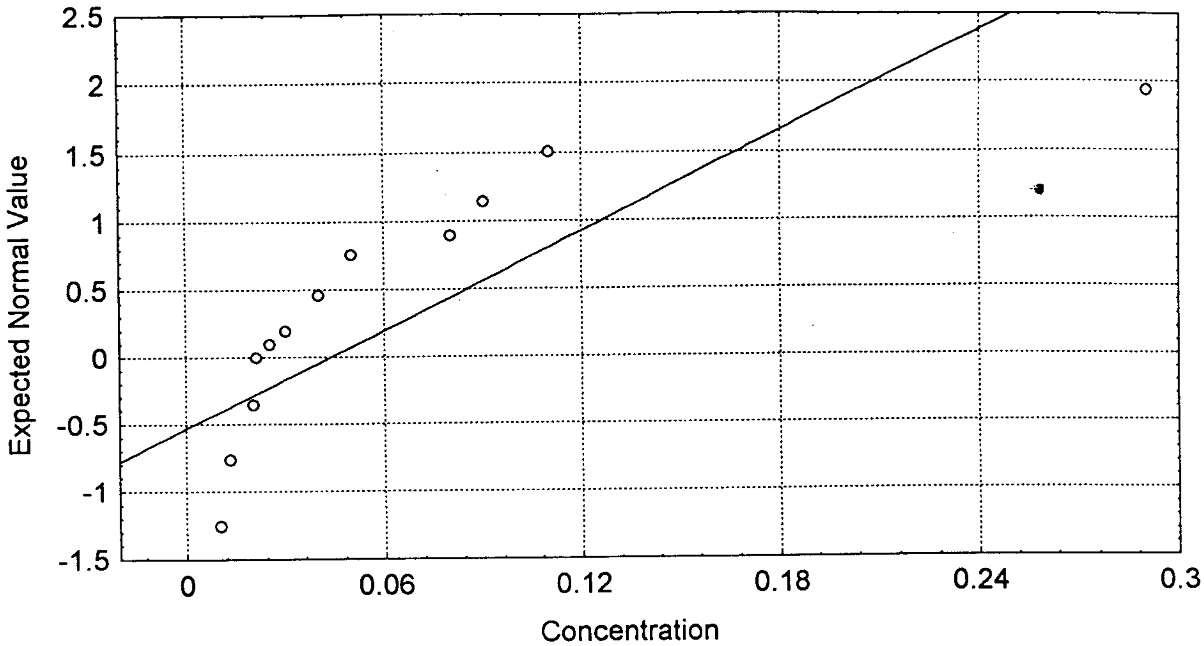

Normal Probability Plot
Cadmium - Untransformed Data
Expected Normal Value
Concentration (mg/L)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
0.005
0.015
0.025
0.035
0.045
0.055
0.065


Normal Probability Plot
Cadmium - Log Transformed Data
Expected Normal Value
Concentration (LnX)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-4.8
-4.4
-4
-3.6
-3.2
-2.8
-2.4

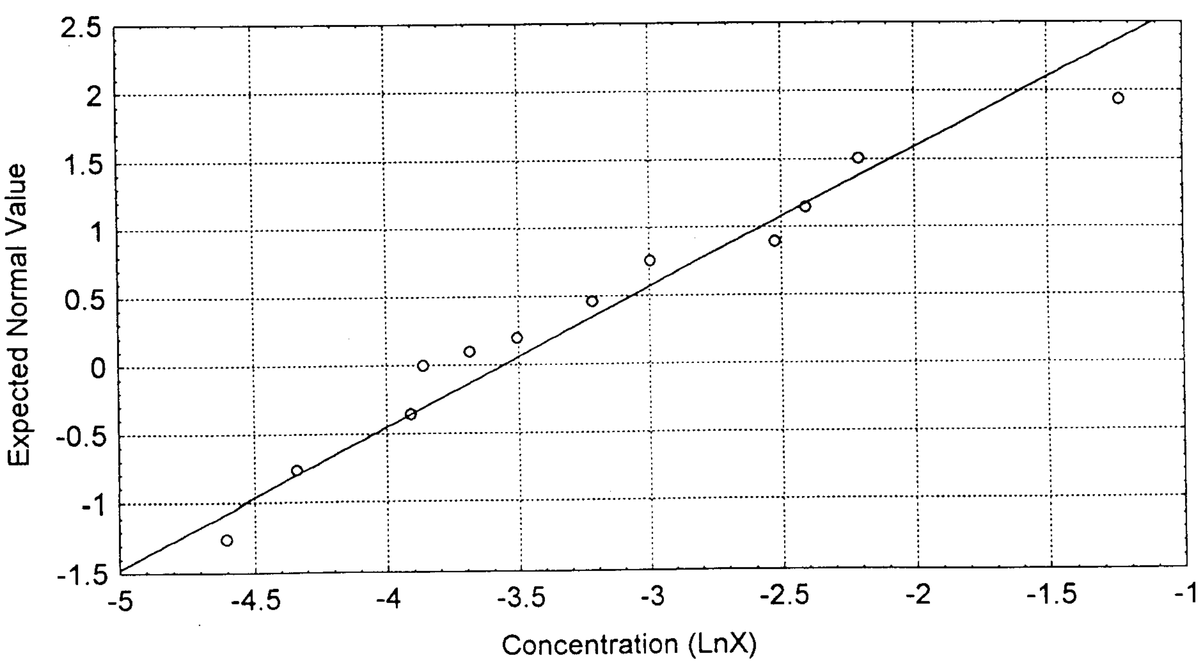

Normal Probability Plot
Calcium - Untransformed Data
Expected Normal Value
Concentration (mg/L)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-50
0
50
100
150
200
250
300
350

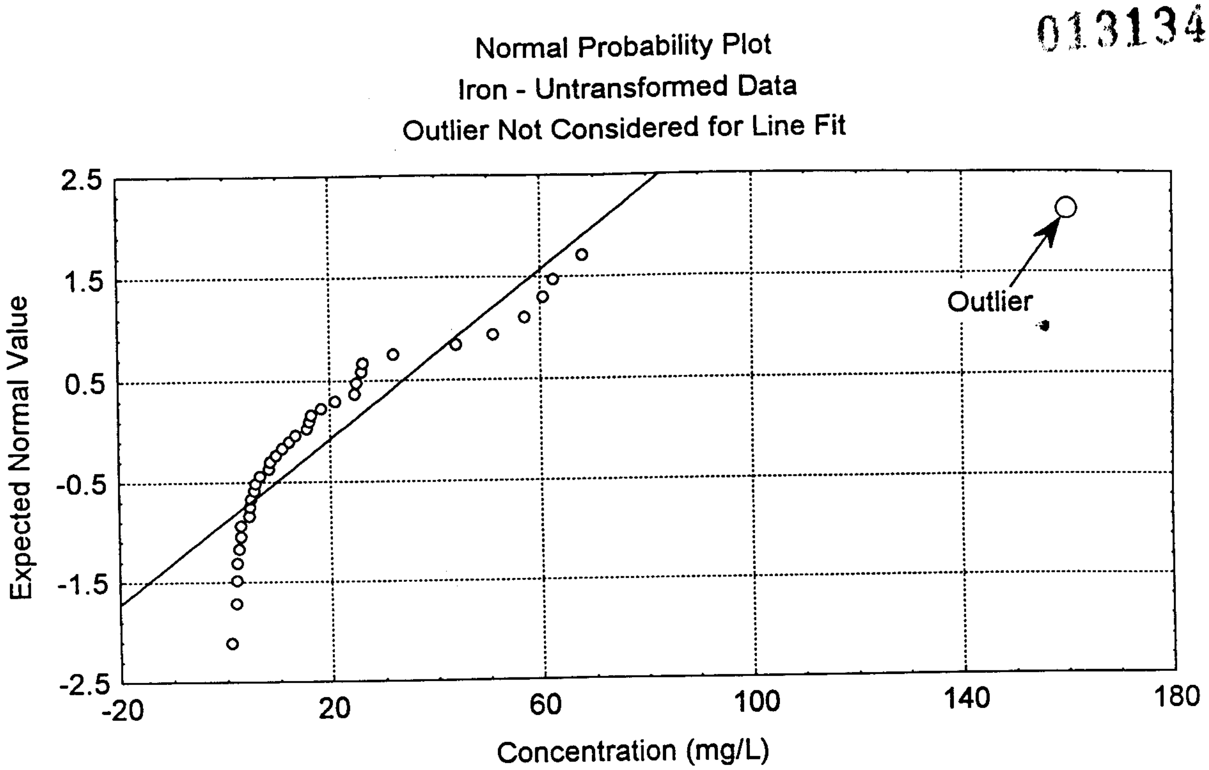

Normal Probability Plot
Calcium - Log Transformed Data
Expected Normal Value
Concentration (LnX)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
1.5
2.5
3.5
4.5
5.5
6.5

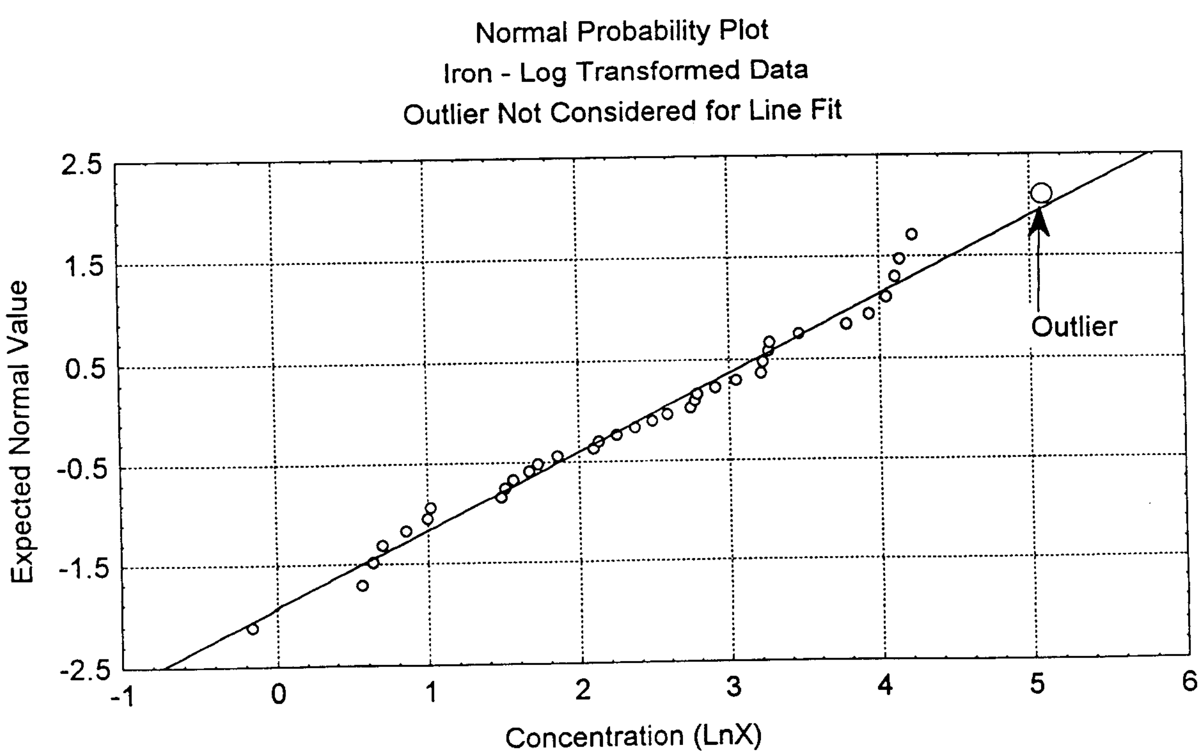
Normal Probability Plot
Chromium - Untransformed Data

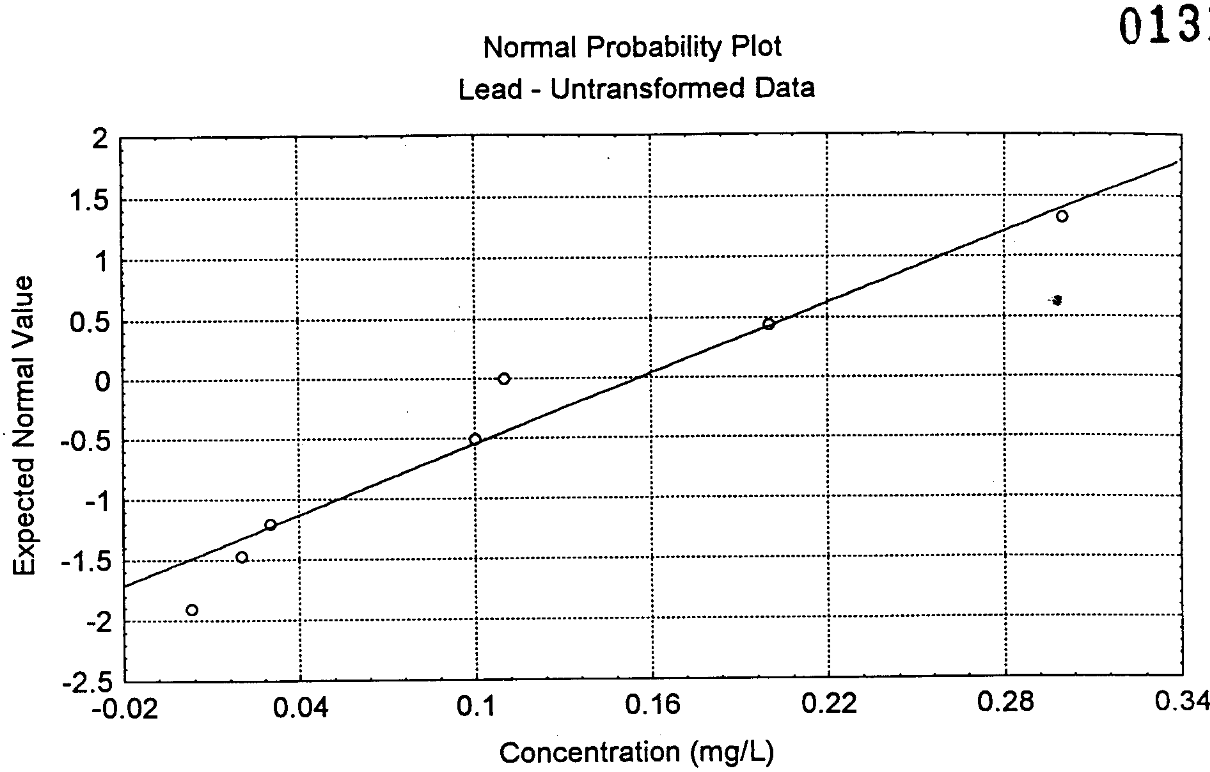


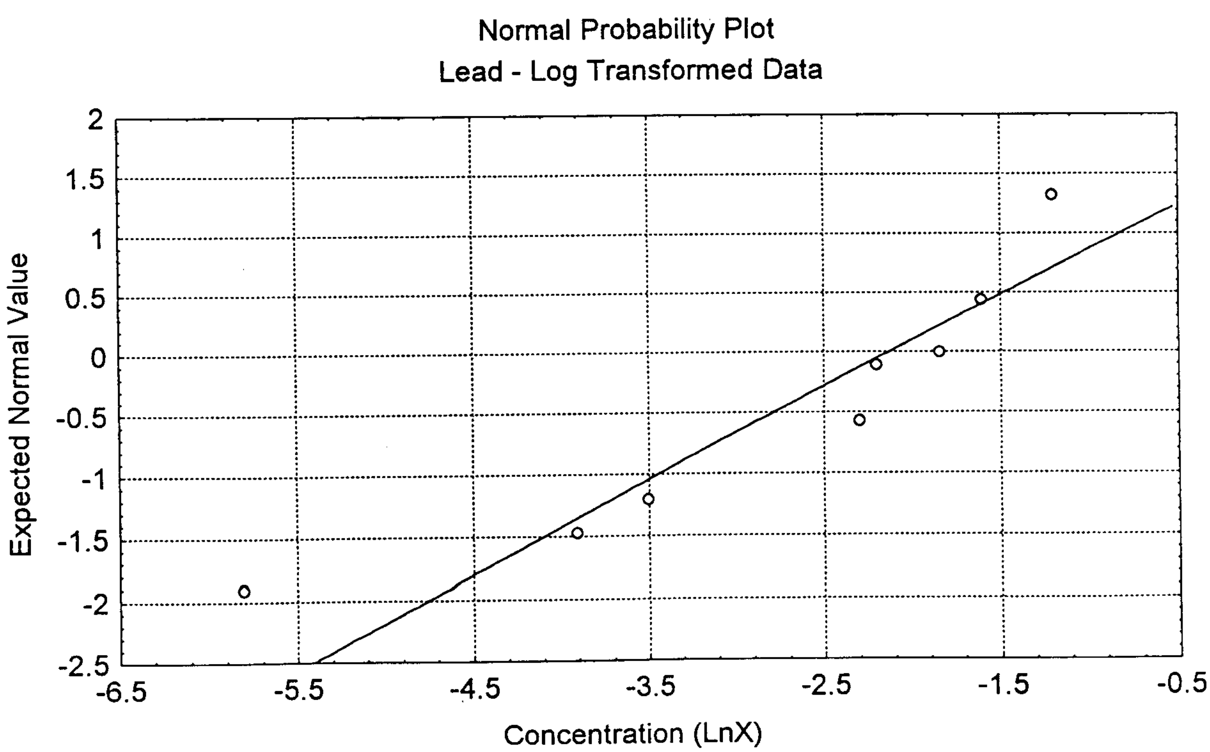
Normal Probability Plot
Chromium - Log Transformed Data




Normal Probability Plot
Iron - Untransformed Data
Outlier Not Considered for Line Fit
Expected Normal Value
2.5
1.5
0.5
-0.5
-1.5
-2.5
-20
20
60
100
140
180
Concentration (mg/L)
Outlier

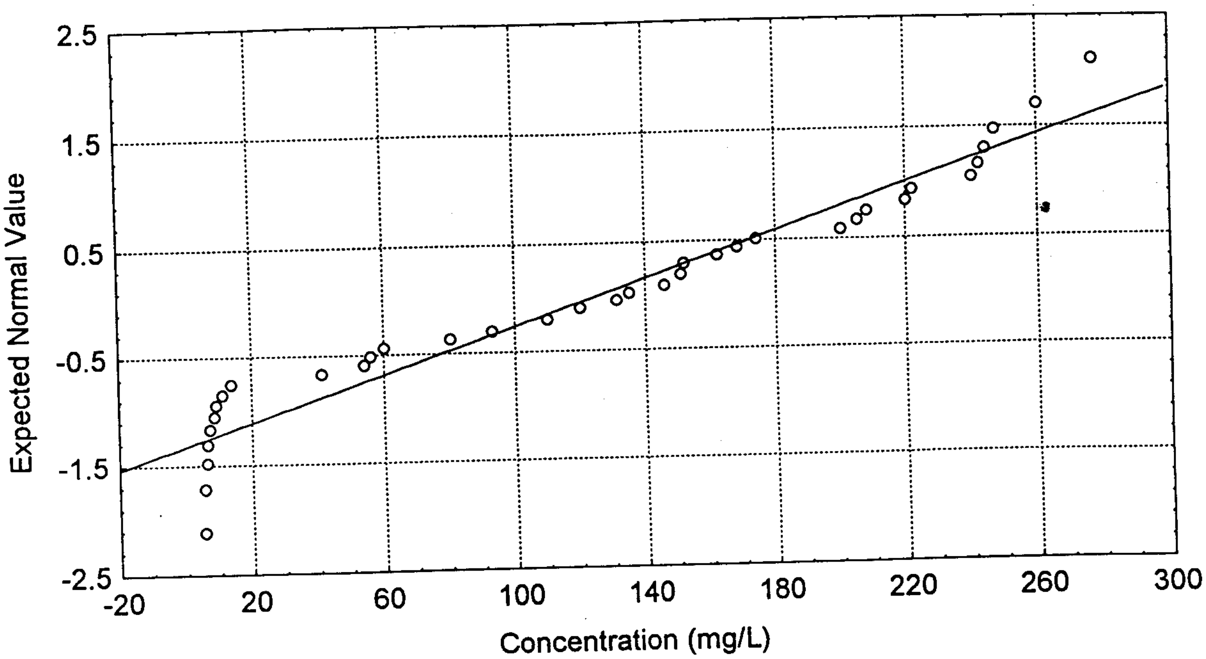

Normal Probability Plot
Iron - Log Transformed Data
Outlier Not Considered for Line Fit
Expected Normal Value
2.5
1.5
0.5
-0.5
-1.5
-2.5
-1
0
1
2
3
4
5
6
Concentration (LnX)
Outlier


Normal Probability Plot
Lead - Untransformed Data
Expected Normal Value
Concentration (mg/L)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-0.02
0.04
0.1
0.16
0.22
0.28
0.34

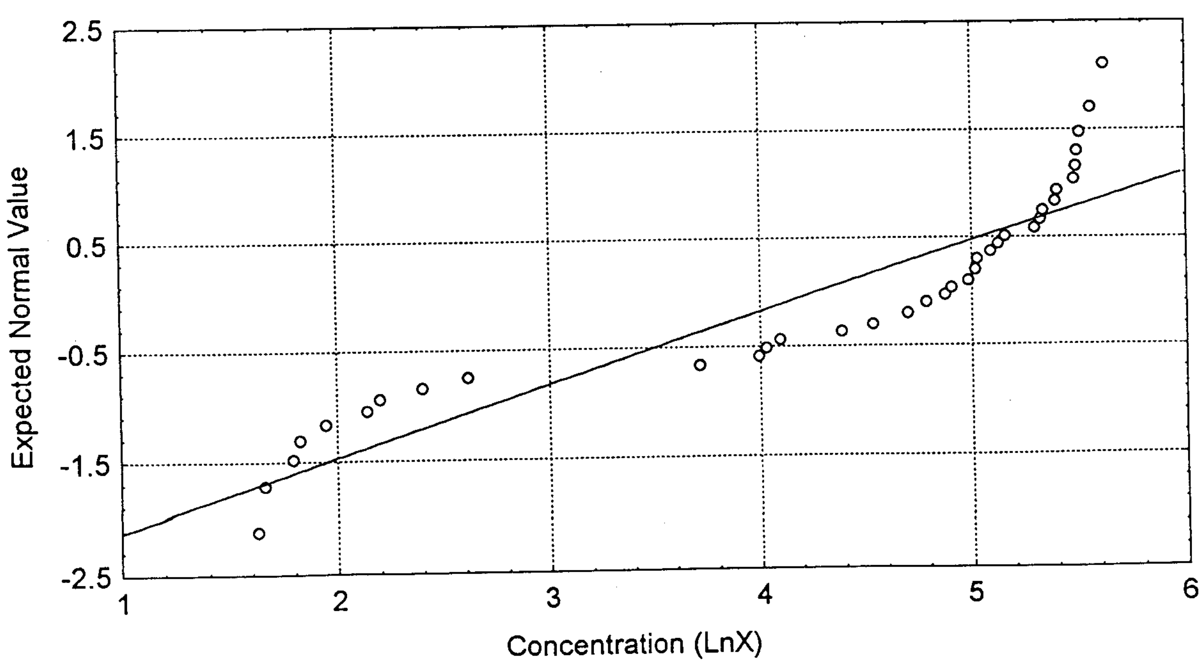

Normal Probability Plot
Lead - Log Transformed Data
Expected Normal Value
Concentration (LnX)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-6.5
-5.5
-4.5
-3.5
-2.5
-1.5
-0.5

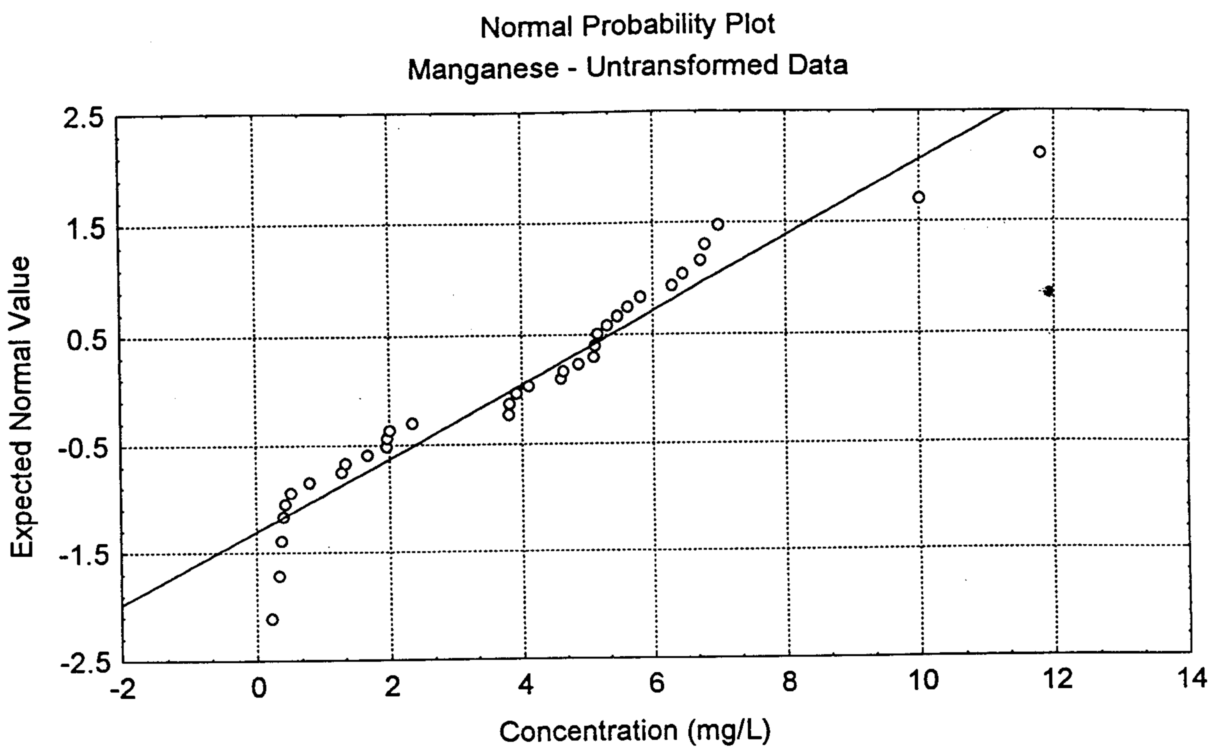
013136

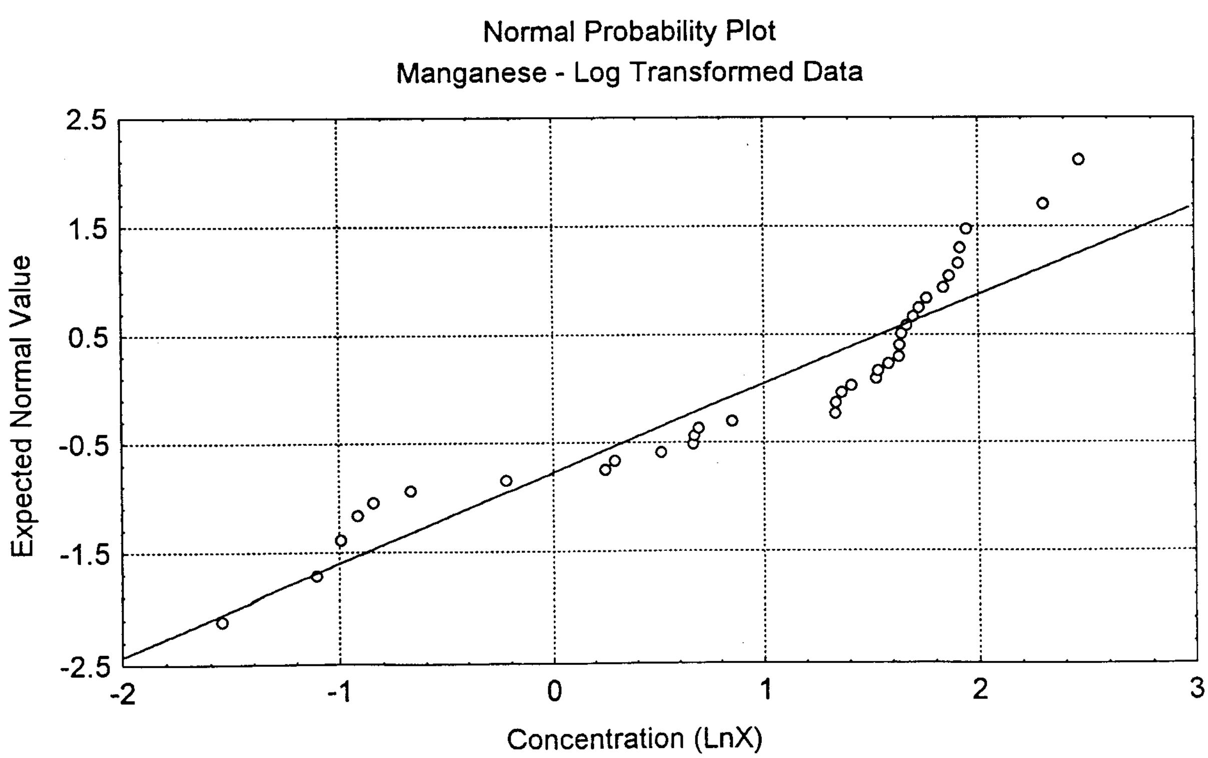
Normal Probability Plot
Magnesium - Untransformed Data

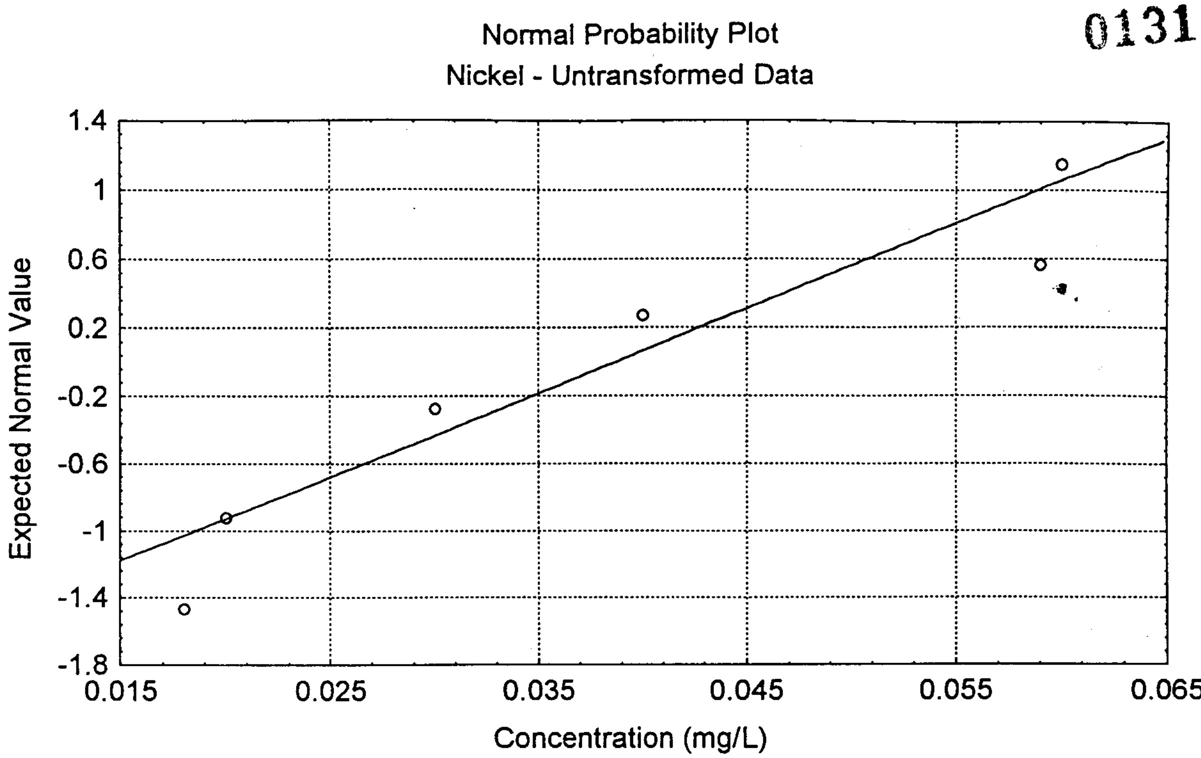


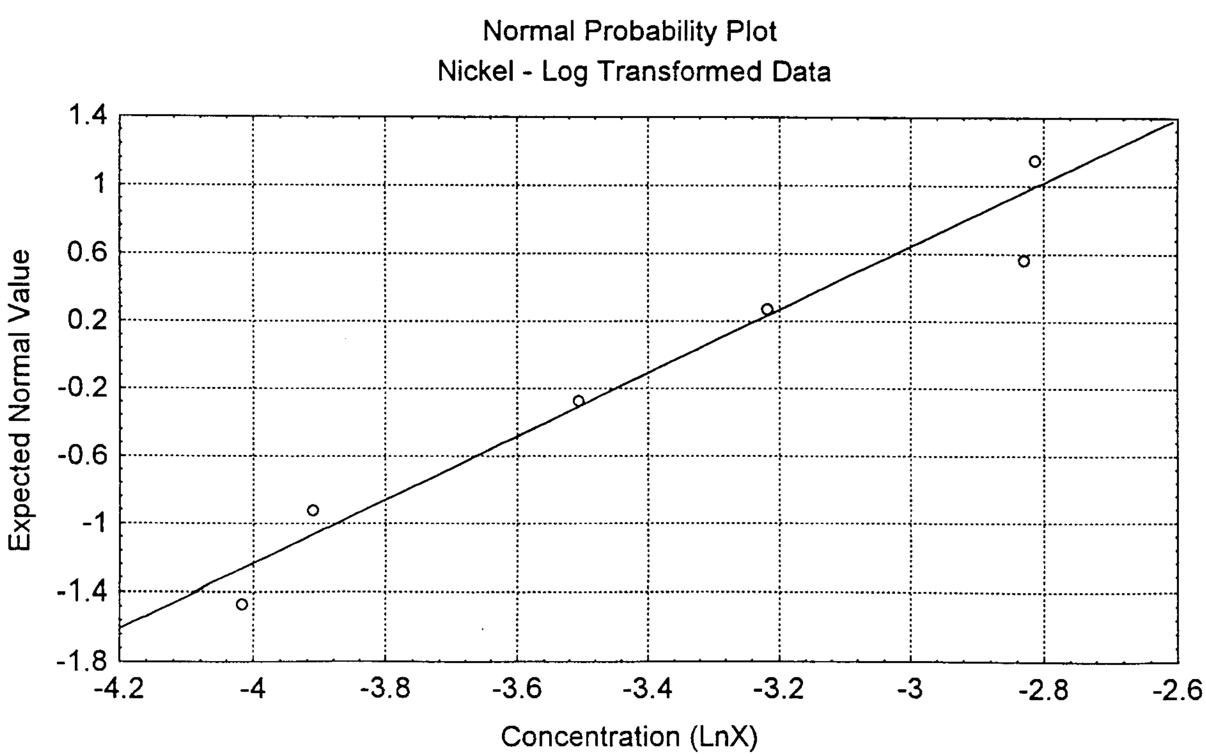
Normal Probability Plot
Magnesium - Log Transformed Data



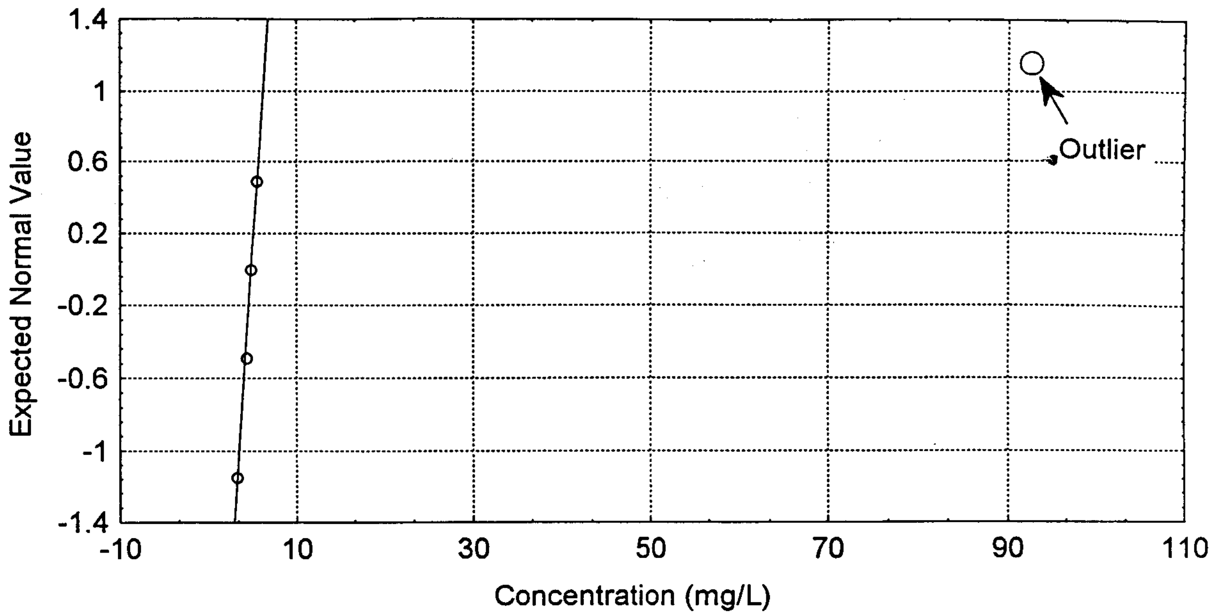

Normal Probability Plot
Manganese - Untransformed Data
Expected Normal Value
Concentration (mg/L)
2.5
1.5
0.5
-0.5
-1.5
-2.5
-2
0
2
4
6
8
10
12
14


Normal Probability Plot
Manganese - Log Transformed Data
Expected Normal Value
Concentration (LnX)
2.5
1.5
0.5
-0.5
-1.5
-2.5
-2
-1
0
1
2
3

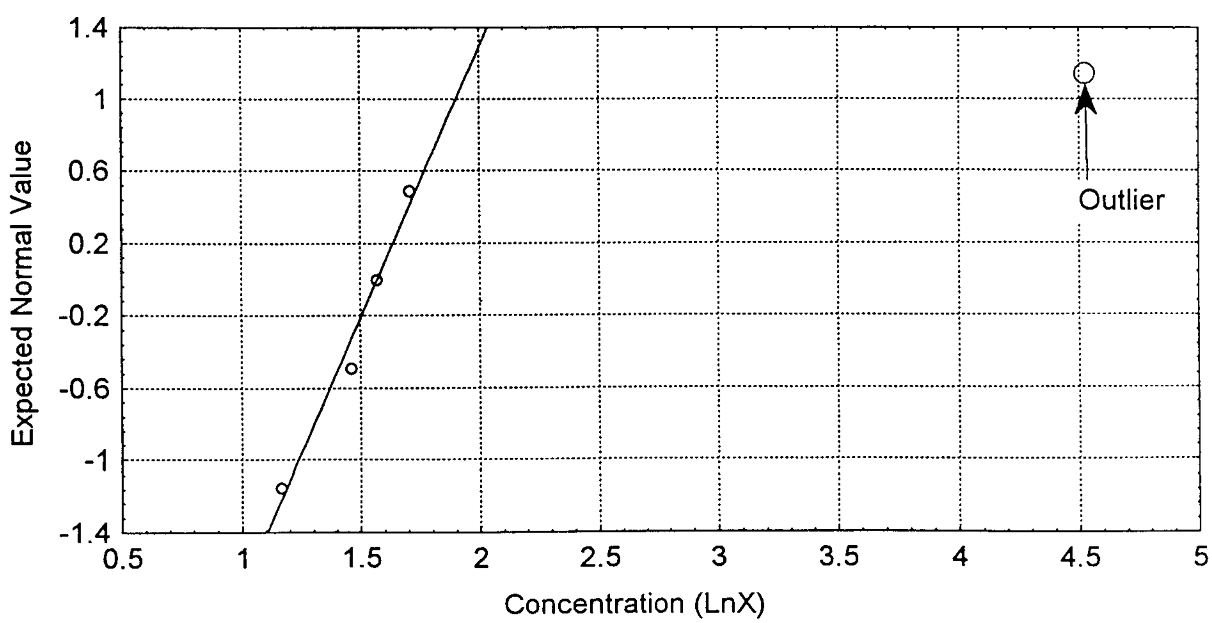

Normal Probability Plot
Nickel - Untransformed Data
Expected Normal Value
1.4
1
0.6
0.2
-0.2
-0.6
-1
-1.4
-1.8
0.015
0.025
0.035
0.045
0.055
0.065
Concentration (mg/L)

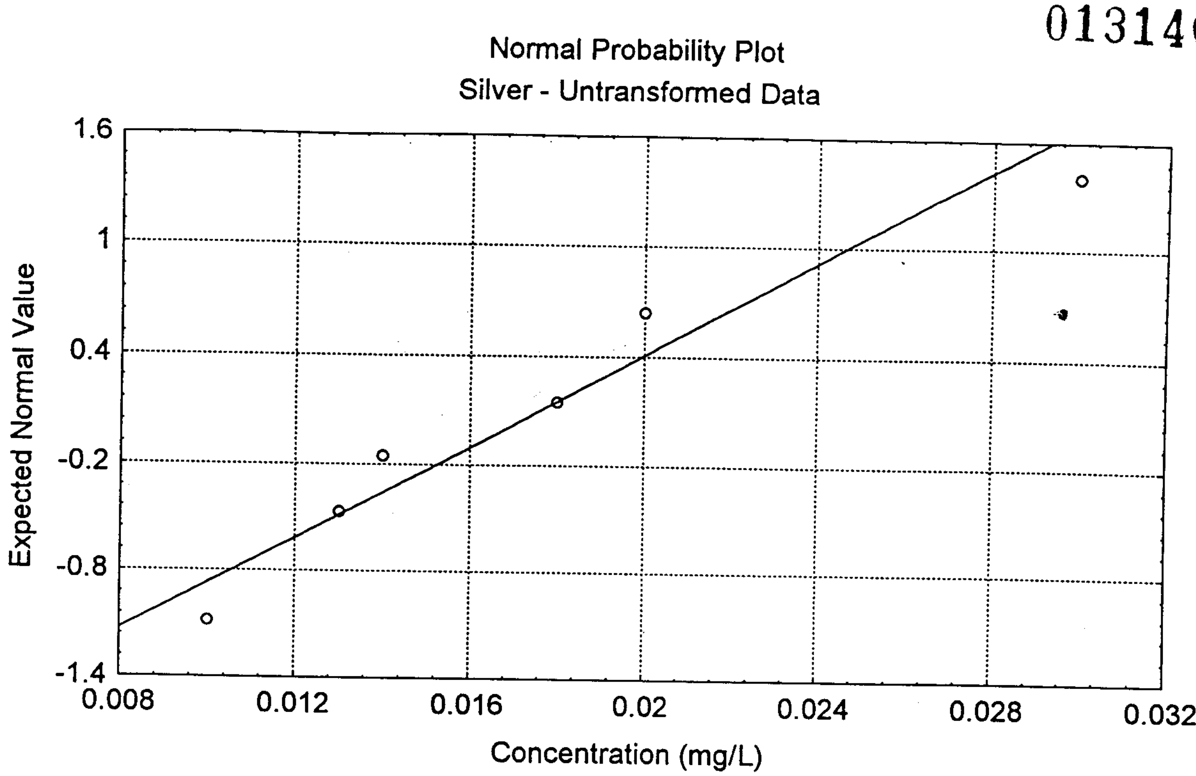

Normal Probability Plot
Nickel - Log Transformed Data
Expected Normal Value
1.4
1
0.6
0.2
-0.2
-0.6
-1
-1.4
-1.8
-4.2
-4
-3.8
-3.6
-3.4
-3.2
-3
-2.8
-2.6
Concentration (LnX)

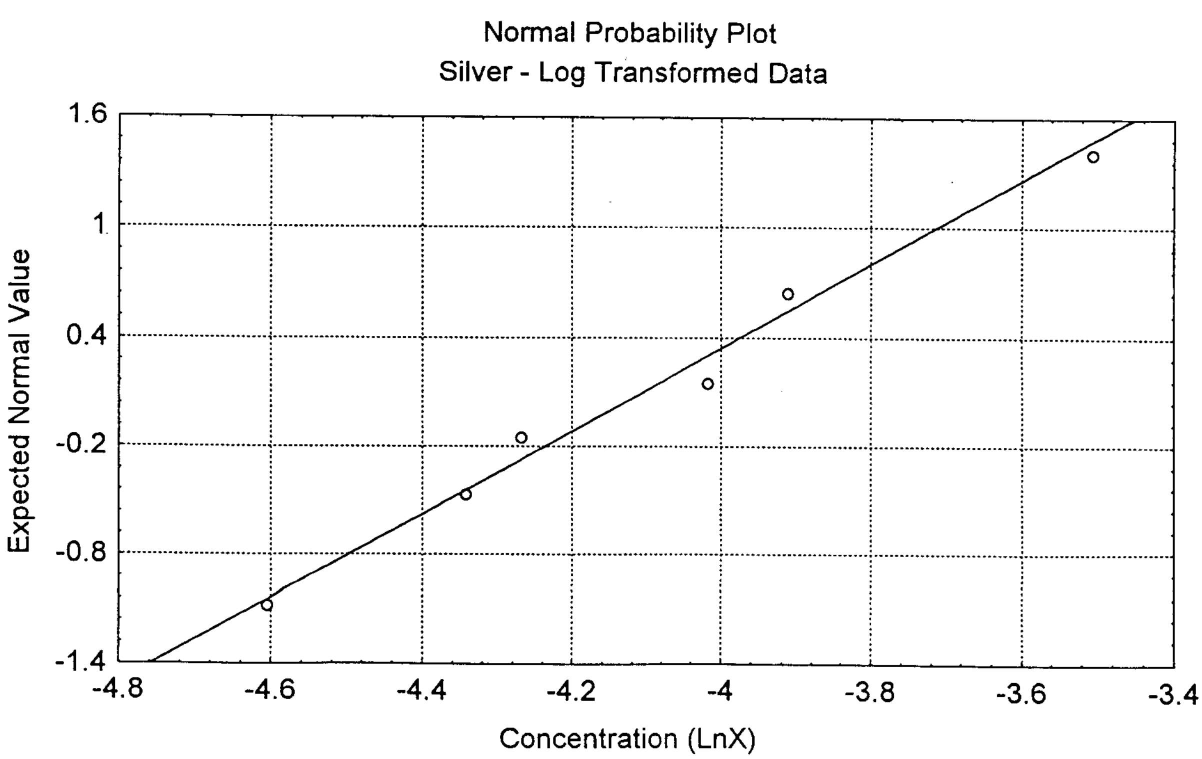
Normal Probability Plot
Potassium - Untransformed Data
Outlier Not Considered for Line Fit

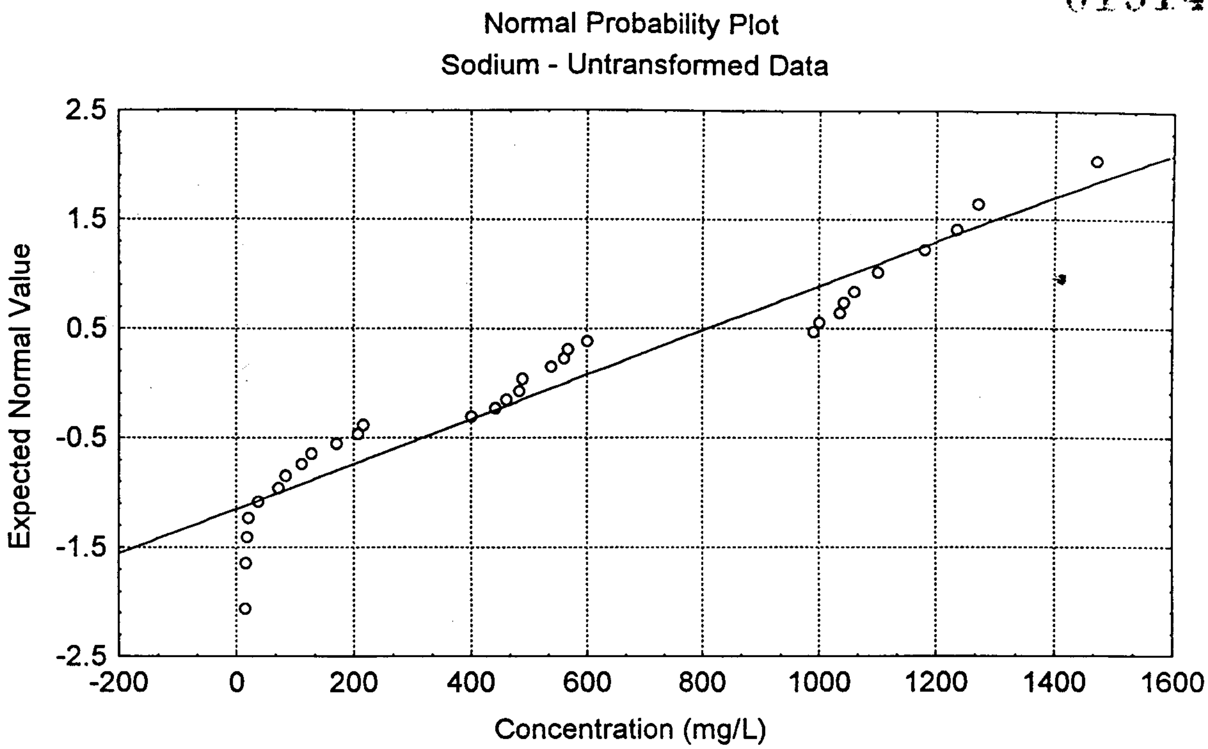


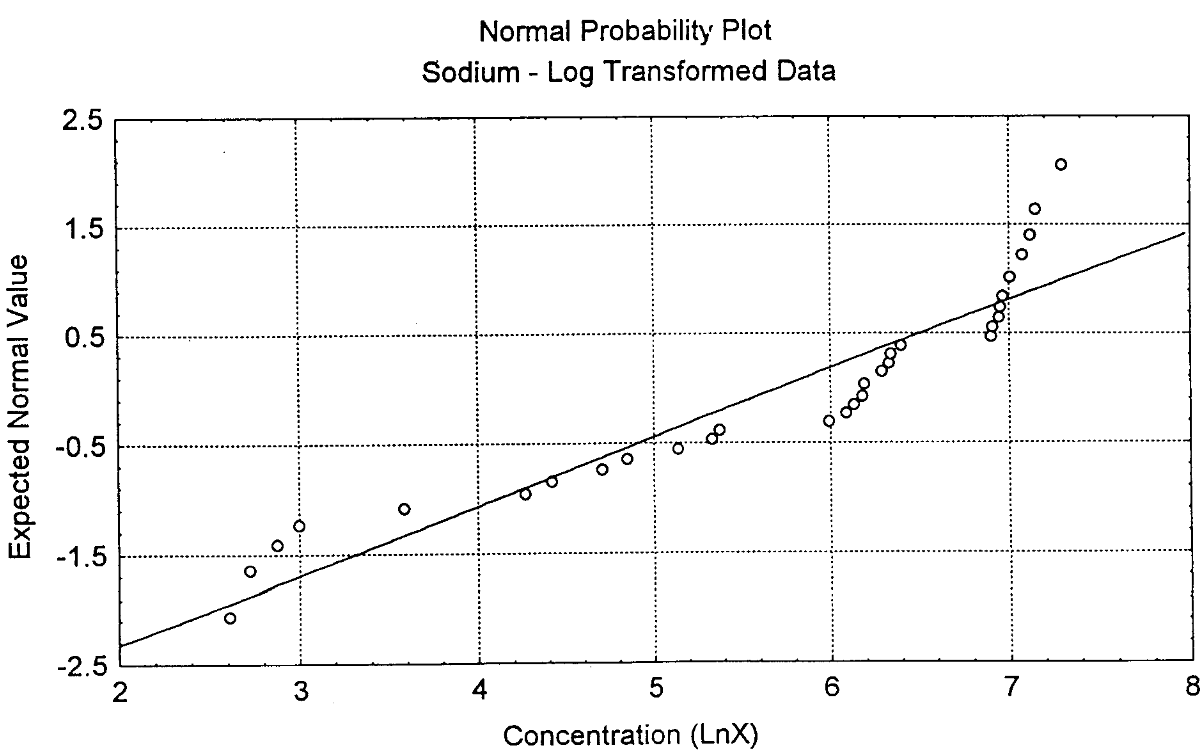
Normal Probability Plot
Potassium - Log Transformed Data
Outlier Not Considered for Line Fit




Normal Probability Plot
Silver - Untransformed Data
Expected Normal Value
1.6
1
0.4
-0.2
-0.8
-1.4
0.008
0.012
0.016
0.02
0.024
0.028
0.032
Concentration (mg/L)

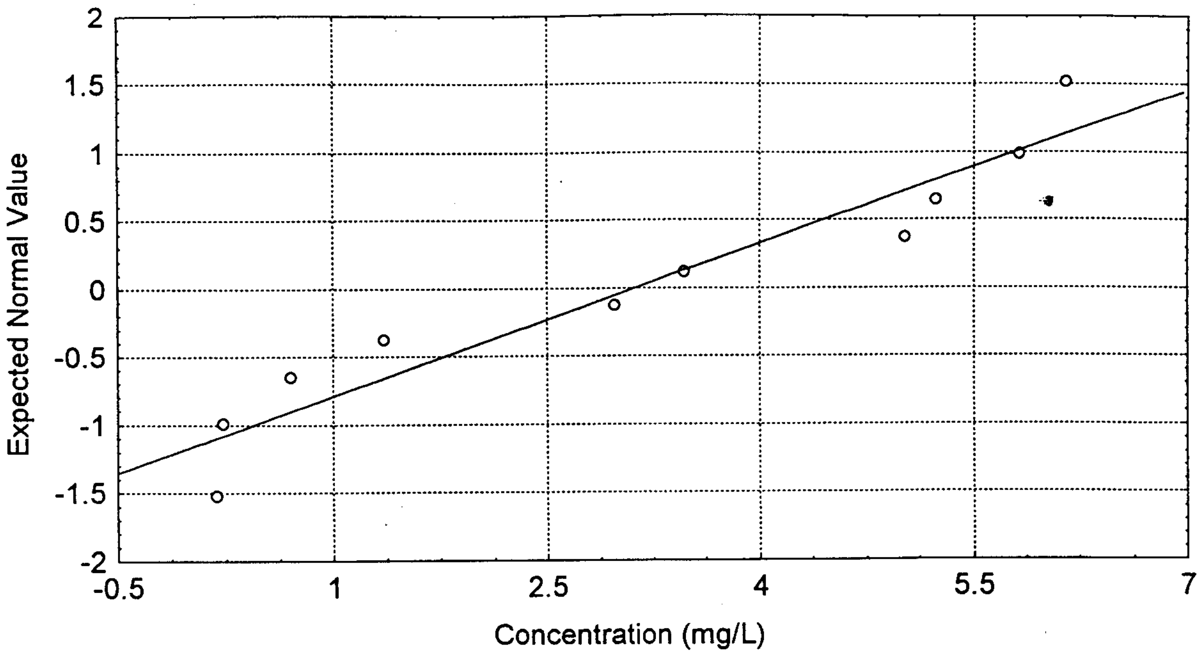

Normal Probability Plot
Silver - Log Transformed Data
Expected Normal Value
1.6
1
0.4
-0.2
-0.8
-1.4
-4.8
-4.6
-4.4
-4.2
-4
-3.8
-3.6
-3.4
Concentration (LnX)


Normal Probability Plot
Sodium - Untransformed Data
Expected Normal Value
2.5
1.5
0.5
-0.5
-1.5
-2.5
-200
0
200
400
600
800
1000
1200
1400
1600
Concentration (mg/L)

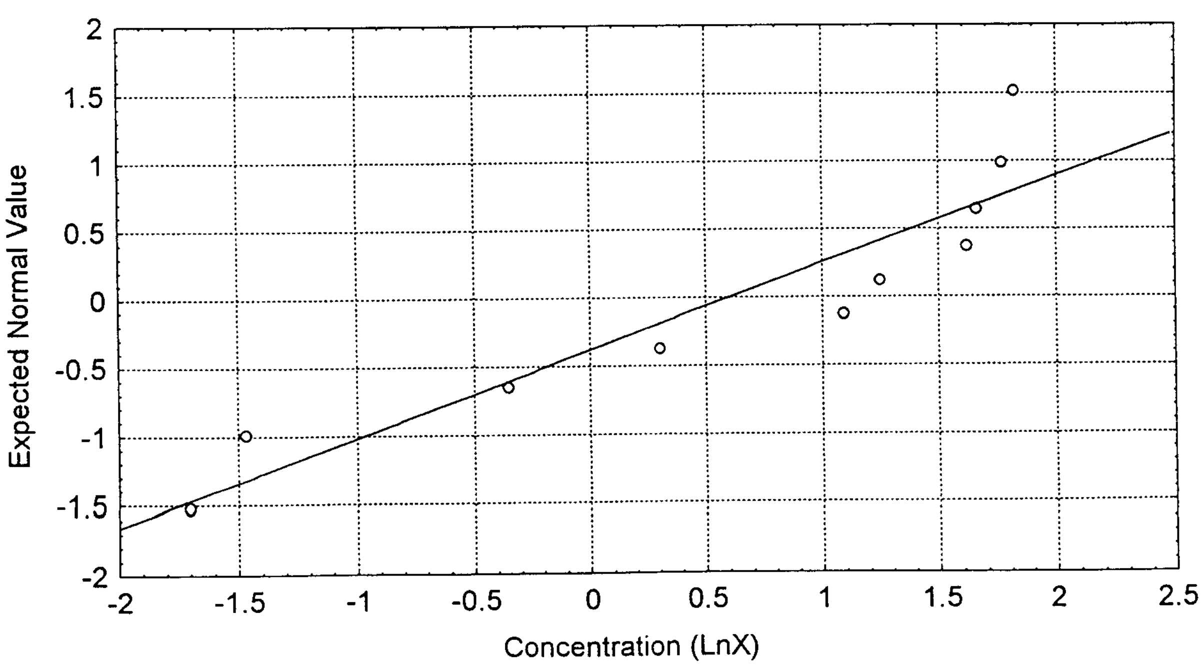

Normal Probability Plot
Sodium - Log Transformed Data
Expected Normal Value
2.5
1.5
0.5
-0.5
-1.5
-2.5
2
3
4
5
6
7
8
Concentration (LnX)

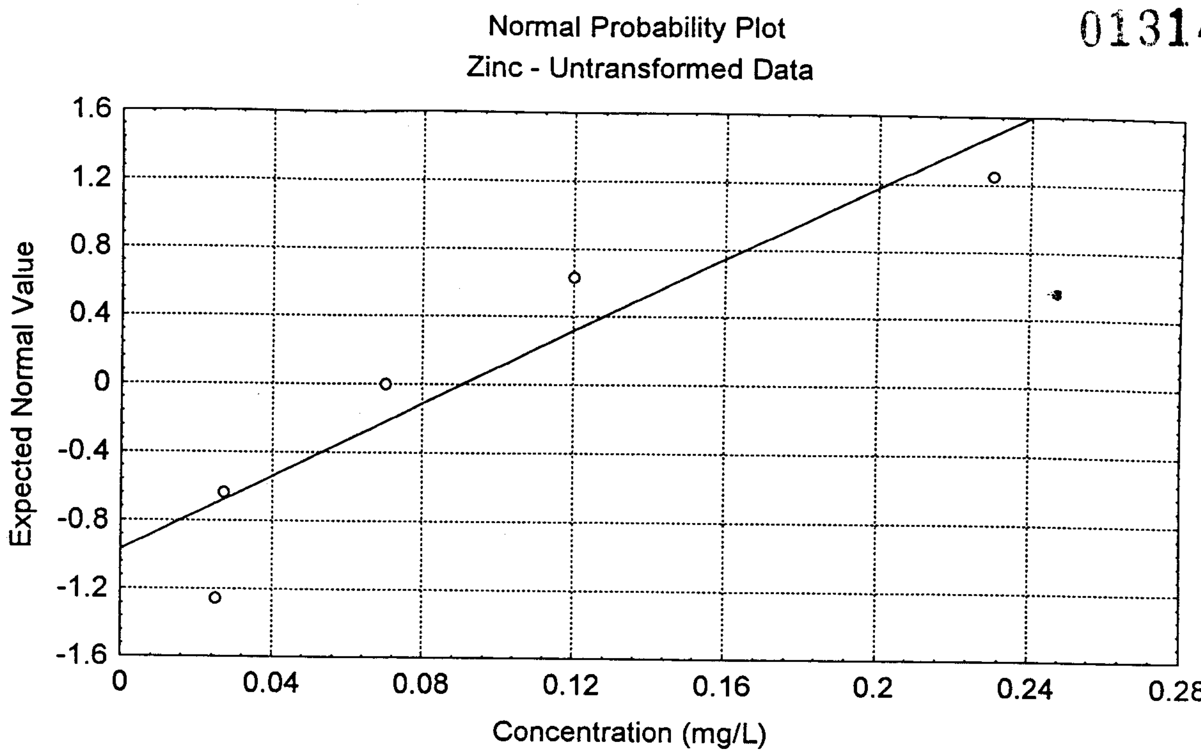
013142

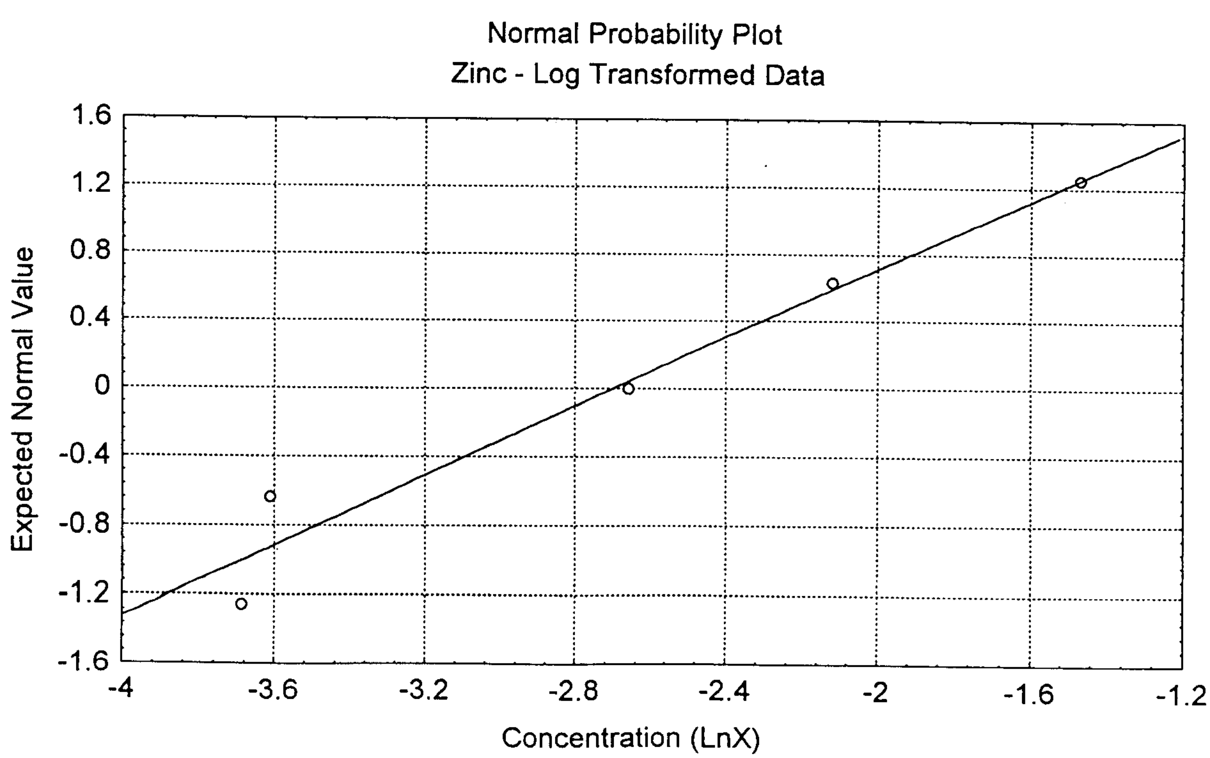
Normal Probability Plot
Strontium - Untransformed Data



Normal Probability Plot
Strontium - Log Transformed Data



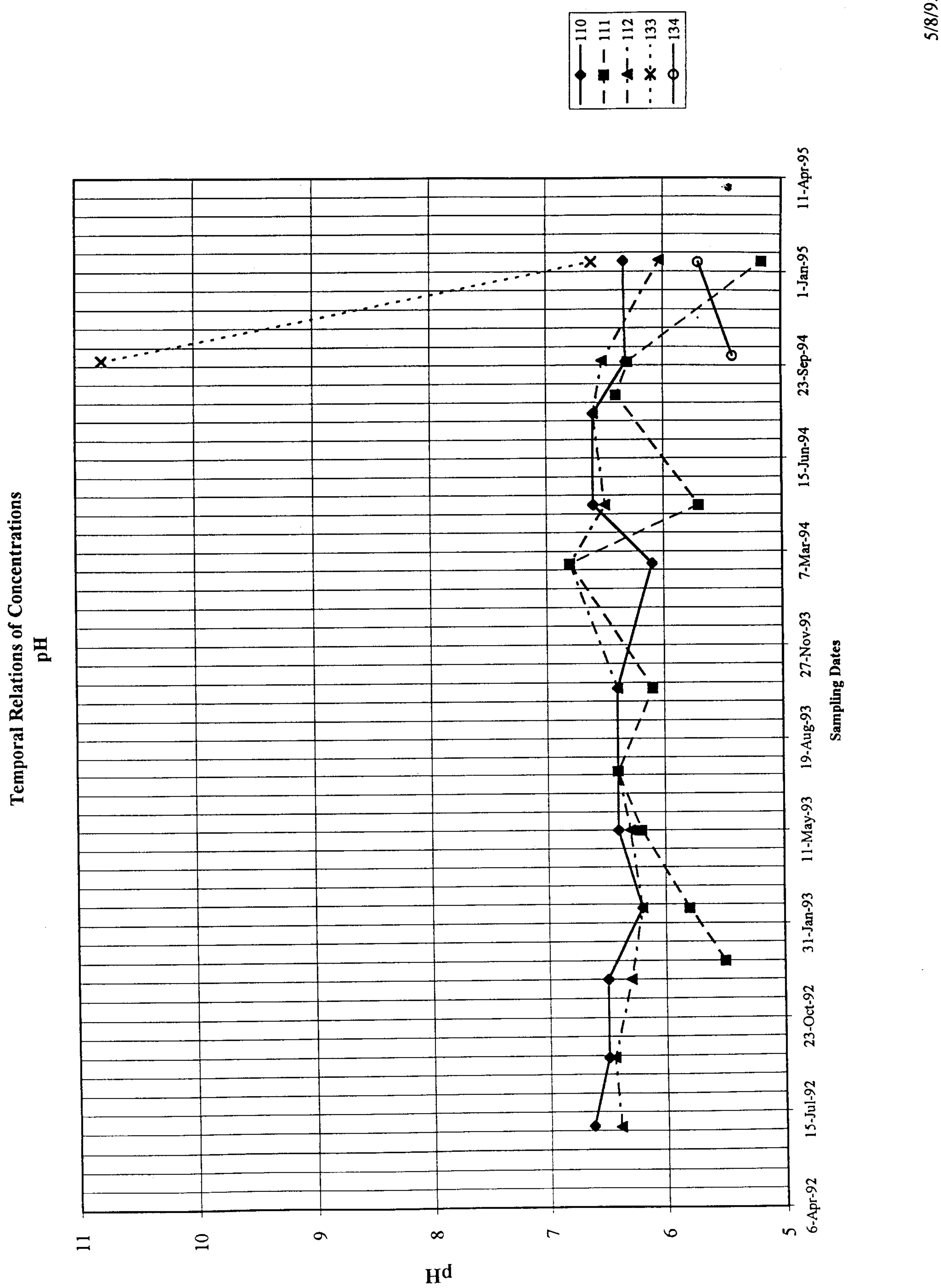

Normal Probability Plot
Zinc - Untransformed Data
Expected Normal Value
1.6
1.2
0.8
0.4
0
-0.4
-0.8
-1.2
-1.6
0
0.04
0.08
0.12
0.16
0.2
0.24
0.28
Concentration (mg/L)


Normal Probability Plot
Zinc - Log Transformed Data
Expected Normal Value
1.6
1.2
0.8
0.4
0
-0.4
-0.8
-1.2
-1.6
-4
-3.6
-3.2
-2.8
-2.4
-2
-1.6
-1.2
Concentration (LnX)

Appendix F

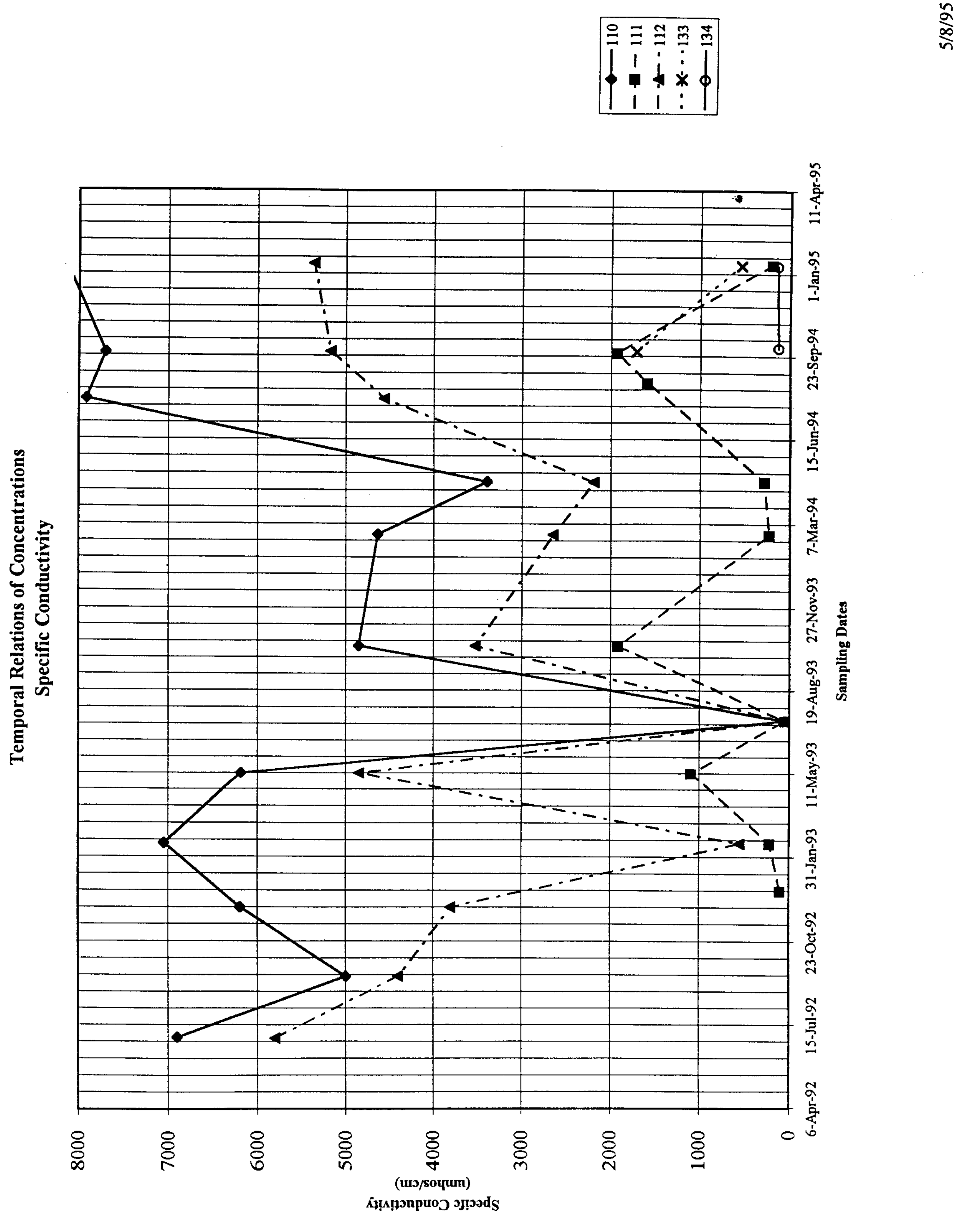
Temporal Plots of Water Quality Parameters and Chemical Concentrations in Background Monitoring Wells

013145



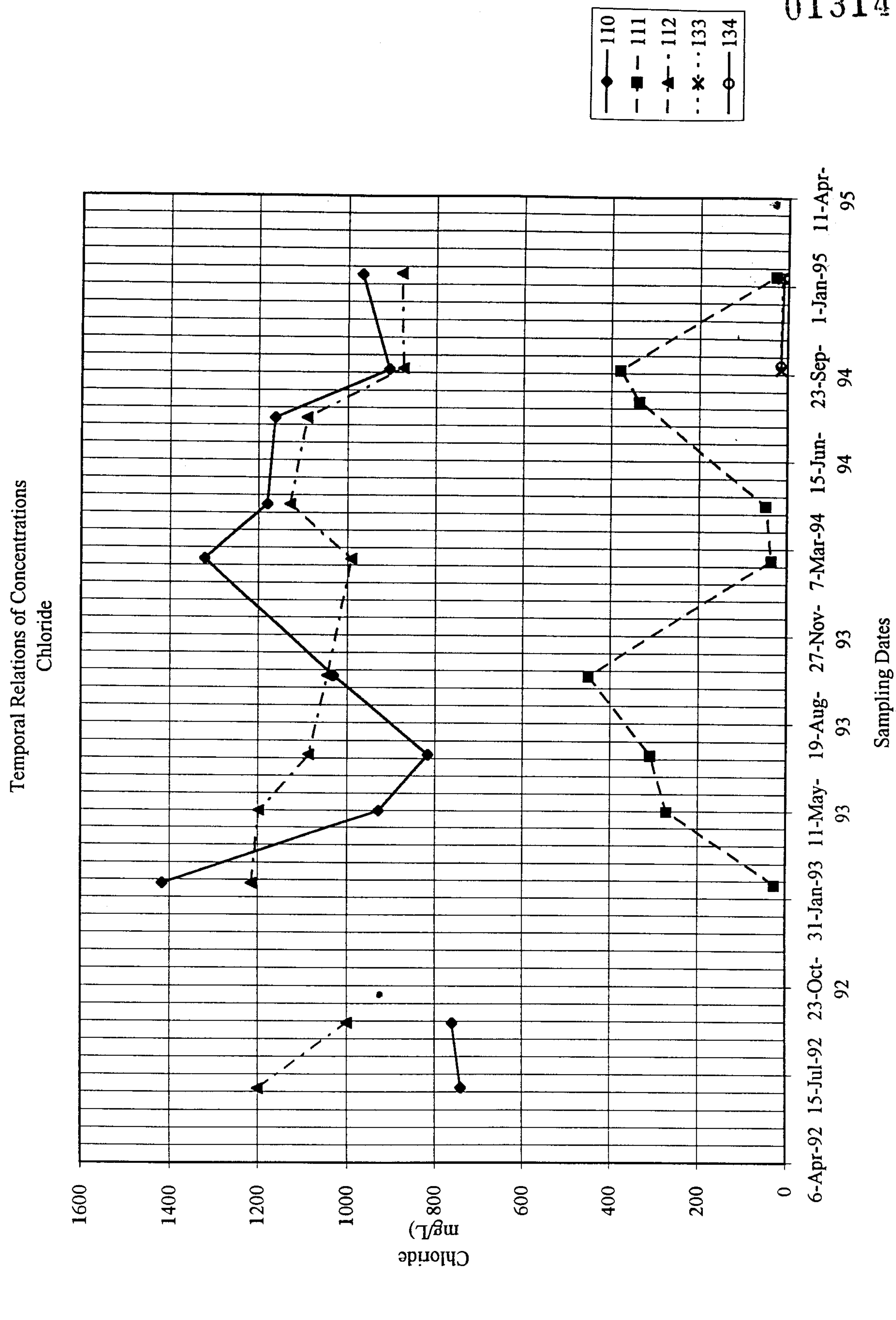
Temporal Relations of Concentrations
pH
110
111
112
133
134
pH
11
10
9
8
7
6
5
6-Apr-92
15-Jul-92
23-Oct-92
31-Jan-93
11-May-93
19-Aug-93
27-Nov-93
7-Mar-94
15-Jun-94
23-Sep-94
1-Jan-95
11-Apr-95
Sampling Dates
5/8/95

5/8/95


Temporal Relations of Concentrations
Specific Conductivity
110
111
112
133
134
Specific Conductivity
(umhos/cm)
0
1000
2000
3000
4000
5000
6000
7000
8000
Sampling Dates
6-Apr-92
15-Jul-92
23-Oct-92
31-Jan-93
11-May-93
19-Aug-93
27-Nov-93
7-Mar-94
15-Jun-94
23-Sep-94
1-Jan-95
11-Apr-95

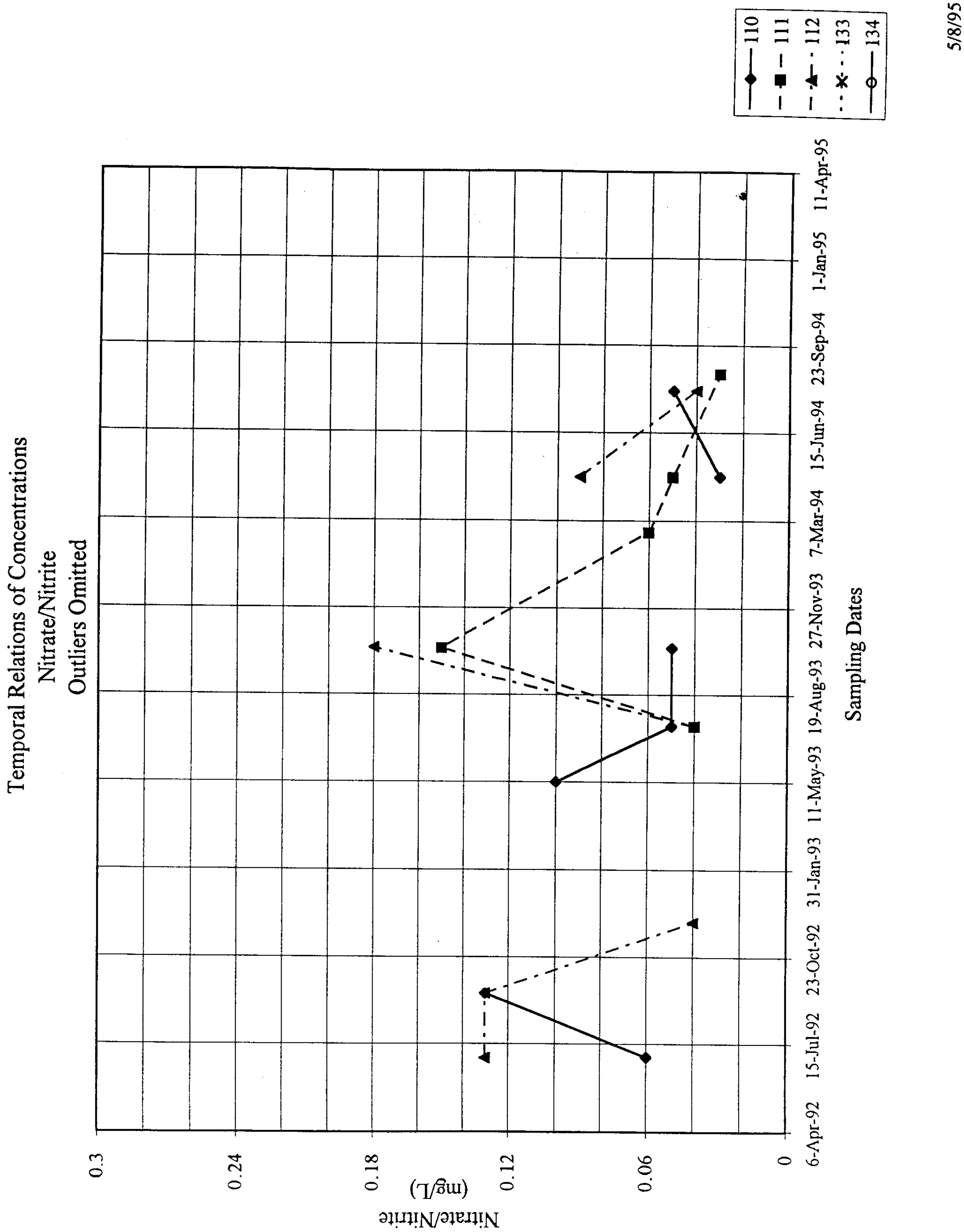
013147

5/8/95

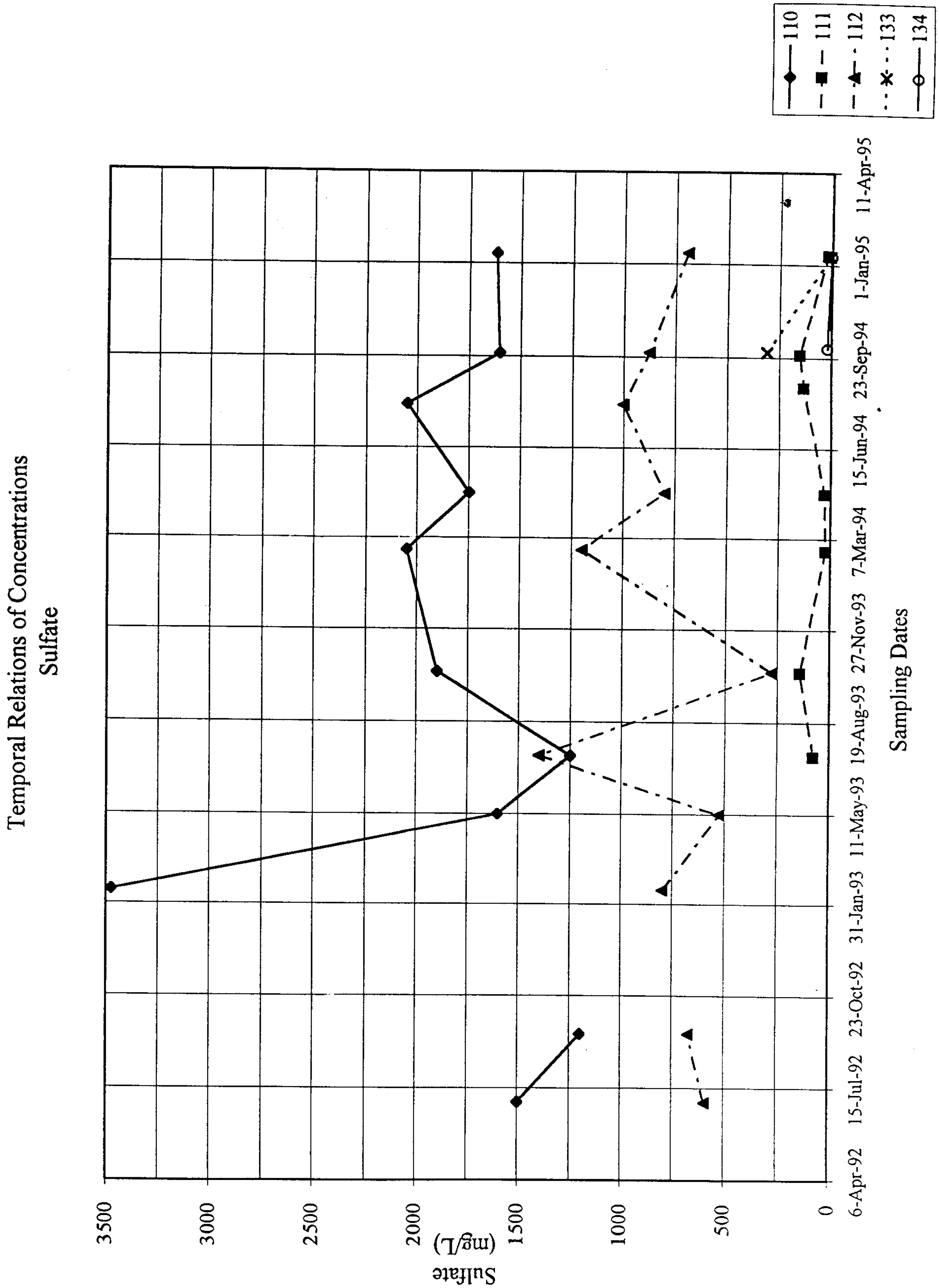


Temporal Relations of Concentrations
Chloride
Chloride mg/L)
1600
1400
1200
1000
800
600
400
200
0
6-Apr-92
15-Jul-92
23-Oct-92
31-Jan-93
11-May-93
19-Aug-93
27-Nov-93
7-Mar-94
15-Jun-94
23-Sep-94
1-Jan-95
11-Apr-95
Sampling Dates
110
111
112
133
134

013146


Temporal Relations of Concentrations
Nitrate/Nitrite
Outliers Omitted
Nitrate/Nitrite (mg/L)
0
0.06
0.12
0.18
0.24
0.3
6-Apr-92
15-Jul-92
23-Oct-92
31-Jan-93
11-May-93
19-Aug-93
27-Nov-93
7-Mar-94
15-Jun-94
23-Sep-94
1-Jan-95
11-Apr-95
Sampling Dates
110
111
112
133
134
5/8/95

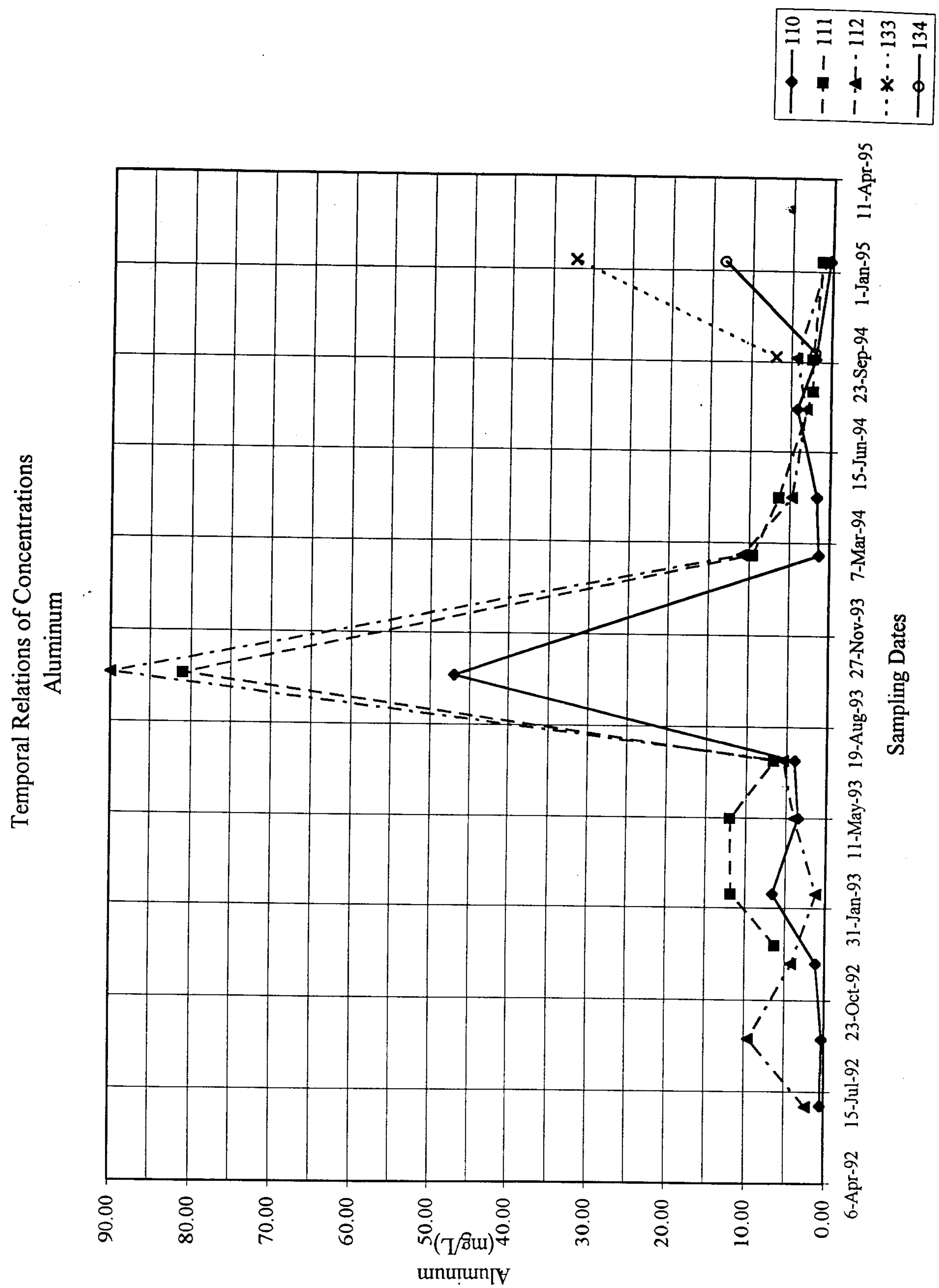
013149



Temporal Relations of Concentrations
Sulfate
Sulfate (mg/L)
0
500
1000
1500
2000
2500
3000
3500
6-Apr-92
15-Jul-92
23-Oct-92
31-Jan-93
11-May-93
19-Aug-93
27-Nov-93
7-Mar-94
15-Jun-94
23-Sep-94
1-Jan-95
11-Apr-95
Sampling Dates
110
111
112
133
134

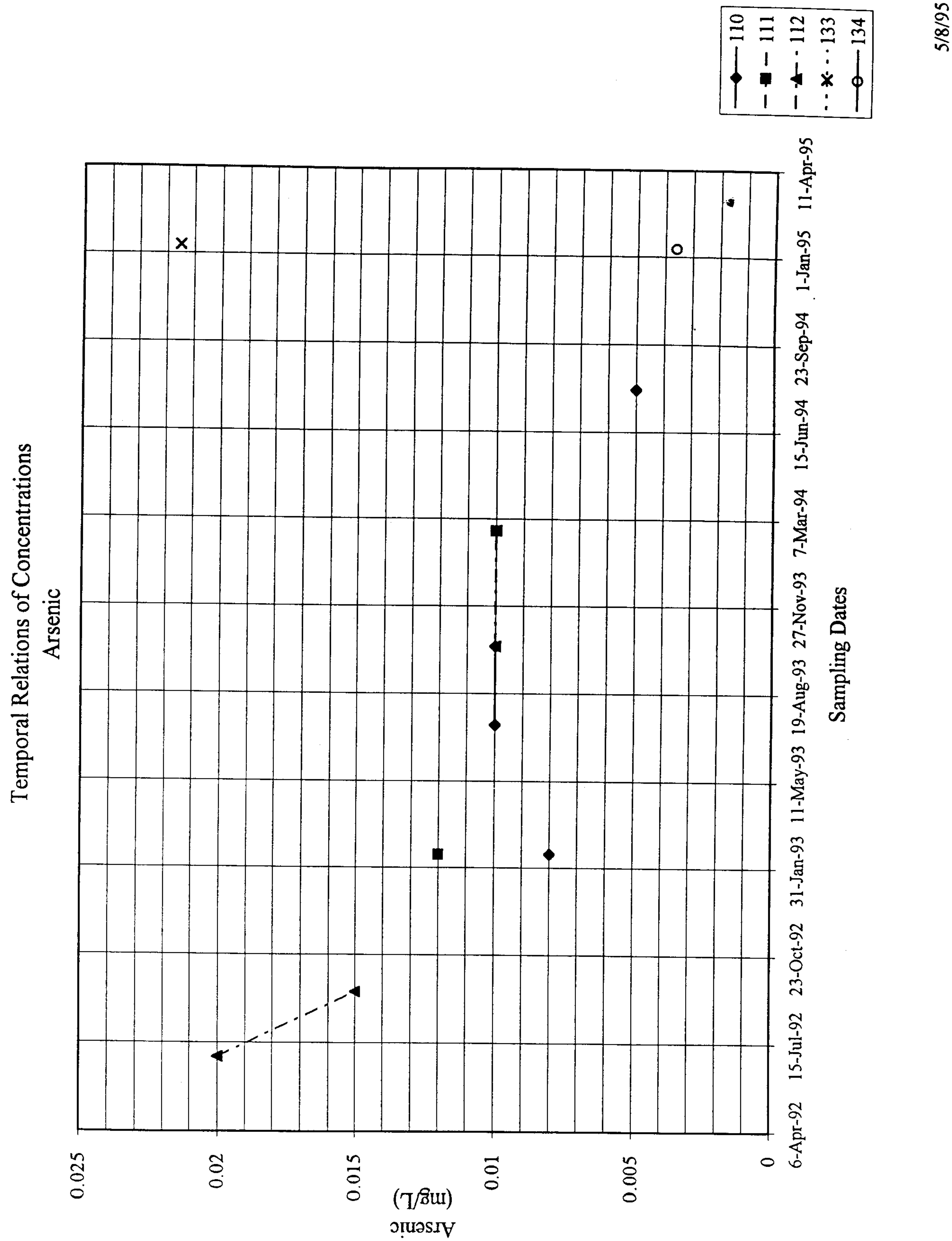
5/8/95

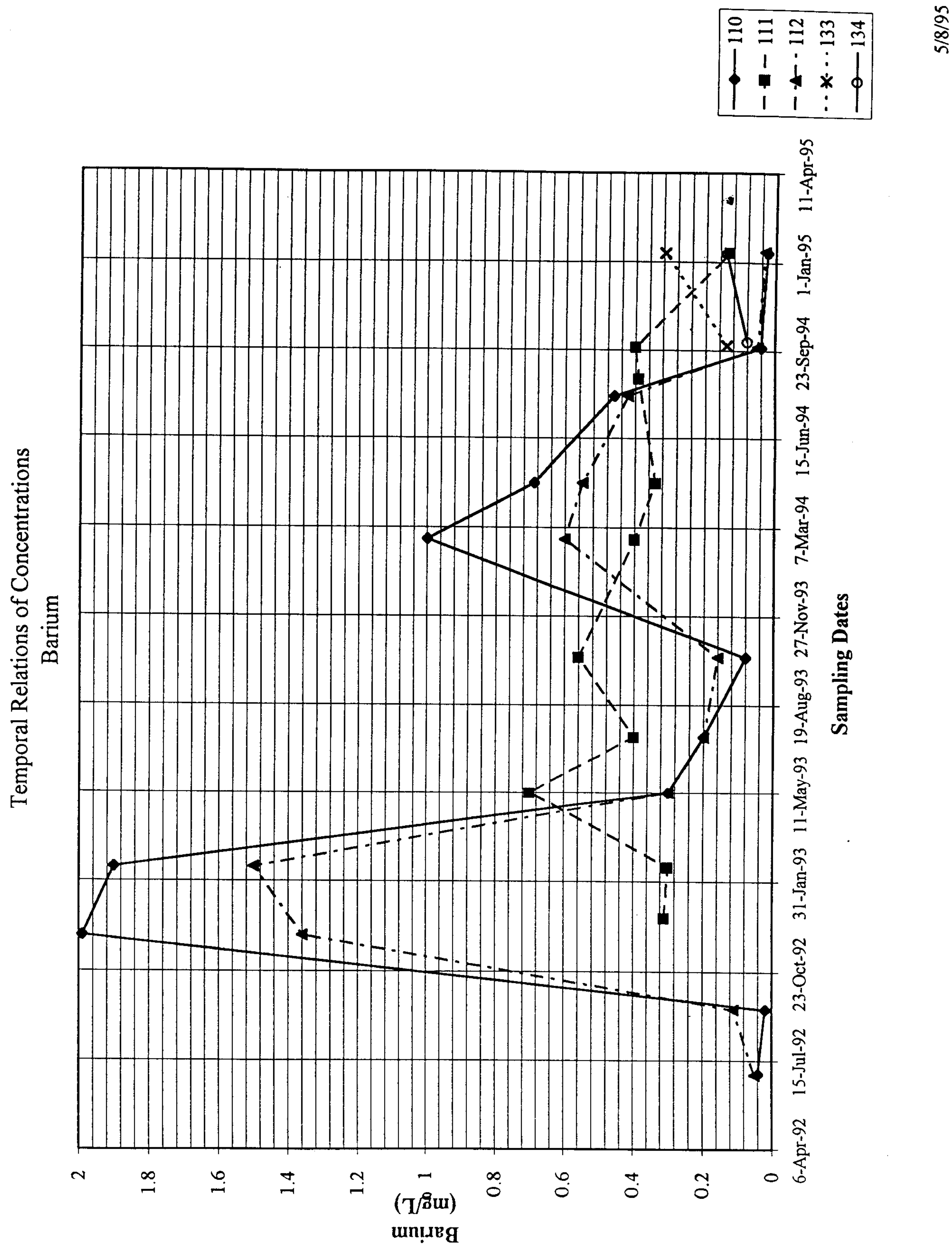
013150



Temporal Relations of Concentrations
Aluminum
Aluminum (mg/L)
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
6-Apr-92
15-Jul-92
23-Oct-92
31-Jan-93
11-May-93
19-Aug-93
27-Nov-93
7-Mar-94
15-Jun-94
23-Sep-94
1-Jan-95
11-Apr-95
Sampling Dates
110
111
112
133
134

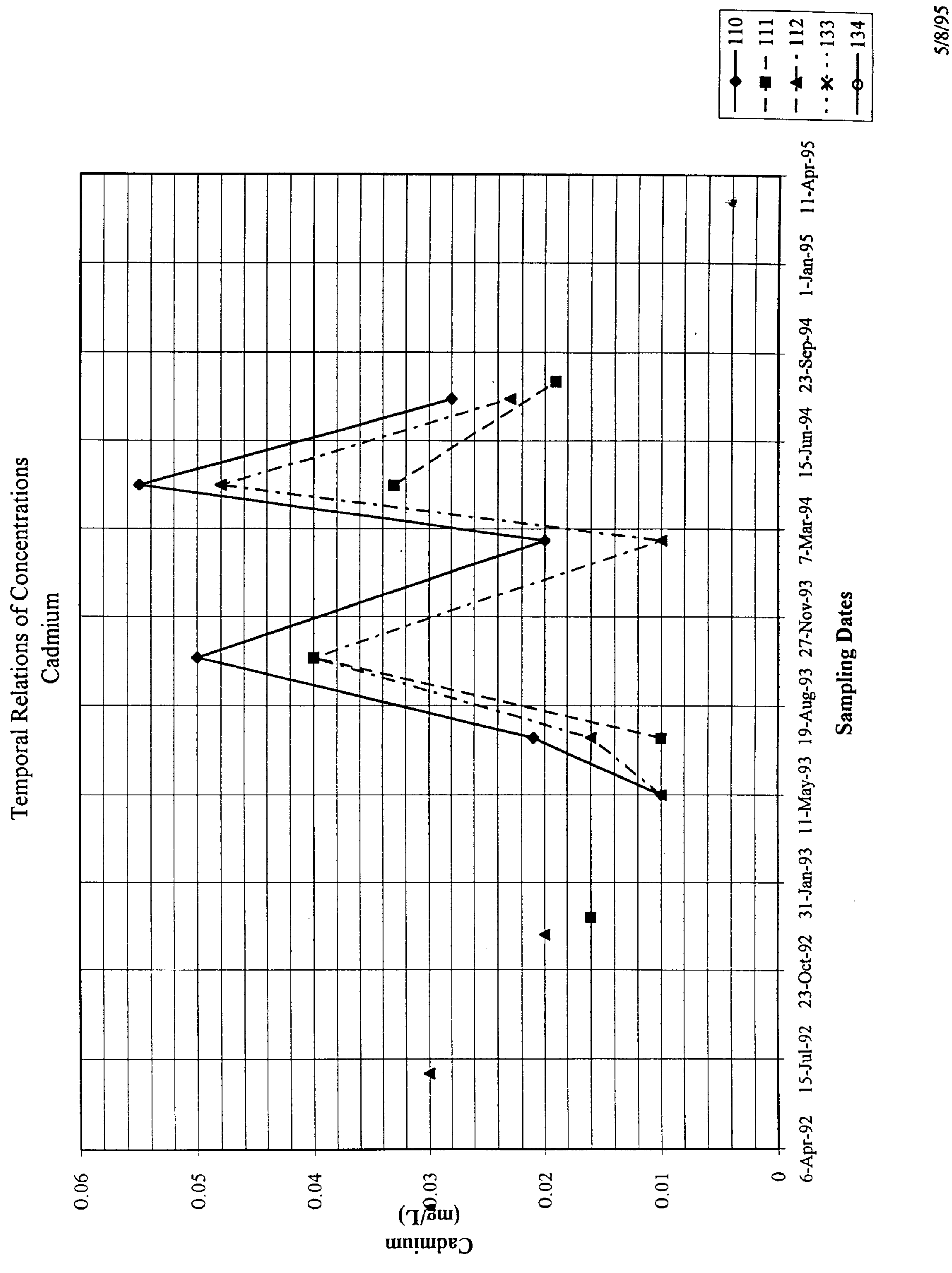
5/8/95


Temporal Relations of Concentrations
Arsenic
Arsenic
(mg/L)
0.025
0.02
0.015
0.01
0.005
0
6-Apr-92
15-Jul-92
23-Oct-92
31-Jan-93
11-May-93
19-Aug-93
27-Nov-93
7-Mar-94
15-Jun-94
23-Sep-94
1-Jan-95
11-Apr-95
Sampling Dates
110
111
112
133
134
5/8/95

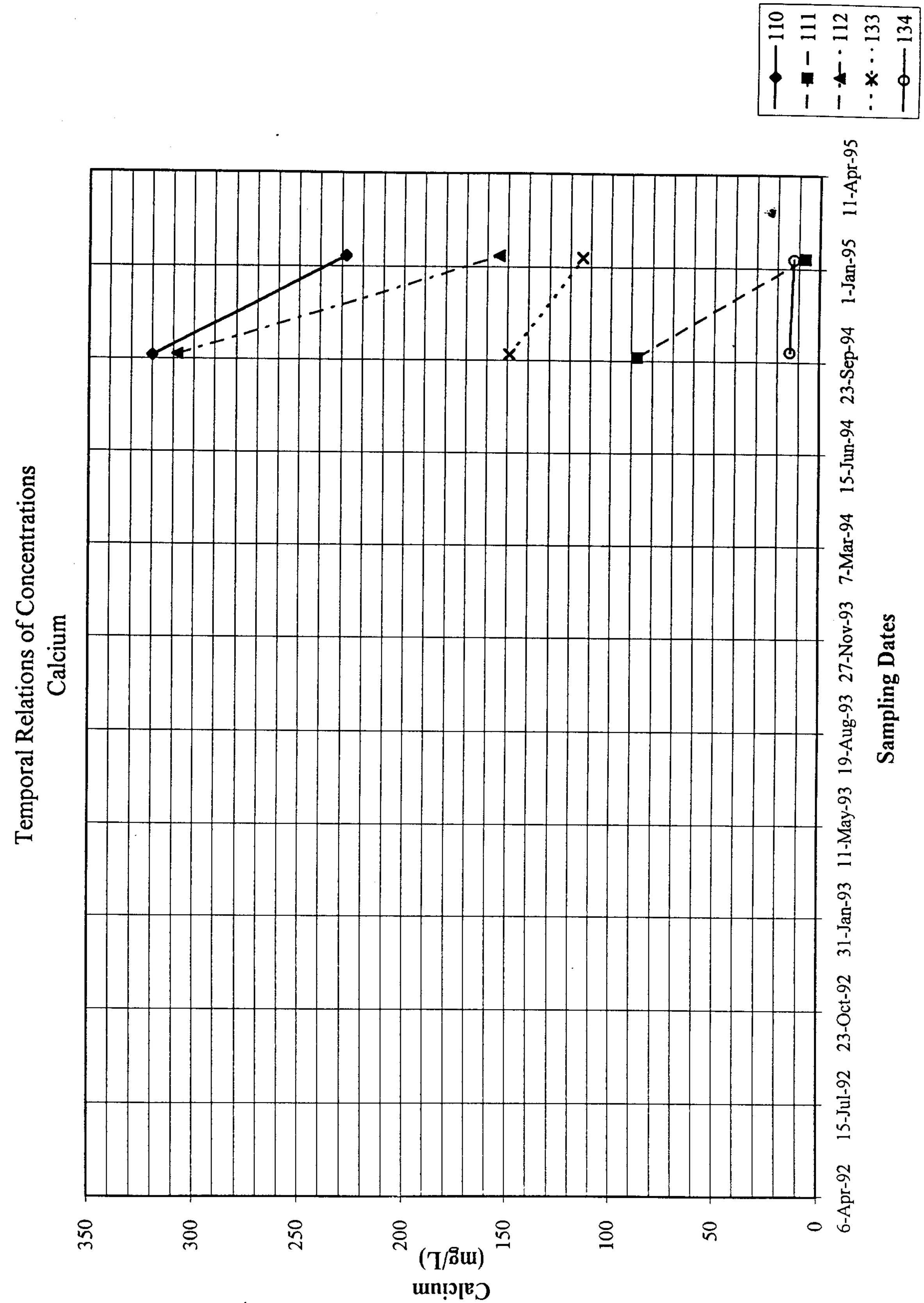


Temporal Relations of Concentrations
Barium
Barium (mg/L)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
6-Apr-92
15-Jul-92
23-Oct-92
31-Jan-93
11-May-93
19-Aug-93
27-Nov-93
7-Mar-94
15-Jun-94
23-Sep-94
1-Jan-95
11-Apr-95
Sampling Dates
110
111
112
133
134
5/8/95

013153

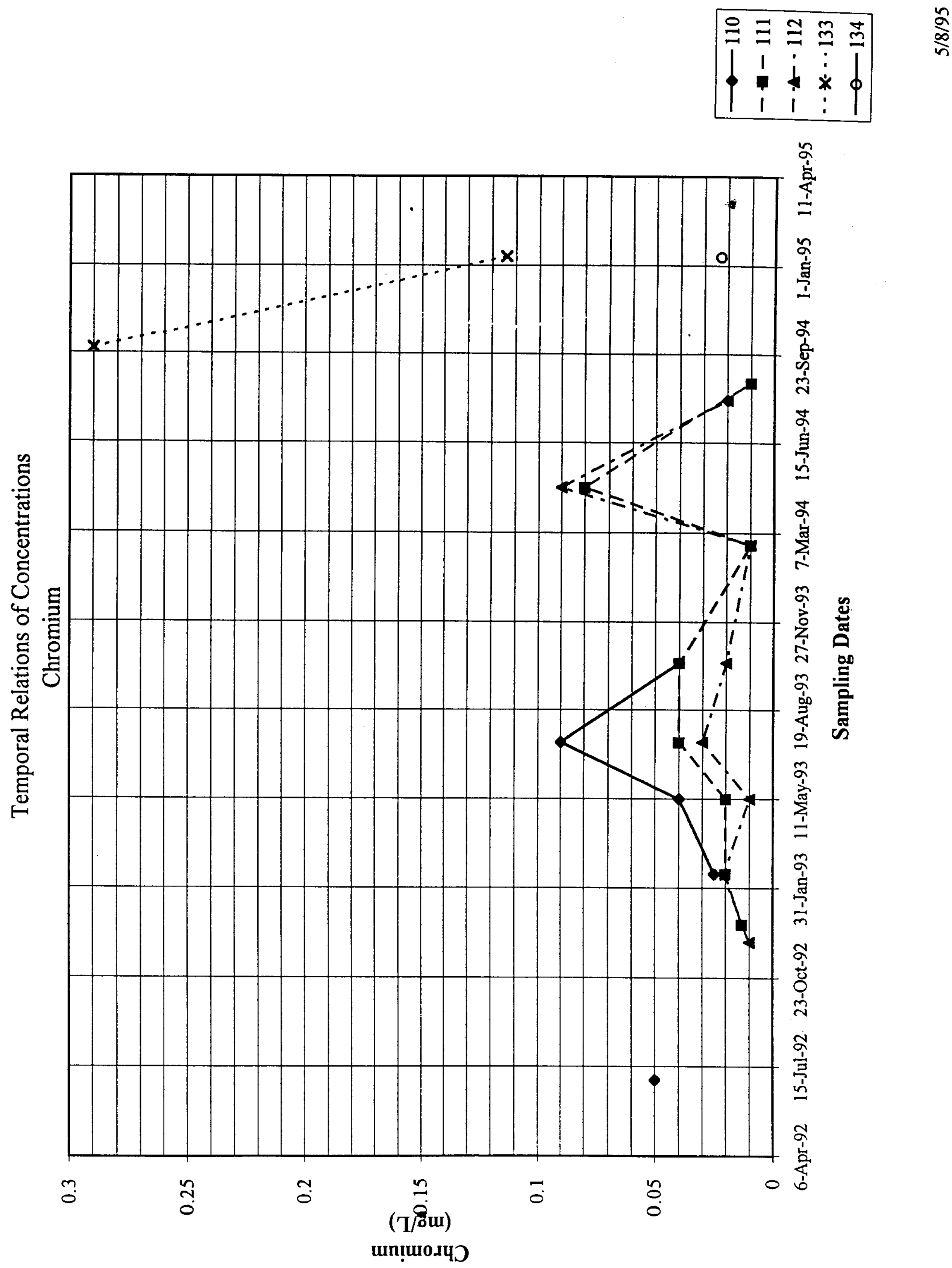

Temporal Relations of Concentrations
Cadmium
Cadmium
(mg/L)
0.06
0.05
0.04
0.03
0.02
0.01
0
6-Apr-92
15-Jul-92
23-Oct-92
31-Jan-93
11-May-93
19-Aug-93
27-Nov-93
7-Mar-94
15-Jun-94
23-Sep-94
1-Jan-95
11-Apr-95
Sampling Dates
110
111
112
133
134
5/8/95

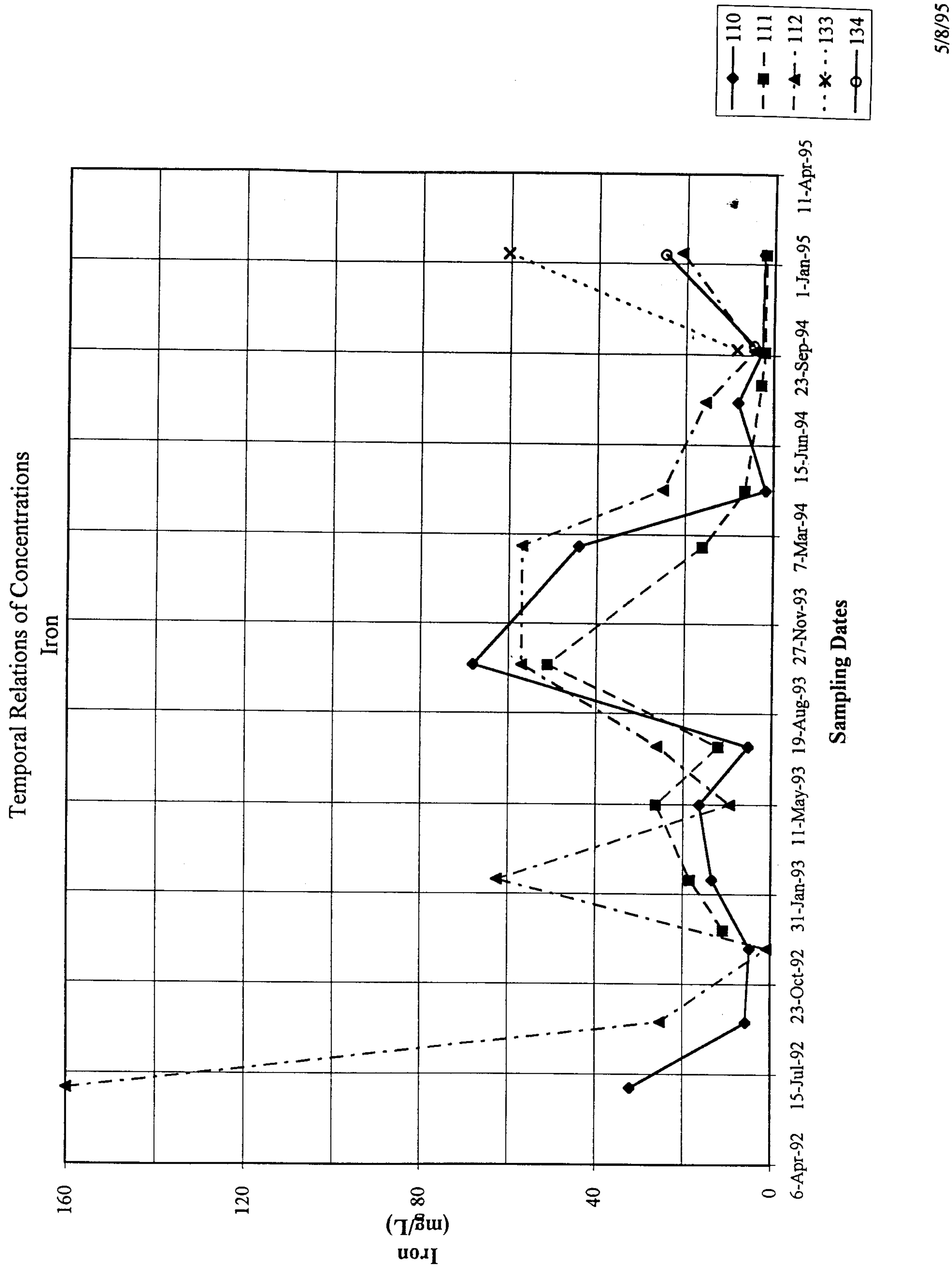
013154

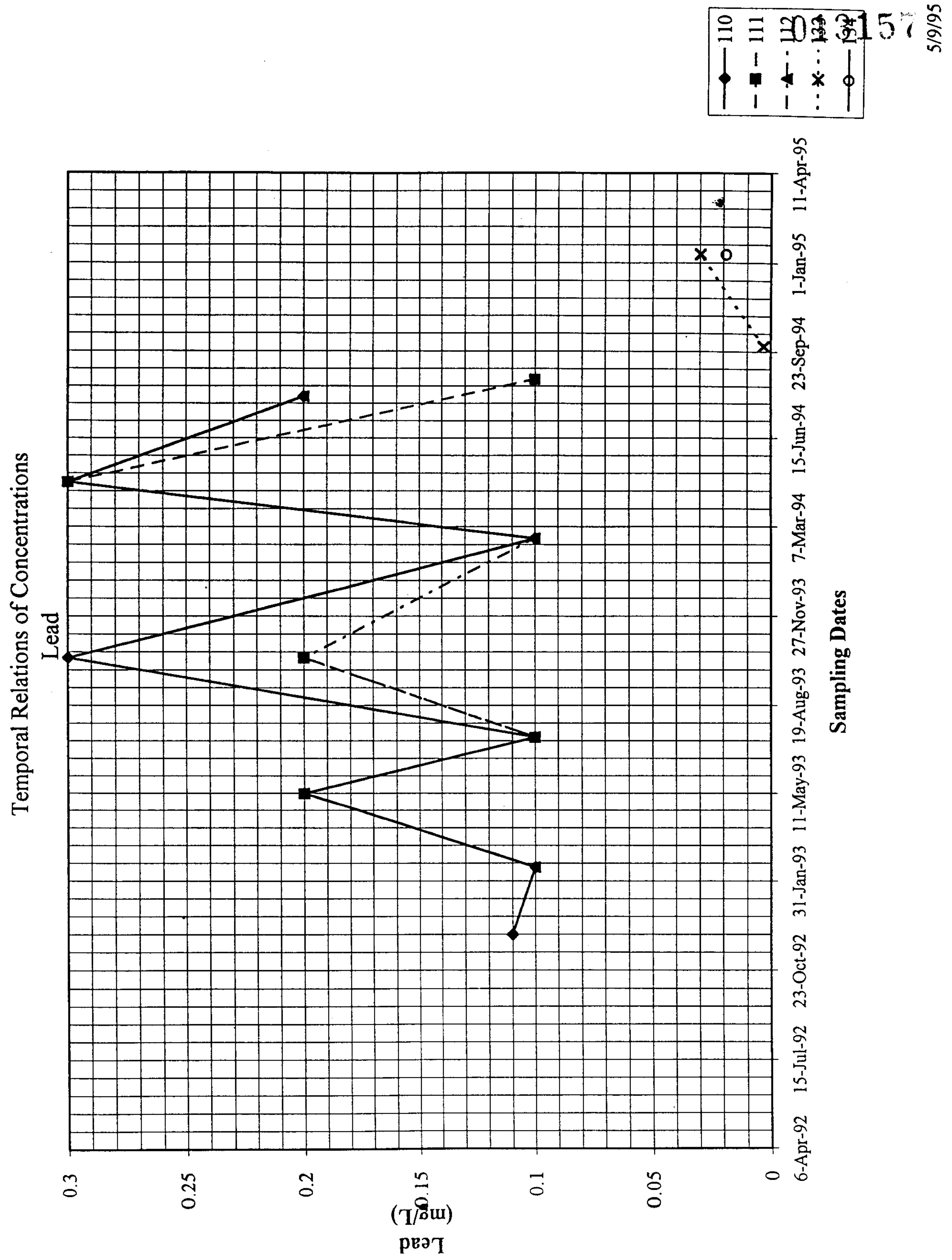


Temporal Relations of Concentrations
Calcium
Calcium (mg/L)
350
300
250
200
150
100
50
0
6-Apr-92
15-Jul-92
23-Oct-92
31-Jan-93
11-May-93
19-Aug-93
27-Nov-93
7-Mar-94
15-Jun-94
23-Sep-94
1-Jan-95
11-Apr-95
Sampling Dates
110
111
112
133
134

5/8/95


Temporal Relations of Concentrations
Chromium
Chromium
(mg/L)
0
0.05
0.1
0.15
0.2
0.25
0.3
6-Apr-92
15-Jul-92
23-Oct-92
31-Jan-93
11-May-93
19-Aug-93
27-Nov-93
7-Mar-94
15-Jun-94
23-Sep-94
1-Jan-95
11-Apr-95
Sampling Dates
110
111
112
133
134
5/8/95

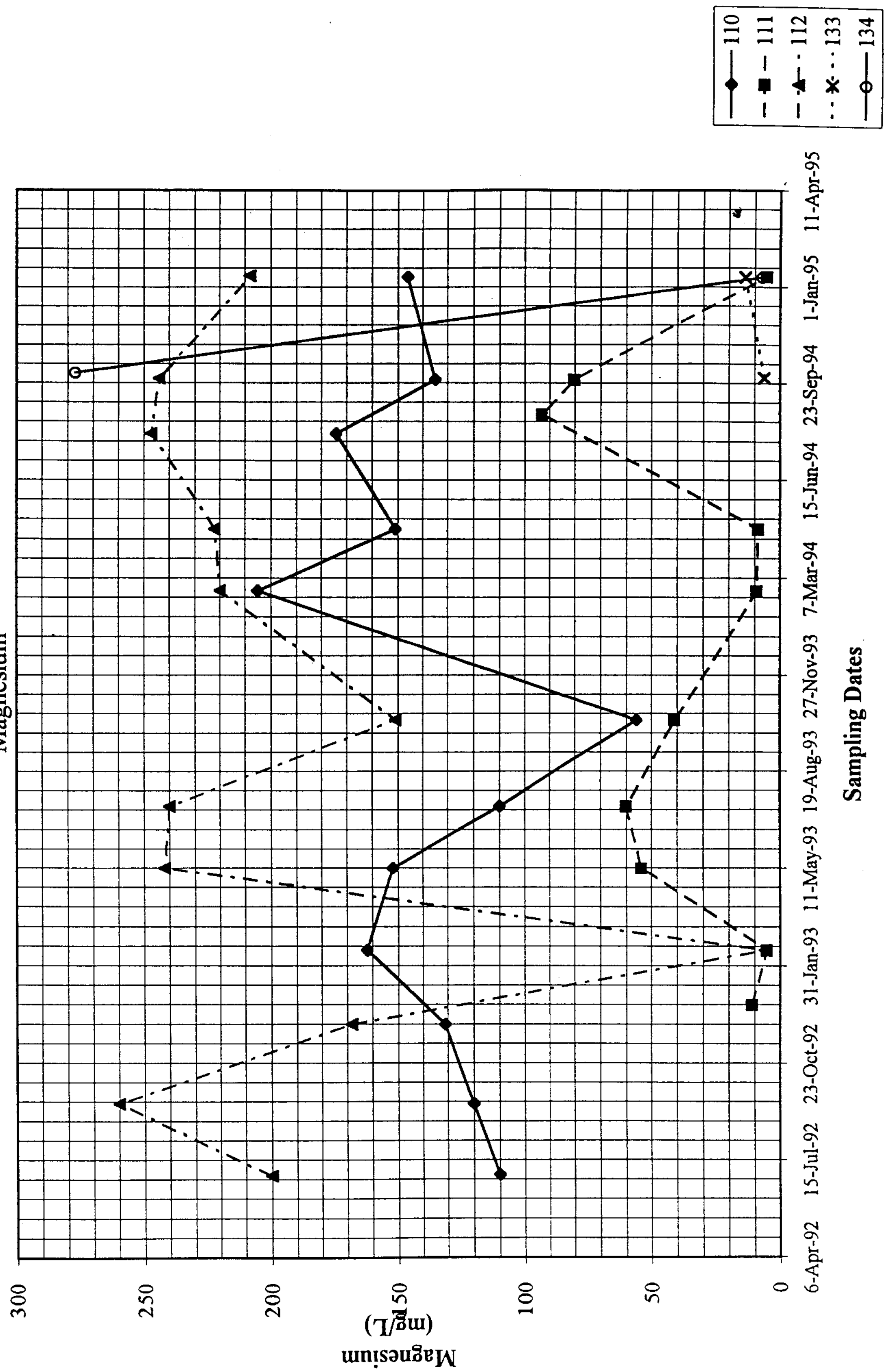

Temporal Relations of Concentrations
Iron
Iron
(mg/L)
160
120
80
40
0
6-Apr-92
15-Jul-92
23-Oct-92
31-Jan-93
11-May-93
19-Aug-93
27-Nov-93
7-Mar-94
15-Jun-94
23-Sep-94
1-Jan-95
11-Apr-95
Sampling Dates
110
111
112
133
134
5/8/95


Temporal Relations of Concentrations
Lead
Lead (mg/L)
0.3
0.25
0.2
0.15
0.1
0.05
0
6-Apr-92
15-Jul-92
23-Oct-92
31-Jan-93
11-May-93
19-Aug-93
27-Nov-93
7-Mar-94
15-Jun-94
23-Sep-94
1-Jan-95
11-Apr-95
Sampling Dates
110
111
112
5/9/95

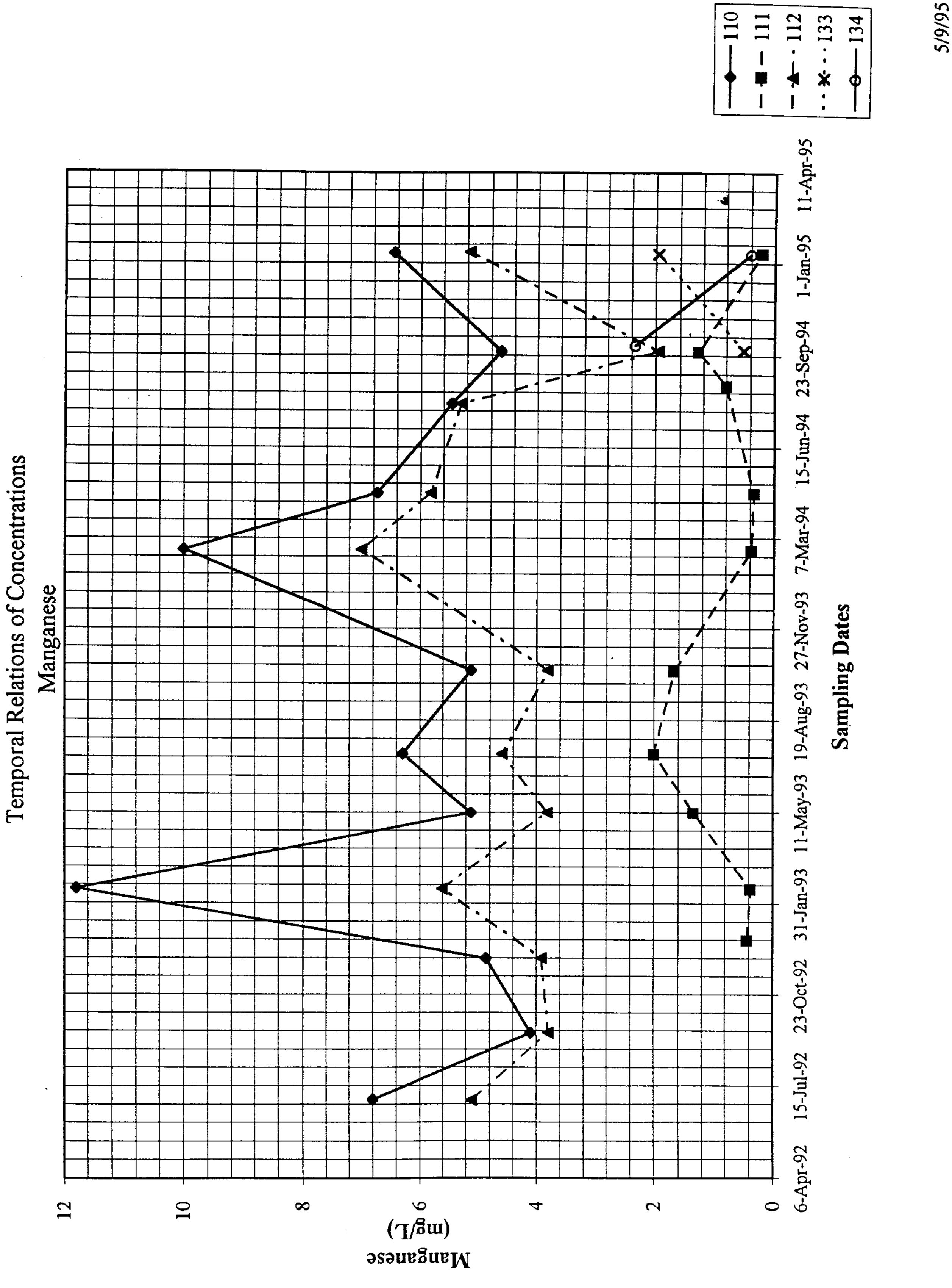
013158

5/9/95

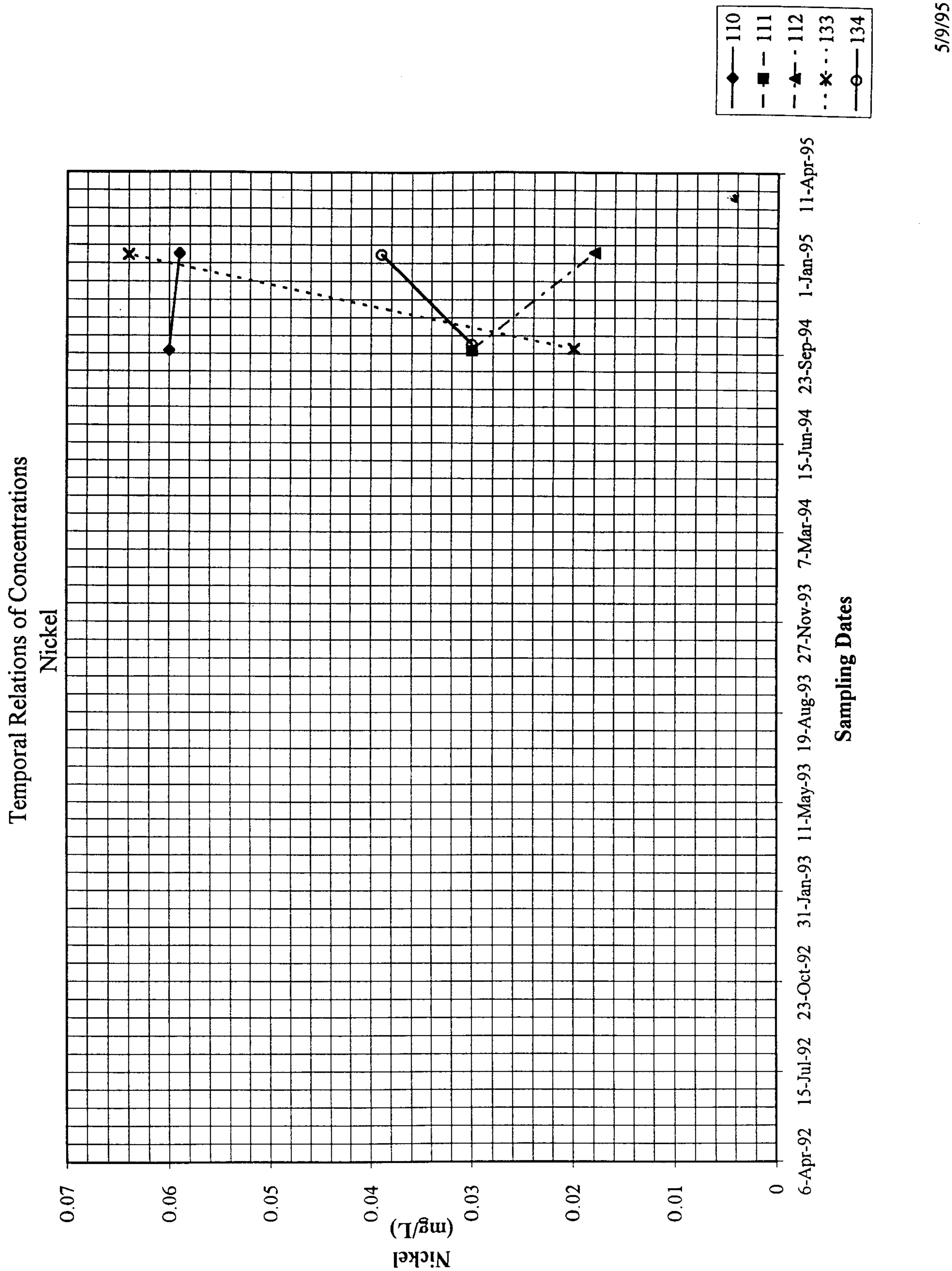
Temporal Relations of Concentrations
Magnesium



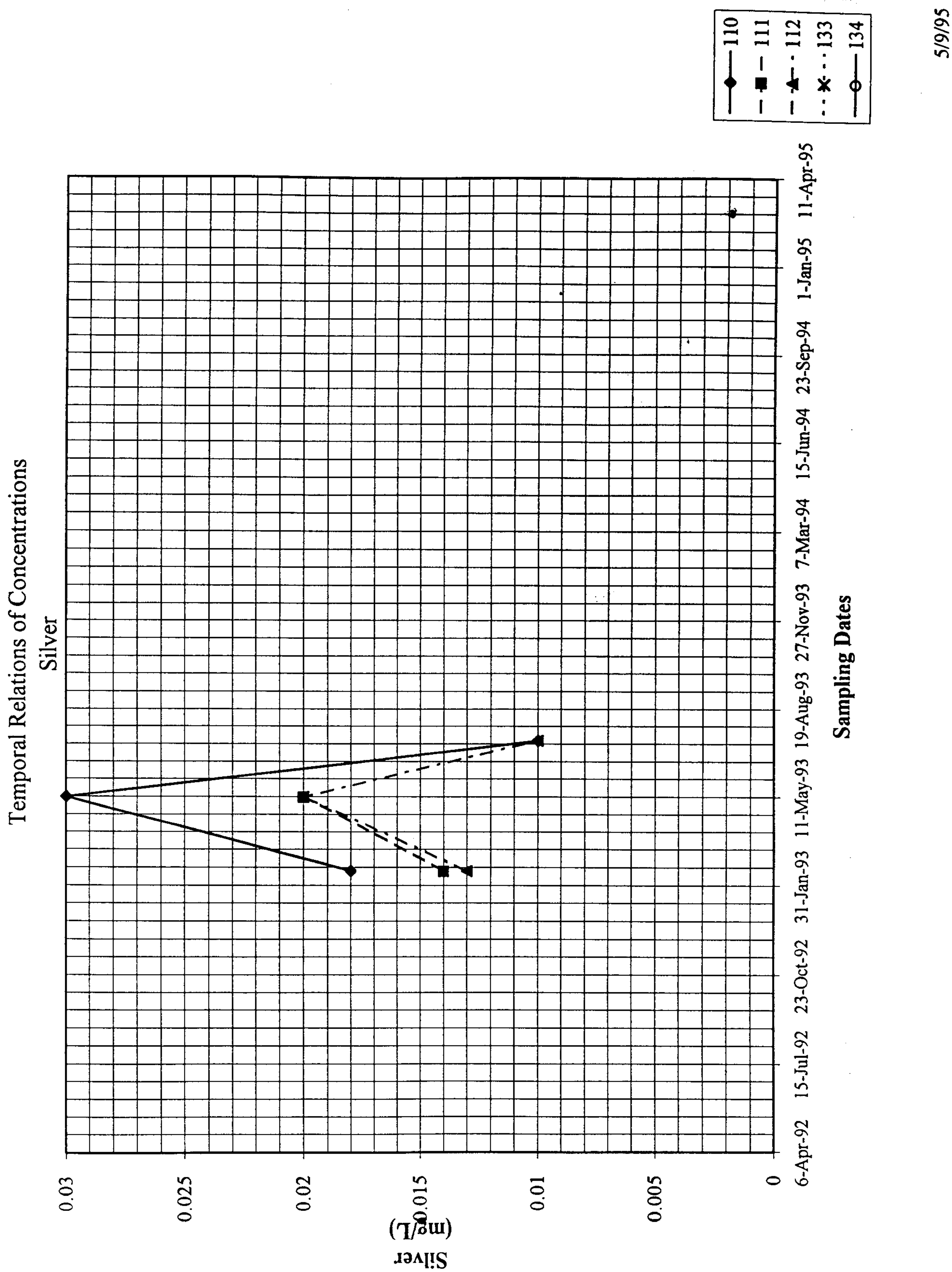
013159



Temporal Relations of Concentrations
Manganese
Manganese (mg/L)
0
2
4
6
8
10
12
Sampling Dates
6-Apr-92
15-Jul-92
23-Oct-92
31-Jan-93
11-May-93
19-Aug-93
27-Nov-93
7-Mar-94
15-Jun-94
23-Sep-94
1-Jan-95
11-Apr-95
110
111
112
133
134
5/9/95

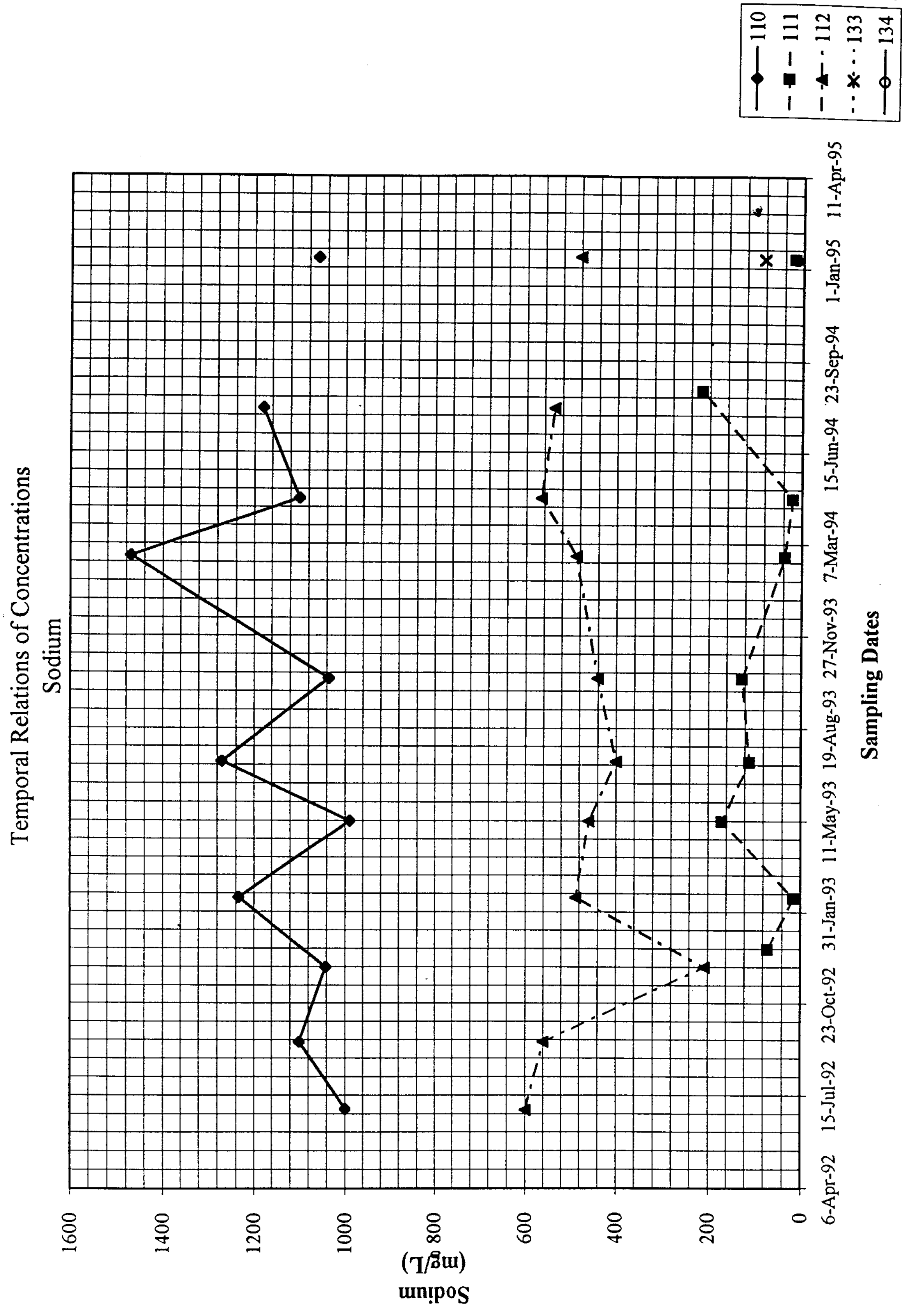

Temporal Relations of Concentrations
Nickel
Nickel (mg/L)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
6-Apr-92
15-Jul-92
23-Oct-92
31-Jan-93
11-May-93
19-Aug-93
27-Nov-93
7-Mar-94
15-Jun-94
23-Sep-94
1-Jan-95
11-Apr-95
Sampling Dates
110
111
112
133
134
5/9/95

013161



Temporal Relations of Concentrations
Silver
Silver (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
6-Apr-92
15-Jul-92
23-Oct-92
31-Jan-93
11-May-93
19-Aug-93
27-Nov-93
7-Mar-94
15-Jun-94
23-Sep-94
1-Jan-95
11-Apr-95
Sampling Dates
110
111
112
133
134
5/9/95

013162
5/9/95


Temporal Relations of Concentrations
Sodium
Sodium
(mg/L)
1600
1400
1200
1000
800
600
400
200
0
6-Apr-92
15-Jul-92
23-Oct-92
31-Jan-93
11-May-93
19-Aug-93
27-Nov-93
7-Mar-94
15-Jun-94
23-Sep-94
1-Jan-95
11-Apr-95
Sampling Dates
110
111
112
133
134

DEPARTMENT OF THE ARMY
LONGHORN/LOUISIANA ARMY AMMUNITION PLANTS
MARSHALL, TEXAS 75671-1059

013163

REPLY TO ATTENTION OF

June 6, 1995

SMCLO-EN

Mr. Mike Moore, Project Manager
Superfund Investigations
Texas Natural Resource Conservation Commission
P. O. Box 13087
Austin, Texas 78711-3087

Dear Mr. Moore:

We request approval for final disposition of CERCLA Investigative-Derived Solid Material (IDM) at the Old Landfill, Site 16, as discussed during the June 6, 1995 Monthly Manager's Meeting. Solids will be placed on the Landfill, then covered with 40 mil HDPE to prevent rainwater infiltration and runoff, and for control of fugitive emissions including dust. The IDM will be covered by the landfill capping system being implemented as the Interim Remedial Action.

Sincerely,

Lawrence J. Sowa
Lieutenant Colonel, U.S. Army
Commanding Officer

013164

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION

Protecting Texas by Reducing and Preventing Pollution

June 7, 1995

CERTIFIED MAIL
P 028 126 709
RETURN RECEIPT REQUESTED

David Tolbert, Project Manager
Longhorn Army Ammunition Plant
Attn: SMCLO-EN
Marshall, Texas 75671-1059

Re: Longhorn Army Ammunition Plant
Management of Investigation Derived Waste

Dear Mr. Tolbert:

The Texas Natural Resource Conservation Commission (TNRCC) staff concur with the Army's approach for management of its current inventory of investigation derived waste (solid, drummed materials only), as discussed at the June 6, 1995 project managers' meeting. Your request (letter dated June 6, 1995) is approved, in accordance with the terms and conditions stated in the request letter and discussed during the project managers' meeting.

If you have any questions or comments, please contact me at (512) 239-2483.

Sincerely yours,

Michael A. Moore (MC-143)
RI/FS II Unit
Superfund Investigation Section
Pollution Cleanup Division

cc: Jonna Polk, COE Tulsa District (CESWT-PP-EA)
Lisa Price, EPA Region VI (6H-ET)

REPLY TO: REGION 5 • 2916 TEAGUE DRIVE • TYLER, TEXAS 75701 • AREA CODE 903/595-5466

P.O. Box 13087 • Austin, Texas 78711-3087 • 512/239-1000

DEPARTMENT OF THE ARMY
LONGHORN/LOUISIANA ARMY AMMUNITION PLANTS
MARSHALL, TEXAS 75671-1059

REPLY TO
ATTENTION OF

013165

June 13, 1995

SMCLO-EN

Ms. Lisa Price
Superfund Enforcement
U.S. Environmental Protection Agency
1445 Ross Avenue
Dallas, Texas 75202

SUBJECT: Volume I Final Hydrogeological Assessment for Longhorn Army Ammunition Plant, Marshall, Texas

Dear Ms. Price:

Enclosed is one copy of the Volume I Final Hydrogeological Assessment you requested on June 6, 1995 at the Managers Meeting for Longhorn Army Ammunition Plant, Marshall, Texas.

If you have any questions, please contact Mr. David Tolbert, at 903-679-2728.

Sincerely,

Lawrence J. Sowa
Lieutenant Colonel, U.S. Army
Commanding Officer

Enclosures

LONGHORN/LOUISIANA ARMY AMMUNITION PLANTS
MARSHALL, TEXAS 75671-1059

REPLY TO ATTENTION OF

June 13, 1995

013166

SMCLO-EN

Mr. Michael Moore
Superfund Investigation Section
Texas Natural Resource Conservation Commission
Post Office Box 13087
Austin, Texas 78711-3087

SUBJECT: Volume I Final Hydrogeological Assessment for Longhorn Army Ammunition Plant, Marshall, Texas

Dear Mr Moore:

Enclosed is one copy of the Volume I Final Hydrogeological Assessment you requested on June 6, 1995 at the Managers Meeting for Longhorn Army Ammunition Plant, Marshall, Texas.

If you have any questions, please contact Mr. David Tolbert, at 903-679-2728.

Sincerely,

Lawrence J. Sowa
Lieutenant Colonel, U.S. Army
Commanding Officer

Enclosures

LONGHORN/LOUISIANA ARMY AMMUNITION PLANTS
MARSHALL, TEXAS 75671-1059

013167

REPLY TO
ATTENTION OF

June 13, 1995

SMCLO-EN

Ms. Lisa Price
Superfund Enforcement
U.S. Environmental Protection Agency
1445 Ross Avenue
Dallas, Texas 75202

SUBJECT: Final DERPMIS/RMIS Resolution Document for Longhorn Army Ammunition Plant, Marshall, Texas

Dear Ms. Price:

Enclosed is one copy of the Final DERPMIS/RMIS Resolution Document for Longhorn Army Ammunition Plant, Marshall, Texas.

If you have any questions, please contact Mr. David Tolbert, at 903-679-2728.

Sincerely,

Lawrence J. Sowa
Lieutenant Colonel, U.S. Army
Commanding Officer

Enclosure

06-13-1995 03:00PM FROM TO 5650942719186697235 P.03

LONGHORN/LOUISIANA ARMY AMMUNITION PLANTS
MARSHALL, TEXAS 75671-1059

013168

REPLY TO
ATTENTION OF

June 13, 1995

SMCLO-EN

Mr. Michael Moore
Superfund Investigation Section
Texas Natural Resource Conservation Commission
Post Office Box 13087
Austin, Texas 78711-3087

SUBJECT: Final DERPMIS/RMIS Resolution Document for Longhorn Army Ammunition Plant, Marshall, Texas

Dear, Mr Moore:

Enclosed is one copy of the Final DERPMIS/RMIS Resolution Document for Longhorn Army Ammunition Plant, Marshall, Texas.

If you have any questions, please contact Mr. David Tolbert, at 903-679-2728.

Sincerely,

Lawrence J. Sowa
Lieutenant Colonel, U.S. Army
Commanding Officer

Enclosure

06-13-1995 03:00PM FROM TO 5650942719186697235 P.02

DEPARTMENT OF THE ARMY
LONGHORN/LOUISIANA ARMY AMMUNITION PLANTS
MARSHALL, TEXAS 75671-1059

013169

June 15, 1995

REPLY TO ATTENTION OF
SMCLO-EN

Ms. Lisa Price
Superfund Enforcement
U.S. Environmental Protection Agency
1445 Ross Avenue
Dallas, Texas 75202

SUBJECT: Schedules for Longhorn Army Ammunition Plant, Marshall, Texas

Dear Ms. Price:

Enclosed is one copy of the schedules for your review and approval.

Please return comments or approval back to this office by 26 June 1995.

If you have any questions, please contact Mr. David Tolbert, at 903-679-2728.

Sincerely,

Lawrence J. Sowa
Lieutenant Colonel, U.S. Army
Commanding Officer

Enclosure

DEPARTMENT OF THE ARMY
LONGHORN/LOUISIANA ARMY AMMUNITION PLANTS
MARSHALL, TEXAS 75671-1059

June 15, 1995

013170

REPLY TO
ATTENTION OF

SMCLO-EN

Mr. Michael Moore
Superfund Investigation Section
Texas Natural Resource Conservation Commission
Post Office Box 13087
Austin, Texas 78711-3087

SUBJECT: Schedules for Longhorn Army Ammunition Plant, Marshall, Texas

Dear Mr. Moore:

Enclosed is one copy of the schedules for your review and approval.

Please return comments or approval back to this office by 26 June 1995.

If you have any questions, please contact Mr. David Tolbert, at 903-679-2728.

Sincerely,

Lawrence J. Sowa
Lieutenant Colonel, U.S. Army
Commanding Officer

Enclosure

DEPARTMENT OF THE ARMY
LONGHORN/LOUISIANA ARMY AMMUNITION PLANTS
MARSHALL, TEXAS 75671-1059

REPLY TO
ATTENTION OF

013171

June 15, 1995

SMCLO-EN

Mr. H.L. Jones
Texas Natural Resource Conservation Commission
2916 Teague Drive
Tyler, Texas 75701

SUBJECT: Schedules for Longhorn Army Ammunition Plant, Marshall, Texas

Dear Mr. Jones:

Enclosed is one copy of the schedules for your review and approval.

Please return comments or approval back to this office by 26 June 1995.

If you have any questions, please contact Mr. David Tolbert, at 903-679-2728.

Sincerely,

Lawrence J. Sowa
Lieutenant Colonel, U.S. Army
Commanding Officer

Enclosure

013172

DEPARTMENT OF THE ARMY
U.S. ARMY CENTER FOR HEALTH PROMOTION AND PREVENTIVE MEDICINE (PROVISIONAL)
ABERDEEN PROVING GROUND, MARYLAND 21010-5422

REPLY TO ATTENTION OF

MCHB-DE-HR (40)

21 JUN 1995

MEMORANDUM FOR Commander, U.S. Army Corps of Engineers, Tulsa District, ATTN: CESWT-PP-EA/Ms. Jonna Polk, Post Office Box 61, Tulsa, Oklahoma 74121-0061

SUBJECT: Review of the Draft Record of Decision for Early Interim Remedial Action at Landfill Sites 12 & 16 for Longhorn Army Ammunition Plant, Marshall, Texas

1. The U.S. Army Center for Health Promotion and Preventive Medicine (Provisional) (USACHPPM(PROV)) has reviewed the subject document on behalf of the Office of The Surgeon General. The selected interim remedial action is designed to prevent further migration of contaminants into the ground water, and is therefore protective of human health. We concur with the selected interim remedial action.

2. The scientists reviewing this document were: Mr. Mark A. Dossey, Health Risk Assessment and Risk Communication Program; Dr. Wilfred C. McCain, Health Effects Research Program; and Dr. Don MacCorquodale, Occupational and Environmental Medicine Division. The point of contact is Mr. Dossey at DSN 584-2953 or commercial (410) 671-2953.

FOR THE COMMANDER:

Dennis E. Druck
for ARTHUR P. LEE, P.E.
MAJ, MS
Program Manager, Health Risk Assessment and Risk Communication

CF:
HQDA (SGPS-PSP-E)
CDR, USAMEDCOM, ATTN: MCHO-CL-P
CDR, CEMRD, ATTN: CEMRD-ET-EH
CDR, USAEC, ATTN: SFIM-AEC-IRP
CDR, LHAAP, ATTN: SMCLO-EN

DEPARTMENT OF THE ARMY
U.S. ARMY CENTER FOR HEALTH PROMOTION AND PREVENTIVE MEDICINE (PROVISIONAL)
ABERDEEN PROVING GROUND, MARYLAND 21010-5422

013173

REPLY TO
ATTENTION OF

MCHB-DE-HR (40)

22 JUN 1995

MEMORANDUM FOR Commander, U.S. Army Corps of Engineers, Tulsa District, ATTN: CESWT-PP-EA/Ms. Jonna Polk, Post Office Box 61, Tulsa, Oklahoma 74121-0061

SUBJECT: Review of the Schedules for Longhorn Army Ammunition Plant, Marshall, Texas

1. The U.S. Army Center for Health Promotion and Preventive Medicine (Provisional) (USACHPPM(PROV)) has reviewed the proposed schedules for Longhorn Army Ammunition Plant on behalf of the Office of The Surgeon General. We concur with all schedules and timelines.

2. The schedules were reviewed by Mr. Mark A. Dossey, Health Risk Assessment and Risk Communication Program, at DSN 584-2953 or commercial (410) 671-2953.

FOR THE COMMANDER:

for Dennis E. Druck
ARTHUR P. LEE, P.E.
MAJ, MS
Program Manager, Health Risk
Assessment and Risk Communication

CF:
HQDA (SGPS-PSP-E)
CDR, USAMEDCOM, ATTN: MCHO-CL-P
CDR, CEMRD, ATTN: CEMRD-ET-EH
CDR, USAEC, ATTN: SFIM-AEC-IRP
CDR, LHAAP, ATTN: SMCLO-EN

DEPARTMENT OF THE ARMY
LONGHORN/LOUISIANA ARMY AMMUNITION PLANTS
MARSHALL, TEXAS 75671-1059 013174

REPLY TO
ATTENTION OF

June 29, 1995

SMCLO-EN

Ms. Lisa Price
Superfund Enforcement
U. S. Environmental Protection Agency
1445 Ross Avenue
Dallas, TX 75202

Dear Ms. Price:

We concur with all of Environmental Protection Agency's comments regarding the subject schedules, and have incorporated appropriate changes in the enclosed final schedules.

We agree with your concerns expressed in Comment No. 1, and will make every effort to expedite these schedules.

If you have any questions, please contact Mr. David Tolbert at 903-679-2728.

Sincerely,

Darrell W. Chinn
Captain, U. S. Army
Executive Officer

Enclosure

015321

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION

Protecting Texas by Reducing and Preventing Pollution

June 28, 1995

CERTIFIED MAIL
P 836 901 701
RETURN RECEIPT REQUESTED

David Tolbert, Project Manager
Longhorn Army Ammunition Plant
Attn: SMCLO-EN
Marshall, Texas 75671-1059

Re: Longhorn Army Ammunition Plant
Updated Project Schedule, Dated June 15, 1995

Dear Mr. Tolbert:

The Texas Natural Resource Conservation Commission (TNRCC) staff have completed its review of the Updated Project Schedule, dated June 15, 1995, which was received on June 16, 1995. We concur with the U. S. Environmental Protection Agency comments, dated June 23, 1995, and have no additional comments.

If you any questions or comments, please contact me at (512) 239-2483.

Sincerely yours,

Michael A. Moore (MC-143)
RI/FS II Unit
Superfund Investigation Section
Pollution Cleanup Division

Enclosures

cc: Jonna Polk, COE Tulsa District (CESWT-PP-EA)
Lisa Price, EPA Region VI (6H-ET)

DEPARTMENT OF THE ARMY
LONGHORN/LOUISIANA ARMY AMMUNITION PLANTS
MARSHALL, TEXAS 75671-1059

REPLY TO
ATTENTION OF

015322

June 29, 1995

SMCLO-EN

Ms. Lisa Price
Superfund Enforcement
U.S. Environmental Protection Agency
1445 Ross Avenue
Dallas, Texas 75202

SUBJECT: Draft Work Plan for Phase III of the Interim Remedial Action, Burning Ground No. 3 and UEP, LHAAP 18 & 24 for Longhorn Army Ammunition Plant in Karnack, Texas - Full-Size Drawings

Dear Ms. Price:

Enclosed is one copy of the subject drawing. The drawing was inadvertently left out of the package, sent to you on 27 June 1995, which transmitted the subject Draft Work Plan.

If you have any questions, please contact Mr. David Tolbert, at 903-679-2728.

Sincerely,

Darrell W. Chinn
Captain, U.S. Army
Executive Officer

Enclosure

DEPARTMENT OF THE ARMY
LONGHORN/LOUISIANA ARMY AMMUNITION PLANT
MARSHALL, TEXAS 75671-1059

REPLY TO
ATTENTION OF

June 29, 1995

015323

SMCLO-EN

Mr. Michael Moore
Superfund Investigation Section
Texas Natural Resource Conservation Commission
Post Office Box 13087
Austin, Texas 78711-3087

SUBJECT: Draft Work Plan for Phase III of the Interim Remedial Action, Burning Ground No. 3 and UEP, LHAAP 18 & 24 for Longhorn Army Ammunition Plant in Karnack, Texas - **Full-Size Drawings**

Dear Mr. Moore:

Enclosed are two copies of the subject drawing. The drawing was inadvertently left out of the package, sent to you on 27 June 1995, which transmitted the subject Draft Work Plan.

If you have any questions, please contact Mr. David Tolbert, at 903-679-2728.

Sincerely,

for Darrell W. Chinn
Captain, U.S. Army
Executive Officer

Enclosures