CLOSURE PLAN

for

SEWAGE LAGOONS A THROUGH G
US AIR FORCE/
HOLLOMAN AIR FORCE BASE

issued by
NEW MEXICO ENVIRONMENT
DEPARTMENT
Santa Fe, New Mexico

MAY 1997

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CONDITIONS FOR APPROVAL OF CLOSURE PLAN
FOR

SEWAGE LAGOONS A THROUGH G
US AIR FORCE/ HOLLOMAN AIR FORCE BASE

Number	Condition
1.	**Permit conditions.** This Closure Plan must meet all requirements for closure provided in the New Mexico Administrative Code, Title 20, Chapter 4, Part 1 (20 NMAC 4.1), Subpart VI, 40 CFR 265.111 through 265.116, as applicable.
2.	**Quarterly reporting.** Quarterly reporting regarding closure activities must be submitted to the New Mexico Environment Department for review and approval. Reporting should include: Updates on activities carried out during the previous quarter and on scheduled activities for the current quarter; Discussion of any necessary changes or modifications in closure activities as approved in the Closure Plan; and Identification of any actual or anticipated changes to the schedule contained in the Closure Plan, Table 6-2, *Schedule of Closure*.
3.	**Final Closure Report.** In support of the Closure Certification (20 NMAC 4.1, Subpart VI, 40 CFR 265.115, *Certification of Closure*), a final Closure Report must be submitted. This report must include: A summary of activities performed; Any variances from the plan and the reason for each variance; Location and custodian of all closure documentation; and A site map of each lagoon. The boundaries of the lagoons must be tied in to some generally accepted reference point, such as latitude-longitude.

Number	Condition
	The location and custodian at Holloman Air Force Base of the laboratory sample analysis sheets and quality assurance/quality control documentation for the laboratory analyses for the 1994 sampling and any other sampling used to evaluate appropriate risk and remedial actions at the lagoons;
4.	**Long-Term Groundwater Monitoring.** The Long-Term Groundwater Monitoring Program must continue until the New Mexico Environment Department has verified completion of closure.
5.	**Future Land Use.** The New Mexico Environment Department approves this site-specific, risk-based Closure Plan only for the following human health risk levels: Ponds A through F — Current worker (12 days a year for 25 years) Pond G — Current worker, hunter, and trespasser Consequently, for purposes of human health-based land uses, the US Air Force/Holloman Air Force Base may not use these site for purposes which would require more restrictive human health risk levels.
6.	**Deed restriction.** Not later than 60 days after certification of closure of each hazardous waste disposal unit, the US Air Force/Holloman Air Force Base must submit to the local zoning authority, or the authority with jurisdiction over local land use, and to the Secretary of the New Mexico Environment Department, a record of the type, location, and quantity of hazardous wastes disposed of within each sewage lagoon and a survey plat of each lagoon. Within 60 days of certification of closure, the US Air Force/Holloman Air Force Base must: Record, in accordance with State law, a notation on the deed to the facility property - or on some other instrument which is normally examined during title search - that will in perpetuity notify any potential purchaser of the property that: The land has been used to manage hazardous waste;

CONDITIONS FOR APPROVAL OF CLOSURE PLAN
FOR
SEWAGE LAGOONS A THROUGH G
US AIR FORCE/HOLLOMAN AIR FORCE BASE (con.d)

Number	Condition
	Its use is restricted under 20 NMAC 4.1, Subpart VI, 40 CFR 265, Subpart G regulations; and
	The survey plat and record of the type, location, and quantity of hazardous wastes disposed of within each lagoon have been filed with the local zoning authority or the authority with jurisdiction over local land use and with the Secretary of the New Mexico Environment Department; and
	Submit to the Secretary of the New Mexico Environment Department a certification signed by the US Air Force/Holloman Air Force Base that it has recorded the notation specified above and a copy of the document in which the notation has been placed.

PURPOSE OF DOCUMENT

A. The *Sewage Lagoons Closure Plan* describes closure activities for the Holloman Air Force Base (AFB) sewage lagoons. It is the intent of this closure plan to summarize all investigations of the sewage lagoons, to demonstrate that the nature and extent of contamination have been determined, and to show that no further sampling is necessary prior to proceeding with closure activities. This closure plan describes closure through site-specific equivalency demonstration (i.e., current worker risk-based) and supersedes all previous sewage lagoon closure plans.

B. This closure plan is a summary of all other plans and reports prepared for the investigation, assessment and corrective measures study. A list of other reports is presented in Appendix D. More recent reports are as follows:

March 1995, *Project Assessment Report, Sewage Lagoons and Lakes Investigation, Holloman Air Force Base, NM.*

June 1995, *Site Characterization Report, Sewage Lagoons Closure Project, Holloman Air Force Base, NM.*

March 1996, *Risk Assessment Addendum, Sewage Lagoons Closure Project, Holloman Air Force Base, NM.*

June 1996, *Biological Resource Report, Sewage Lagoons Closure Project, Holloman Air Force Base, NM.*

June 1996, *Corrective Measures Study, Sewage Lagoons Closure Project, Holloman Air Force Base, NM* (Appendix C to this Report).

C. This closure plan contains a list of issues that may affect closure strategy (e.g., land disposal restrictions, endangered species, funding), a chronological outline of past investigations and activities that serve as the basis for closure. The appendices present a summary of all surface water, groundwater, sludge, and soil data obtained from the sewage lagoons between 1990 and 1995.

TABLE OF CONTENTS

1	INTRODUCTION		1-1
	1.1	Closure Concept	1-1
	1.2	Background	1-1
	1.3	Organization of Closure Plan	1-2
2.	CLOSURE ISSUES		2-1
	2.1	New Wastewater Treatment Facility	2-1
	2.2	Land Disposal Restrictions	2-2
	2.3	Regulatory Considerations Other than RCRA	2-2
		2.3.1 Wetlands	2-2
		2.3.2 Endangered Species	2-2
	2.4	Funding for Closure	2-4
	2.5	Federal Facilities Closure and Property Transfer Policy	2-6
3.	FACILITY DESCRIPTION		3-1
	3.1	Holloman AFB Mission	3-1
	3.2	Physiography	3-1
	3.3	Geology	3-3
	3.4	Surrounding Wildlife	3-3
	3.5	Physical Description of Sewage Lagoons	3-3
		3.5.1 Lagoon System Dimensions	3-7
		3.5.2 Approximate Depth of Sludge	3-7
	3.6	Groundwater Quality	3-7
4.	PREVIOUS INVESTIGATIONS		4-1
	4.1	Sludge, Soil, Surface Water, and Biota Investigations	4-1
		4.1.1 1981 Water and Sludge Sampling - EP Toxicity	4-1
		4.1.2 1983 Water and Sludge Sampling - Chromium and Organics	4-2
		4.1.3 1984 Priority Pollutant Sampling	4-2
		4.1.4 1987 Appendix IX Sampling in Support of Delisting Petition	4-2
		4.1.5 May 1988 Preliminary Investigation for Sludge Removal	4-3
		4.1.6 August 1988 Additional Investigation for Sludge Removal	4-3
		4.1.7 1990 Sludge Removal Project	4-3
		4.1.8 1990 Surface Water Sampling	4-3
		4.1.9 March 1990 Sludge and Soil Sampling at Pond C	4-4
		4.1.10 1991 U.S. Fish and Wildlife Biota Sampling	4-4

TABLE OF CONTENTS
(Continued)

	4.1.11	1991-1992 Sewage Lagoon Investigation in Support of the PCCP Application	4-4
	4.1.12	1993 Background Sampling	4-5
	4.1.13	1993 Biota Sampling	4-5
4.2	Groundwater Investigations		4-5
	4.2.1	August 1989-January 1991 Detection Monitoring Program	4-7
	4.2.2	1991 and 1992 Groundwater Assessment Monitoring	4-7
	4.2.3	1992 Geoprobe and Piezometer Sampling	4-8
	4.2.4	1993 Background Groundwater Sampling	4-8
	4.2.5	1993 Groundwater Assessment Monitoring - Phase I	4-8
	4.2.6	1996 Long-Term Groundwater Monitoring	4-9
4.3	Risk Assessment		4-9
	4.3.1	1991 Risk Assessment for Entire Sewage Lagoon System	4-9
	4.3.2	1993 Risk Assessment for Each Sewage Lagoon, Lake, and Ditch	4-10
	4.3.3	1996 Risk Assessment Addendum	4-11
5.	1994 INVESTIGATION		5-1
5.1	Monitored Constituents		5-1
5.2	Monitored Media		5-1
5.3	Sample Locations		5-1
5.4	Analytical Results		5-1
6.	CLOSURE DOCUMENTATION SUMMARY AND OTHER REGULATORY ISSUES		6-1
6.1	Summary of Documents		6-1
	6.1.1	Project Assessment Report	6-1
	6.1.2	Long-Term Monitoring Project	6-1
	6.1.3	Site Characterization Report	6-1
	6.1.4	Risk Assessment Addendum	6-2
	6.1.5	Biological Resources Report	6-3
	6.1.6	Corrective Measures Study	6-4
	6.1.7	Decision Documents	6-5
6.2	Wildlife and Wetland Issues Pertaining to Closure		6-5
	6.2.1	Clean Water Act	6-6
	6.2.2	NEPA	6-6
	6.2.3	Fish and Wildlife Coordination Act	6-6
6.3	Initiation of Closure		6-6
7,	REFERENCES		7-1

TABLE OF CONTENTS
(Continued)

APPENDIX A:	Analytical Summary of Sewage Lagoons Investigation
APPENDIX B:	October 1994 Field Sampling Plan with Addendum
APPENDIX C:	Corrective Measures Study
APPENDIX D:	List of Reports Prepared Regarding the Sewage Lagoons at Holloman AFB
APPENDIX E:	Risk Assessment Addendum, Sewage Lagoons Closure Project, Holloman Air Force Base, NM

LIST OF FIGURES

3-1	Location of Holloman AFB	3-2
3-2	Stratigraphic Fence Diagram	3-4
3-3	Site Stratigraphy	3-5
3-4	Location of Sewage Lagoons	3-6

LIST OF TABLES

2-1	Listed Wastes Alledgedly Disposed of in the Sewage Lagoons	2-3
2-2	Threatened, Endangered, and Sensitive Species Potentially Present at Sewage Lagoons and Lakes Area	2-5
3-1	Sewage Lagoon Construction Dates and Dimensions	3-8
3-2	1994 Investigation Water Depth and Sludge Thickness Measurements	3-8
4-1	Biological Samples Collected from the Sewage Lagoons and Lakes in 1993, Holloman AFB	4-6
6-1	List of Documents and Activities in Support of the Sewage Lagoons Closure Plan	6-2
6-2	Schedule for Closure	6-7

ACRONYMS

ACC	Air Combat Command
AFB	Air Force Base
AOC	Area of Contamination
CERCLA	Compreshesive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CMS	Corrective Measures Study
DERA	Defense Environmental Restoration Account
DOC	Dissolved Organic Carbon
DoD	Department of Defense
DRMO	Defense Reutilization Marketing Office
EA	Environmental Assessment
EPA	U.S. Environmental Protection Agency
FFCA	Federal Facilities Compliance Agreement
FONPA	Finding of No Practicable Alternative
FONSI	Finding of No Significant Impact
FS	Feasibility Study
HHSs	Human Health Standards
HQ	Headquarters
HSWA	Hazardous and Solid Waste Amendments
HWIR	Hazardous Waste Identification Rule
HWMR	Hazardous Waste Management Regulations
IRP	Installation Restoration Program
HWMUs	Hazardous Waste Management Units
LTM	Long-term Monitoring
MCLs	Maximum Contaminant Levels
NEPA	National Environmental Protection Act
NMED	New Mexico Environment Department
NMSU	New Mexico State University
NMSWB	New Mexico Surface Water Bureau
NPDES	National Pollutant Discharge Elimination System
PAR	Project Assessment Report
PCBs	Polychlorinated biphenyls
PCCP	Post-Closure Care Permit
RCRA	Resource Conservation and Recovery Act
SARA	Superfund Amendments and Reauthorization Act
SMCLs	Secondary Drinking Water Maximum Contaminant Levels
SWMUs	Solid Waste Management Unit
TAC	Tactical Air Command

ACRONYMS
(Continued)

TCLP	Toxicity Characteristic Leaching Procedure
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
USAF	United States Air Force
USFWS	U.S. Fish and Wildlife Service
WSMR	White Sands Missile Range

Section 1
INTRODUCTION

The primary objective of the sewage lagoons closure plan is to describe activities necessary for an equivalency demonstration (risk-based to protect current and future workers) to clean closure for the Holloman Air Force Base (AFB) sewage lagoons. This objective is in accordance with the 1988 Federal Facilities Compliance Agreement (FFCA), which was signed by the New Mexico Environment Department (NMED), United States Environmental Protection Agency (EPA) Region VI, and Holloman AFB. In addition, this closure plan intends to 1) show how the Holloman AFB sewage lagoons differ from a typical Resource Conservation and Recovery Act (RCRA) unit, 2) summarize all investigations that have occurred at the sewage lagoons, and 3) demonstrate that the nature and extent of contamination have been determined, and show that no further sampling is necessary prior to proceeding with closure activities.

This closure document supersedes the sewage lagoon closure plans that were submitted to NMED and EPA Region VI in November 1985, January 1989, July 1990, and May 1995. Some pages, specifically those that discuss the *Corrective Measures Study* (Appendix C), were revised in November 1996 as indicated at the bottom of the pages.

1.1 Closure Concept

The Holloman AFB sewage lagoons differs from that of a typical RCRA unit. Unlike other RCRA units that are designed to treat or dispose of hazardous wastes, the Holloman AFB sewage lagoons were never intended to treat hazardous wastes. From the time the lagoons were created, their primary function has been to treat domestic wastewater prior to discharge to Lake Holloman. Any hazardous wastes that have entered the lagoons have done so through releases prior to 1985. Therefore, because there are no wastes records that are typically associated with a RCRA unit, it is difficult to evaluate the amount of waste that must be remediated without first conducting a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or RCRA Corrective Action-like investigation to characterize the underlying soils, sludge, and surface water. Consequently, this closure plan follows a RCRA Corrective Action-like format in establishing closure activities for the sewage lagoons. This closure plan outlines the procedures that were used to determine the appropriate remedial alternatives for closing the sewage lagoons.

This closure plan provides a historical look at the investigations conducted at the sewage lagoons and provides details as to the nature and extent of contamination associated with the lagoons. The plan also summarizes and references other documents that support this plan. Comments received at the 3 April 1996 stakeholders meeting included the desire to keep water in Pond G to maintain the aquatic habitat it has developed over the past years since it has been part of the wastewater treatment system. The *Corrective Measures Study,* provided as Appendix C to this report, discusses this issue and others mentioned at the stakeholders meeting and provides the basis for selecting the proposed closure alternative.

1.2 Background

The original domestic wastewater treatment facility at Holloman AFB consisted of seven sewage lagoons (Ponds A through G) that discharged through a ditch to Lake Holloman, which during low evaporation periods can overflow to Lake Stinky. This document describes closure of the sewage lagoons; however, it does not address the ditch or lakes.

The distinction between the lagoons and the lakes is a result of the water bodies' different

regulatory classifications and the requirements of the FFCA. In 1994, NMED and EPA Region VI determined that the lakes and the ditch would be regulated under the Hazardous and Solid Waste Amendments (HSWA) program as two solid waste management units (SWMUs). The sewage lagoons, however, are regulated as hazardous waste management units (HWMUs).

This position was presented in an EPA Region VI letter to NMED (David Neleigh, personal communication, 4 April 1994) and an NMED letter to Holloman AFB (Barbara Hoditschek, personal communication, 6 April 1994). The NMED letter stated that the ditch, Lake Holloman, and Lake Stinky would be regulated by EPA Region VI under the HSWA corrective action program, and the seven sewage lagoons would be regulated by NMED under the New Mexico Hazardous Waste Management Regulations (HWMR-7), Part V, 40 CFR 265. Since this time, NMED has received authorization to run the HSWA program in New Mexico. In addition, NMED has confirmed that the sewage lagoons have lost interim status under RCRA because of two Notices of Noncompliance that cited Holloman AFB in violation of 40 CFR 264 and 265. The Notices of Noncompliance cited the Base's failure to submit a complete Part A permit application and failure to establish a groundwater monitoring program.

1.3 Organization of Closure Plan

The sewage lagoons closure plan consists of seven sections, including this introduction. Section 2 presents the issues that may affect selection of the final closure methodology for the sewage lagoons. Section 3 presents a facility description, including Base location, regional environmental setting, physical description of the sewage lagoons, the lagoon system usage, and groundwater quality. Section 4 summarizes the history of investigations and removal activities that have occurred at the lagoons between 1981 and 1993. Included in Section 4 are summaries of sludge, soil, biota, and surface water sampling; groundwater monitoring; and risk assessment results. Section 5 summarizes the 1994 investigation, and describes the purpose of the investigation and the constituents, media, and sample locations that were monitored. Section 6 summarizes recent documentation and regulatory issues applicable to the closure of the sewage lagoons. Section 7 presents a bibliography of documents prepared for the sewage lagoons closure project, and references.

Appendix A summarizes the analytical results from 1990 to 1995. Appendix B presents the 1994/95 investigation sampling plan. Appendix C presents the *Corrective Measures Study*, which identifies and gives detail on the closure alternatives evaluated and selected. Appendix D lists all the documents available related to the sewage lagoons. Appendix E contains the text of the 1996 *Risk Assessment Addendum*, the basis for risk levels approved.

Section 2
CLOSURE ISSUES

A closure plan was originally submitted to NMED and EPA Region VI on 22 November 1985. This plan proposed that an administrative, rather than physical, closure be performed to allow for continued treatment of nonhazardous wastes in the sewage lagoons. However, EPA interpreted this plan as a delisting petition and determined that it was unsatisfactory for a closure plan.

Following review of the 1985 closure plan, NMED and EPA Region VI agreed that the sewage lagoons must be closed in accordance with 40 CFR Part 265, Subparts G and K, which present two options for closure: "clean closure" or "closure in-place." Clean closure involves removal of all hazardous wastes and hazardous waste constituents. Closure in-place involves leaving wastes and waste constituents in-place and closing the facility as a landfill. This would include a permanent cap and a postclosure care permit. The closure plan submitted in January 1989 incorporated the closure in place concept.

During meetings in January 1991 with NMED and EPA Region VI, Holloman AFB requested that the sewage lagoons be allowed to undergo a risk-based closure supported by a site-specific demonstration (i.e., risk assessment) which would show equivalency to clean closure. The basis for this request is contained in the *New Mexico Hazardous Waste Management Regulations*, 20 NMAC 4.1,, Subpart IX, 40 CFR 270.1(c)(5) and the discussion of site-specific equivalency demonstration of clean closure in the preamble of the final rule for *Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities* (52 *Federal Register* 8704, 8706, 19 March 1987). The agencies agreed in the January 1991 meetings that a site-specific equivalency demonstration of clean closure would be an option for the sewage lagoons, assuming that any lagoon that could not meet the site-specific health-based standard would undergo closure in-place. This position was confirmed by NMED in a 17 August 1992 letter to Holloman AFB. This revised closure plan advocates closure of the sewage lagoons by site-specific equivalency demonstration.

The closure objectives and criteria are as follows.

Closure Objectives

- Ensure the protection of human health and the environment at the sewage lagoons after closure;
- Provide an adequate habitat for the wildlife associated with the sewage lagoons; and
- Ensure that closure eliminates disease vectors and odors that may be associated with the sewage lagoons and that the closure is aesthetically suitable.

Closure Criteria

- Protect human health and the environment;
- Minimize the need for further maintenance;
- Comply with applicable waste manage ment standards; and
- Prevent human exposure to constituents in soil and/or sludge that would lead to an unacceptable risk for a residential exposure scenario.

2.1 New Wastewater Treatment Facility

Headquarters Air Combat Command (HQ ACC) gave approval to Holloman AFB to construct a new wastewater treatment plant (WWTP) that will replace the existing sewage lagoon system. HQ ACC also requested the United States Army Corps of Engineers (USACE) Albuquerque District to hire a con-

tractor to design the facility. Construction was expected to begin in late 1994, but delays occurred because the environmental assessment (EA) prepared for the new wastewater treatment plant project revealed the proposed evaporation ponds had significant impacts on wetlands and wildlife habitat (Geo-Marine, 1995). New effluent disposal alternatives were developed and analyzed to eliminate these impacts and to reduce the potential for future RCRA compliance problems. The design was completed and construction of the new wastewater treatment system began in May 1995. The facility went on line in July 1996 ahead of schedule. Upon start-up of the new WWTP, domestic wastewater was diverted from the existing sewage lagoons to the new facility and discharge of wastewater to the sewage lagoons ceased.

2.2 Land Disposal Restrictions

NMED has determined that some listed wastes (Table 2-1) were disposed of in the ponds before 1985, making the sludge itself a hazardous waste under the "mixture" rule (20 NMAC 4.1, Subpart II, 40 CFR 261.3(a)(2)(iv)). Thus, land disposal restrictions could apply if the sludge is removed from the sewage lagoons. However, NMED has also determined that the sludges and soils in the ponds no longer exhibit the characteristics for which the wastes were listed and the concentrations of the listed constituents are below contaminant-specific health-based rules.

2.3 Regulatory Considerations Other than RCRA

Regulatory considerations other than RCRA center on the habitat that the sewage lagoons provide for area wildlife. Ponds A and B were constructed in 1943, Ponds C through F between 1955 and 1959, and Pond G in its current form in 1970. Pond G was a playa lake, prior to being included as part of the wastewater treatment facility in 1970. These ponds, as well as Lake Holloman, contained water year round, and as such became habitat for wildlife in the desert environment.

2.3.1 Wetlands

When Holloman AFB decided to construct a new wastewater treatment facility to replace the facility, the closure of the sewage lagoons and the jurisdictional status of Pond G with respect to regulation as a wetland was discussed. The USACE determined that Pond G was currently exempt from regulation under Section 404 of the Clean Water Act because it was functioning as a part of the wastewater treatment system; however, if Pond G was disconnected from the wastewater treatment system, it would lose the exemption and would be subject to a Section 404 permit in order to dredge the site. In addition, Lake Holloman is a playa lake which is classified as Waters of the United States by 40 CFR 122.2.

The new wastewater treatment facility will discharge to Pond G and to Lake Holloman through two separate National Pollutant Discharge Elimination System (NPDES) permitted outfalls. Both water bodies will be considered waters of the United States. At this time, Holloman AFB believes that discharging to Pond G will help preserve the wildlife habitats associated with Lake Holloman and Pond G. The EA prepared for the construction of the new wastewater treatment plant identified the loss of Pond G (65 acres of wetlands) as a significant impact (Geo-Marine, 1995). The selected alternatives include construction of up to 170 acres of wetlands. Currently, 120 acres of new wetlands are under construction, of which 14 acres are jurisdictional wetlands subject to regulation under Section 404 of the Clean Water Act.

2.3.2 Endangered Species

Lake Holloman has been classified as a wildlife habitat area owing to the migratory waterfowl that inhabit the lake during the spring and fall migrations. Endangered species have also been sighted in the area. The U. S, Fish

Table 2-1
Listed Wastes Allegedly Disposed of in Sewage Lagoons

EPA Waste Code[a]	*Description*	*Source Identified in Interviews*
F001	*Halogenated degreasing solvents*	*Corrosion Control (Bldg. 308) and DMEL*
F003	*Nonhalogenated degreasing solvents*	*NDI*
U228	*Trichloroethene*	*Flightline Area*
U161	*Methyl isobutyl ketone*	*NDI*
U227	*1,1,2-trichloroethane*	*Bldg. 308 and AGE*
U188	*Phenol*	*Bldg. 308*
U154	*Methanol*	*Hospital, Dental Clinic, NMSU PRL, Photo Labs, Solar Observatory, Dyna Corp.*
U002	*Acetone*	*Hospital, Dental Clinic, NMSU PRL*
U122	*Formaldehyde*	*Hospital, Dental Clinic, Photo Lab, Dyna Corp.*
U165	*Naphthalene*	*NMSU PRL*
U220	*Toluene*	*NMSU PRL*
U239	*Xylene*	*NMSU PRL*
U003	*Acetonitrile*	*NMSU PRL*
U211	*Carbon tetrachloride*	*Flightline Area*
U233	*Propionic acid* [b]	*Photo Labs One Time Use*
P095	*Phosgene*	*Flightline Area*
P012	*Arsenic trioxide*	*West Area Photo Lab*
P106	*Sodium cyanide*	*Test Group (Bldg. 824)*

Source: 1984 Response to RCRA 3007 Request and 1987 Notice of Noncompliance and Interview Notes.

Notes: NDI = Non destructive inspection. NMSU PRL = New Mexico State University Primate Research Lab.

[a] *Considering DoD's practice of using the DRMO for redistributing chemicals, it is highly unlikely that "P" and "U" listed wastes (pure or off-spec chemicals) were discharged to the sewer system. It is more likely that the spent chemicals or "F" listed wastes were discharged to the sewer system.*
[b] *U233 [2-(2,4,5-trichlorophenoxy) propionic acid)] was eliminated from 40 CFR 261.33 by USEPA in 1984 and replaced with a reference to F027 (relating to tri-, tetra-, and pentachlorophenol formulations).*

and Wildlife Service (USFWS) is charged with protecting migratory waterfowl (under the Migratory Bird Treaty Act) and endangered species (under the Endangered Species Act). The USFWS is concerned about the potential bioaccumulation of hazardous constituents in lake organisms and the subsequent endangerment of migratory waterfowl (USFWS, 1994). They are also concerned about the impact to area wildlife if water is removed from all the sewage lagoons (especially Pond G).

During 1991, the USFWS conducted an investigation to assess whether harmful concentrations of contaminants could be present in water and biota at the sewage lagoons or Lake Holloman (USFWS, 1994). The objective of the study was to make an initial determination of the concentrations of organic and inorganic contaminants within biotic and abiotic components of the sewage lagoons and Lake Holloman aquatic ecosystems. Birds were collected from Ponds A, B, and G, and from Lake Holloman.

A summary of the results was presented in the draft *Preliminary Survey of Contaminants Present in Biota, Pore-Water, and Sediment, at the Holloman AFB WWTP* (USFWS, 10 January 1994). This report has not been finalized. The results primarily indicated that risks resulting from the presence of potentially toxic substances in aquatic systems were difficult to assess. Some of the analytical results collected from sediment samples indicated that the concentrations could cause some adverse biological effects; however, there were no analyses to determine if the constituents were bioavailable. Tissue samples collected contained generally low concentrations of these constituents.

In April 1993, Holloman AFB requested a list of threatened and endangered species that potentially inhabit the sewage lagoons and lakes area, and opened informal consultation with USFWS under Section 7 of the Endangered Species Act. Table 2-2 presents an updated list of endangered species (as of May 1995) potentially present at or near the sewage lagoons. The Base informed the USFWS of plans to construct a new wastewater treatment plant to replace the current sewage lagoons. This plan indicated Ponds A through F would be eliminated as water bodies, Pond G and Lake Holloman would receive treated wastewater and would continue to allow seasonal water overflow from Lake Holloman to Lake Stinky. The Mesilla Valley Audobon Society has requested that Lake Stinky be preserved as a shorebird habitat.

Holloman AFB has collected biota samples from the sewage lagoons and lakes. These data were used to prepare an ecological risk assessment that evaluated if a threat to the local environment exists as a result of the sewage lagoons. This is discussed in Section 4.3.

In addition, The *Biological Resources Report* (Radian and Foster Wheeler, June 1996) has been prepared to determine alternative closure methods for the sewage lagoons and how they might affect the existing biota's habitat. This report integrates those issues raised during the 3 April 1996 stakeholders meeting; specifically, the preservation of shorebird habitat.

The conclusions of this meeting were considered when selecting the proposed closure alternative presented in Section 6.1.6.

2.4 Funding for Closure

The sewage lagoons are included in the Installation Restoration Program (IRP) being conducted at Holloman AFB, and are designated IRP Site 49. The IRP was established to investigate past hazardous waste disposal sites at DoD installations. Implementation of the IRP generally follows the provisions of the Superfund Amendments and Reauthorization Act (SARA). These regulations mandate that the provisions of the National Contingency Plan apply to federal facilities.

As a DoD facility, Holloman AFB receives funding for the IRP from the Defense Environmental Restoration Account (DERA). Consequently, investigation and remediation activities at the sewage lagoons must be coordinated through the IRP. To date, over $10 million have been spent performing initial removal actions of sludge contaminated with polychlorinated biphenyls (PCBs) from Ponds A and B, and on characterizing the sewage la-

Table 2-2
Threatened, Endangered, and Sensitive Species Potentially Present at Sewage Lagoons and Lakes Area

Species	Observed	Habitat Use	Federal Status	State Status
White-Faced Ibis	yes	migrant	C2[a]	none
Bald Eagle	yes	winter resident/migrant	Endangered	Endangered
Northern Goshawk	yes	migrant	C2	none
Ferruginous Hawk	yes	winter resident/migrant	C2	none
Northern Aplomado Falcon	no	migrant/resident	Endangered	Endangered
Peregrine Falcon	yes	migrant	Endangered	Endangered
Whooping Crane	no	migrant	Endangered	Endangered
Western Snowy Plover	yes	resident breeder/migrant	C2	none
Interior Least Tern	no	migrant	Endangered	Endangered
Loggerhead Shrike	yes	resident breeder/migrant	C2	none
Southwestern Willow Flycatcher	no	resident/migrant	Proposed Endangered	Threatened
Baird's Sparrow	no	migrant/winter resident	C2	Threatened
Burrowing Owl	no[b]	resident breeder	C2	none
Neotropic Cormorant	no	migrant	None	Threatened
Greater Western Mastiff Bat	no	forages over water for insects	C2	None
New Mexico Jumping Mouse	no	wetland habitats and permanent ditches	C1	Threatened
Occult Little Brown Bat	no	forages over water for insects	C2	none
Small Footed Bat	no	forages over water for insects	C2	none
Swift Fox	no	open desert and grassland	C2	none
Texas Horned Lizard	no	desert grasslands/shrub lands, playas	C2	none
White Sands Pup Fish	no	alkaline springs, seeps, pools, and streams in Tularosa Basin	C2	Threatened
Gramma Grass Cactus	yes	relatively well-drained soils with alkali sacaton	C2	Endangered
Gypsum Scalebroom Grass	no	Alkali/gypsum playas in southern Otero County	C2	Endangered

Note: This list is based on approximately one year of monthly field observations by the NM Natural Heritage Program, recorded observations by Mesilla Valley Audubon Society, and USFWS guidance. About 140-150 other bird species have been observed using Lake Holloman or Pond G. The Federal and State status are as of May 1995.

[a]Category Two (proposed for study).
[b]Observed on Base but not in Lake Holloman/Lagoon G area.

goons, the ditch, and Lakes Holloman and Stinky. The majority of these funds were spent on the removal activities in Ponds A and B. These funds exclude the 1981, 1983, and 1984 investigations performed internally by USAF.

2.5 Federal Facilities Closure and Property Transfer Policy

As described later in Section 3 of this report, the mission of this Base is such that closure of the AFB in the near future is very unlikely. Holloman AFB supports a variety of unique and critical missions and has available a large relatively unencumbered air space to provide realistic combat training. If Holloman AFB were to close, CERCLA Section 120(h)(3)(B)(ii) requires closing bases to warrant a covenant in the deed that during closure or before property transfer:

1) All remedial action necessary to protect human health and the environment with respect to any such substance remaining on the property has been taken before the date of such transfer, and

2) Any additional remedial action found to be necessary after the data of such transfer shall be conducted by the United States.

Section 3
FACILITY DESCRIPTION

Holloman AFB is situated in south-central New Mexico, in the northwest central portion of Otero County. The Base occupies about 53,000 acres including lands around Lakes Holloman and Stinky that were recently transferred from the Bureau of Land Management (BLM). The main cantonment area is located in the northeast quarter of Section T.17S, R.8E. The High Speed Test Track extends northward into T.15S. The Base is situated approximately seven miles west of Alamogordo, NM, the only town of appreciable size within 50 miles of the Base. The remote location and the large DoD presence (White Sands Missile Range, Fort Bliss, and Holloman AFB) has helped Holloman AFB to avoid many problems (e.g., encumbered air space and urban encroachment) associated with other bases.

The desert terrain of the area surrounding Holloman AFB has limited development in the immediate vicinity of the Base. There are no farming operations, residential communities, or large industrial operations located adjacent to the Base. Future land use in the area is not expected to differ significantly from current land use. Holloman AFB is an active military installation and is expected to remain active for the foreseeable future. No transfer of military property to the public domain is anticipated. Public access to the Base is restricted.

3.1 Holloman AFB Mission

The host organization of Holloman AFB is the 49th Fighter Wing, whose mission it is to support national security objectives worldwide with F-117 stealth fighters and HH-60 helicopters. The helicopters are associated with the 48th Rescue Squadron. Additionally, the wing provides fighter fundamentals training using T-38 and AT-38 aircraft to U.S. and selected allied nation air crews. Training in F-4 aircraft is provided to the German Air Force (GAF). The Base is in the process of constructing support facilities for the GAF PA-200 Tornado fighter bombers. The 49th Material Maintenance Group deploys worldwide to provide physical infrastructure to remote air bases.

Over 30 tenant organizations are present on base, including the 46th Test Group, the Army Air Operations Directorate, Primate Research Lab, and the DRMO.

The 46th Test Group sponsors a variety of activities, including operating a variety of test bed aircraft and operating the 10-mile-long high speed test track. The test track is used for ground testing ejection seats, missiles, and other defense activities. Army Air operates aircraft in support of WSMR located to the north and west of Holloman AFB. The Primate Research Lab, formerly operated by New Mexico State University (NMSU), is now privately operated and performs medical research. DRMO is directly responsible for operating the Holloman AFB treatment, storage, and disposal facility.

3.2 Physiography

Holloman AFB is located in the Tularosa Basin in the southern part of New Mexico, as shown in Figure 3-1. The basin is approximately 120 miles long and 35 miles wide, extending from the southern end of Chupadera Mesa almost to the Texas Border. In the vicinity of the Base, the Tularosa Basin is bound 8 miles to the east by the Sacramento Mountains and 20 miles to the west by the San Andres Mountains.

Elevations within the Tularosa Basin range from 4400 ft above mean sea level (ft-msl) at the northeast corner to 4000 ft-msl in the southwest corner, sloping downward to the southwest. Elevations at the Base range from approximately 3900 to 4100 ft-msl, excluding Tularosa Peak. Elevations in the Sacramento Mountains reach 12,000 ft-msl and range from 7000 to 9000 ft-msl within the San Andres Mountains.

The Tularosa Basin is a closed basin with regard to surface drainage. No surface water leaves the basin, and there is very little surface water in the basin. Surface water is

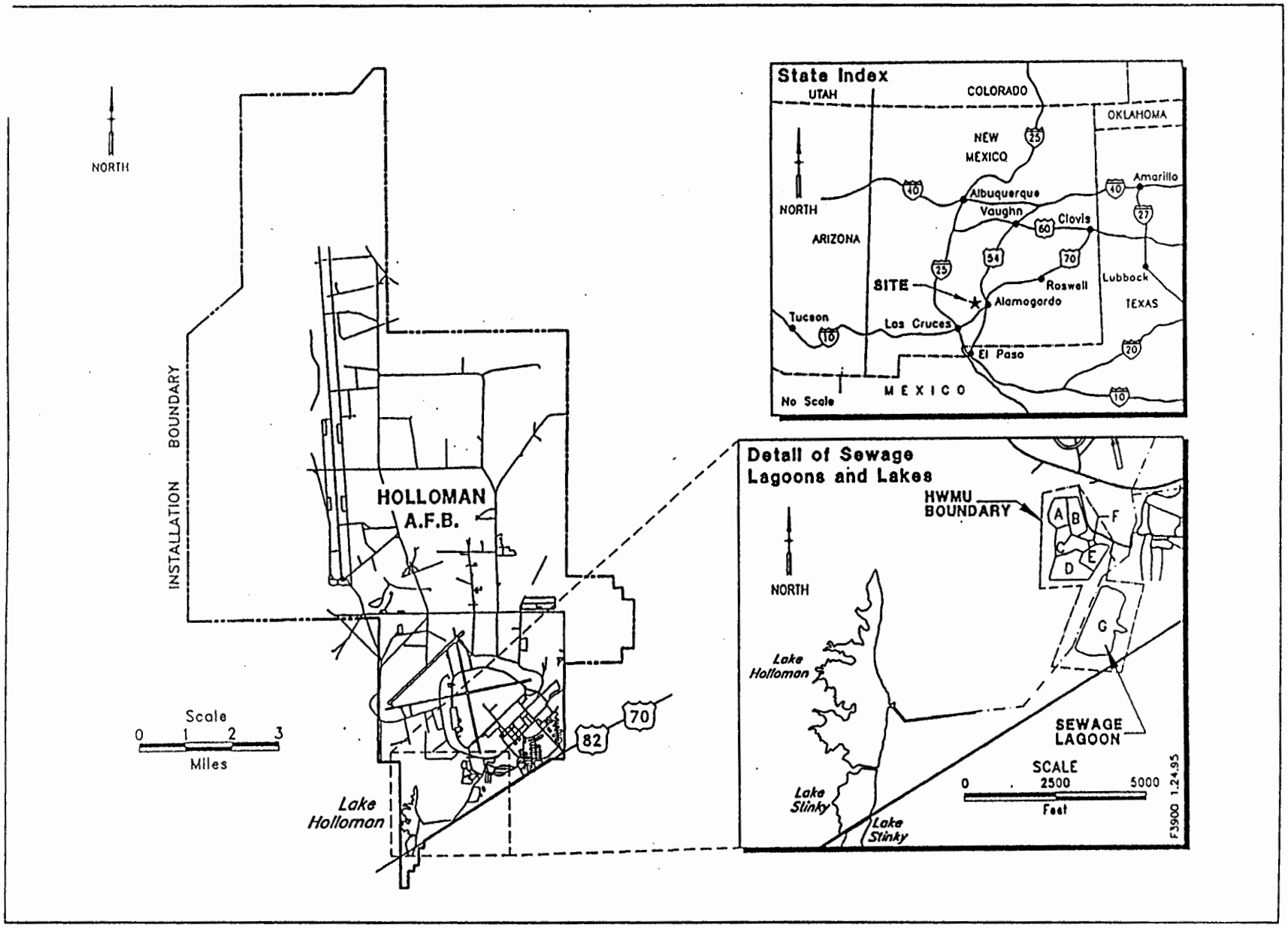

Figure 3-1. Location of Holloman AFB

either lost to evaporation or infiltration. Lake Lucero is the low point in the Basin, but has no direct surface water connection with Holloman AFB.

The Base is crossed by several southwest-trending "arroyos," or intermittent stream beds, including Lost River (the largest), Dillard Draw, Malone Draw, Ritas Draw and Hay Dray. Lost River is fed by groundwater seeps and springs resulting from LaLuz Creek/Fresnal Canyon Watershed. The river appears and disappears along its course as groundwater adds to and evapotranspiration and infiltration recapture the river's volume. Within the Base's boundaries, there is a very low volume of water in the Lost River.

3.3 Geology

The subsurface conditions at the sewage lagoons were defined by direct sampling and observation of the drilling operations of soil and monitor well borings drilled between 1987 and 1993. Figures 3-2 and 3-3 illustrate and describe the general stratigraphy of the site.

The sediments consist of sand, silt, and clay, and are subdivided into six very broadly definable units that appear to be continuous across the site (Figure 3-2). This interpretation is supported by available data; however, irregularities exist on a smaller scale because of the discontinuous nature of alluvial and lacustrine deposits.

Area soils are either Holloman-Gypsum Land-Yesum or Mead silty clay loam soil complexes. The Mead silty clay loam is found in low-lying areas and is sometimes associated with wetlands. The soil complexes grade into the upper sand unit, which consists of 6 to 40 ft of sand, silt, or silty sand. Clay lenses are common in the upper sand unit, and a discontinuous middle clay unit underlies the upper sand layer. The middle clay is reddish brown with abundant gypsum crystals, and ranges from 10 to 40 ft thick where present. A lower sand unit consisting of interbedded sand, clay, and silt lies beneath the middle clay. This unit is lithologically heterogeneous and ranges from 10 to 20 ft thick.

3.4 Surrounding Wildlife

Wildlife surrounding the Holloman AFB lagoons and lakes consists generally of waterfowl (e.g., mallards and mergansers), shorebirds (e.g., killdeer), and raptors. A sufficient number of mallards reside in the area to support seasonal hunting activities. In addition, migratory birds occasionally inhabit the sewage lagoons, especially Pond G. Fish are not endemic to the lagoon system. The mosquito fish were introduced to control the population of mosquitos, and are now thought to be an important food source. The mosquito fish are routinely found in Lake Holloman, Pond G, and the ditch. The upper sewage lagoons are poor habitat for fish and are unlikely to support healthy fish populations.

3.5 Physical Description of Sewage Lagoons

As illustrated in Figure 3-4, the sewage lagoons are located in the southwestern corner of the Base. They consist of seven aeration/ evaporation lagoons and receive approximately 1.2 million gal. of residential and industrial wastewater per day. The first three sewage lagoons, Ponds A, B, and C, are aerated. Ponds A and B are generally operated in parallel fashion and, occasionally, in sequence to increase residence time. Afterward, the wastewater flows in series from Pond C through Ponds D, E, and G. Pond F is a sump that recirculates wastewater from Pond E back to the headworks of the system when needed. Discharge from the last sewage lagoon (Pond G) flows via an open ditch to Lake Holloman.

Lake Holloman was formed by constructing a nonengineered dam to collect surface water drainage and wastewater discharge. The original dam was constructed in 1964 and upgraded to the present size in 1968. The 166-acre lake was intended to be the final impoundment for evaporation; however, because of seasonal low evaporation and increased wastewater generation from the Base activities, water from Lake Holloman occasionally overflows into Lake Stinky, a small salina. Any overflow into Lake Stinky eventually dissipates through evaporation.

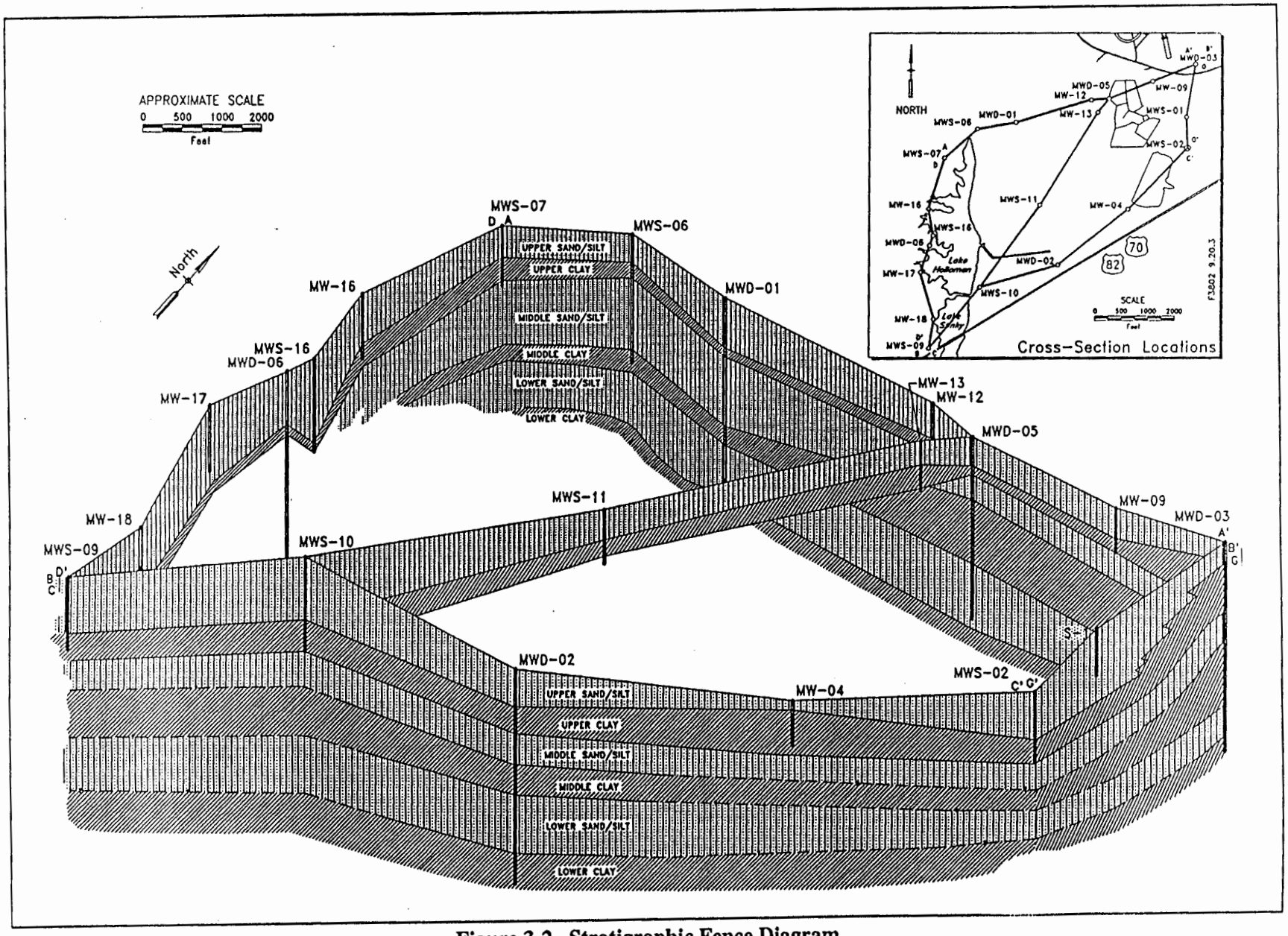

Figure 3-2. Stratigraphic Fence Diagram

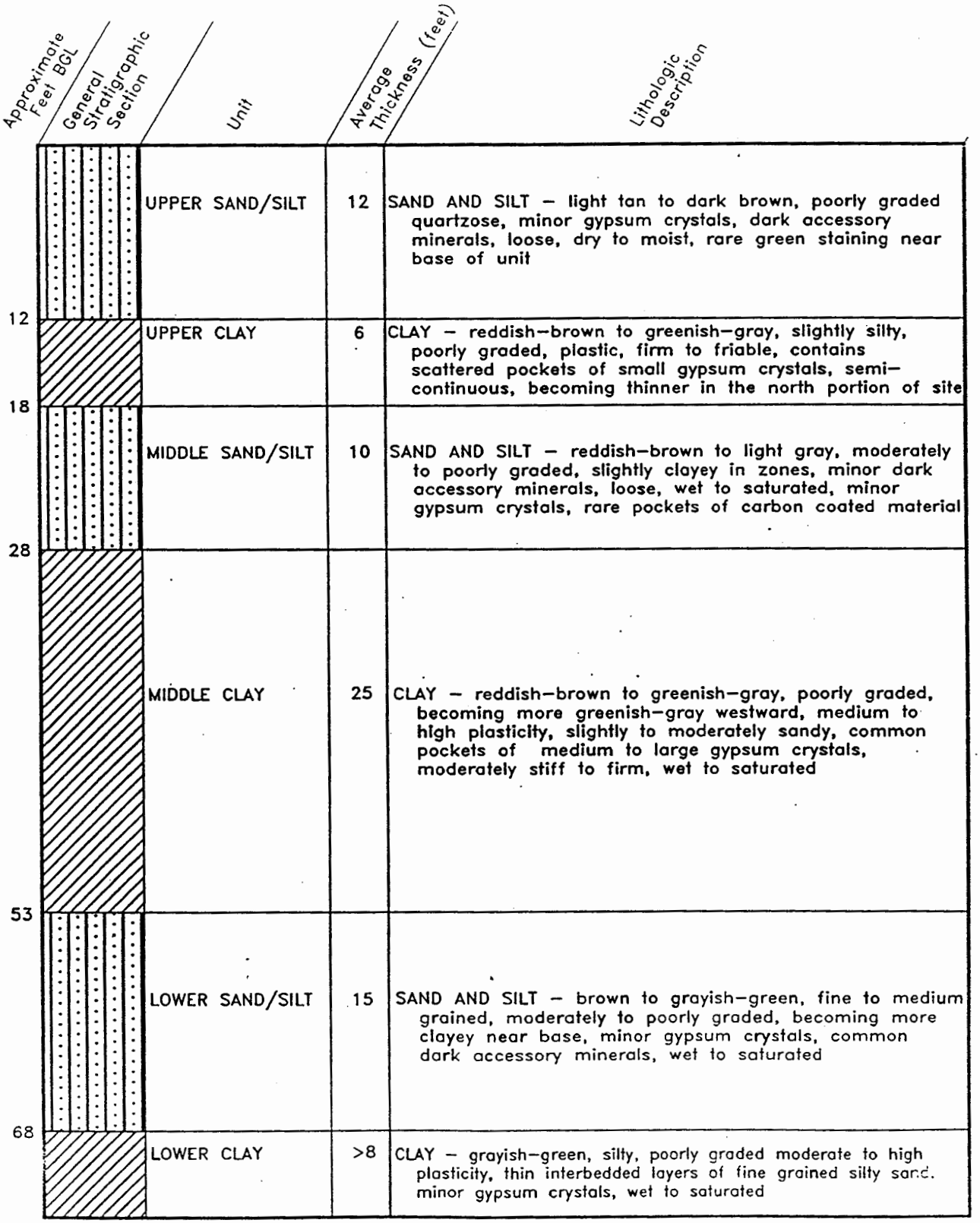

Figure 3-3. Site Stratigraphy

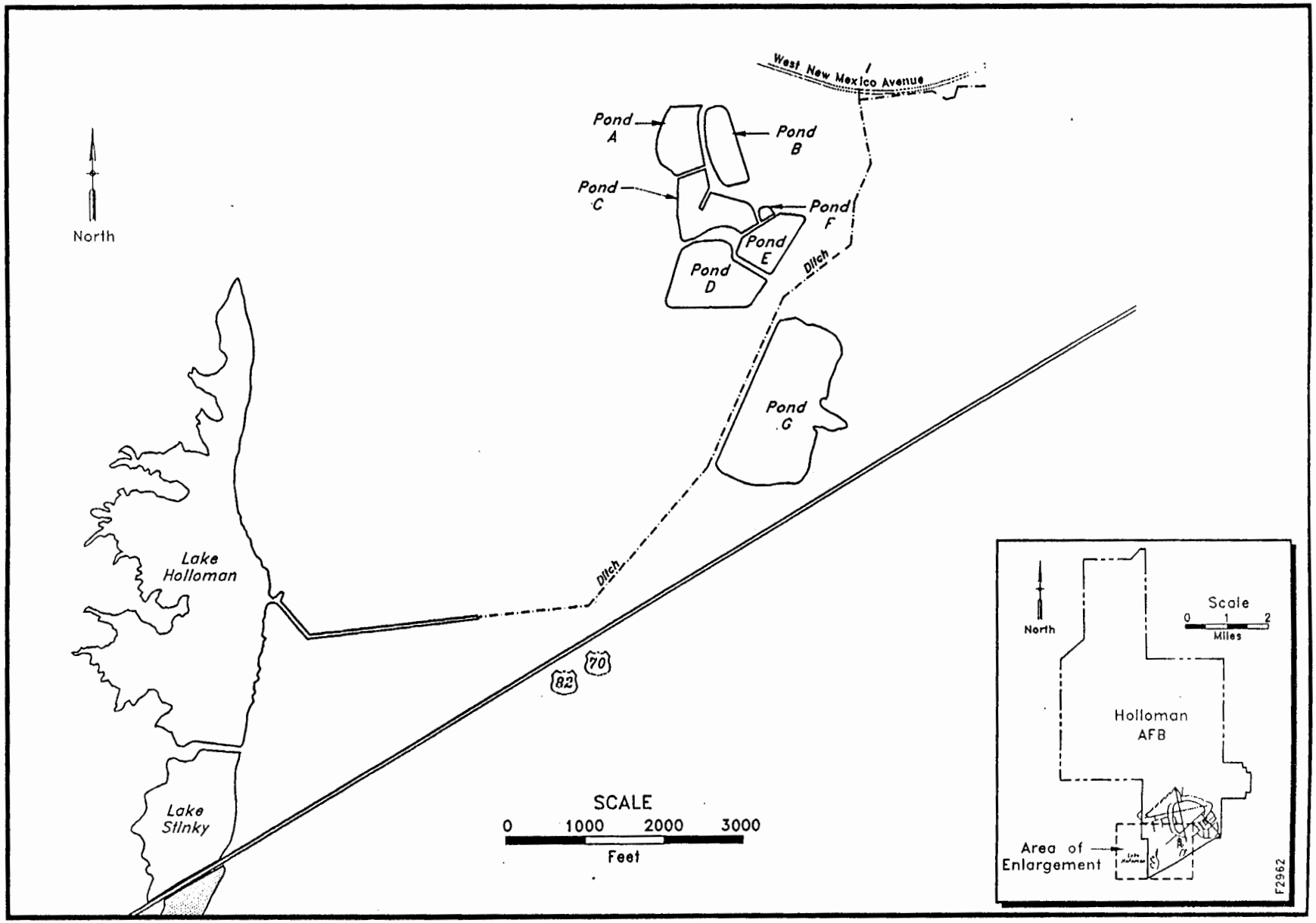

Figure 3-4. Location of Sewage Lagoons

3.5.1 Lagoon System Dimensions

Table 3-1 presents the surface area and capacity of the seven sewage lagoons within the lagoon system, as well as each pond's year of construction. The edges of Ponds A through F are steeply sloped and lined to prevent bank erosion. The edges of Pond G are not lined. All seven sewage lagoons are diked to prevent overflow. None of the ponds have bottom liners.

3.5.2 Approximate Depth of Sludge

A preliminary investigation in October 1991 was performed to determine the water depth and sludge thickness in Ponds C, D, E, F, and G, as well as Lakes Holloman and Stinky. At the time of the study, Lake Stinky was dry. Results of this investigation are documented in the *Conceptual Plan for Sludge and Soil Sampling: Sewage Lagoon Investigation* (Radian, 1991c). Similar measurements were conducted during the 1994 investigation. As with the 1991 measurements, Lake Stinky was dry in 1994. No measurements were collected from Pond F during the 1994 investigation. Measurements from the more recent 1994 investigation are presented in Table 3-2.

3.6 Groundwater Quality

Groundwater quality in the Tularosa Basin is potable at the Boles and San Andres water well fields located at the foot of the Sacramento Mountains, 14 miles southeast of Holloman AFB. Groundwater becomes progressively more mineralized as it flows downgradient toward the interior of the basin. This decrease in water quality can be attributed to slow groundwater migration from recharge to discharge areas and the presence of readily soluble minerals in the Bolson sediments. Total dissolved solids (TDS) exceed 100,000 mg/L in some portions of the Tularosa Basin (USGS, 1985).

The groundwater beneath Holloman AFB is designated as unfit for human consumption, based on New Mexico Water Quality Control Commission Regulations (NM WQCC 82-1, as amended through August 18, 1991 Parts 3-100 through 3-103) because it exceeds New Mexico human health standards (HHSs) for TDS and sulfate. Average values of other groundwater quality parameters measured at Holloman AFB (chloride, fluoride, and nitrate-nitrite) also exceed HHSs and, except for fluoride, also exceed federal primary and secondary drinking water maximum contaminant levels (MCLs and SMCLs, respectively). Water quality parameters reflect that the groundwater in this area is not potable under natural conditions.

Although EPA guidelines for groundwater classification are not recognized by the State of New Mexico, the EPA guidelines (1986) classify the groundwater beneath Holloman AFB as a Class III B aquifer. Class III groundwater, characterized by having a TDS concentration greater than 10,000 mg/L, is not considered a potential source of drinking water. Class III B groundwater is characterized by a low degree of interconnection to adjacent surface waters or groundwater of a higher class. The average measured TDS value of groundwater at Holloman AFB is greater than 10,000 mg/L (Radian, 1992a). Because the Tularosa Basin is a closed basin, its groundwater does not discharge or connect to any adjacent aquifers. Adjacent surface waters include groundwater surfacing in Malone Draw and Lakes Holloman and Stinky. The TDS in Lake Holloman range from a winter low of 12,400 mg/L to a summer high of 17,000 mg/L; therefore, groundwater at Holloman AFB is not interconnected with surface water of a higher class. During the 1993 groundwater investigation, TDS concentrations ranged from 11,000 to 12,000 mg/L in Lake Holloman and were 14,000 mg/L in Lake Stinky as reported in *Results of Confirmation Sampling and Comparison to Appendix IX Sampling Assessment Monitoring Program* (Radian, 1992a).

Table 3-1
Sewage Lagoon
Construction Dates and Dimensions

Pond	Year Constructed[a]	Surface Area (acres)	Capacity (million gal.)
A	1943	10.1	16.1
B	1943	11.2	16.1
C	1955-1959	12.5	21.3
D[b]	1955-1959	18.7	28.5
E	1955-1959	7.8	12.5
F	1955-1959	0.5	1.6
G	1970	39.8	64.6

[a]Ponds C, D, E, and F were constructed during the stated time interval; however, no dates were available to indicate the sequence of completion.
[b]Pond D was reconstructed in 1980.

Table 3-2
1994 Investigation Water Depth and Sludge Thickness Measurements

Pond	No. of Sample Locations	Water Depth (ft)			Sludge Thickness (in)		
		Minimum	Maximum	Average	Minimum	Maximum	Average
A	6	4.8	7.3	6.0	6	13	8.5
B	6	5.8	7.0	6.4	9	30	16.3
C	13	3.3	6.8	5.4	2	28	17.3
D	10	3.6	6.6	5.4	0.25	12	2.5
E	16	2.2	6.5	4.9	2	24	11.8
F[a]	4	5.0	5.0	5.0	6	10	7.5
G	19	1.1	4.6	3.4	1	16	4.6
Lake Holloman	25	0	6.2	3.5	0	18	5.2

[a]October 1991 measurements

Section 4
PREVIOUS INVESTIGATIONS

Over the past 15 years, several investigations have taken place in and around the sewage lagoons that provide analytical insight into the nature and extent of contamination connected with the sewage lagoons. These investigations have analyzed the soil, sludge, surface water, biota, groundwater, and human and ecological risks associated with the sewage lagoons. This closure plan intends to incorporate this information into the knowledge base that will serve as the basis for determining potential risk stemming from the sewage lagoons and for selecting a strategy for final closure.

A summary of the median and maximum concentrations of constituents detected in each sewage lagoon between 1990 and 1995 are reported in Appendix A of this report. The *Site Characterization Report* (Radian and Foster Wheeler, June 1995) appendices include a summary of analytical data for each individual investigation. Presented below is a summary of the investigative activities that have occurred. Where applicable, emphasis is placed on 1) the purpose of the sampling, 2) the analytical results and conclusions of the sampling, and 3) the recommendations stemming from the sampling event. In particular, the significance of each sampling event is presented with regards to the contaminants observed and how the findings contribute to final closure of the sewage lagoons. Additional information may be obtained from the documents cited in each section. Information is presented chronologically and by type of investigation.

4.1 Sludge, Soil, Surface Water, and Biota Investigations

Several environmental investigations and one removal project have taken place within the sewage lagoons since 1981. The investigations have analyzed contaminants associated with sewage lagoon sludges and soils, as well as the solubility and bioavailability of these contaminants. The removal project involved a voluntary removal of approximately 4000 tons of sludge from Ponds A and B. Twelve of these investigations are presented below. The most recent investigations, the 1994 investigation, is presented in Section 5 of this report and detailed in the *Site Characterization Report* (Radian and Foster Wheeler, June 1995). Appendix A presents the location of surface water, groundwater, sludge, and soil samples collected from 1990 through 1994 in each of the lagoons. Results from these investigations were used to determine potential risk and to support closure activities.

4.1.1 1981 Water and Sludge Sampling—EP Toxicity

In November 1981, water and sludge samples were collected from the sewage lagoons and Lake Holloman for analysis by the EP toxicity procedure. This evaluation was conducted to determine whether the wastewater that the sewage lagoon received contained levels of heavy metals or other constituents that would cause the wastewater to be classified as hazardous waste. Samples of both the wastewater and sludge were collected and analyzed. Most of the constituents were below detectable levels and none exceeded the EP toxicity criteria defined in 40 CFR 261.24. The data was presented in the January 1982 report, *Evaluation for Hazardous Waste at Holloman AFB Sewage Treatment Plant* (HAFB, 1982). The following conclusions were made:

1) The wastewater and sludge samples appear not to be contaminated by the heavy metals arsenic, barium, cadmium, chromium, lead, mercury, selenium, or silver. (Detectable levels of arsenic, cadmium, chromium, and silver, were found in the wastewater, but at concentrations less than 10 percent of the regulatory limits. No contamination was detected in the sludge.) Chromium levels in the wastewater did fluctuate during a 24-hour period but were well within EPA standards thought to be applicable.

2) The sludge samples collected from the

sewage lagoons did not exceed EPA criteria for EP toxicity, corrosivity, or reactivity. (Since the sewage lagoons receive only wastewater, there is very little chance for ignitability problems.)

4.1.2 1983 Water and Sludge Sampling—Chromium and Organics

In October 1983, sludge and wastewater samples were collected from Ponds A and B. This sampling event was primarily in response to an EPA letter issued on 31 March 1983. Chromium was becoming an increasing concern of the EPA, and this sampling event was intended to substantiate the earlier findings of low concentrations of chromium in the wastewater. Organic compounds (1,1,1-trichloroethane, trichloroethylene, and total organic halogens) and chromium were targeted for testing.

Analytical results were presented in the 22 December 1983 document, *Report to EPA Regarding Holloman Air Force Base Lagoons and T-38 Washrack Oil-Water Separator* (HAFB, 1983). The conclusions were essentially the same as the January 1982 report, although chromium was detected in the wastewater stream. However, chromium was not detected in the sludge contained in Ponds A or B. (Samples were analyzed by the EP toxicity method, which has a chromium detection limit of 50 μg/L.) Theoretical calculations were presented, and it was found that, by means of a mass balance, the amount of chromium present in the wastewater was significantly below allowable amounts established in the EP toxicity criteria.

4.1.3 1984 Priority Pollutant Sampling

In response to a 15 August 1984 request by EPA Region VI, Holloman AFB proposed a protocol outlining sampling and analytical procedures for the list of 129 priority pollutants (Holloman AFB, 1984). The protocol was developed to test for the listed wastes that were suspected of being discharged to the sewage lagoons. In December 1984, a total of 11 sludge and wastewater samples were collected from Ponds A, B, and C and analyzed for priority pollutants. Eight heavy metals and five pesticides were analyzed using EP toxicity and total extraction procedures. Analyses were conducted for purgeable organics (EPA Method 624), base/neutral and acid compounds (EPA Method 625), pesticides and PCBs (EPA Method 608), cyanides, and total phenols.

The analytical results of the December 1984 sampling were presented both in a meeting to EPA Region VI in April 1985 and in the March 1986 report, *Evaluation for 129 Priority Pollutants, Holloman AFB Sewage Ponds* (Holloman Air Force Base, 1986). Of the 11 sludge and 6 water samples that were analyzed, one pollutant (PCBs) was found in concentrations that warranted some concern. Sludge concentrations of PCB-1254 ranged from nondetect to 130 ppm. A bioassay study was recommended by USFWS to investigate the possibility of PCBs accumulating in the indigenous biological organisms and transferring to larger animals via the food chain.

4.1.4 1987 Appendix IX Sampling in Support of Delisting Petition

In 1987, Holloman AFB contracted with Computrac, Inc., to prepare a preliminary delisting petition to delist the waste in the sewage lagoons. The purpose of the preliminary report was to determine whether delisting was a feasible option, prior to conducting an extensive sampling plan. In support of the preparation of this preliminary delisting petition, a comprehensive sampling and analysis program on one sludge and one surface water sample from each sewage lagoon, Lake Holloman, and Lake Stinky was recommended, using EPA-approved protocols. The sampling effort was conducted in July 1987. The results of the analyses indicated that several metals (antimony, barium, cadmium, and mercury) were present in concentrations that could negatively affect the delisting petition. Furthermore, these concentrations were not limited to individual water bodies but were found throughout the sewage lagoon system. None of the organic constituents identified as potential problems by EPA in earlier samples (chloroform, PCB-1254, and benzo(a)pyrene) were detected in these new samples. Since only one sludge sample and one surface water sample were taken from each water body, no definitive conclusions were drawn from this sampling event. However, the delisting petition was aban-

doned.

Analytical results are presented in an 18 August 1987 report, *Analytical Summary of Holloman Air Force Base Delisting Assessment* (Computrac, 1987).

4.1.5 May 1988 Preliminary Investigation for Sludge Removal

As the probability of a cost effective successful delisting was decreasing, HQ Tactical Air Command (TAC) (currently HQ ACC) began exploring the possibility of developing a revised closure scenario that would include the removal of the sludge mounds in Ponds A and B. The removal of the sludge required determining the height and areal extent of the mounds and the regions of PCB contamination. The mounds were contoured and a total of 18 depth-integrated samples (9 from each sludge mound) were collected in May 1988. These were composited into six samples and submitted for laboratory analysis of PCBs and other organic and inorganic constituents. Results showed the PCB concentrations in the sludge ranged from 24 to 63 ppm.

4.1.6 August 1988 Additional Investigation for Sludge Removal

The May 1988 investigation estimated the size of the sludge mounds approximately 10 times greater than the size originally estimated during the preliminary delisting petition. Consequently, a more extensive sampling plan was developed to better define the overall extent of contamination with respect to volatile and semivolatile organic constituents, PCBs, and metals. In August 1988, a total of 45 locations in Pond A and 40 locations in Pond B were sampled. In addition, four points near the periphery of each sewage lagoon were sampled. Samples were again analyzed for PCBs and other organic and inorganic constituents. Results of the sampling effort were included in the *Draft A-E Quality Control Summary Report (A-E QCSR) for Additional Sampling at Sewage Lagoons* (Radian, 1989).

Of the seven PCB species quantified by Method 8080, only two were detected: PCB-1254 and PCB-1260. The total PCB concentrations (arithmetic sum of PCB-1254 and PCB-1260) ranged from 1.6 to 190 ppm. Concentrations of the two PCB compounds were added to present a worst-case scenario to evaluate the extent of contamination for sludge removal. No volatile organic compounds were detected in any sludge sample by Method 8240 analysis, which was consistent with previous sample results. Nineteen semivolatile organic compounds were detected at low concentrations by Method 8270. The majority of the compounds were polynuclear aromatic hydrocarbons. Twelve metals were detected in the sludge samples, but no EP toxicity metals were detected above regulatory limits in soils beneath the sludge mounds.

On the basis of these results, HQ TAC concluded that PCBs were the most significant contaminants of concern, and by removing the PCB-contaminated sludges, nearly all other known hazardous constituents would also be removed. A closure plan was developed to provide an 80 percent confidence level for removal of all sludge with a PCB concentration of 25 ppm or greater.

4.1.7 1990 Sludge Removal Project

In January 1990, Holloman AFB began the removal of 1316 tons of sludge from Pond B and 2663 tons from Pond A. The project was completed in October 1990. Subsequent to sludge removal, verification sampling was conducted from a 37-point sampling grid and samples were analyzed for PCBs. A single sludge sample collected from a point outside the removal zone was found to contain 27 ppm PCBs; however, follow-up sampling of three points surrounding this location showed that the sludge contained less than 18 ppm PCBs. Western Technologies performed additional confirmation sampling in Pond A after the sludge was removed. No concentrations higher than 11 ppm were detected. Analytical data is presented in *Holloman Air Force Base Hazardous Waste Sewage Sludge Removal, Contractor's Chemical Quality Control Summary Report* (Western Technologies, 1991).

4.1.8 1990 Surface Water Sampling

In October 1990, surface water samples were collected from the sewage lagoons and

analyzed. The objective of this effort was to obtain accurate surface water quality data for input to the risk assessment being prepared.

Two samples were collected from the wastewater treatment facility headworks, and five samples were collected from Ponds B, C, D, E, and G, and Lake Holloman. Sample locations were chosen to represent the areal distribution and variation of water quality within each impoundment.

Samples were analyzed for semivolatile organic compounds, pesticides, PCBs, and metals. Organolead was also detected at less than five times the reporting limit; however, these low concentrations have been a risk driver. There is some uncertainty with the results of the organolead since the reported values are greater than the total lead concentrations reported. The equipment rinsate results also reported similar concentrations of organolead. Holloman AFB personnel are not aware of any spills of aviation gasoline (leaded) to the sewage lagoon system that could have led to detecting the concentrations of organolead reported. The uncertainty of organic lead was addressed in the additional sampling of sludge and surface water performed during the 1994 investigation. The recent samples did not detect any organolead in surface water samples. Analytical results from this 1990 sampling are presented in a December 1990 *Draft A-E Quality Control Summary Report (A-E QCSR) for Sewage Lagoon Surface Water Sampling* (Radian, 1990).

4.1.9 March 1990 Sludge and Soil Sampling at Pond C

As part of the March 1990 verification sampling, sludge and soil samples were collected from Pond C. Sampling in Pond C focused on the area around the influent points from Ponds A and B. A total of six locations, three at each area approximately 25 ft in a radial distance from the influent point, were selected to collect samples of sludge and underlying soil. Analytical results of the investigation are reported in the June 1991 report entitled *A-E Sampling and Quality Control Summary Report (A-E QCSR) for Field Investigation to Support Sewage Lagoon Closure* (Radian, 1991a).

No PCBs were detected in any of the soil or sludge samples collected from Pond C. Pesticides (4,4'-DDD and 4,4'-DDE) were detected in two sludge samples at concentrations ranging from 6 to 16 ppm. By analyzing underlying soil samples, it was concluded that these compounds had not migrated to the underlying soil.

4.1.10 1991 U.S. Fish and Wildlife Biota Sampling

During the summer of 1991, the USFWS conducted an investigation of the Holloman AFB sewage lagoons and Lake Holloman to determine whether migratory birds were being exposed to organic and inorganic contamination present in these surface waters. Eleven sediment, 1 pondwater, and 35 biological samples were collected from several locations at the sewage lagoons and Lake Holloman. The samples were assayed for various metals, metalloids, and organic compounds.

Study results indicate that risks resulting from the presence of potentially toxic substances in aquatic systems were difficult to assess. Sediment samples revealed the potential for adverse biological effects; however, no analyses were performed to determine the bioavailability of the contaminants. Collected tissue samples contained generally low concentrations of these constituents. Analytical results of the investigation are reported in a draft survey report entitled *Preliminary Survey of Contaminants Present in Biotic, Pore-Water and Sediments at the Holloman AFB WWTF* (USFWS, 1994). This report has not been finalized by the USFWS.

4.1.11 1991-1992 Sewage Lagoon Investigation in Support of the PCCP Application

In June 1991, Holloman AFB submitted a postclosure care permit (PCCP) application for the sewage lagoons. The purpose of the PCCP was to allow the Base to continue treating nonhazardous waste at the sewage lagoons under the "delay of closure" option. NMED declared that the PCCP application was administratively complete; however, the document has never been technically reviewed by NMED. One condition for review, as stated in a letter from

NMED dated 22 May 1991, was that a sampling and analysis program be conducted in all impoundments downstream of Pond C.

Following NMED's condition, the Base performed a two-phase investigation of the sewage lagoons during October 1991 and February/March 1992. The objectives of the investigation were the following:

- To support review of the PCCP application;
- To characterize the sewage lagoons and provide a preliminary estimate of the nature and extent of contamination and the resulting effect on final closure; and
- To provide a Phase I RFI report for Lakes Holloman and Stinky as required by the HSWA permit.

On the basis of the preliminary October 1991 investigation in which the depth of sludge and water was measured in each of the sewage lagoons, a sampling protocol was prepared and agreed on by HAFB, NMED, EPA Region VI, USACE, and HQ ACC. This was documented in the *Conceptual Plan for Sludge and Soil Sampling* (Radian, 1991b). The sampling plan was accepted by NMED in a letter dated 18 November 1991 and by EPA Region VI in a letter dated 17 December 1991. Both of these are presented in Appendix E of the *Project Assessment Report* (Radian and Foster Wheeler, March 1995).

The site was then investigated in February and March 1992 by sampling and analyzing the sludge and underlying soil in the sewage lagoons, lakes, and ditch for Appendix IX constituents. The results of the investigation were documented in Sections 4 through 6 of the *Site Characterization Report* (Radian, 1992b). This investigation indicated that the primary contaminants in the sludge samples from the sewage lagoons and lakes were metals and organochloride pesticides. Metals detected in the soil were not significantly different from background levels and pesticides were significantly below proposed Subpart S action levels.

4.1.12 1993 Background Sampling

During February and March 1993, Basewide background soil samples were collected. These samples represented background metal concentrations for Basewide investigative activities. To characterize background soil conditions, 10 sampling locations were selected from the Holloman-Gypsum Land-Yesum soil complex. Each sample location was carefully selected to avoid collecting samples affected by historical waste management practices. These background soil samples were representative of surface soil throughout the Base. Analytical results from this investigation are combined with background groundwater data that were collected concurrently, and are presented in Appendix B-1 in the December 1993 *Draft Final Phase 1-Groundwater Assessment Monitoring Report, Sewage Lagoons and Lakes Investigation* (Radian, 1993a).

4.1.13 1993 Biota Sampling

Biota samples were collected to prepare an ecological risk assessment in response to the USFWS's request. Biota samples were collected in all sewage lagoons and lakes, as well as in the ditch connecting Pond G and Lake Holloman. All biota sampling started downstream (Lake Stinky) and moved upstream, so that contaminants potentially stirred up during sampling activities would not interfere with analytical results from the samples collected. Table 4-1 presents a summary of biological samples collected.

Biota samples were analyzed for chlorinated pesticides, PCBs, semivolatile organic compounds, polychlorinated dioxins and furans, and some metals. Analytical results were evaluated as part of the ecological risk assessment. Analytical data are reported in Appendix D of the March 1996 *Risk Assessment Addendum* (Radian and Foster Wheeler, March 1996). The conclusions drawn from this data are presented in Sections 5 and 6 of the same report.

4.2 Groundwater Investigations

Groundwater investigation activities were initiated as part of the FFCA to comply with RCRA regulations for surface impoundments. In July 1989 a groundwater monitoring system, which consisted of eight new and two existing

Table 4-1
Biological Samples Collected from the Sewage Lagoons and Lakes in 1993
Holloman AFB

Sample Location	Biological Sample			Media Sampled
	Plankton	Benthos	Vertebrates	
Pond A	Rotifers	Chironomids, Corixids	None	Surface Water, Near Surface Sediment
Pond B	None	None	None	Surface Water
Pond C	Rotifers	Corixids	YOY Black-Neck Stilts (3)	Surface Water
Pond D	Rotifers	None	None	Surface Water
Pond E	Rotifers	Chironomids	None	Surface Water, Near Surface Sediment
Pond F	Rotifers	None	None	Surface Water
Pond G	Rotifers	Corixids	Gambusia (2), Whole Salamander (4), Sala mander Muscle, Salamander Organs, YOY Mallard Muscle (2), YOY Mallard Organs, YOY Mallard Carcass	Surface Water
Ditch	Rotifers	Chironomids, Lotic insects	Gambusia	Surface Water
Lake Holloman (Lower)	Rotifers	None	Gambusia	Surface Water
Lake Holloman (Middle)	Rotifers	None	Gambusia	Surface Water
Lake Holloman (Upper)	Rotifers	None	Gambusia	Surface Water
Lake Stinky (North)	Mixed	None	None	Surface Water
Lake Stinky (South)	Mixed	Ostracods	None	Widgeon Grass
Runoff Ditch	None	None	Gambusia	None
Runoff Ditch	None	None	Gambusia	None

YOY = Young of Year

wells, was installed. Four additional background wells were installed in 1991, and five more in 1993. Figure 4-1 presents the location of monitored groundwater wells. Presented below is a chronological summary of groundwater sampling events that have occurred for the sewage lagoon system.

4.2.1 August 1989-January 1991 Detection Monitoring Program

Background concentrations were developed on a 5-month accelerated schedule with samples collected during August, September, November, and December 1989. Following the determination of background concentrations, semiannual detection monitoring began in January 1990. The second round was performed in July 1990 (a resample was also collected in September 1990), and the third in January 1991.

The groundwater detection monitoring program was performed in accordance with 40 CFR 265.92(d)(1) and (2) and the FFCA. Wells were monitored for the groundwater indicator parameters specified in 40 CFR 265.92(b)(3)—pH, specific conductance, purgeable organic halides, and total organic carbon (TOC). Each time the wells were monitored, static water level and total well depth measurements were obtained. Immiscible organic layers were also looked for, but were never found. The following wells were monitored during the program: MW-1, S-2, MW-2, MW-3, MW-4, MW-5, MW-6, MW-7, MW-8, and S-4. (See Appendix A, Figure A-12 for well locations.)

Holloman AFB was notified by EPA Region VI in January 1991 that a significant increase in TOC had been detected and assessment monitoring would be necessary. EPA's evaluation of monthly and semiannual sampling events indicated a statistically significant increase in TOC between upgradient and downgradient wells. Holloman AFB requested EPA's evaluation in writing during a 31 January 1991 meeting. The EPA provided this in a 3 May 1991letter to Holloman AFB. An assessment monitoring plan was submitted in September 1991.

4.2.2 1991 and 1992 Groundwater Assessment Monitoring

The first step in assessment monitoring was to determine whether the elevated downgradient TOC values were indicative of a release of organic hazardous waste/waste constituents. Samples were collected in September 1991 from the monitor well network and analyzed for Appendix IX organic constituents and TOC.

Subsequent discussion of the Appendix IX sampling results with NMED concluded that organochlorine pesticides were the only contaminants of concern, and that confirmation sampling should be conducted to confirm the presence of these constituents in the groundwater. The occurrence of volatile and semivolatile compounds was attributed to laboratory contamination. The confirmation sampling was conducted in February 1992 for SW-846 Method 8080 compounds. Results of the confirmation sampling indicated that two organochlorine pesticides, alpha-BHC and delta-BHC, are present in the groundwater in monitor wells MW-5 and MW-7, respectively. In addition, the following organochlorine pesticides were detected during either the Appendix IX or confirmation sampling rounds: aldrin, dieldrin, beta-BHC, gamma-BHC, 4,4'-DDD, endosulfan I, endosulfan sulfate, endrin, heptachlor, and heptachlor epoxide. Aldrin and dieldrin were above the action levels. However, since these constituents were not present in both sampling rounds in comparable wells, their presence in the groundwater was not confirmed. Analytical results are presented in Sections 4 and 5 and Appendix B of the April 1992 report entitled *Results of Confirmation Sampling and Comparison to Appendix IX Sampling Assessment*

Monitoring Programs (Radian, 1992a).

TOC and dissolved organic carbon (DOC) were also detected in several samples. Results showed no strong correlation between the presence of TOC/DOC and organic contaminants. A cause of elevated TOC levels is the location of monitor wells with respect to the sewage lagoons, and the impact of biological activity associated with wastewater treatment on water quality of the uppermost aquifer. TOC concentrations in domestic wastewater of greater than 100 mg/L are commonly found as a result of biological decomposition (Metcalf and Eddy, Inc., 1991).

The following recommendations for the groundwater monitoring program were made: 1) Modify the RCRA groundwater monitoring network to include two upgradient monitors wells installed in February 1992 (MW-9 and MW-10) and abandon piezometer S-2 (found to have a variable gradient), and 2) install additional wells southwest of Ponds A and C to determine whether organochlorine pesticides have migrated beyond monitoring wells MW-5 and MW-7.

4.2.3 1992 Geoprobe and Piezometer Sampling

Groundwater samples were collected in December 1992 at 14 downgradient locations of Ponds A and D to determine lateral extent of groundwater contamination from organochlorine pesticides. The results were used to determine where additional permanent monitoring wells were to be installed and added to the groundwater monitoring network system. A Geoprobe® screen point groundwater sampler or a piezometer were used to collect samples. Results from this investigation are reported in the *Sampling and Quality Control Summary Report (A-E SQCSR) Sewage Lagoons and Lakes Investigation, Draft Final* (Radian, 1993c).

4.2.4 1993 Background Groundwater Sampling

Four new monitor wells were installed in areas upgradient of potential contamination and in areas unaffected by past waste management practices. Samples were collected from these 4 wells and 10 existing background monitor wells. Samples were analyzed for total metals using unfiltered groundwater and for dissolved metals using 0.45-micron filtered groundwater. Analytical results from the background investigation are presented as Appendix B-1 in the *Draft Final Phase 1-Groundwater Assessment Monitoring Report for the Sewage Lagoons and Lakes Investigation* (Radian, 1993a).

4.2.5 1993 Groundwater Assessment Monitoring—Phase 1

The primary objectives of the Phase 1 assessment monitoring were to define the lateral extent of Method 8080 pesticides in the uppermost aquifer and to make recommendations for future monitoring requirements. In addition, Appendix IX parameters were collected from newly installed monitor wells and deep piezometers to evaluate potential lateral and vertical migration of other constituents that may have gone undetected in previous sampling.

Three new monitor wells (MW-11 through MW-13) were installed downgradient of Pond A and two new monitor wells (MW-14 and MW-15) were installed downgradient of Pond D. In addition, one existing piezometer (MWS-05) was added to the network downgradient of Pond D. Three deep piezometers (MWD-03 through MWD-05) were sampled to assess the potential for vertical migration of constituents.

Data evaluation criteria to ascertain the presence or absence of constituents were based on the first determination false positives (see the long-term monitoring plan,

Radian, 1995a, for additional information).

The presence of Method 8080 pesticides was considered to be certain only in monitor wells MW-03 (heptachlor epoxide) and MW-04 (4,4'-DDD) immediately downgradient of the sewage lagoons. The presence of Method 8080 pesticides in other wells is considered either uncertain or unlikely. The lateral extent of pesticides has been defined downgradient of monitor wells MW-05 and MW-07 (Pond A) and MW-03 (Pond D). The extent of 4,4'-DDD in MW-04 (Pond G) is unknown because of the lack of monitor wells located further downgradient. However, on the basis of results from monitor wells downgradient of Ponds A and D, it is anticipated that the presence of pesticides will be uncertain or unlikely further downgradient of MW-04.

The metals analyses indicate cadmium concentrations in the wells downgradient of Pond A to be higher than background concentrations for the entire base. Analysis of samples from monitoring wells MW-11, MW-12, and MW-13 detected higher average concentrations than background for mercury and tin, but all downgradient results were within the range of concentrations measured for background. For MW-14, MW-15, and MWS-05, data for antimony, tin, and cadmium showed lower average concentrations than background, but some individual concentrations were above the upper tolerance limits.

Analytical results are presented in the December 1993 report, *Phase I Groundwater Assessment Monitoring Report* (Radian, 1993b). Appendix C, Sections 3 through 5 of that report present the results and conclusions.

4.2.6 1995 Long-Term Groundwater Monitoring

Ten wells were sampled during September and October 1995 for organochlorine pesticides and metals during the 1995 long-term monitoring (LTM) sampling event for the sewage lagoons. The analytical results of this sampling were compared with established alternate concentration levels for each analyte. The results of this comparison are presented in *1995 Sampling Report, Sewage Lagoons Long-Term Groundwater Monitoring Program* (Radian, February 1996). Analytical data is summarized in Appendix A of that report. No analyte was detected at levels above its respective alternate concentration level. If clean closure is achieved, long-term groundwater monitoring will be discontinued.

4.3 Risk Assessment

Since 1991 three quantitative risk assessments have been performed on the sewage lagoon system. The first looked at the entire system as a single component. The second assessment looked at the sewage lagoons, lakes, and ditch as individual units. The third assessment updated the second assessment using the 1994 investigation results and completely reassessed the ecological risks. Presented below are summaries of the three risk assessments.

4.3.1 1991 Risk Assessment for Entire Sewage Lagoon System

A quantitative risk assessment was conducted for the sewage lagoons at Holloman AFB to determine the health risk associated with exposure to existing contamination. The contaminants included in the risk assessment were those identified from environmental sampling conducted at the site prior to 1991 and for which toxicity data were available. Four potential exposure scenarios were identified: 1) occupational exposure to workers at the sewage lagoons, 2) exposure of children living on Base and playing at the sewage lagoons, 3) recreational exposure of birders at Lakes Holloman and Stinky, and 4) recreational

exposure of hunters at the lakes. At the time the risk assessment was performed, HQ ACC was considering using the lagoons in the new wastewater treatment system. However, since this time, HQ ACC has decided that Ponds A-F will be closed. Pond G will revert back to a waters of the United States and become a permitted discharge point for the new wastewater treatment system.

The risk assessment considered both carcinogenic and noncarcinogenic effects. The carcinogenic risks estimated for all exposure scenarios were found to be well below 1 in 1 million (10^{-6}). The estimates of noncarcinogenic effects associated with occupational and recreational activities at the sewage lagoons and lakes indicated little likelihood of adverse effects. Exposure for children playing at the sewage lagoons was found to be unacceptable, however, due primarily to the now disproven concentration of organolead in the surface water. The presence of organolead was suspect because it was detected at concentrations higher than those reported for total lead, and it was also found in the equipment rinsate samples. Later during the 1994 investigation, organolead was not detected; therefore, the risk has been disproven.

This risk assessment is reported in *Risk Assessment for the Sewage Lagoon System* (Radian, February 1991).

4.3.2 1993 Risk Assessment for Each Sewage Lagoon, Lake, and Ditch

Separate risk assessments for each of the seven sewage lagoons (Ponds A, B, C, D, E, F, and G), the ditch from Pond G to Lake Holloman, and Lakes Holloman and Stinky were conducted to evaluate current and potential future effects on human health and the environment and to support closure of the sewage lagoons as a HWMU. Recommendations for the sites included four general categories: 1) continued current operation, 2) continued current operation with access control, 3) additional sampling suggested, and 4) closure suggested.

The individual risk assessments present an assessment of the carcinogenic risks and noncancer hazards to human health and the environment associated with current and potential future activities at the sewage lagoons and lakes. At the request of NMED, a baseline risk assessment was conducted that assumed residential development and domestic water use over the entire contaminant source area (i.e., sewage lagoons) with little or no remedial activity. Highly conservative, worst-case exposure scenarios were evaluated as the baseline assessment. Although these exposures are not likely to ever occur, they were used as a screening tool to determine whether risks/hazards are potentially present at the site.

To ensure adequate characterization of the risk/hazard that may realistically be incurred at or near the sewage lagoons and lakes, site-specific risk assessments considered four populations in eight exposure scenarios: six chronic and two subchronic scenarios. These potential exposure scenarios evaluated included:

1) Occupational exposure at Ponds A through G and the ditch;

2) Teenager recreational exposure at Pond G;

3) Bird watcher/recreational hunter exposure at Pond G;

4) Current agricultural exposure at Lakes Holloman and Stinky;

5) Future agricultural exposure at Ponds A through G; and

6) Future construction worker exposure at Ponds A through F. Target risks were set at 10^{-6} for carcinogens and a hazard quotient of 1 for noncarcinogens. These benchmark values are designed to protect human health and are considered to be *de minimis* risks.

Numerous uncertainties are associated with the results of this risk assessment. Human health risks/hazards associated with Ponds A and E, as well as the ditch were based primarily on single sediment/soil samples in which heptachlor epoxide was detected. Although the levels were high, they were not confirmed hits and do not necessarily represent site conditions. The organolead results that drive the recreational and agricultural hazards at Lake Holloman were obtained during a surface water sampling investigation, and the origin of the organolead is unknown and could not have been related to past waste disposal practices at the sewage lagoons. As discussed previously, the concentrations of organolead were suspect since their values were higher than the total lead concentrations reported and organolead was reported in the equipment rinsate. Additional samples were collected from the sewage lagoons and lakes in October 1994 to address these uncertainties. No organolead was detected in these surface water samples.

The ecological risks were calculated using modeled data. Biota sample results were received after the ecological risk assessment was performed in 1993. The results and conclusion for this risk assessment are recorded in *Holloman Risk Assessment, Sewage Lagoon and Lakes Investigation* (Radian, December 1993).

4.3.3 1996 Risk Assessment Addendum

This risk assessment was an addendum to the 1993 risk assessment discussed previously. Additional data were collected to address the uncertainties identified in the 1993 risk assessment, and during that time more details on the construction of the new wastewater treatment plant were defined. The issues affecting the risk assessment were: 1) Ponds A through F would not be used in the new wastewater treatment facility, and 2) ecological risks were recalculated using biological data.

Site-specific risk assessments were updated for each component of the sewage lagoons and lakes. The evaluation is presented in a report entitled *Risk Assessment Addendum, Sewage Lagoons Closure Project* (Radian and Foster Wheeler, March 1996).

Data from the 1994 investigation, along with the supportable data from previous investigations were used to calculate the risks to human health. The exposure pathways evaluated included:

1) Current on-site worker at Ponds A through G;

2) Current/future recreational hunters at Pond G, the ditch, and the lakes;

3) Current/future teenager trespasser at Pond G; and

4) Future beef consumer at Lake Stinky.

The calculated human health risks were evaluated using the National Contingency Plan's acceptable risk range of 10^{-4} to 10^{-6}. All human health risks derived for the sewage lagoons were below or within this range.

Ecological risks were evaluated for Pond G only, since Ponds A through F are planned to be closed and will no longer serve as a habitat for aquatic wildlife. The

potential for adverse ecological effects was evaluated using a combination of basic uptake modeling from lower trophic levels to higher trophic levels, and actual biological tissue sample data taken from the sewage lagoons and lakes. The potential for adverse effects was estimated by comparing chemical concentrations in the media at Pond G with safe concentrations determined from literature studies. Adverse effects were defined as attributes that may threaten the survivorship and productivity of the aquatic food chain. DDD and DDE (derivatives of DDT) were the only constituents found to have the potential to cause adverse effects in Pond G. These results were within the 1 to 10 EQ range, indicating only slight cause for concern. DDT is no longer used at the Base and these constituents have been decreasing in concentrations (an order of magnitude between 1992 and 1994) over time as documented in the *Site Characterization Report* (Radian and Foster Wheeler, June 1995). It is unlikely that the survivorship and productivity of the aquatic food chains are threatened.

Section 5
1994 INVESTIGATION

The 1994 investigation served as the final sampling event prior to closure, and aided in selecting an appropriate closure alternative. The investigation's strategy was based on previous investigations and was intended to address identified data limitations. In particular, the sampling was intended to further define the nature and extent of contamination within the sewage lagoons; answer uncertainties identified in the risk assessment for each lagoon; provide analysis for developing cleanup standards if appropriate; help select an appropriate remedial alternative if necessary; and define the volume of sludge potentially requiring remedial action.

In March 1995 additional sampling in association with the 1994 investigation was con ducted. Ponds A and B were sampled to determine the presence of any characteristically hazardous wastes and to gather data for the CMS. Additional samples were collected from Ponds C and D to supplement the 1994 investigation. These samples are expected to be the final samples collected prior to closure. The 1994 investigation's field sampling plan is presented in Appendix B of the closure plan.

5.1 Monitored Constituents

On the basis of the types of contaminants detected during previous sampling events, sludge and soil samples were analyzed for organochlorine pesticides and metallic constituents in Ponds C through G. Samples from Ponds A and B were analyzed for toxicity characteristic leaching procedure (TCLP) metals, PCBs, and reactive sulfides. Surface water samples were analyzed for organolead.

5.2 Monitored Media

A total of 122 sludge and soil samples were collected from the sewage lagoons and lake system in October 1994. Sludge samples were collected from Ponds C, D, E, and G and Lake Holloman; surface soil samples were collected from Lake Stinky and the ditch. Soil samples were collected in these latter areas because no sludge was present. In March 1995 a total of 25 sludge samples were collected from Ponds A, B, C, and D.

In addition to the sludge and soil samples, surface water samples were collected from Ponds C, D, E, and G, Lake Holloman, and the Ditch. A total of 35 sample locations were selected from these areas. In order to reevaluate the results of previous samples collected for the 1991 risk assessment, these surface water samples were collected and analyzed for organolead and total lead.

5.3 Sample Locations

Sample locations for the sludge, soil, and surface water samples were selected through probability krieging, a geostatistical procedure. This procedure allows for the use of nonparametric statistics to generate estimates of unknown concentrations. Nonparametric statistics are a group of "distribution-free" techniques that can be applied without prior information about the actual underlying statistical distribution of the concentrations of interest. A full description of the geostatistical procedures used to identify sample locations is presented in Appendix B.

5.4 Analytical Results

Analytical results from the 1994 investigation are presented in the *Site Characterization Report* (Radian and Foster Wheeler, June 1995). Results are summarized in Section 5 of that report. Results indicate the following:

- Heptachlor epoxide was not detected in the samples collected. Previously, unconfirmed reporting of heptachlor epoxide suggested that a potential risk existed. Method 8080 was supplemented by GC/MS to determine if heptachlor epoxide was present. In all cases, GC/MS analysis did not detect heptachlor epoxide as being present. Since no heptachlor epoxide is present, no risk exists for this constituent.

- Organolead was not detected in the samples collected. In 1990, organolead levels reported in the surface water were greater than the total lead concentrations and were similar to levels found in equipment rinsates, making the data questionable. Further sampling has been unable to detect organolead in the surface water; therefore this risk was not present.
- Kepone was not detected at or above concentrations posing a risk. Previous analyses of kepone had too much interference in the sample matrix, which caused a high reporting limit. Another analytical method specific for kepone was used to lower the interferences and the reporting limits.
- Pesticide concentrations in the sludge throughout the sewage lagoon system have decreased from the previous investigations. These declining concentrations indicate better pesticide management on the Base and a decrease of pesticides entering the sewage lagoons. In addition, most organochlorine pesticides have not been used at the Base since 1985.
- Samples collected in Ponds A, B, and C for TCLP metals and reactive sulfide did not indicate that the sludge was characteristically hazardous. Sulfides are expected to be present in domestic sewage sludge in anaerobic conditions.

Section 6
CLOSURE DOCUMENTATION SUMMARY AND OTHER REGULATORY ISSUES

In support of this closure plan, several other activities were performed to assist in selecting the closure alternative. The sewage lagoons closure is being performed under the IRP. As discussed previously, the IRP generally follows the provisions of CERCLA, although the sewage lagoons investigation has more closely followed the RCRA corrective action process. As a result of this, several investigations have been performed at the sewage lagoons to define the nature and extent of contamination, and risks posed by existing constituents to both human health and the environment. These investigations have been performed in a phased approach resulting in several reports. To include each of these again in this closure plan would result in an oversized document. Therefore, this closure plan summarizes the conclusions drawn from the most recent reports that have aided in the selection of the closure alternative and provides references to the other documents for further details. The analytical results of all past investigations are summarized in Appendix A. The documents summarized inthis section are listed in the order they were submitted to the NMED for review. The document describing the closure alternative for the sewage lagoons is the ***Corrective Measures Study***, and has therefore been included in its entirety as Appendix C of this closure plan.

6.1 Summary of Documents

6.1.1 Project Assessment Report (PAR)

The PAR (Radian and Foster Wheeler, March 1995) presents a comprehensive history of regulatory and sampling activities that have occurred during the Holloman AFB sewage lagoons closure project, between the years 1980-1994 (excluding the results of the 1994 investigation). The primary objective of this report is to provide a historical review of events leading up to the closure of the sewage lagoons. The report contains a chronology of key events and an overview of key issues for the sewage lagoons closure project. The PAR was completed and submitted to NMED and EPA Region VI in March 1995.

6.1.2 Long-term Monitoring (LTM) Plan

The LTM plan (Radian, April 1995) outlines the long-term groundwater monitoring program for the sewage lagoons. Contained in this document is a description of the sampling locations, parameters, and frequency, as well as the standard operating procedures for collecting groundwater samples. In addition, the plan contains the methods and procedures that will be used to evaluate and document the results of groundwater sampling data collected during field LTM investigations, a general schedule for implementation of the plan, and a discussion of data management issues specific to the program. The LTM plan was completed and submitted to NMED and EPA Region VI in April 1995. If an equivalency demonstration of clean closure is achieved, long-term monitoring is not expected to continue.

6.1.3 Site Characterization Report

The *Site Characterization Report* (Radian and Foster Wheeler, March 1995) provides a summary of investigative information collected from 1990 to 1995 for each of the sewage lagoons. In particular, the report presents results of the 1994 investigation. The information provided by the *Site Characterization Report* (Radian and Foster Wheeler, March 1995) has been used for the *Corrective Measures Study*. The *Site Char-acterization Report* (Radian and Foster Wheeler, March 1995) was submitted to NMED and EPA Region VI in June of 1995.

Several investigations have been performed at the sewage lagoons since 1990. These investigations were conducted on surface water, sludge, and soil. These investigations have been phased in order to best characterize the sewage lagoons. In 1990 surface water samples were collected and analyzed for PCBs, organochlorine pesticides, metals, and semivolatile organic compounds. Sludge and underlying soil samples were collected from Ponds A through C to confirm that no PCBs above the TSCA reporting level of 25 ppm were present.

Table 6-1
List of Documents and Activities in Support of the Sewage Lagoons Closure Plan

Document/Activity	Submittal Date	Reviewing Agency
Project Assessment Report	March 1995	NMED
Long-term Monitoring Plan	April 1995	NMED
Site Characterization Report	June 1995	NMED
Risk Assessment Addendum	March 1996	NMED
Biological Resources Report	June 1996	USFWS
Corrective Measures Study (Appendix C of this report)	June 1996	NMED
Decision Documents	TBD	NMED
Initiation of Closure	TBD	NMED

Notes: NMED = New Mexico Environment Department. USFWS = U.S. Fish and Wildlife Service. TBD = To be determined.

The 1992 investigation was performed to define the nature of contaminationin Ponds C through G, therefore samples were collected and analyzed for the Appendix IX constituents. The 1992 investigation determined that the only significant constituents were metals and organochlorine pesticides in the sludge. The 1994 investigation was performed to define more precisely the extent of the constituents in the sludge.

The objective of the 1994 investigation was to gather data to support closure of the sewage lagoons. One purpose was to define the extent of metals and organochlorine pesticides. The results indicated that 4,4'-DDD and 4,4'-DDE were the primary constituents present in the sewage lagoons, and the trend for these constituents since the 1990 investigation is that they are declining significantly in concentration. Another purpose of the 1994 investigation was to clear up the uncertainties identified in the risk assessment for organic lead, heptachlor epoxide and kepone. It was determined from this investigation that these constituents were not of concern. Additional data were gathered in support of the corrective measures study such as sludge depths and volumes, and samples were collected to determine if the sludge was characteristically hazardous. Results indicated it was not hazardous. A summary of results for Ponds A through G are presented in Sections 4 and 5 of the *Site Characterization Report* (Radian and Foster Wheeler, March 1995). Analytical results for all investigations are summarized in the Appendices of the *Site Characterization Report* (Radian and Foster Wheeler, 1995).

6.1.4 Risk Assessment Addendum

The *Risk Assessment Addendum* (Radian and Foster Wheeler, March 1996) is based on the 1994 investigation and 1993 biota sampling results. This report is an addendum to the November 1993 risk assessment that individually addressed Ponds A through G, Lakes Holloman and Stinky, and the ditch connecting Pond G and Lake Holloman. The report presents results and conclusions based on the carcinogenic risks and noncancer hazards to human health, and on ecological risks from current and potential future activities at the lagoons and lakes.

Site-specific human health risk assessments were Site-specific human health risk assessments were updated for Ponds A through G. The lakes and the ditch connecting the sewage lagoons and lakes were also evaluated; however, this closure plan only addresses the sewage lagoons. Four exposure scenarios were evaluated in the addendum, including: 1) current on-site worker (chronic and subchronic) for Ponds A through G; 2) current/future recreational use identified as hunters for Pond G (chronic and subchronic); 3) current/future trespasser identified as a teenager for Pond G (subchronic); and 4) future beef consumer at Lake Stinky (chronic). The fourth exposure scenario will not be addressed in this closure plan since it relates only to Lake Stinky. The results of the risk assessment addendum indicated there were no unacceptable risks identified at the sewage lagoons. All carcinogenic risk estimates were less than or within the acceptable risk range of 10^{-4} to 10^{-6}. All noncarcinogenic risk estimates were below the hazard quotient of 1. Section 4 of the *Risk Assessment Addendum* (Radian and Foster Wheeler, March 1996) presents a summary of the human health risks for Ponds A through G.

The ecological risk assessment evaluation presented in the *Risk Assessment Addendum* (Radian and Foster Wheeler, March 1996) replaces the ecological risk assessment presented previously in the December 1993 risk assessment report. Biological tissue data were available for the addendum which were not available in 1993. Risks to the environment were considered for Pond G, the ditch, and the lakes. Ponds A through F were not evaluated because it was known that these sewage lagoons would be drained and closed, and would no longer serve as an aquatic habitat. The following assessment endpoint species were evaluated: mosquito fish, mallards, mergansers, black-necked stilts, and killdeer. Tissue samples were available for all endpoint species except the mergansers and killdeer. Two approaches were used to evaluate the data: 1) using food uptake modeled from food source samples collected; and 2) using body burden tissue data collected for the mosquito fish, one mallard, and black-necked stilts. The results of the assessment indicated that DDD and DDE (derivatives of DDT) are the only constituents of concern. However, as described in the *Site Characterization Report* (Radian and Foster Wheeler, June 1995), these constituents are no longer entering the system and since 1990 have been decreasing in concentration through natural attenuation. A more detailed description of the results of the ecological risk assessment can be found in Section 6 of the *Risk Assessment Addendum* (Radian and Foster Wheeler, March 1996).

6.1.5 Biological Resources Report

Holloman AFB has prepared a *Biological Resources Report* (Radian and Foster Wheeler, June 1996) that presents an assessment of the impacts of closure alternatives to threatened and endangered (both Federal and State) species. The following closure alternatives are addressed in the *Biological Resources Report*:

1) No action—let lagoon dry out;

2) Dewater sludge, backfill Ponds A through F, and construct 120 acres of new wetlands; and

3) Dewater sludge, dredge Pond G, backfill Ponds A through F, and construct 120 acres of new wetlands.

These alternatives are similar, but not the same as the alternatives presented in the *Corrective Measures Study*. The review of the effects of dredging Pond G in the *Biological Resources Report* helped eliminate this alternative for consideration in the *Corrective Measures Study*.

The Biological Resources Report was submitted to the USFWS, NMED, and EPA Region VI in June of 1996,

A list of 21 animal and two plant threatened, endangered and sensitive species (Table 2-2) have been identified as potentially occurring near the lagoons. These were selected to determine if the proposed action at Holloman AFB would result in the loss of sensitive habitat for endangered and threatened species. Of the 23 species assessed, only eight have actually been

sighted in the project area, and three of these occur as migrants.

Based on the results of the risk assessment, contaminants in the sewage lagoons are not causing unacceptable risk to human or ecological receptors. However, ducks and black-necked stilts may have increased levels of DDE in their tissues, either as a result of foraging in the lagoons or because DDT and breakdown products have become common contaminants in the ecosystem as a whole. Because contamination is more concentrated in Ponds A through F, it would be preferable to close these lagoons and construct wetlands west of Pond G to replace surface water that would be lost. It is very important to note that Pond G, an impounded playa, is a larger and more ecologically valuable pond that should remain open. Pond G provides sensitive habitat to some of the bird species and also supports associated wetlands.

The species observed in the project area do not depend heavily on Ponds A through F for forage or cover. However, without the development of additional waterbodies to replace these sewage lagoons, species abundance may decrease with the loss of forage. In addition, the loss of evaporative surface would result in increased water levels in the lakes. Under the proposed action, Holloman AFB plans to construct at least 120 acres of wetland habitat southwest of Pond G to help compensate for this loss. The additional wetlands would provide a cleaner, healthier aquatic system and would result in increased forage and cover.

6.1.6 Corrective Measures Study

A *Corrective Measures Study* (CMS) (Radian, June 1996, revised November 1996) was prepared to identify, develop, and evaluate alternatives for closure of the sewage lagoons. The CMS was prepared to comply with RCRA and CERCLA requirements for closure of the lagoons. Because the closure of the sewage lagoons is being carried out as part of the IRP program and is funded by DERA (DoD implementation of CERCLA), CERCLA requirements had to be met. The CMS is presented in Appendix C. The closure objectives and closure criteria for the sewage lagoons are presented in Section 2 of this closure plan.

It should be noted that a risk assessment has shown that the constituents in sludge do not pose unacceptable risks to human health or the environment. One of the primary objectives of the closure is to ensure the control of disease vectors and odors that may be associated with the sludge.

Ponds A Through F

The proposed alternative for Ponds A through F involves containment of the sludge through the addition of a soil cover. The proposed alternative was selected by evaluating the ability of each alternative to meet the closure and other evaluation criteria. The proposed alternative protects human health and the environment by eliminating potential exposure pathways to any constituents in sludge.

In the proposed alternative, the water will be drained from the lagoons; the sludge will be dewatered; the berms that are above grade around the lagoons will be removed; and the resulting soil will be placed in the lagoons as a soil cover over the dewatered sludge so the site can be restored to the approximate natural contours. More detailed descriptions of these actions are provided below.

The first step for the alternative for Ponds A through F involves shutting off the influent to Ponds A and B and redirecting the flow of the new WWTP. This step has already been completed. The water from Ponds D, E, and F has been pumped into Ponds A and B. Because of the high water table and the cool weather, the evaporation of the remaining waters in Ponds A, B, and C will be very slow in the winter months. It is estimated that it will take more than 6 months for the water in the lagoons to infiltrate and evaporate. Therefore, Holloman AFB is exploring options to remove the remaining water. Any discharges from the lagoons will comply with the Clean Water Act and the New Mexico Water Quality Control Commission regulations.

Once the surface water has been removed, the sludge will be dewatered. Natural evaporation will play an important role in dewatering the sludge, which ranges in thickness from 2 to 48 in. within Ponds A through F. Mixing and turning the sludge with a dozer or front-endloader will help with the natural dewatering process. This process will be expedited by mixing in soil with the sludge. Soil or a commercial chemical additive may be mixed with the sludge to reduce odors. A soil cover that is at least 12 in. thick will be added to Ponds A through F once the sludge is dewatered sufficiently.

The south berms which are elevated as much as 10 ft above grade will be broken down and used to provide the soil cover. This soil will be spread and compacted using standard backfilling techniques and standard earthmoving equipment. The finished surface of the compacted backfill will be graded to provide for adequate drainage. The area will be vegetated. Approximately 200,000 yd^3 of soil from the abovegrade berms will be placed in the lagoons as a soil cover over the sludge.

Care will be taken throughout the closure to minimize erosion and control dust. All equipment will be decontaminated using a decontamination pad. Rinse water from decontamination procedures will be stored on site and will be released to the surface if analyses indicate that no constituent concentrations pose a potential risk. Although this alternative will minimize the need for need for maintenance, semiannual maintenance of the vegetaive cover will be carried out to ensure the integrity of the cover. Monitoring of storm water runoff will be conducted in accordance with the general provisions of Sector L of the multi-sector general permit (MSGP) reported in the 29 September 1995 *Federal Register*.

After the closure is completed, the land use for the area where Ponds A through F are located will be restricted open space. The area will be fenced and will remain a restricted area because it is in a designated runway clear zone. This land use cannot be changed unless the potential risks associated with the new land use are reevaluated and the land use designation is changed in the Base Comprehensive Plan.

Pond G

The proposed alternative for Pond G is the no action alternative. Pond G is an important wildlife habitat, and the risk assessment results have indicated no unacceptable human health or ecological risks. There is a slight potential for black-necked stilts to have increased levels of DDE in their tissues; however, the *Site Characterization Report* (Radian and Foster Wheeler, June 1995) has shown that concentrations of DDT and its derivatives are decreasing rapidly. The results presented in the *Biological Resources Report* (Radian and Foster Wheeler, June 1996) indicated that adverse effects on wildlife habitat would likely be associated with removal of sludge from Pond G.

A pipeline will be constructed from the new WWTP to Pond G. The pipeline will ensure that the lagoon receives water and continues to provide the ecological habitat that it does currently. The evaluation of this alternative indicates that it will meet the closure objectives and satisfy the closure criteria.

6.1.7 Decision Documents

The sewage lagoons are being closed under the IRP and are funded through DERA. As such, a decision document must be prepared and signed by the Air Force and NMED prior to closure. The decision document will be a short, concise report that summarizes the approved approach to closure for the sewage lagoons. It will be prepared following the review and approval of this closure plan by NMED.

6.2 Wildlife and Wetland Issues Pertaining to Closure

Holloman AFB may address a series of issues pertaining to wildlife and wetlands prior to final closure of the sewage lagoons. These issues are not part of the closure plan, but may have an effect on the closure activities

6.2.1 Clean Water Act

Closure activities will follow the intent of Clean Water Act permit requirements. Two requirements that could be impacted by the closure of the sewage lagoons are the storm water construction permit and the 404 permit.

Appropriate measures to prevent erosion and runoff of sediments and wastes during storm events will be taken during the closure activities. The Base will meet the substantive requirements for storm water pollution prevention described in the 9 September 1992 *Federal Register* (page 41176, Final NPDES General Permits for Storm Water Runoff from Construction Sites).

Any disturbance of the wetlands adjacent to the sewage lagoons (i.e., south of Pond E) during the closure activities will comply with the substantive requirements of Section 404 of the Clean Water Act. The specific requirements applicable for this site are found in the nationwide Permit 26 for isolated waters (33 CFR 330, Appendix A).

6.2.2 NEPA

Holloman AFB conducted an EA as required by the National Environmental Protection Act (NEPA) for construction of the new wastewater treatment plant. This EA determined that closing Pond G was a significant impact. The assessment is presented in the 13 April 1995 *Wastewater Treatment Plant for Holloman Air Force Base New Mexico, Final Environmental Assessment* GeoMarine, 1995).

The closure of the sewage lagoons is DERA funded (CERCLA action) and, therefore, formal NEPA documentation and compliance is not required. However, CERCLA actions must consider NEPA, and this is accomplished collectively through the WWTP EA and the *Biological Resources Report* (Radian and Foster Wheeler, June 1996).

6.2.3 Fish and Wildlife Coordination Act

Holloman AFB has coordinated with the USFWS throughout the investigation of the sewage lagoon. Coordination with USFWS will continue through closure activities.

6.3 Initiation of Closure

After approval of the closure plan by NMED, the Base will begin closure procedures. It is expected that a demonstration of equivalency to clean closure will be achieved; however, if it is not, a post-closure care plan will be prepared and submitted to NMED. It will include documentation on how to maintain the integrity of the soil cover and long-term groundwater monitoring.

A preliminary schedule for closure is presented in Table 6-2. After closure is completed, an independent registered professional engineer will prepare and seal documentation describing the actual closure activities. This certification will also be signed by Holloman AFB and submitted to NMED.

As noted in the schedule presented in Table 6-2, wastewater stopped entering the sewage lagoons in July 1996. Interim closure measures are already in progress to prevent the exposure of disease vectors that potentially exist and control odors. These hese interim measures will involve dewatering the sludge by mixing in soil

sure measures are already in progress to prevent the exposure of disease vectors that potentially exist and control odors. These hese interim measures will involve dewatering the sludge by mixing in soil from the berms and covering the dewatered sludge with approximately 6 in. of soil.

Table 6-2
Schedule for Closure

Activity	Dates
Date when wastewater (nonhazardous waste) no longer received in the sewage lagoons	July 1996
Public Notice	Initiated by NMED
Start of Closure	Date of NMED approval of closure plan
Design Completion	30 days after start of closure
Begin Closure Actions	90 days after start of closure
Complete Dewatering of Lagoons	180 days after start of closure
Complete Final Cover	270 days after start of closure
Written Certification of Closure	330 days after start of closure

Section 7
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APPENDIX A

Analytical Summary of Sewage Lagoons Investigations

Appendix A

Analytical Summary of Sewage Lagoons Investigations

This appendix summarizes the analytical results from all surface water, sludge, and soil investigations conducted at the Holloman AFB sewage lagoons between 1990 and 1995. The data collected in Ponds A and B during 1988 to define the extent of PCB concentrations greater than 25 ppm is not included in this summary because the sludge was removed in 1990 and many of the 1988 sample locations were within the area of removal. Therefore, the 1988 data is no longer representative of the sludge currently in Ponds A and B.

The *Site Characterization Report* (Radian and Foster Wheeler, June 1995) presents a summary of data collected by individual investigations in Appendices A through F.

Table A-1 outlines the media analyzed, and the analyses performed for all surface water, sludge, soil, sediment, and groundwater investigations for 1990 to 1995. The remainder of this appendix presents an analytical summary of all groundwater, surface water, sludge, and soil investigations conducted at the sewage lagoons between 1990 and 1995. Results are provided by pond, media, analyses, and constituent. In addition, Figures A-1 through A-11 show the location of sludge and soil samples collected from each sewage lagoon. Figure A-12 shows the groundwater monitoring locations.

Tables A-2 through A-8 summarize the analytical data for surface water, sludge, and soil samples. Table A-9 summarizes groundwater assessment monitoring data collected from 1992 and 1993 for the sewage lagoons. Table A-10 summarizes the results of the 1995 long-term groundwater monitoring program. Each table provides the frequency of detection, the median concentration, the maximum concentration, and the sample location, along with year, for maximum detections. Analytical flags are also presented with the data. The flags may vary depending on the laboratory used, and therefore a summary of the analytical flags is presented as follows:

1990 Sampling Event

B	=	Parameter was also detected in the blank sample; result is uncorrected
C	=	Confirmed on second column or by GC/MS
G	=	Indicates an estimated GC value due to interference
h	=	Sample analyzed 4 days past allowable holding time
J	=	Result is less than the method specified detection limit. These results should be considered approximate.
@	=	Result is less than five times the method detection limit. Studies have shown that the uncertainty of the analysis will increase exponentially as the MDL is approached. These results should be considered approximate.
X	=	Not confirmed on second column

1992 and 1993 Sampling Events

X	=	Qualitative confirmation of analyte on both columns. Quantification differed by a factor of two or more between columns. Value determined by the first column is reported.
@	=	Measured result is less than five times the detection limit
C	=	Presence and quantitation of the analyte confirmed by second column analysis
D	=	Secondary dilution required for this analyte
J	=	Detected below the method detection limit
B	=	Analyte detected in laboratory blank analysis, no blank subtraction performed
G	=	Indicates an estimated GC value due to interference

1994 Sampling Event

T	=	Primary column concentration is the preferred result
V	=	Second column concentration is the preferred result
J	=	Result is less than the reporting limit

Although the 1993 investigation focused on biological sampling, surface water and sediment samples were collected from the sewage lagoons. Sampling consisted of single surface water samples from each lagoon, along with two sediment samples from Ponds A and E. The sediment samples were collected from the near surface sediment (upper few inches of sludge) to compare the constituents found in the lagoons' benthic organisms with their immediate environment. These sediment samples are included with the sludge samples in the analytical summary tables, and can be identified by those maximum sludge concentrations noted with a [93] sampling date. The location of sediment and surface water samples collected in 1993 are not identified in Figure A-1 through A-11 due to their composite nature.

The data set for the median and maximum concentrations included detected, non-detect, and J-flagged data (concentrations below the reporting limit). J-flagged data are counted as "hits" or detections in the summary tables even though they are below the reporting limit. Reporting limits vary for each constituent between samples due to matrix interferences. For example, some samples were diluted and therefore would have a higher reporting limit than those that were not diluted. The median concentration is derived by ordering the values reported for each constituent in a particular media and pond in descending order and then identifying that value that is in the middle. For example if there were 15 samples collected, the 8th value in descending order would be the median. If there are 14 samples, the median value would be the average of the 7th and 8th value in descending order. In some cases the median value is below the reporting limit. If a median or maximum value is nondetect, the value is reported as less than the reporting limit (i.e., <0.5 means that the constituent was not detected and the reporting limit was 0.5). In some cases, the median or maximum value may be a flagged value that is less than the reporting limit (i.e., J flagged data), in this case the value will be reported as the flagged value (i.e., 0.038J means that 0.038 is a value that is less than the reporting limit).

Table A-1
Summary of Analytical Investigations and Analyses Performed

Year of Investigation	Report A 1995	Report B 1994	Report C[a] 1993	D 1993	Report E[a] 1992	Report F[a] 1992	Report G 1991	Report H 1991
Matrices								
Surface Water		X		X				X
Groundwater	X		X			X		
Soil		X			X		X	
Sludge		X			X		X	
Sediment				X				
Analyses Performed								
Metals	X	X (TCLP)	X	X	X	X	X	X
SW8240			X		X	X	X	
SW8270		X	X	X	X	X	X	X
SW8280			X		X	X		
SW8080	X	X	X	X	X	X	X	X
SW8150			X		X	X	X	
SW8140			X		X	X		
Cyanide			X		X	X	X	X
Sulfide		X	X		X	X		
Total Organic Carbon					X	X		
Organolead		X						X
Chromium VI								X
Kepone		X						

[a]Investigation included Appendix IX analyses.

Report Key:

A = 1995 Sampling Report, Sewage Lagoons Long-Term Groundwater Monitoring Program.
B = Site Characterization Report, June 1995.
C = Phase 1 Groundwater Assessment Monitoring Report - December 1993.
D = Results of surface water and sediment samples collected during biota sampling submitted in the Risk Assessment Addendum, March 1996.
E = Site Characterization Report: Sewage Lagoons Investigation - August 1992 (Ponds C, D, E, F, G, Lake Holloman, Ditch, Lake Stinky).
F = Assessment Monitoring Results: Appendix IX and Confirmation Detection and Compliance Monitoring - April 1992
G = QCSR for Field Investigation to Support Sewage Lagoon Closure - June 1991 (Ponds A, B, and C)
H = QCSR for Sewage Lagoon Surface Water Sampling - June 1991 (Headworks, Ponds B, C, D, E, G, and Lake Holloman)

Pond A

Table A-2
Analytical Summary For Pond A

Analyte	Surface Water				Sludge				Soils			
	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location
E130.2 - Hardness (mg/L)												
Hardness, as CaC03	1/1	2400	2400	A-01 [93]	NA	NA	NA	NA	NA	NA	NA	NA
E160.1 - Total Dissolved Solids (mg/L)												
Total dissolved solids	1/1	5500	5500	A-01 [93]	NA	NA	NA	NA	NA	NA	NA	NA
SW6010 - Metals (mg/kg)												
Aluminum	NA	NA	NA	NA	NA	NA	NA	NA	17/18	6900	130000	A-5 [90]
Antimony	NA	NA	NA	NA	1/1	5.7 @	5.7 @	A-01 [93]	0/18	ND	ND	NA
Barium	NA	NA	NA	NA	1/1	64	64	A-01 [93]	18/18	78	120	A-3 [90]
Beryllium	NA	NA	NA	NA	1/1	0.17 @	0.17 @	A-01 [93]	17/18	0.65 @	0.99 @	A-1 [90]
Cadmium	NA	NA	NA	NA	1/1	0.68 @	0.68 @	A-01 [93]	0/18	ND	ND	NA
Calcium	NA	NA	NA	NA	NA	NA	NA	NA	18/18	99500	140000	A-3 [90]
Chromium	NA	NA	NA	NA	1/1	24	24	A-01 [93]	18/18	7.5	11	A-5 [90]
Cobalt	NA	NA	NA	NA	1/1	2 @	2 @	A-01 [93]	15/18	3.3 @	5.2 @	A-1 [90]
Copper	NA	NA	NA	NA	1/1	40	40	A-01 [93]	18/18	5.4 @	21	A-2 [90]
Iron	NA	NA	NA	NA	NA	NA	NA	NA	18/18	6450	9500	A-5 [90]
Magnesium	NA	NA	NA	NA	NA	NA	NA	NA	18/18	32000	52000	A-3 [90]
Manganese	NA	NA	NA	NA	NA	NA	NA	NA	18/18	165	250	A-1 [90]
Nickel	NA	NA	NA	NA	1/1	4.4 @	4.4 @	A-01 [93]	16/18	7.1 @	10 @	A-5 [90]
Potassium	NA	NA	NA	NA	NA	NA	NA	NA	18/18	1300 @	2900	A-2 [90]
Silicon	NA	NA	NA	NA	NA	NA	NA	NA	18/18	195 @	410	A-2 [90]
Silver	NA	NA	NA	NA	1/1	14	14	A-01 [93]	0/18	ND	ND	NA
Sodium	NA	NA	NA	NA	NA	NA	NA	NA	18/18	2300	5900	A-1 [90]
Thallium	NA	NA	NA	NA	1/1	0.61 @	0.61 @	A-01 [93]	13/18	46 @	94 @	A-6 [90]
Tin	NA	NA	NA	NA	1/1	3.9 @	3.9 @	A-01 [93]	0/18	ND	ND	NA
Vanadium	NA	NA	NA	NA	1/1	13	13	A-01 [93]	18/18	18	26	A-2 [90]
Zinc	NA	NA	NA	NA	1/1	68	68	A-01 [93]	18/18	27	44	A-5 [90]
SW7060 - Arsenic (mg/kg)												
Arsenic	NA	NA	NA	NA	1/1	4.5 @	4.5 @	A-01 [93]	18/18	4.5 @	6.0 @	A-5 [90]

Table A-2
(Continued)

Analyte	Surface Water				Sludge				Soils			
	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location
SW7421 - Lead (mg/kg)												
Lead	NA	NA	NA	NA	1/1	12	12	A-01 [93]	18/18	9.2	39	A-5 [90]
SW7471 - Mercury (mg/kg)												
Mercury	NA	NA	NA	NA	1/1	0.38	0.38	A-01 [93]	NA	NA	NA	NA
SW7740 - Selenium (mg/kg)												
Selenium	NA	NA	NA	NA	1/1	0.73 @	0.73 @	A-01 [93]	11/18	0.67	1.3	A-2 [90]
TCLP Metals												
Arsenic	NA	NA	NA	NA	0/7	NA	NA	NA	NA	NA	NA	NA
Barium	NA	NA	NA	NA	7/7	0.38	0.6 B	05A [95]	NA	NA	NA	NA
Cadmium	NA	NA	NA	NA	0/7	NA	NA	NA	NA	NA	NA	NA
Chromium	NA	NA	NA	NA	0/7	NA	NA	NA	NA	NA	NA	NA
Lead	NA	NA	NA	NA	0/7	NA	NA	NA	NA	NA	NA	NA
Mercury	NA	NA	NA	NA	0/7	NA	NA	NA	NA	NA	NA	NA
Selenium	NA	NA	NA	NA	0/7	NA	NA	NA	NA	NA	NA	NA
Silver	NA	NA	NA	NA	1/7	ND (0.02)	ND (0.02)	06A	NA	NA	NA	NA
SW7841 - Thallium (mg/kg)												
Thallium	NA	NA	NA	NA	1/1	0.065 @	0.065 @	A-01 [93]	NA	NA	NA	NA
SW8080 - Organochlorine Pesticides and PCBs (µg/L or µg/kg)												
delta-BHC	1/1	0.037 X@	0.037 X@	A-01 [93]	0/1	ND	ND	NA	0/18	ND	ND	NA
gamma-Chlordane	0/1	ND	ND	NA	1/1	490 JX	490 JX	A-01 [93]	0/18	ND	ND	NA
4,4'-DDD	1/1	0.028 X@	0.028 X@	A-01 [93]	0/1	ND	ND	NA	0/18	ND	ND	NA
4,4'-DDE	0/1	ND	ND	NA	1/1	630 X@	630 X@	A-01 [93]	0/18	ND	ND	NA
4,4'-DDT	1/1	0.02 X@	0.02 X@	A-01 [93]	0/1	ND	ND	NA	0/18	ND	ND	NA
Dieldrin	1/1	0.015 X@	0.015 X@	A-01 [93]	0/1	ND	ND	NA	0/18	ND	ND	NA
Endosulfan I	0/1	ND	ND	NA	1/1	530 XJ	530 XJ	A-01 [93]	0/18	ND	ND	NA
Endosulfan II	0/1	ND	ND	NA	1/1	1.1 XJ	1.1 XJ	A-01 [93]	0/18	ND	ND	NA
Endosulfan Sulfate	1/1	0.013 JB	0.013 JB	A-01 [93]	1/1	420 XJB	420 XJB	A-01 [93]	0/18	ND	ND	NA
Endrin	1/1	0.095 X@	0.095 X@	A-01 [93]	0/1	ND	ND	NA	0/18	ND	ND	NA

Table A-2
(Continued)

Analyte	Surface Water				Sludge				Soils			
	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location
Heptachlor	1/1	0.012 X@	0.012 X@	A-01 [93]	1/1	230 XJ	230 XJ	A-01 [93]	0/18	ND	ND	NA
Heptachlor epoxide	1/1	0.01 G@	0.01 G@	A-01 [93]	1/1	180000 X	180000 X	A-01 [93]	0/18	ND	ND	NA
PCB-1254	NA	NA	NA	NA	NA	NA	NA	NA	1/18	<42	<220	A-1 [90]
SW8240 - Volatile Organic Compounds (µg/kg)												
Acetone	NA	NA	NA	NA	NA	NA	NA	NA	18/18	34 @	97	A-4 [90]
Methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	17/18	8 @	14 @	A-2 [90]
1,1,2-Trichloroethane	NA	NA	NA	NA	NA	NA	NA	NA	2/18	<7	<7	A-2 [90]
SW8270 - Semivolatile Organic Compounds (mg/kg)												
Benzo(a)pyrene	NA	NA	NA	NA	1/1	0.11 J	0.11 J	A-01 [93]	0/18	ND	ND	NA
Benzo(b)fluoranthene	NA	NA	NA	NA	1/1	0.14 JX	0.14 JX	A-01 [93]	0/18	ND	ND	NA
Benzo(k)fluoranthene	NA	NA	NA	NA	1/1	0.14 JX	0.14 JX	A-01 [93]	0/18	ND	ND	NA
4-Chloroaniline	NA	NA	NA	NA	1/1	1.7 J	1.7 J	A-01 [93]	0/18	ND	ND	NA
Diethylphthalate	NA	NA	NA	NA	1/1	0.12 J	0.12 J	A-01 [93]	0/18	ND	ND	NA
bis(2-Ethylhexyl)phthalate	NA	NA	NA	NA	1/1	6.5 @	6.5 @	A-01 [93]	11/18	0.09 J	0.39 J	A-5 [90]
Fluoranthene	NA	NA	NA	NA	1/1	0.12 J	0.12 J	A-01 [93]	0/18	ND	ND	NA
Molecular sulfur	NA	NA	NA	NA	1/1	62	62	A-01 [93]	0/18	ND	ND	NA
Pyrene	NA	NA	NA	NA	1/1	0.12 J	0.12 J	A-01 [93]	0/18	ND	ND	NA
SW8280 - Polychlorinated Dibenzo-Dioxins (PCDD) (µg/kg)												
PCDD	NA	NA	NA	NA	1/1	0.76	0.76	A-01 [93]	NA	NA	NA	NA

Hits = Frequency of detection (i.e. 1/15 means 1 out of 15 samples reported a detected concentration)
NA = Not applicable, or not analyzed
ND = Not detected
[90] = Year that the sample reporting the maximum value was collected
< = Value reported after < is the reporting limit

Legend for Analytical Flags varies with each year of sampling as shown below.

Table A-2
(Continued)

1990 Sampling Event

B - Parameter was also detected in the blank sample; result is uncorrected
C - Confirmed on second column or by GC/MS
G - Indicates an estimated GC value due to interference
h - Sample analyzed 4 days past allowable holding time
J - Result is less than the method specified detection limit. These results should be considered approximate.
@ - Result is less than five times the method detection limit. Studies have shown that the uncertainty of the analysis will increase exponentially as the MDL is approached. These results should be considered approximate
X - Not confirmed on second column

1992 and 1993 Sampling Events

X - Qualitative confirmation of analyte on both columns. Quantification differed by a factor of two or more between columns. Value determined by the first column is reported.
@ - Measured result is less than five times the detection limit
C - Presence and quantitation of the analyte confirmed by second column analysis
D - Secondary dilution required for this analyte
J - Detected below the method detection limit
B - Analyte detected in laboratory blank analysis, no blank subtraction performed
G - Indicates an estimated GC value due to interference.

1994 Sampling Event

T - Primary column concentration is the preferred result
V - Second column concentration is the preferred result
J - Result is less than the reporting limit

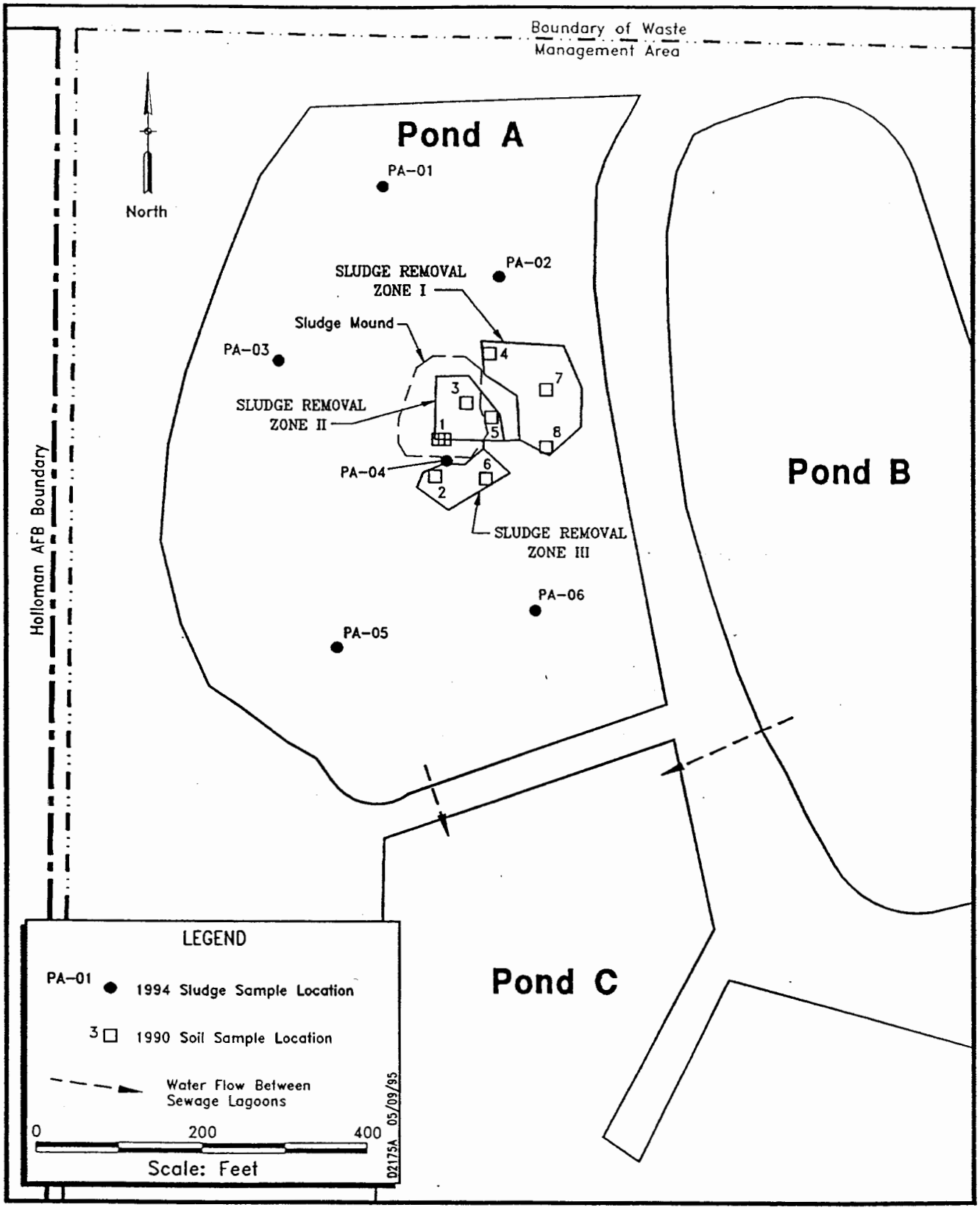

Figure A-1. Pond A Sludge and Soil Sample Locations

Pond B

Table A-3
Analytical Summary For Pond B

Analyte	Surface Water				Sludge				Soils			
	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location
E130.2 - Hardness (mg/L)												
Hardness, as CaC03	1/1	1600	1600	B-01 [93]	NA	NA	NA	NA	NA	NA	NA	NA
E160.1 - Total Dissolved Solids (mg/L)												
Total dissolved solids	1/1	3800	3800	B-01 [93]	NA	NA	NA	NA	NA	NA	NA	NA
E239.1 - Organic Lead (mg/L)												
Lead (organic) [a]	4/8	<0.1	0.13 @	B-2 [90]	NA	NA	NA	NA	NA	NA	NA	NA
SW6010 - Metals (mg/L or mg/kg)												
Aluminum	4/8	0.0265	0.11 @	HW-1 [90]	NA	NA	NA	NA	14/14	11500	20000	B-4 [90]
Antimony	1/8	<0.028	0.078 @	B-5 [90]	NA	NA	NA	NA	NA	NA	NA	NA
Barium	7/8	0.0325 @	0.04	B-6 [90]	NA	NA	NA	NA	14/14	50.5	160	B-4 [90]
Beryllium	0/8	ND	ND	NA	NA	NA	NA	NA	14/14	0.565 @	0.82 @	B-3 [90]
Boron	8/8	0.32 @	0.74	HW-2 [90]	NA	NA	NA	NA	NA	NA	NA	NA
Calcium	8/8	360	410	B-6 [90]	NA	NA	NA	NA	14/14	82500	200000	B-5 [90]
Chromium	1/8	<0.004	0.0046 @	B-5 [90]	NA	NA	NA	NA	14/14	12	17	B-4 [90]
Cobalt	0/8	ND	ND	NA	NA	NA	NA	NA	14/14	4 @	6.2	B-3 [90]
Copper	2/8	<0.005	0.0075 @	HW-1 [90]	NA	NA	NA	NA	14/14	6.3 @	9.1 @	B-4 [90]
Iron	8/8	0.09	0.19	HW-1 [90]	NA	NA	NA	NA	14/14	8150	14000	B-4 [90]
Magnesium	8/8	180	200	B-1 [90]	NA	NA	NA	NA	14/14	18000	49000	B-4 [90]
Manganese	8/8	0.0495	0.092	B-6 [90]	NA	NA	NA	NA	14/14	135	250	B-4 [90]
Nickel	0/8	ND	ND	NA	NA	NA	NA	NA	14/14	8.05 @	13	B-4 [90]
Potassium	8/8	11.5	13	B-1 [90]	NA	NA	NA	NA	14/14	2300	5200	B-4 [90]
Silicon	8/8	14.5	17	B-1 [90]	NA	NA	NA	NA	14/14	1310 @	6000	B-6 [90]
Silver	2/2	0.0168 @	0.026	HW-1 [90]	NA	NA	NA	NA	0/14	ND	ND	NA
Sodium	8/8	540	580	B-1 [90]	NA	NA	NA	NA	14/14	1035	4300	B-2 [90]
Vanadium	8/8	0.0088 @	0.011 @	HW-1 [90]	NA	NA	NA	NA	14/14	26	39	B-4 [90]
Zinc	8/8	0.0155 @	0.033	HW-1 [90]	NA	NA	NA	NA	14/14	25	40	B-4 [90]

Table A-3
(Continued)

Analyte	Surface Water				Sludge				Soils			
	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location
SW7060 - Arsenic (mg/L or mg/kg)												
Arsenic	2/8	<0.006	<0.006	B-1 [90]	NA	NA	NA	NA	10/14	2.4 @	10	B-2 [90]
SW7196 - Chromium VI (mg/L)												
Chromium VI	1/8	<0.01	<0.01	B-1 [90]	NA	NA	NA	NA	NA	NA	NA	NA
SW7421 - Lead (mg/L or mg/kg)												
Lead	5/8	0.0041	<0.01	B-1 [90]	NA	NA	NA	NA	14/14	3.35	7.8	B-3 [90]
SW7470 - Mercury (mg/L)												
Mercury	5/8	0.0004 @	0.0006 @	B-1 [90]	NA	NA	NA	NA	NA	NA	NA	NA
SW7740 - Selenium (mg/L or mg/kg)												
Selenium	4/8	0.0027 @	<0.004	B-4 [90]	NA	NA	NA	NA	0/14	ND	ND	NA
TCLP Metals												
Arsenic	NA	NA	NA	NA	0/6	NA	NA	NA	NA	NA	NA	NA
Barium	NA	NA	NA	NA	6/6	0.46 B	0.51 B	02B [95]	NA	NA	NA	NA
Cadmium	NA	NA	NA	NA	0/6	NA	NA	NA	NA	NA	NA	NA
Chromium	NA	NA	NA	NA	1/6	NA	NA	NA	NA	NA	NA	NA
Lead	NA	NA	NA	NA	0/6	NA	NA	NA	NA	NA	NA	NA
Mercury	NA	NA	NA	NA	0/6	NA	NA	NA	NA	NA	NA	NA
Selenium	NA	NA	NA	NA	0/6	NA	NA	NA	NA	NA	NA	NA
Silver	NA	NA	NA	NA	0/6	NA	NA	NA	NA	NA	NA	NA
SW8080 - Organochlorine Pesticides and PCBs (µg/L or µg/kg)												
alpha-BHC	1/9	<0.5	<0.5	B-1 [90]	NA	NA	NA	NA	0/14	ND	ND	NA
delta-BHC	1/9	0.017 X@	0.017 X@	B-01 [93]	NA	NA	NA	NA	0/14	ND	ND	NA
gamma-BHC	4/9	<1.5	<1.5	B-1 [90]	NA	NA	NA	NA	0/14	ND	ND	NA
Chlordane	4/8	3.6	<28	B-3 [90]	NA	NA	NA	NA	0/14	ND	ND	NA
alpha-Chlordane	1/1	0.0034 JX	0.0034 JX	B-01 [93]	NA	NA	NA	NA	0/14	ND	ND	NA
4,4'-DDD	1/9	0.043 X@	0.043 X@	B-01 [93]	NA	NA	NA	NA	0/14	ND	ND	NA
4,4'-DDE	2/9	<1.5	<6	B-3 [90]	NA	NA	NA	NA	0/14	ND	ND	NA
4,4'-DDT	1/9	0.018 JX	0.018 JX	B-01 [93]	NA	NA	NA	NA	0/14	ND	ND	NA

Table A-3
(Continued)

Analyte	Surface Water				Sludge				Soils			
	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location
Dieldrin	1/9	0.022 X@	0.022 X@	B-01 [93]	NA	NA	NA	NA	0/14	ND	ND	NA
Endosulfan I	0/9	ND	ND	NA	NA	NA	NA	NA	2/14	<1.4	180 X	B-2 [90]
Endosulfan Sulfate	1/9	0.012 JB	0.012 JB	B-01 [93]	NA	NA	NA	NA	0/14	N/D	ND	NA
Endrin	1/9	0.0093 JX	0.0093 JX	B-01 [93]	NA	NA	NA	NA	0/14	ND	ND	NA
Heptachlor epoxide [b]	1/9	0.01 G@	0.01 G@	B-01 [93]	NA	NA	NA	NA	0/14	ND	ND	NA
PCB-1254	NA	NA	NA	NA	3/3	13000 C@	13000 C@	B-S1-SA [90]	0/14	ND	ND	NA
SW8240 - Volatile Organic Compounds (µg/kg)												
Acetone	NA	NA	NA	NA	NA	NA	NA	NA	6/14	<13.5	39 B@	B-5 [90]
Carbon disulfide	NA	NA	NA	NA	NA	NA	NA	NA	2/14	<6.6	<7.2	B-6 [90]
Methylene chloride	NA	NA	NA	NA	NA	NA	NA	NA	8/14	2.1 JB	6.7 J	B-5 [90]
SW8270 - Semivolatile Organic Compounds (mg/L or mg/kg)												
Dibutylphthalate	0/8	ND	ND	NA	NA	NA	NA	NA	1/14	<0.215	170 J	B-6 [90]
bis(2-Ethylhexyl)phthalate	7/8	0.0075	<0.02	B-6 [90]	NA	NA	NA	NA	4/14	<0.44	1100 @	B-2 [90]

[a]Organic lead data results for the 1990 Investigation were questionable data. The organic lead concentrations detected in surface water were greater than total lead concentrations detected. Additional sampling was conducted in the 1994 Investigation using an analytical method specific for organic lead and it was not detected. Therefore, organic lead is not present in the surface water in the sewage lagoon system.

[b] Heptachlor epoxide data was questionable since it was only detected on one of two columns using a GC methodology. Therefore, this constituent was resampled in the 1994 investigation and any sample that was detected on one column only was reanalyzed using a GC/MS methodology to determine if heptachlor epoxide was present. In all cases, no heptachlor epoxide was detected using the GC/MS methodology. Holloman AFB has verified that no heptachlor epoxide is present.

Hits = Frequency of detection (i.e. 1/15 means 1 out of 15 samples reported a detected concentration)
NA = Not applicable, or not analyzed
ND = Not detected
[90] = Year that the sample reporting the maximum value was collected
< = Value reported after < is the reporting limit

Legend for Analytical Flags varies with each year of sampling as shown below.

Table A-3
(Continued)

1990 Sampling Event

B - Parameter was also detected in the blank sample; result is uncorrected
C - Confirmed on second column or by GC/MS
G - Indicates an estimated GC value due to interference
h - Sample analyzed 4 days past allowable holding time
J - Result is less than the method specified detection limit. These results should be considered approximate.
@ - Result is less than five times the method detection limit. Studies have shown that the uncertainty of the analysis will increase exponentially as the MDL is approached. These results should be considered approximate
X - Not confirmed on second column

1992 and 1993 Sampling Events

X - Qualitative confirmation of analyte on both columns. Quantification differed by a factor of two or more between columns. Value determined by the first column is reported.
@ - Measured result is less than five times the detection limit
C - Presence and quantitation of the analyte confirmed by second column analysis
D - Secondary dilution required for this analyte
J - Detected below the method detection limit
B - Analyte detected in laboratory blank analysis, no blank subtraction performed
G - Indicates an estimated GC value due to interference.

1994 Sampling Event

T - Primary column concentration is the preferred result
V - Second column concentration is the preferred result
J - Result is less than the reporting limit

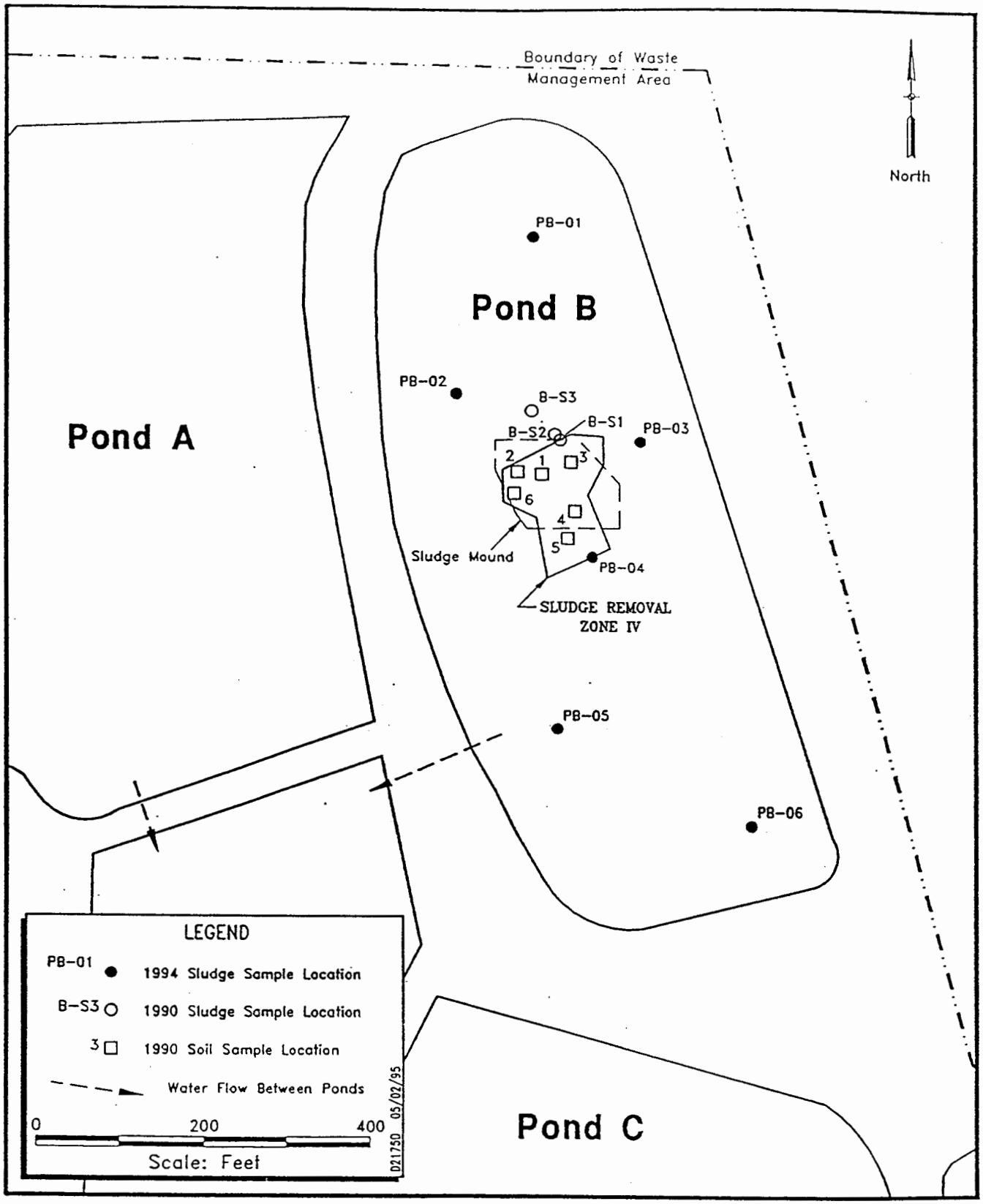

Figure A-2. Pond B Sludge and Soil Sample Locations

Pond C

Table A-4
Analytical Summary For Pond C

Analyte	Surface Water				Sludge				Soils			
	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location
E130.2 - Hardness (mg/L)												
Hardness, as CaC03	1/1	1900	1900	C-01 [93]	NA	NA	NA	NA	NA	NA	NA	NA
E160.1 - Total Dissolved Solids (mg/L)												
Total dissolved solids	1/1	4400	4400	C-01 [93]	NA	NA	NA	NA	NA	NA	NA	NA
MRI-SOP - Kepone (mg/kg)												
Kepone	NA	NA	NA	NA	1/8	<0.07	<0.07	11C [94]	NA	NA	NA	NA
SW6010 - Metals (mg/L or mg/kg)												
Aluminum	1/5	<0.024	0.053 @	C-2 [90]	6/6	9750	13000	C-3 [90]	6/6	10500	11000	C-2 [90]
Barium	4/5	0.03 @	0.038 @	C-1 [90]	25/25	92	159	05C [94]	14/14	86	160	C-3 [90]
Beryllium	0/5	ND	ND	NA	8/25	<0.56	<2.00	C-05 [92]	6/14	0.67	<0.89	C-06 [92]
Boron	5/5	0.21 @	0.3 @	C-1 [90]	NA	NA	NA	NA	NA	NA	NA	NA
Cadmium	0/5	ND	ND	NA	6/19	<2.9	6 @	C-05 [92]	0/8	ND	ND	NA
Calcium	5/5	290	350	C-1 [90]	6/6	110000	120000	C-3 [90]	6/6	105000	190000	C-3 [90]
Chromium	0/5	ND	ND	NA	25/25	39.1	120	C-01 [92]	12/14	7.55 @	<15	C-2 [90]
Cobalt	0/5	ND	ND	NA	20/25	3.9	<10.0	C-05 [92]	6/14	3.9 @	4.4	C-03 [92]
Copper	0/5	ND	ND	NA	25/25	88.4	260	C-05 [92]	6/14	8.1	18	C-2 [90]
Iron	5/5	0.053 @	0.076	C-2 [90]	6/6	7050	9000	C-3 [90]	6/6	7150	8200	C-2 [90]
Magnesium	5/5	140	170	C-1 [90]	6/6	10500	13000	C-1 [90]	6/6	8850	25000	C-5 [90]
Manganese	5/5	0.063	0.077	C-2 [90]	6/6	145	210	C-1 [90]	6/6	92.5	150	C-1 [90]
Molybdenum	0/5	ND	ND	NA	0/6	ND	ND	NA	1/6	<6.35	12 @	C-2 [90]
Nickel	0/5	ND	ND	NA	21/25	10.4 J	<20.0	C-05 [92]	6/14	8.6	<8.9	C-06 [92]
Potassium	5/5	9.3	12	C-2 [90]	6/6	2350	2700 @	C-1 [90]	6/6	2700	2800	C-3 [90]
Silicon	5/5	13	16	C-1 [90]	6/6	1610	8200	C-5 [90]	6/6	1115	4000	C-4 [90]
Silver	0/5	ND	ND	NA	20/25	84.3	320	C-01 [92]	0/14	ND	ND	NA
Sodium	5/5	410	520	C-2 [90]	6/6	1150	2300	C-5 [90]	6/6	670	1200	C-5 [90]
Tin	0/5	ND	ND	NA	7/19	<39.1	<600.0	C-05 [92]	0/8	ND	ND	NA
Vanadium	5/5	0.0056 @	0.0078 @	C-2 [90]	25/25	32.3	55 @	C-01 [92]	12/14	18.5	30	C-3 [90]
Zinc	2/5	<0.003	0.013 @	C-2 [90]	25/25	121	330	C-01 [92]	12/14	15.5	210	C-2 [90]

Table A-4
(Continued)

Analyte	Surface Water				Sludge				Soils			
	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location
SW7060 - Arsenic (mg/L or mg/kg))												
Arsenic	2/5	<0.003	0.0041 @	C-1 [90]	16/25	1.7 J	<3.80	C-05 [92]	11/14	1.2	2.6	C-06 [92]
SW7196 - Chromium VI (mg/L)												
Chromium VI	2/5	<0.0002	0.014	C-2 [90]	NA	NA	NA	NA	NA	NA	NA	NA
SW7421 - Lead (mg/L or mg/kg))												
Lead	5/8	0.0066	<0.01	PC-08 [94]	25/25	13	64	C-05 [92]	14/14	2.9	5.3	C-2 [90]
SW7470 Mercury (mg/L)												
Mercury	0/5	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
SW7471 - Mercury (mg/kg)												
Mercury	NA	NA	NA	NA	15/19	<0.72	1.6 @	C-01 [92]	0/8	ND	ND	NA
SW7740 - Selenium (mg/L or mg/kg)												
Selenium	0/5	ND	ND	NA	16/25	1.5 J	6.3 @	C-05 [92]	0/14	ND	ND	NA
TCLP Metals												
Arsenic	NA	NA	NA	NA	0/7	NA	NA	NA	NA	NA	NA	NA
Barium	NA	NA	NA	NA	7/7	0.55 B	1.1 B	03C [95]	NA	NA	NA	NA
Cadmium	NA	NA	NA	NA	0/7	NA	NA	NA	NA	NA	NA	NA
Chromium	NA	NA	NA	NA	0/7	NA	NA	NA	NA	NA	NA	NA
Lead	NA	NA	NA	NA	0/7	NA	NA	NA	NA	NA	NA	NA
Mercury	NA	NA	NA	NA	0/7	NA	NA	NA	NA	NA	NA	NA
Selenium	NA	NA	NA	NA	0/7	NA	NA	NA	NA	NA	NA	NA
Silver	NA	NA	NA	NA	4/7	ND (0.01)	0.011 J	03C [95] 10C [95]	NA	NA	NA	NA
SW8080 - Organochlorine Pesticides and PCBs (µg/L or µg/kg)												
Aldrin	0/6	ND	ND	NA	0/25	ND	ND	NA	3/14	1.8	<21.0	C-01 [92]
alpha-BHC	0/6	ND	ND	NA	5/25	<16	<120	C-05 [92]	0/14	ND	ND	NA
beta-BHC	1/6	<1.5	<1.5	C-5 [90]	0/25	ND	ND	NA	2/14	<1.4	63	C-01 [92]
delta-BHC	0/6	ND	ND	NA	6/25	<16	5000 X	C-05 [92]	1/14	<1.4	<21.0	C-01 [92]
gamma-BHC	0/6	ND	ND	NA	4/25	<25	<120	C-05 [92]	0/14	ND	ND	NA
alpha-Chlordane	0/1	ND	ND	NA	1/6	70.5	<120	C-05 [92]	0/8	ND	ND	NA
gamma-Chlordane	0/1	ND	ND	NA	4/6	107.5	210 C@	C-05 [92]	0/8	ND	ND	NA
Chlordane	0/5	ND	ND	NA	0/19	[illegible]	ND	NA	0/6	ND	ND	NA

Table A-4
(Continued)

Analyte	Surface Water				Sludge				Soils			
	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location
4,4'-DDD	0/6	ND	ND	NA	24/25	310 C@	16000 C	C-5 [90]	9/14	56.5	180 C@	C-2 [90]
4,4'-DDE	0/6	ND	ND	NA	23/25	220 V	8100 CG	C-5 [90]	7/14	14	240 C@	C-2 [90]
4,4'-DDT	0/6	ND	ND	NA	9/25	36.0 J	360 X@	C-05 [92]	1/14	<2.7	<42.0	C-01 [92]
Dieldrin	0/6	ND	ND	NA	3/25	<31	<180	02C [94]	0/14	ND	ND	NA
Endosulfan I	0/6	ND	ND	NA	5/25	<32	4400 X	C-5 [90]	3/14	<3.9	440 X	C-2 [90]
Endosulfan Sulfate	0/6	ND	ND	NA	0/25	ND	ND	NA	3/14	<6.4	<14.0	C-03 [92]
Endrin Aldehyde	0/6	ND	ND	NA	0/25	ND	ND	NA	1/14	<2.7	<42.0	C-01 [92]
Heptachlor epoxide[4]	0/1	ND	ND	NA	0/25	ND	ND	NA	2/14	<1.4	<21.0	C-01 [92]
Kepone (Mirex)	0/1	ND	ND	NA	4/10	<103	190000 C	C-5 [90]	0/8	ND	ND	NA
SW8150 - Chlorinated Herbicides (µg/kg)												
Dichloroprop	NA	NA	NA	NA	0/6	ND	ND	NA	1/6	<85	153 C@	C-2 [90]
2,4,5-T	NA	NA	NA	NA	1/12	<87	300 X@	C-05 [92]	0/14	ND	ND	NA
SW8240 - Volatile Organic Compounds (µg/kg)												
Acetone	NA	NA	NA	NA	11/12	177.5	2300 @	C-03 [92]	11/14	17	430 J	C-01 [92]
Benzene	NA	NA	NA	NA	1/12	<38	<60	C-05 [92]	0/14	ND	ND	NA
Carbon disulfide	NA	NA	NA	NA	8/12	14 J@	110 @	C-05 [92]	8/14	<6.7	26.8	C-01 [92]
Ethyl benzene	NA	NA	NA	NA	6/12	18	43	C-04 [92]	1/14	<6.75	<53.0	C-01 [92]
Methyl ethyl ketone	NA	NA	NA	NA	7/12	30.5	310	C-05 [92]	0/14	ND	ND	NA
Methylene chloride	NA	NA	NA	NA	5/12	7.55	<60	C-05 [92]	7/14	5.7	<53.0	C-01 [92]
Tetrachloroethene	NA	NA	NA	NA	1/12	<38	<60	C-05 [92]	0/14	ND	ND	C-01 [92]
Toluene	NA	NA	NA	NA	6/12	7.6	15	C-06 [92]	7/14	0.9	<6.8	C-05 [92]
Xylenes	NA	NA	NA	NA	8/12	17	130 @	C-05 [92]	1/14	<6.7	<53.0	C-01 [92]
SW8270 - Semivolatile Organic Compounds (mg/L or mg/kg)												
Acetophenone	0/5	ND	ND	NA	2/12	<6.4	<12.0	C-05 [92]	0/14	ND	ND	NA
Di-n-octylphthalate	0/5	ND	ND	NA	0/12	ND	ND	NA	1/14	1.35	< 1.4	C-01 [92]
Dibenzofuran	0/5	ND	ND	NA	1/12	3.35	<12.0	C-05 [92]	0/14	ND	ND	NA
Dibutylphthalate	0/5	ND	ND	NA	2/12	0.32	<12.0	C-05 [92]	2/14	<1.3	<11.0	C-01 [92]
bis(2-Ethylhexyl)phthalate	2/5	<0.02	<0.02	C-5 [90]	10/12	6.25	36 B@	C-02 [92]	10/14	0.395	7.9 B	C-06 [92]
Fluoranthene	0/5	ND	ND	NA	2/12	<6.4	<12.0	C-05 [92]	0/14	ND	ND	NA
2-Methylnaphthalene	0/5	ND	ND	NA	2/12	<3.35	14 @	C-5 [90]	0/14	ND	ND	NA

Table A-4
(Continued)

Analyte	Surface Water				Sludge				Soils			
	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location
Phenanthrene	0/5	ND	ND	NA	9/12	0.75	11 @	C-5 [90]	1/14	<1.3	<11.0	C-01 [92]
Phenol	0/5	ND	ND	NA	1/12	<3.35	<12.0	C-05 [92]	0/14	ND	ND	NA
Pyrene	0/5	ND	ND	NA	3/12	0.405	<12.0	C-05 [92]	1/14	<1.3	<11.0	C-01 [92]
SW9012 - Total Cyanide (mg/kg)												
Cyanide	NA	NA	NA	NA	2/6	<2.15	330	C-01 [92]	4/8	0.355	1.2 @	C-03 [92]
SW9030 - Sulfides (mg/kg)												
Sulfide	NA	NA	NA	NA	5/6	1500	2800	C-01 [92]	2/8	<34	130 @	C-01 [92]
SW9060 Total Organic Carbon (µg/kg)												
Total organic carbon	NA	NA	NA	NA	NA	NA	NA	NA	2/2	2600 @	3200 @	C-01 [92]

* Heptachlor epoxide data was questionable since it was only detected on one of two columns using a GC methodology. Therefore, this constituent was resampled in the 1994 investigation and any sample that was detected on one column only was reanalyzed using a GC/MS methodology to determine if heptachlor epoxide was present. In all cases, no heptachlor epoxide was detected using the GC/MS methodology. Holloman AFB has verified that no heptachlor epoxide is present.

Hits = Frequency of detection (i.e. 1/15 means 1 out of 15 samples reported a detected concentration)
NA = Not applicable, or not analyzed
ND = Not detected
[90] = Year that the sample reporting the maximum value was collected
< = Value reported after < is the reporting limit

Legend for Analytical Flags varies with each year of sampling as shown below.

1990 Sampling Event

B - Parameter was also detected in the blank sample; result is uncorrected
C - Confirmed on second column or by GC/MS
G - Indicates an estimated GC value due to interference
h - Sample analyzed 4 days past allowable holding time
J - Result is less than the method specified detection limit. These results should be considered approximate.
@ - Result is less than five times the method detection limit. Studies have shown that the uncertainty of the analysis will increase exponentially as the MDL is approached. These results should be considered approximate
X - Not confirmed on second column

1992 and 1993 Sampling Events

X - Qualitative confirmation of analyte on both columns. Quantification differed by a factor of two or more between columns. Value determined by the first column is reported.
@ - Measured result is less than five times the detection limit
C - Presence and quantitation of the analyte confirmed by second column analysis
D - Secondary dilution required for this analyte
J - Detected below the method detection limit
B - Analyte detected in laboratory blank analysis, no blank subtraction performed
G - Indicates an estimated GC value due to interference.

1994 Sampling Event

T - Primary column concentration is the preferred result
V - S[illegible]d column concentration is the preferred result
J - R[illegible] [illegible]n the reporting limit

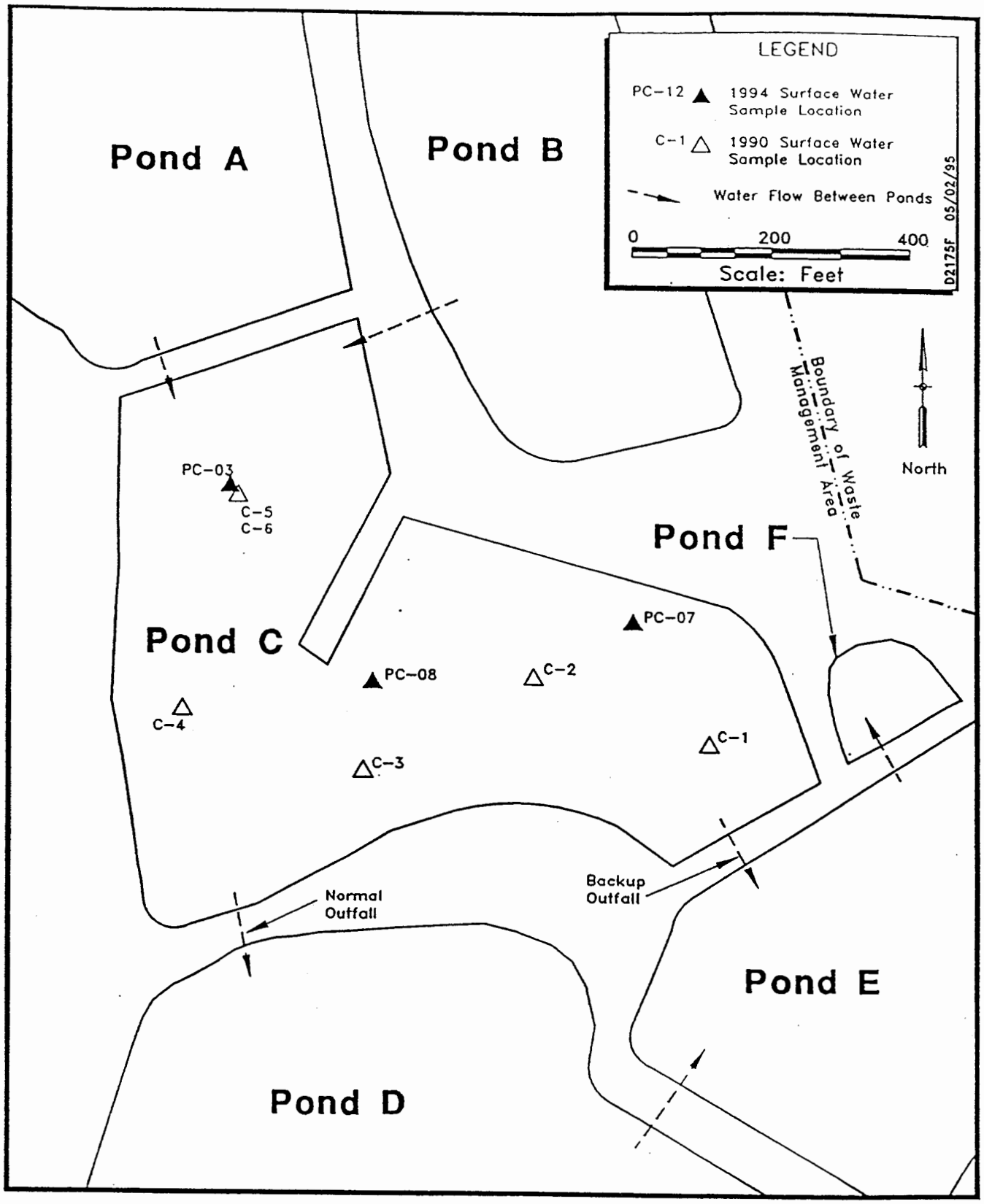

Figure A-3. Pond C Surface Water Sample Locations

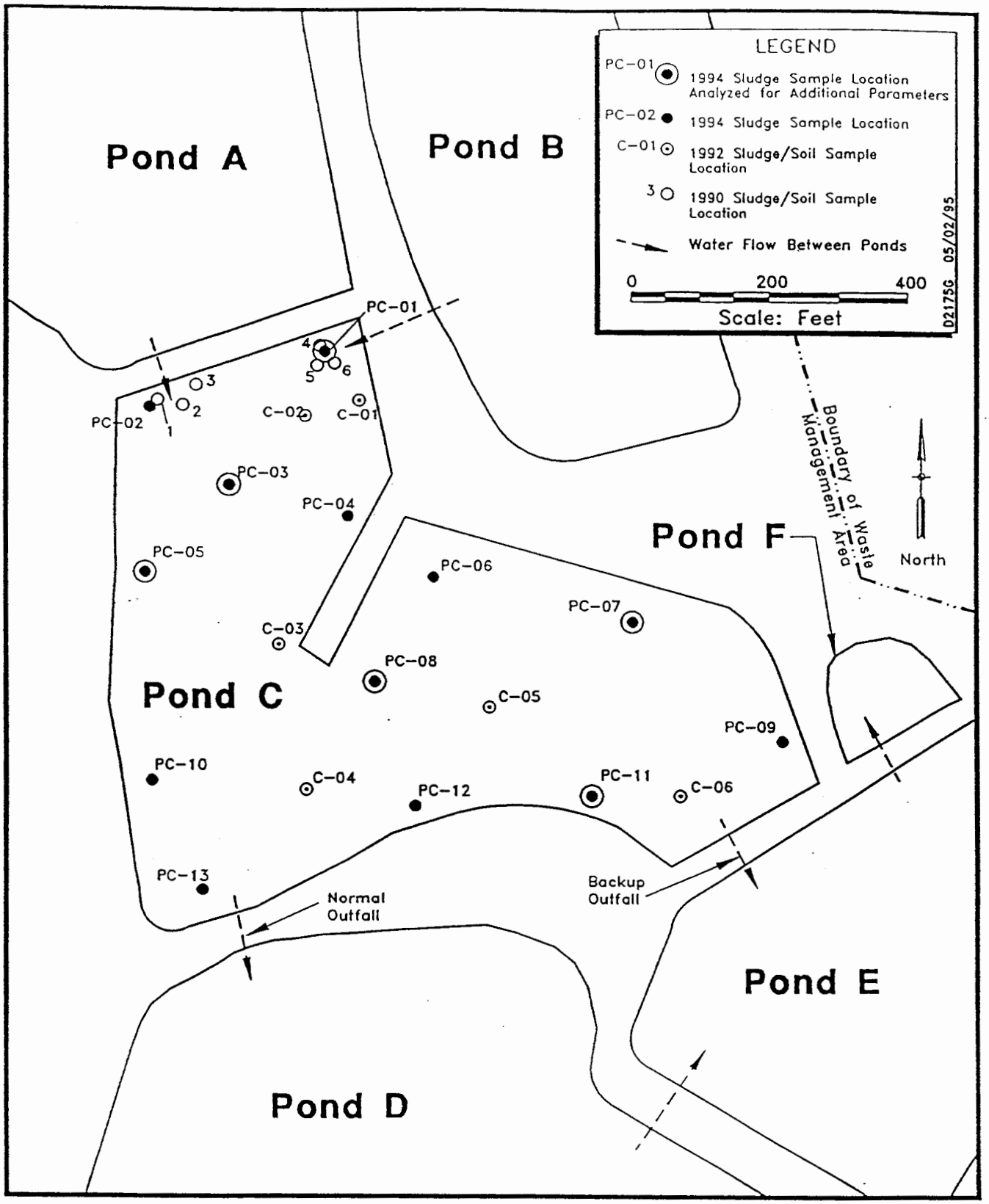

Figure A-4. Pond C Sludge and Soil Sample Locations

Pond D

Table A-5
Analytical Summary For Pond D

Analyte	Surface Water				Sludge				Soils			
	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location
E130.2 - Hardness (mg/L or mg/kg)												
Hardness, as CaC03	1/1	2100	2100	D-01 [93]	NA	NA	NA	NA	NA	NA	NA	NA
E160.1 - Total Dissolved Solids (mg/L)												
Total dissolved solids	1/1	4600	4600	D-01 [93]	NA	NA	NA	NA	NA	NA	NA	NA
E239.1 - Organic Lead (mg/L)												
Lead (organic) [a]	2/6	<0.1	0.12 @	D-5 [90]	NA	NA	NA	NA	NA	NA	NA	NA
SW6010 - Metals (mg/L or mg/kg)												
Barium	6/6	0.037 @	0.039 @	D-3 [90]	10/10	50.2	91.7	PD-0D [94]	9/9	38.0	82.0	D-06 [92]
Beryllium	NA	NA	NA	NA	1/10	1.02	<1.8	PD-06 [94]	0/9	ND	ND	NA
Boron	6/6	0.29 @	0.3 @	D-4 [90]	NA	NA	NA	NA	NA	NA	NA	NA
Calcium	6/6	330	340	D-3 [90]	NA	NA	NA	NA	NA	NA	NA	NA
Chromium	0/6	ND	ND	NA	8/10	4.6	<8.9	PD-06 [94]	4/9	<4.8	9.4 @	D-01 [92]
Cobalt	NA	NA	NA	NA	8/10	2.55	<5.8	PD-10 [94]	0/9	ND	ND	NA
Copper	0/6	ND	ND	NA	10/10	12.05	35.5	PD-06 [94]	0/9	ND	ND	NA
Iron	6/6	0.0325 @	0.054 @	D-6 [90]	NA	NA	NA	NA	NA	NA	NA	NA
Magnesium	6/6	170	180	D-3 [90]	NA	NA	NA	NA	NA	NA	NA	NA
Manganese	6/6	0.056	0.074	D-1 [90]	NA	NA	NA	NA	NA	NA	NA	NA
Nickel	NA	NA	NA	NA	9/10	4.2 J	<23.3	PD-10 [94]	1/9	<9	<11	D-05 [92]
Potassium	6/6	12	12	D-1 [90]	NA	NA	NA	NA	NA	NA	NA	NA
Silicon	6/6	15	17	D-1 [90]	NA	NA	NA	NA	NA	NA	NA	NA
Silver	NA	NA	NA	NA	9/10	2.85 J	7.5	PD-09 [94]	0/9	ND	ND	NA
Sodium	6/6	495	520	D-3 [90]	NA	NA	NA	NA	NA	NA	NA	NA
Thallium	NA	NA	NA	NA	1/10	<2.85	<8.9	PD-06 [94]	NA	NA	NA	NA
Tin	NA	NA	NA	NA	0/10	ND	ND	NA	0/9	ND	ND	NA
Vanadium	3/6	0.0051	0.0063 @	D-3 [90]	10/10	15.75	24.9	PD-08 [94]	4/9	<10	26 @	D-01 [92]
Zinc	4/6	0.0045 @	0.0081 @	D-5 [90]	10/10	23.1	53.6	PD-08 [94]	5/9	<11	23 @	D-01 [92]

Table A-5
(Continued)

Analyte	Surface Water				Sludge				Soils			
	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location
SW7060 - Arsenic (mg/L or mg/kg)												
Arsenic	3/6	<0.006	0.0062 @	D-3 [90]	8/10	2.15 J	<5.8	PD-10 [94]	9/9	0.9 @	2.9	D-01 [92]
SW7421 - Lead (mg/L or mg/kg)												
Lead	6/9	0.0047 @	<0.01	PD-08 [94]	10/10	1.25 J	6 J	PD-08 [94]	9/9	1.7	4.5	D-01 [92]
SW7470 - Mercury (mg/L)												
Mercury	3/6	0.0004	0.00074 @	D-5 [90]	NA	NA	NA	NA	NA	NA	NA	NA
SW7471 - Mercury (mg/kg)												
Mercury	NA	NA	NA	NA	0/10	ND	ND	NA	0/9	ND	ND	NA
SW7740 - Selenium (mg/L or mg/kg)												
Selenium	2/6	<0.002	0.003 @	D-5 [90]	8/10	1.3 J	<2.9	PD-05 [94]	1/9	<0.55	<0.64	D-01 [92]
SW8080 - Organochlorine Pesticides and PCBs (µg/L or µg/kg)												
Aldrin	0/7	ND	ND	NA	0/10	ND	ND	NA	0/9	ND	ND	NA
alpha-BHC	0/7	ND	ND	NA	0/10	ND	ND	PD-03 [94]	0/9	ND	ND	NA
beta-BHC	0/7	ND	ND	NA	0/10	ND	ND	NA	3/9	<3.6	26 X	D-03 [92]
delta-BHC	1/7	0.021 X@	0.021 X@	D-01 [93]	6/10	1.7 VJ	<9.7	PD-08 [94]	1/9	<1.4	17 X	D-03 [92]
gamma-BHC	1/7	<0.6	<1.5	D-3 [90]	0/10	ND	ND	NA	1/9	<3.4	21 X	D-01 [92]
Chlordane	0/6	ND	ND	NA	0/10	ND	ND	NA	NA	NA	NA	NA
alpha-Chlordane	0/1	ND	ND	NA	NA	NA	NA	NA	1/9	7.25	<13	D-04 [92]
gamma-Chlordane	1/1	0.0058 J	0.0058 J	NA	NA	NA	NA	NA	0/9	ND	ND	NA
4,4'-DDD	1/7	0.03 X@	0.03 X@	D-01 [93]	9/10	4.9 VJ	32	PD-06 [94]	2/9	<1.4	240 C	D-04 [92]
4,4'-DDE	0/7	ND	ND	NA	8/10	4.1 J	14 VJ	PD-06 [94]	1/9	<1.4	35 X@	D-04 [92]
4,4'-DDT	0/7	ND	ND	NA	6/10	9.3	97	PD-06 [94]	3/9	<2.8	52 C@	D-04 [92]
Dieldrin	1/7	0.015 X@	0.015 X@	D-01 [93]	0/10	ND	ND	NA	0/9	ND	ND	NA
Endosulfan II	0/7	ND	ND	NA	0/10	ND	ND	NA	0/9	ND	ND	NA
Endosulfan Sulfate	1/7	0.013 JB	0.013JB	D-01 [93]	1/10	15	<30	PD-06 [94]	3/9	34.5	<64	D-04 [92]
Endrin	1/7	0.0097 X@	0.0097 X@	D-01 [93]	0/10	ND	ND	NA	0/9	ND	ND	NA
Heptachlor	0/7	ND	ND	NA	1/10	<3.1	<15	PD-06 [94]	0/9	ND	ND	NA
Heptachlor epoxide [b]	1/7	0.01 X@	0.01 X@	D-01 [93]	0/10	NA	ND	NA	0/9	ND	ND	NA

Table A-5
(Continued)

Analyte	Surface Water				Sludge				Soils			
	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location
Methoxychlor	1/7	<10	<25	D-3 [90]	0/10	ND	ND	NA	0/9	ND	ND	NA
SW8240 - Volatile Organic Compounds (µg/kg)												
Acetone	NA	NA	NA	NA	NA	NA	NA	NA	3/9	<130	<150	D-01 [92]
2-Hexanone	NA	NA	NA	NA	NA	NA	NA	NA	1/9	<67	<74	D-01 [92]
SW8270 - Semivolatile Organic Compounds (mg/L or mg/kg)												
Benzoic acid	1/6	<0.05	<0.1	D-1 [90]	NA	NA	NA	NA	0/9	ND	ND	NA
Butylbenzylphthalate	1/6	<0.01	<0.02	D-1 [90]	NA	NA	NA	NA	0/9	ND	ND	NA
Dibutylphthalate	1/6	<0.01	<0.02	D-1 [90]	NA	NA	NA	NA	0/9	ND	ND	NA
Diethylphthalate	1/6	<0.01	<0.02	D-1 [90]	NA	NA	NA	NA	0/9	ND	ND	NA
bis(2-Ethylhexyl)phthalate	5/6	0.01	0.02 @	D-4 [90]	NA	NA	NA	NA	4/9	<1.35	<1.5	D-01 [92]
4-Hydroxy-4-methyl-2-pentanone	0/6	ND	ND	NA	NA	NA	NA	NA	1/9	13	13	D-01 [92]
Phenol	1/6	<0.01	<0.02	D-1 [90]	NA	NA	NA	NA	0/9	ND	ND	NA
SW9030 - Sulfides (mg/kg)												
Sulfide	NA	NA	NA	NA	NA	NA	NA	NA	1/9	<33.5	82 @	D-04 [92]
SW9060 - Total Organic Carbon (mg/kg)												
Total organic carbon	NA	NA	NA	NA	NA	NA	NA	NA	6/6	2400 @	3200 @	D-01 [92]

[a]Organic lead data results for the 1990 Investigation were questionable data. The organic lead concentrations detected in surface water were greater than total lead concentrations detected. Additional sampling was conducted in the 1994 Investigation using an analytical method specific for organic lead and it was not detected. Therefore, organic lead is not present in the surface water in the sewage lagoon system.

[b] Heptachlor epoxide data was questionable since it was only detected on one of two columns using a GC methodology. Therefore, this constituent was resampled in the 1994 investigation and any sample that was detected on one column only was reanalyzed using a GC/MS methodology to determine if heptachlor epoxide was present. In all cases, no heptachlor epoxide was detected using the GC/MS methodology. Holloman AFB has verified that no heptachlor epoxide is present.

Hits = Frequency of detection (i.e. 1/15 means 1 out of 15 samples reported a detected concentration)
NA = Not applicable, or not analyzed
ND = Not detected
[90] = Year that the sample reporting the maximum value was collected
< = Value reported after < is the reporting limit

Table A-5
(Continued)

Legend for Analytical Flags varies with each year of sampling as shown below.

1990 Sampling Event

B - Parameter was also detected in the blank sample; result is uncorrected
C - Confirmed on second column or by GC/MS
G - Indicates an estimated GC value due to interference
h - Sample analyzed 4 days past allowable holding time
J - Result is less than the method specified detection limit. These results should be considered approximate.
@ - Result is less than five times the method detection limit. Studies have shown that the uncertainty of the analysis will increase exponentially as the MDL is approached. These results should be considered approximate
X - Not confirmed on second column

1992 and 1993 Sampling Events

X - Qualitative confirmation of analyte on both columns. Quantification differed by a factor of two or more between columns. Value determined by the first column is reported.
@ - Measured result is less than five times the detection limit
C - Presence and quantitation of the analyte confirmed by second column analysis
D - Secondary dilution required for this analyte
J - Detected below the method detection limit
B - Analyte detected in laboratory blank analysis, no blank subtraction performed
G - Indicates an estimated GC value due to interference.

1994 Sampling Event

T - Primary column concentration is the preferred result
V - Second column concentration is the preferred result
J - Result is less than the reporting limit

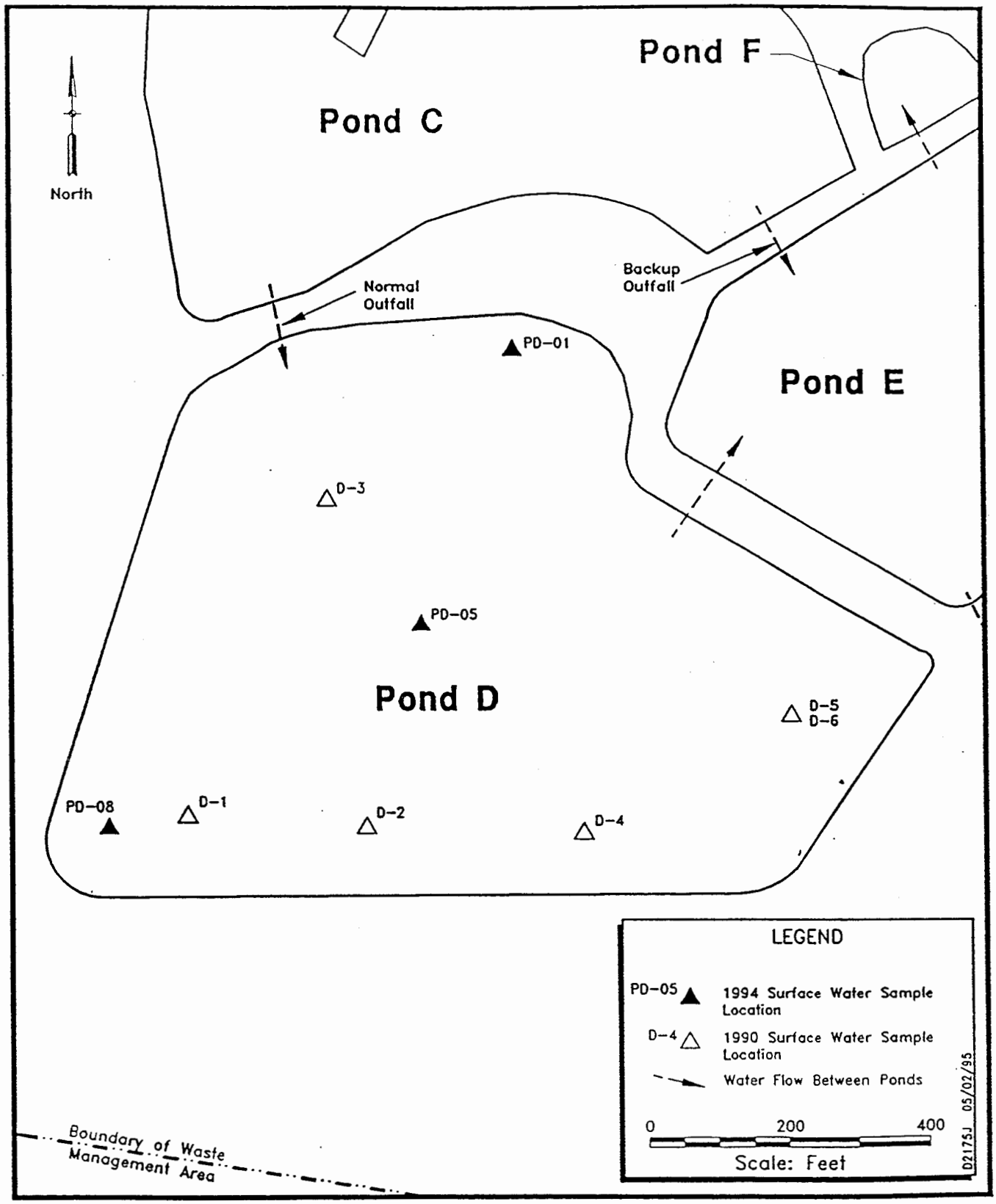

Figure A-5. Pond D Surface Water Sample Locations

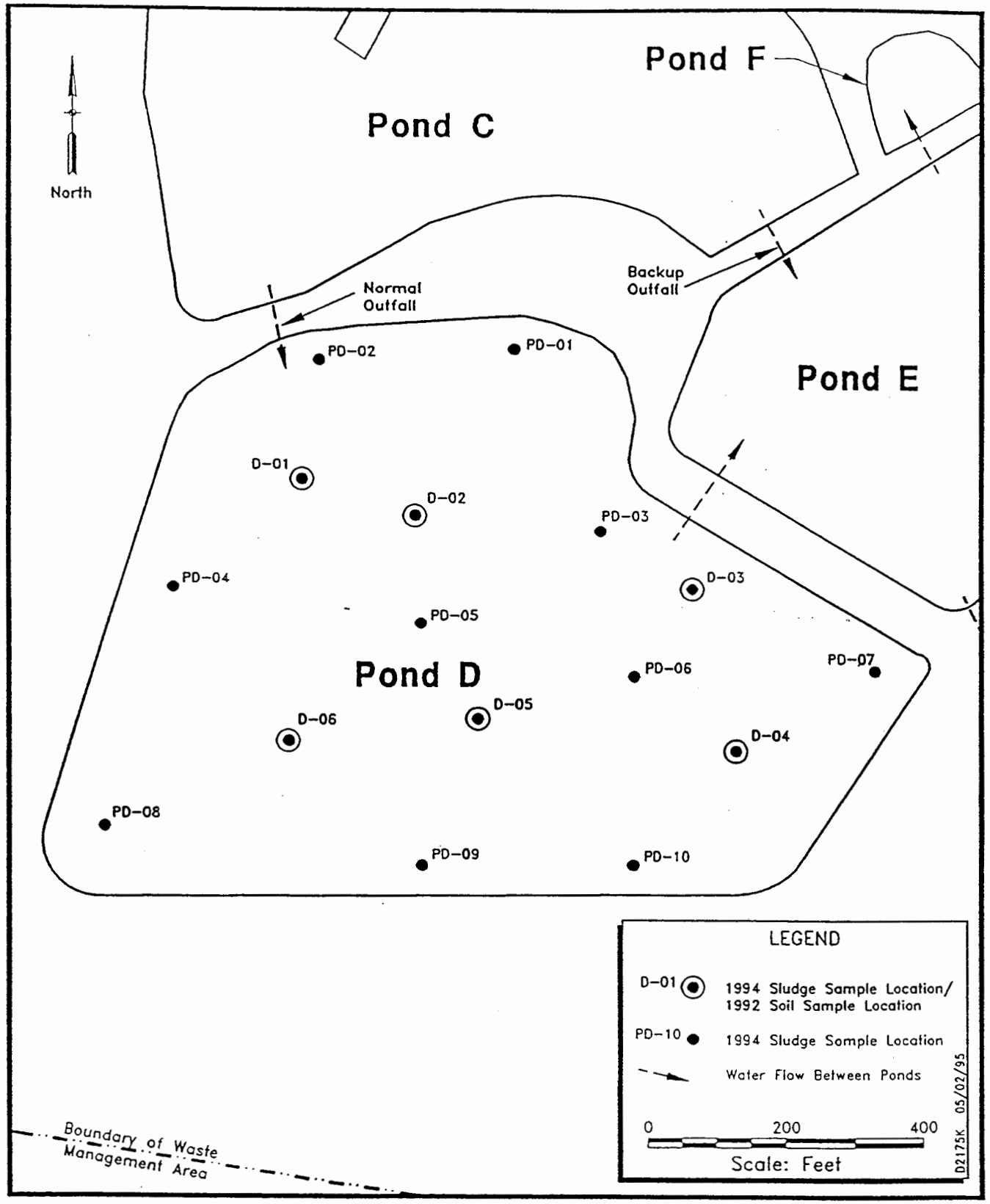

Figure A-6. Pond D Sludge and Soil Sample Locations

Pond E

Table A-6
Analytical Summary For Pond E

Analyte	Surface Water				Sludge				Soils			
	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location
E130.2 - Hardness (mg/L)												
Hardness, as CaC03	2/2	2100	2100	E-01 [93]	NA	NA	NA	NA	NA	NA	NA	NA
E160.1 - Total Dissolved Solids (mg/L)												
Total dissolved solids	2/2	4650	4700	E-01 [93]	NA	NA	NA	NA	NA	NA	NA	NA
E239.1 - Organic Lead (mg/L)												
Lead (organic)*	1/6	<0.1	<0.1	E-4 [90]	NA	NA	NA	NA	NA	NA	NA	NA
SW6010 - Metals (mg/L or mg/kg)												
Antimony	0/6	ND	ND	NA	1/22	<20.6	<61.8	E-15 [94]	0/9	ND	ND	NA
Barium	6/6	0.0355 @	0.037 @	E-1 [90]	22/22	81.1	179	E-06 [94]	9/9	67	130	E-05 [92]
Beryllium	NA	NA	NA	NA	8/22	0.59	<2.1	E-15 [94]	0/9	ND	ND	NA
Boron	6/6	0.295 @	0.33 @	E-1 [90]	NA	NA	NA	NA	NA	NA	NA	NA
Cadmium	NA	NA	NA	NA	2/22	<1.7	<5.1	E-15 [94]	0/9	ND	ND	NA
Calcium	6/6	320	350	E-4 [90]	NA	NA	NA	NA	NA	NA	NA	NA
Chromium	0/6	ND	ND	NA	22/22	16.5	72.4	E-15 [94]	4/9	<4.3	5.9 @	E-03 [92]
Cobalt	NA	NA	NA	NA	18/22	3.6	<5.9	E-15 [94]	1/9	<4.3	7 @	E-02 [92]
Copper	0/6	ND	ND	NA	22/22	22.55 @	75	E-01 [92]	0/9	ND	ND	NA
Iron	6/6	0.021 @	0.035 @	E-6 [90]	NA	NA	NA	NA	NA	NA	NA	NA
Magnesium	6/6	165	170	E-1 [90]	NA	NA	NA	NA	NA	NA	NA	NA
Manganese	6/6	0.0355 @	0.039 @	E-1 [90]	NA	NA	NA	NA	NA	NA	NA	NA
Nickel	NA	NA	NA	NA	16/22	7.25	<24.4	E-16 [94]	0/9	ND	ND	NA
Potassium	6/6	11.5	12	E-1 [90]	NA	NA	NA	NA	NA	NA	NA	NA
Silicon	6/6	14	15	E-4 [90]	NA	NA	NA	NA	NA	NA	NA	NA
Silver	NA	NA	NA	NA	22/22	18.2 @	87.1	E-15 [94]	0/9	ND	ND	NA
Sodium	6/6	480	500	E-4 [90]	NA	NA	NA	NA	NA	NA	NA	NA
Thallium	NA	NA	NA	NA	2/17	2.4	<10.3	E-15 [94]	NA	NA	NA	NA
Tin	NA	NA	NA	NA	2/22	46.7	<290	E-01 [92]	0/9	ND	ND	NA
Vanadium	0/6	ND	ND	NA	22/22	27.15 @	52.7	E-04 [94]	6/9	9.9 @	16 @	E-03 [92]
Zinc	0/6	ND	ND	NA	22/22	42.2	118	E-15 [94]	9/9	12 @	19 @	E-03 [92]

Table A-6
(Continued)

Analyte	Surface Water				Sludge				Soils			
	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location
SW7060 - Arsenic (mg/L or mg/kg)												
Arsenic	0/6	ND	ND	NA	20/22	1.7 J	6.6	E-06 [94]	9/9	1.2 @	3.6	E-03 [92]
SW7421 - Lead (mg/L or mg/kg)												
Lead	3/9	0.0029 @	<0.01	E-03 [94]	21/22	6.45 J	21	E-01 [93]	8/9	1.6	4.5	E-03 [92]
SW7470 - Mercury (mg/L)												
Mercury	6/6	0.0005 @	0.00062	E-1 [90]	NA	NA	NA	NA	NA	NA	NA	NA
SW7471 - Mercury (mg/kg)												
Mercury	NA	NA	NA	NA	12/22	<0.275	<1	E-15 [94]	0/9	ND	ND	NA
SW7740 - Selenium (mg/L or mg/kg)												
Selenium	5/6	0.0035 @	0.0055 @	E-1 [90]	17/22	1.04	3.0 J	E-15 [94]	1/9	<0.51	1 @	E-01 [92]
SW7841 - Thallium (mg/kg)												
Thallium	NA	NA	NA	NA	1/6	<1.8	<2.2	E-05 [92]	0/9	ND	ND	NA
SW8080 - Organochlorine Pesticides and PCBs (µg/L or µg/kg)												
Aldrin	0/7	ND	ND	NA	0/22	ND	ND	NA	1/9	<1.4	2.4 X@	E-02 [92]
alpha-BHC	1/7	<0.2	<0.5	E-2 [90]	7/22	<7.9	<66	E-01 [92]	2/9	<1.4	2.4 C@	E-03 [92]
beta-BHC	0/7	ND	ND	NA	0/22	ND	ND	NA	7/9	2.7 X@	9.6 C	E-02 [92]
delta-BHC	1/7	0.021 X@	0.021 X@	E-01 [93]	2/22	<10	<66	E-01 [92]	1/9	<1.4	11 X	E-02 [92]
gamma-BHC	1/7	<0.6	<1.5	E-2 [90]	3/22	0.0092	110 C@	E-01 [92]	0/9	ND	ND	NA
alpha-Chlordane	0/1	ND	ND	NA	0/6	ND	ND	NA	2/9	<1.4	<1.4	E-01 [92]
gamma-Chlordane	1/1	0.0053 J	0.0053 J	E-01 [93]	3/6	64	540 J	E-01 [92]	1/9	<1.4	5.6 X@	E-03 [92]
Chlordane	0/6	ND	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
4,4'-DDD	1/7	0.026 X@	0.026 X@	E-01 [93]	21/22	6.95 V	7300 CD	E-03 [92]	3/9	<1.4	83 C	E-03 [92]
4,4'-DDE	1/7	<0.6	<1.5	E-6 [90]	20/22	30 V	1800 CD	E-03 [92]	2/9	0.0014	7.5 C	E-03 [92]
4,4'-DDT	0/7	ND	ND	NA	9/22	18 V	<130	E-01 [92]	3/9	2.7 X@	4 X@	E-02 [92]
Dieldrin	1/7	0.014 X@	0.014 X@	E-01 [93]	1/22	<20	<66	E-01 [92]	0/9	ND	ND	NA
Endosulfan II	0/7	ND	ND	NA	0/22	ND	ND	NA	2/9	<4.0	<4.2	E-03 [92]
Endosulfan Sulfate	1/7	0.14 JB	0.14 JB	E-01 [93]	0/22	ND	ND	NA	5/9	1.9 J	<7.2	E-02 [92]
Endrin	1/7	0.01 X@	0.01 X@	E-01 [93]	0/22	ND	ND	NA	0/9	ND	ND	NA

Table A-6
(Continued)

Analyte	Surface Water				Sludge				Soils			
	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location
Heptachlor	0/7	ND	ND	NA	1/22	<10	590 J	E-01 [93]	2/9	<1.4	2.1 X@	E-02 [92]
Heptachlor epoxide[b]	1/7	0.01 @	0.01 @	E-01 [93]	1/22	<10	78000 X	E-01 [93]	0/9	ND	ND	NA
SW8240 - Volatile Organic Compounds (µg/kg)												
Acetone	NA	NA	NA	NA	0/5	ND	ND	NA	1/9	<140	<140	E-01 [92]
Carbon disulfide	NA	NA	NA	NA	0/5	ND	ND	NA	3/9	<7	14 @	E-03 [92]
Methylene chloride	NA	NA	NA	NA	0/5	ND	ND	NA	1/9	<6.8	<7.2	E-02 [92]
Toluene	NA	NA	NA	NA	1/5	<540	<660	E-01 [92]	3/9	<6.6	<7.2	E-02 [92]
1,1,2-Trichlorotrifluoroethane	NA	NA	NA	NA	0/5	ND	ND	NA	1/1	17	17	E-05 [92]
Xylenes	NA	NA	NA	NA	1/5	<500	<590	E-05 [92]	0/9	ND	ND	NA
SW8270 - Semivolatile Organic Compounds (mg/L or mg/kg)												
Benzoic acid	1/6	<0.1	<0.1	E-2 [90]	0/6	ND	ND	NA	0/9	ND	ND	NA
Dibutylphthalate	0/6	ND	ND	NA	1/6	<5.4	<6.5	E-01 [92]	0/9	ND	ND	NA
Diethylphthalate	0/6	ND	ND	NA	1/6	<5.4	<6.5	E-01 [92]	0/9	ND	ND	NA
bis(2-Ethylhexyl)phthalate	6/6	0.006 JB	0.015 JB	E-4 [90]	6/6	7.4 @	12 @	E-05 [92]	3/9	<1.3	5.4 @	E-02 [92]
Phenanthrene	0/6	ND	ND	NA	3/6	0.81 J	<5.9	E-05 [92]	0/9	ND	ND	NA
SW9012 - Total Cyanide (mg/kg)												
Cyanide	NA	NA	NA	NA	4/5	3 @	180	E-01 [92]	6/9	0.72 @	2.9	E-04 [92]
SW9030 - Sulfides (mg/kg)												
Sulfide	NA	NA	NA	NA	3/5	470	850	E-05 [92]	4/9	<34	120 @	E-03 [92]
SW9060 - Total Organic Carbon (µg/kg)												
Total organic carbon	NA	NA	NA	NA	NA	NA	NA	NA	2/2	1700 @	2000 @	E-02 [92]

[a]Organic lead data results for the 1990 Investigation were questionable data. The organic lead concentrations detected in surface water were greater than total lead concentrations detected. Additional sampling was conducted in the 1994 Investigation using an analytical method specific for organic lead and it was not detected. Therefore, organic lead is not present in the surface water in the sewage lagoon system.

[b] Heptachlor epoxide data was questionable since it was only detected on one of two columns using a GC methodology. Therefore, this constituent was resampled in the 1994 investigation and any sample that was detected on one column only was reanalyzed using a GC/MS methodology to determine if heptachlor epoxide was present. In all cases, no heptachlor epoxide was detected using the GC/MS methodology. Holloman AFB has verified that no heptachlor epoxide is present.

Hits = Frequency of detection (i.e. 1/15 means 1 out of 15 samples reported a detected concentration)

Table A-6
(Continued)

NA = Not applicable, or not analyzed
ND = Not detected
[90] = Year that the sample reporting the maximum value was collected
< = Value reported after < is the reporting limit

Legend for Analytical Flags varies with each year of sampling as shown below.

1990 Sampling Event

B - Parameter was also detected in the blank sample; result is uncorrected
C - Confirmed on second column or by GC/MS
G - Indicates an estimated GC value due to interference
h - Sample analyzed 4 days past allowable holding time
J - Result is less than the method specified detection limit. These results should be considered approximate.
@ - Result is less than five times the method detection limit. Studies have shown that the uncertainty of the analysis will increase exponentially as the MDL is approached. These results should be considered approximate
X - Not confirmed on second column

1992 and 1993 Sampling Events

X - Qualitative confirmation of analyte on both columns. Quantification differed by a factor of two or more between columns. Value determined by the first column is reported.
@ - Measured result is less than five times the detection limit
C - Presence and quantitation of the analyte confirmed by second column analysis
D - Secondary dilution required for this analyte
J - Detected below the method detection limit
B - Analyte detected in laboratory blank analysis, no blank subtraction performed
G - Indicates an estimated GC value due to interference.

1994 Sampling Event

T - Primary column concentration is the preferred result
V - Second column concentration is the preferred result
J - Result is less than the reporting limit

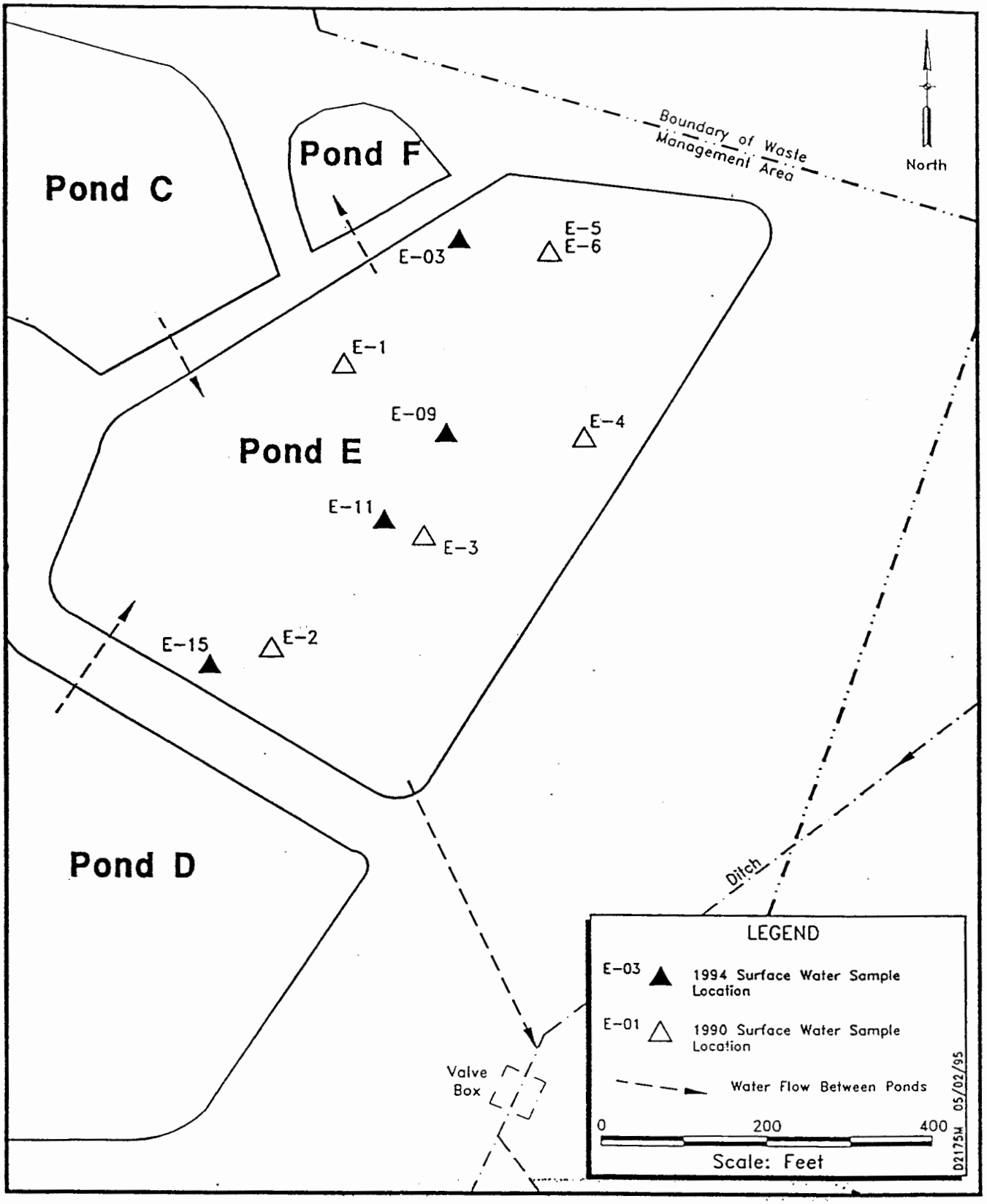

Figure A-7. Pond E Surface Water Sample Locations

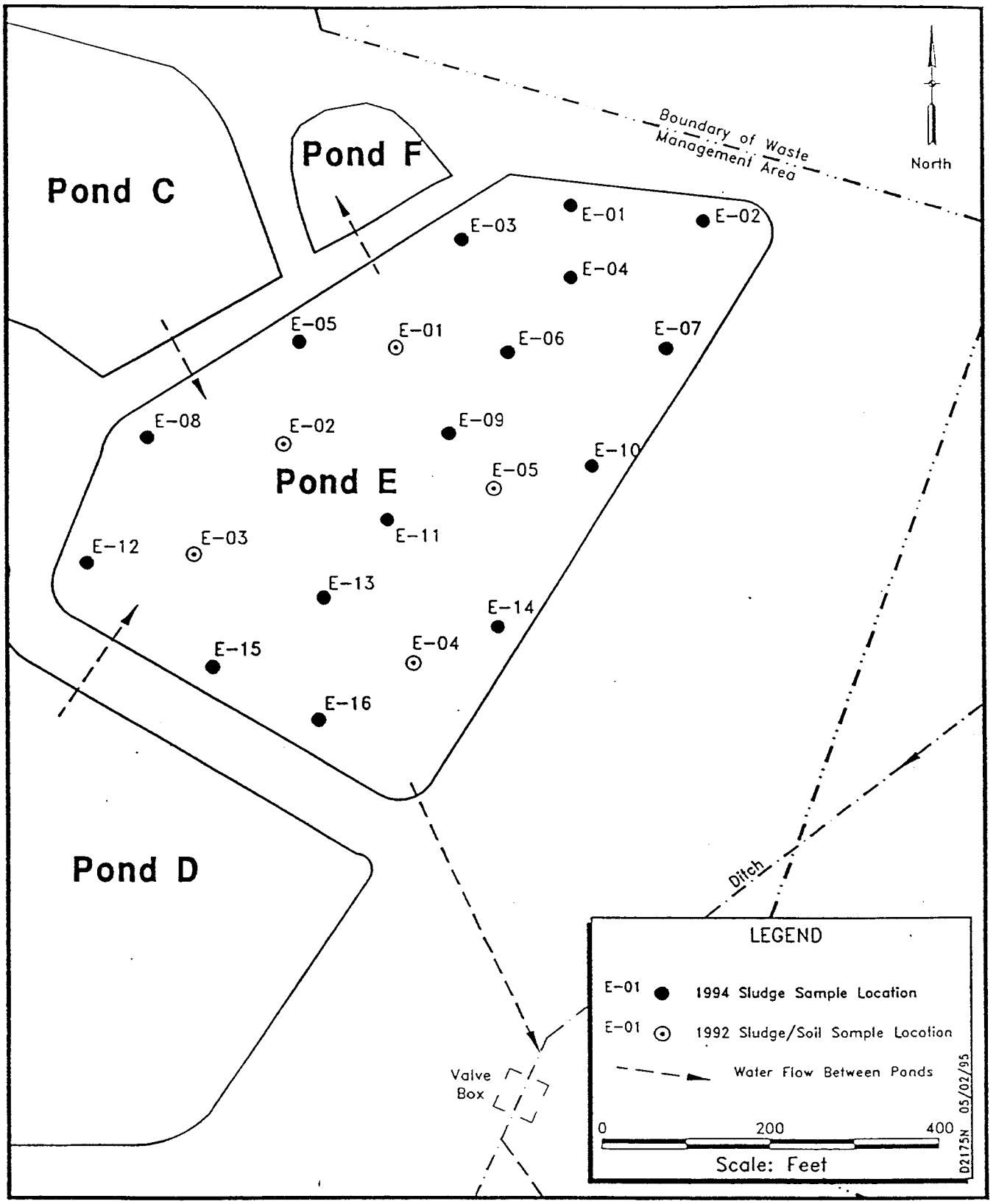

Figure A-8. Pond E Sludge and Soil Sample Locations

Pond F

Table A-7
Analytical Summary for Pond F

Analyte	Surface Water				Sludge				Soils			
	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location
E130.2 - Hardness (mg/L)												
Hardness, as CaC03	1/1	1800	1800	F-01 [93]	NA	NA	NA	NA	NA	NA	NA	NA
E160.1 - Total Dissolved Solids (mg/L)												
Total dissolved solids	1/1	4200	4200	F-01 [93]	NA	NA	NA	NA	NA	NA	NA	NA
SW6010 - Metals (mg/kg)												
Barium	NA	NA	NA	NA	2/2	49	59	F-01 [92]	1/1	28	28	F-01 [92]
Chromium	NA	NA	NA	NA	2/2	29.5	33	F-01 [92]	0/1	ND	ND	NA
Copper	NA	NA	NA	NA	2/2	58.5	75	F-01 [92]	0/1	ND	ND	NA
Nickel	NA	NA	NA	NA	1/2	10.65	13 @	F-01 [92]	0/1	ND	ND	NA
Silver	NA	NA	NA	NA	2/2	48.5	59	F-01 [92]	0/1	ND	ND	NA
Vanadium	NA	NA	NA	NA	2/2	27.5 @	36 @	F-01 [92]	0/1	ND	ND	NA
Zinc	NA	NA	NA	NA	2/2	77.5	98	F-01 [92]	0/1	ND	ND	NA
SW7060 - Arsenic (mg/kg)												
Arsenic	NA	NA	NA	NA	2/2	3.15 @	4 @	F-01 [92]	1/1	0.96 @	0.96 @	F-01 [92]
SW7421 - Lead (mg/kg)												
Lead	NA	NA	NA	NA	2/2	13.3	17	F-01 [92]	1/1	0.5 @	0.5 @	F-01 [92]
SW7471 - Mercury (mg/kg)												
Mercury	NA	NA	NA	NA	2/2	0.355 @	0.43 @	F-01 [92]	0/1	ND	ND	NA
SW7740 - Selenium (mg/kg)												
Selenium	NA	NA	NA	NA	1/2	2.65	<2.8	F-01 [92]	0/1	ND	ND	NA
SW8080 - Organochlorine Pesticides and PCBs (µg/L or µg/kg)												
delta-BHC	1/1	0.029 X@	0.029 X@	F-01 [93]	2/2	3600 X	5000 X	F-01 [92]	1/1	2.7 X@	2.7 X@	F-01 [92]
gamma-BHC	1/1	0.012 X@	0.012 X@	F-01 [93]	1/2	70.5	76 C@	F-02 [92]	0/1	ND	ND	NA
alpha-Chlordane	1/1	0.03 G@	0.03 G@	F-01 [93]	1/2	15.15	250 X@	F-01 [92]	0/1	ND	ND	NA
gamma-Chlordane	1/1	0.01 @	0.01 @	F-01 [93]	2/2	56	64 JX	F-01 [92]	1/1	0.45 JC	0.45 JC	F-01 [92]
4,4'-DDD	1/1	0.035 @	0.035 @	F-01 [93]	2/2	620 C	11000 C	F-01 [92]	1/1	37 C	37 C	F-01 [92]
4,4'-DDE	1/1	0.12 G	0.12 G	F-01 [93]	2/2	1385 XC	1900 C	F-01 [92]	1/1	15 X	15 X	F-01 [92]
4,4'-DDT	0/1	ND	ND	NA	2/2	135 XCE	160 C@	F-01 [92]	1/1	5.8 X@	5.8 X@	F-01 [92]

Table A-7
(Continued)

Analyte	Surface Water				Sludge				Soils			
	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location
Heptachlor	0/1	ND	ND	NA	1/2	51.5	<53	F-02 [92]	0/1	ND	ND	NA
SW8240 - Volatile Organic Compounds (µg/kg)												
Acetone	NA	NA	NA	NA	2/2	905 J@	1400 @	F-01 [92]	0/1	ND	ND	NA
Carbon disulfide	NA	NA	NA	NA	2/2	37.5 @	38 @	F-02 [92]	0/1	ND	ND	NA
Ethyl benzene	NA	NA	NA	NA	1/2	22.5	<33	F-01 [92]	0/1	ND	ND	NA
Methyl ethyl ketone	NA	NA	NA	NA	2/2	136.5 J	220 J	F-01 [92]	0/1	ND	ND	NA
Toluene	NA	NA	NA	NA	2/2	7.5 JB	10 JB	F-02 [92]	1/1	9.4	9.4	F-01 [92]
Xylenes	NA	NA	NA	NA	2/2	26 J@	38 @	F-02 [92]	0/1	ND	ND	NA
SW8270 - Semivolatile Organic Compounds (mg/kg)												
Dibenzofuran	NA	NA	NA	NA	1/2	3.03	<5.2	F-02 [92]	0/1	ND	ND	NA
bis(2-Ethylhexyl)phthalate	NA	NA	NA	NA	2/2	4.5 JB	5.4 JB	F-01 [92]	0/1	ND	ND	NA
Fluorene	NA	NA	NA	NA	1/2	3.01	<5.2	F-02 [92]	0/1	ND	ND	NA
Phenanthrene	NA	NA	NA	NA	2/2	2.575 J	4.6 J	F-01 [92]	0/1	ND	ND	NA
SW9030 - Sulfides (mg/kg)												
Sulfide	NA	NA	NA	NA	2/2	1450	1800	F-01 [92]	1/1	60 @	60 @	F-01 [92]
SW9060 Total Organic Carbon (mg/kg)												
Total organic carbon	NA	NA	NA	NA	NA	NA	NA	NA	1/1	1600	1600 @	F-01 [92]

Hits = Frequency of detection (i.e. 1/15 means 1 out of 15 samples reported a detected concentration)
NA = Not applicable, or not analyzed
ND = Not detected
[92] = Year that the sample reporting the maximum value was collected
< = Value reported after < is the reporting limit

Legend for Analytical Flags:
X - Qualitative confirmation of analyte on both columns. Quantification differed by a factor of two or more between columns. Value determined by the first column is reported.
@ - Measured result is less than five times the detection limit
C - Presence and quantitation of the analyte confirmed by second column analysis
D - Secondary dilution required for this analyte
J - Detected below the method detection limit
B - Analyte detected in laboratory blank analysis, no blank subtraction performed
J - Detected below the method detection limit
B - Analyte detected in laboratory blank analysis, no blank subtraction performed
G - Indicates an estimated GC value due to interference.

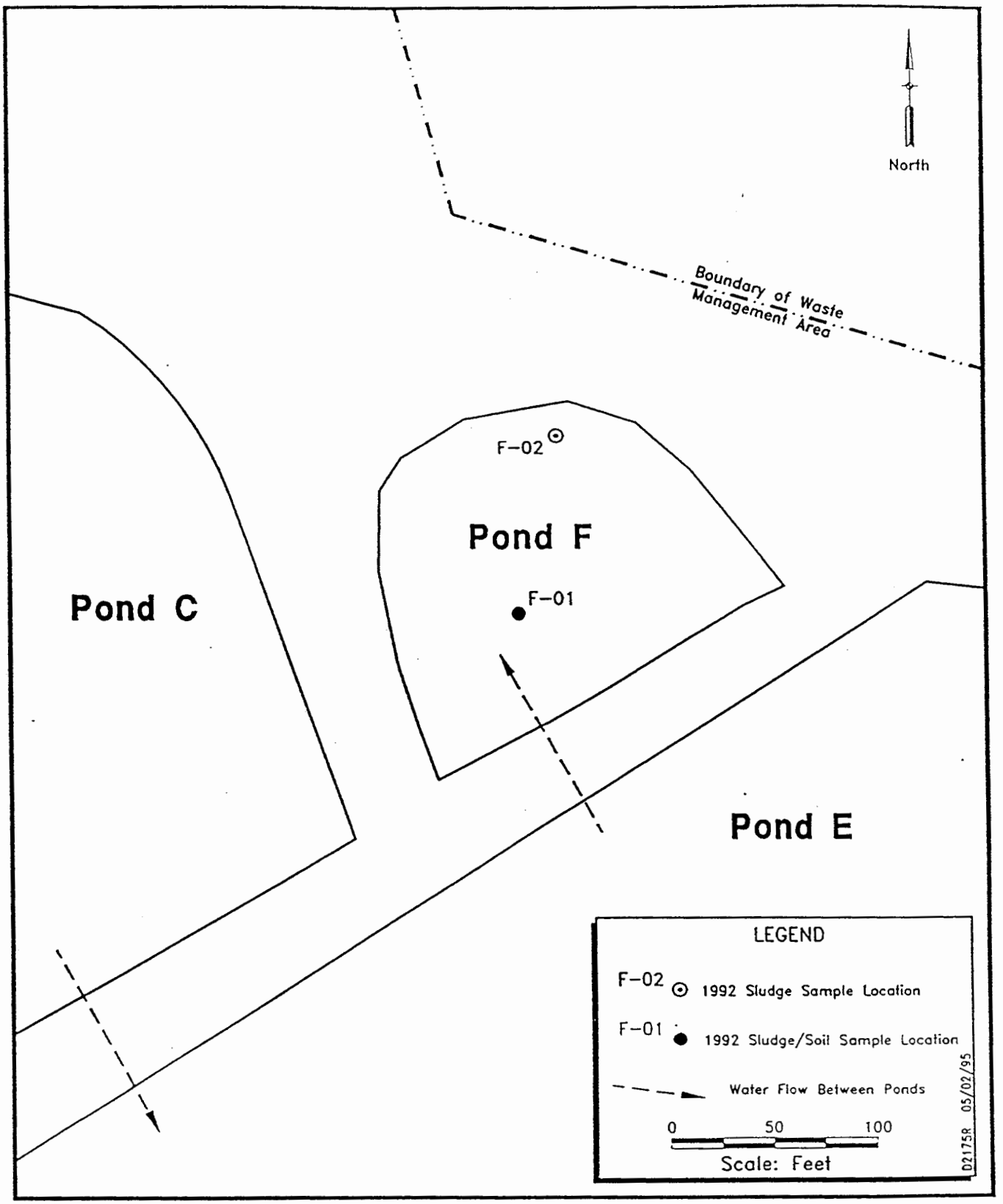

Figure A-9. Pond F Sludge and Soil Sample Locations

Pond G

Table A-8
Analytical Summary For Pond G

Analyte	Surface Water				Sludge				Soils			
	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location
E130.2 - Hardness (mg/L)												
Hardness, as CaC03	1/1	2000	2000	G-01 [93]	NA	NA	NA	NA	NA	NA	NA	NA
E160.1 - Total Dissolved Solids (mg/L)												
Total dissolved solids	1/1	4600	4600	G-01 [93]	NA	NA	NA	NA	NA	NA	NA	NA
E239.1 - Organic Lead (mg/L)												
Lead (organic)[a]	4/14	0.14 @	0.31 @	G-1 [90]	NA	NA	NA	NA	NA	NA	NA	NA
MRI-SOP - Kepone (mg/kg)												
Kepone	NA	NA	NA	NA	1/12	<0.07	<0.07	PG-17 [94]	NA	NA	NA	NA
SW6010 - Metals (mg/L or mg/kg)												
Barium	5/5	0.036 @	0.04 @	G-2 [90]	25/25	83	156	PG-18 [94]	8/8	130	180	G-04 [92]
Beryllium	0/5	ND	ND	NA	10/25	<0.63	<1.7	PG-15 [94]	0/8	ND	ND	NA
Boron	5/5	0.33 @	0.36 @	G-2 [90]	0/25	ND	ND	NA	0/8	ND	ND	NA
Calcium	5/5	390	440	G-2 [90]	0/25	ND	ND	NA	0/8	ND	ND	NA
Chromium	0/5	ND	ND	NA	23/25	9.6	21.2	PG-15 [94]	8/8	11 @	16 @	G-05 [92]
Cobalt	0/5	ND	ND	NA	21/25	3.6 @	<6.2	G-06 [92]	2/8	4.5	<5.4	G-03 [92]
Copper	0/5	ND	ND	NA	24/25	16.4	36.8	PG-15 [94]	1/8	9	9.8 @	G-05 [92]
Magnesium	5/5	220	240	G-2 [90]	0/25	ND	ND	NA	0/8	ND	ND	NA
Manganese	5/5	0.064	0.072	G-4 [90]	0/25	ND	ND	NA	0/8	ND	ND	NA
Nickel	0/5	ND	ND	NA	20/25	8 J	<15.8	PG-19 [94]	3/8	<9.15	<11	G-03 [92]
Potassium	5/5	14	17	G-2 [90]	0/25	ND	ND	NA	0/8	ND	ND	NA
Silicon	5/5	15	16	G-2 [90]	0/25	ND	ND	NA	0/8	ND	ND	NA
Silver	0/5	ND	ND	NA	11/25	<3	6.6	PG-12 [94]	0/8	ND	ND	NA
Sodium	5/5	660	740	G-2 [90]	0/25	ND	ND	NA	0/8	ND	ND	NA
Vanadium	3/5	0.0033 @	0.0047 @	G-4 [90]	25/25	19.6	38.3	PG-18 [94]	8/8	21 @	29 @	G-04 [92]
Zinc	5/5	0.0063 @	0.014 @	G-4 [90]	25/25	39.7	68.4	PG-09 [94]	8/8	29 @	44	G-04 [92]
SW7060 - Arsenic (mg/L or mg/kg)												
Arsenic	3/5	0.0055 @	0.0072 @	G-1 [90]	25/25	2.4 J	5.2 J	PG-08 [94]	8/8	1.65 @	3.1 @	G-04 [92]

Table A-8
(Continued)

Analyte	Surface Water				Sludge				Soils			
	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location
SW7421 - Lead (mg/L or mg/kg)												
Lead	5/14	<0.01	<0.02	12G [94]	25/25	15	38	G-04 [92]	8/8	4.65	120	G-04 [92]
SW7470 - Mercury (mg/L)												
Mercury	5/6	0.0002 @	0.0002 @	G-1 [90]	NA	NA	NA	NA	NA	NA	NA	NA
SW7471 - Mercury (mg/kg)												
Mercury	NA	NA	NA	NA	3/25	<0.19	<0.84	PG-15 [94]	0/8	ND	ND	NA
SW7740 - Selenium (mg/L or mg/kg)												
Selenium	0/6	ND	ND	NA	18/25	1.2 J	<3.6	PG-14 [94]	0/8	ND	ND	NA
SW8080 - Organochlorine Pesticides and PCBs (µg/L or µg/kg)												
alpha-BHC	2/6	<0.5	<0.5	G-1 [90]	4/25	<6.4	79 C@	G-03 [92]	3/8	<1.6	3.3 X@	G-02 [92]
beta-BHC	1/6	<1.5	<1.5	G-1 [90]	0/25	ND	ND	NA	4/8	<1.6	11 XB	G-05 [92]
delta-BHC	0/6	ND	ND	NA	2/25	<6.2	<70	G-06 [92]	0/8	ND	ND	NA
gamma-BHC	1/6	<1.5	<1.5	G-1 [90]	2/25	<6.4	<70	G-06 [92]	3/8	<1.6	3.1 X@	G-02 [92]
Chlordane	0/5	ND	ND	NA	3/19	<28	<320	PG-03 [94]	0/8	ND	ND	NA
alpha-Chlordane	0/1	ND	ND	NA	3/6	<39	110 X@	G-02 [92]	0/8	ND	ND	NA
gamma-Chlordane	0/1	ND	ND	NA	3/6	<39	310 X	G-02 [92]	0/8	ND	ND	NA
4,4'-DDD	0/6	ND	ND	NA	22/25	24 V	3100 C	G-02 [92]	4/8	2.7	7.5 C	G-01 [92]
4,4'-DDE	0/6	ND	ND	NA	19/25	34	450 X	G-02 [92]	2/8	<1.55	3.1 X@	G-04 [92]
4,4'-DDT	0/6	ND	ND	NA	3/25	14 V	<140	G-06 [92]	0/8	ND	ND	NA
Dieldrin	0/6	ND	ND	NA	1/25	<13	<70	G-06 [92]	0/8	ND	ND	NA
Endosulfan II	1/6	0.0009 J	0.0009 J	G-01 [93]	0/25	ND	ND	NA	0/8	ND	ND	NA
Endosulfan Sulfate	0/6	ND	ND	NA	0/25	ND	ND	NA	8/8	1.1	2.1	G-02 [92]
Heptachlor	0/6	ND	ND	NA	0/25	ND	ND	NA	1/8	<1.5	3.3 X@	G-04 [92]
Heptachlor epoxide[b]	0/6	ND	ND	NA	4/25	<6.4	<70	G-06 [92]	0/8	ND	ND	NA
Isodrin	0/6	ND	ND	NA	0/25	ND	ND	NA	1/8	<1.5	4.7 X@	G-05 [92]
Kepone (Mirex)	0/6	ND	ND	NA	1/6	<34.5	<70	G-06 [92]	0/8	ND	ND	NA
SW8240 - Volatile Organic Compounds (µg/kg)												
Acetone	NA	NA	NA	NA	1/6	<6950	<14000	G-06 [92]	4/8	135	<160	G-05 [92]

Table A-8
(Continued)

Analyte	Surface Water				Sludge				Soils			
	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location	Hits	Median	Maximum	Location
Carbon disulfide	NA	NA	NA	NA	1/6	<345	<700	G-06 [92]	4/8	<7.6	14 @	G-02 [92]
Methylene chloride	NA	NA	NA	NA	0/6	ND	ND	NA	6/8	25.5 @	37 @	G-02 [92]
Toluene	NA	NA	NA	NA	0/6	ND	ND	NA	5/8	4.3 J	<7.7	G-02 [92]
SW8270 - Semivolatile Organic Compounds (mg/L or mg/kg)												
Acetophenone	0/5	ND	ND	NA	1/6	<3.05	<6.9	G-06 [92]	0/8	ND	ND	NA
Butylbenzylphthalate	0/5	ND	ND	NA	0/6	ND	ND	NA	1/8	<1.45	<1.6	G-05 [92]
Cyclohexenone	0/5	ND	ND	NA	0/6	ND	ND	NA	1/8	1.2	1.2	G-05 [92]
Di-n-octylphthalate	0/5	ND	ND	NA	0/6	ND	ND	NA	1/8	<1.45	<1.6	G-05 [92]
bis(2-Ethylhexyl)phthalate	5/5	0.006 JB	0.01 JB	G-5 [90]	6/6	1.5 J	3.9 @	G-04 [92]	5/8	<1.45	3.6 @	G-03 [92]
SW9012 - Total Cyanide (mg/kg)												
Cyanide	NA	NA	NA	NA	2/6	<0.86	5.6 @	G-06 [92]	3/8	<0.32	0.61 @	G-04 [92]
SW9030 - Sulfides (mg/kg)												
Sulfide	NA	NA	NA	NA	5/6	660	2000	G-04 [92]	7/8	47.5 @	100 @	G-04 [92]
SW9060 - Total Organic Carbon (µg/kg)												
Total organic carbon	NA	NA	NA	NA	NA	NA	NA	NA	2/2	4800 @	4900 @	G-05 [92]

[a]Organic lead data results for the 1990 Investigation were questionable data. The organic lead concentrations detected in surface water were greater than total lead concentrations detected. Additional sampling was conducted in the 1994 Investigation using an analytical method specific for organic lead and it was not detected. Therefore, organic lead is not present in the surface water in the sewage lagoon system.

[b] Heptachlor epoxide data was questionable since it was only detected on one of two columns using a GC methodology. Therefore, this constituent was resampled in the 1994 and any sample that was detected on one column only was reanalyzed using a GC/MS methodology to determine if heptachlor epoxide was present. In all cases, no heptachlor epoxide was detected using the GC/MS methodology. Holloman AFB has verified that no heptachlor epoxide is present.

Hits = Frequency of detection (i.e. 1/15 means 1 out of 15 samples reported a detected concentration)
NA = Not applicable, or not analyzed
ND = Not detected
[90] = Year that the sample reporting the maximum value was collected
< = Value reported after < is the reporting limit

Legend for Analytical Flags varies with each year of sampling as shown below.

1990 Sampling Event

B - Parameter was also detected in the blank sample; result is uncorrected
C - Confirmed on second column or by GC/MS
G - Indicates an estimated GC value due to interference

Table A-8
(Continued)

h - Sample analyzed 4 days past allowable holding time
J - Result is less than the method specified detection limit. These results should be considered approximate.
@ - Result is less than five times the method detection limit. Studies have shown that the uncertainty of the analysis will increase exponentially as the MDL is approached. These results should be considered approximate
X - Not confirmed on second column

1992 and 1993 Sampling Events

X - Qualitative confirmation of analyte on both columns. Quantification differed by a factor of two or more between columns. Value determined by the first column is reported.
@ - Measured result is less than five times the detection limit
C - Presence and quantitation of the analyte confirmed by second column analysis
D - Secondary dilution required for this analyte
J - Detected below the method detection limit
B - Analyte detected in laboratory blank analysis, no blank subtraction performed
G - Indicates an estimated GC value due to interference.

1994 Sampling Event

T - Primary column concentration is the preferred result
V - Second column concentration is the preferred result
J - Result is less than the reporting limit

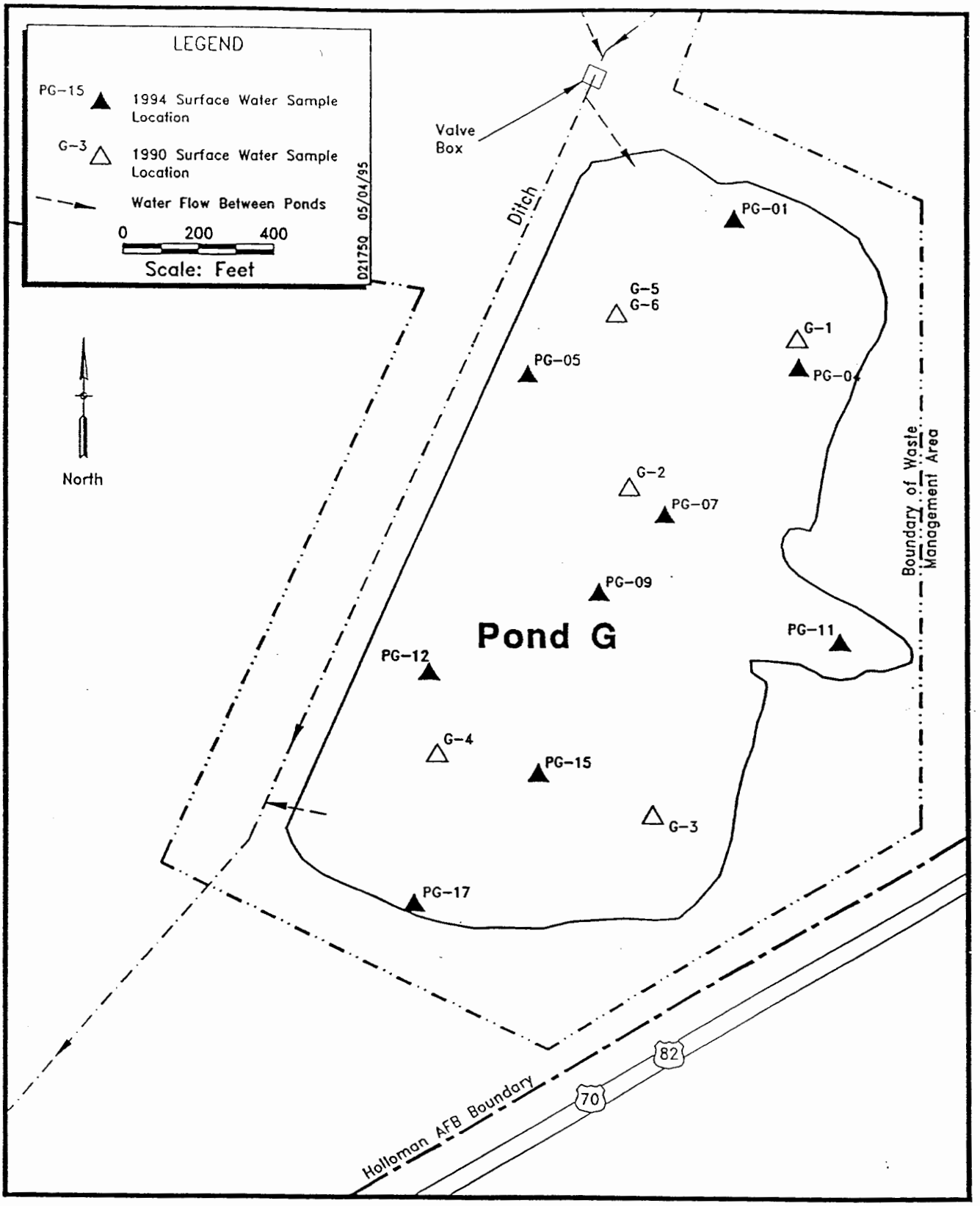

Figure A-10. Pond G Surface Water Sample Locations

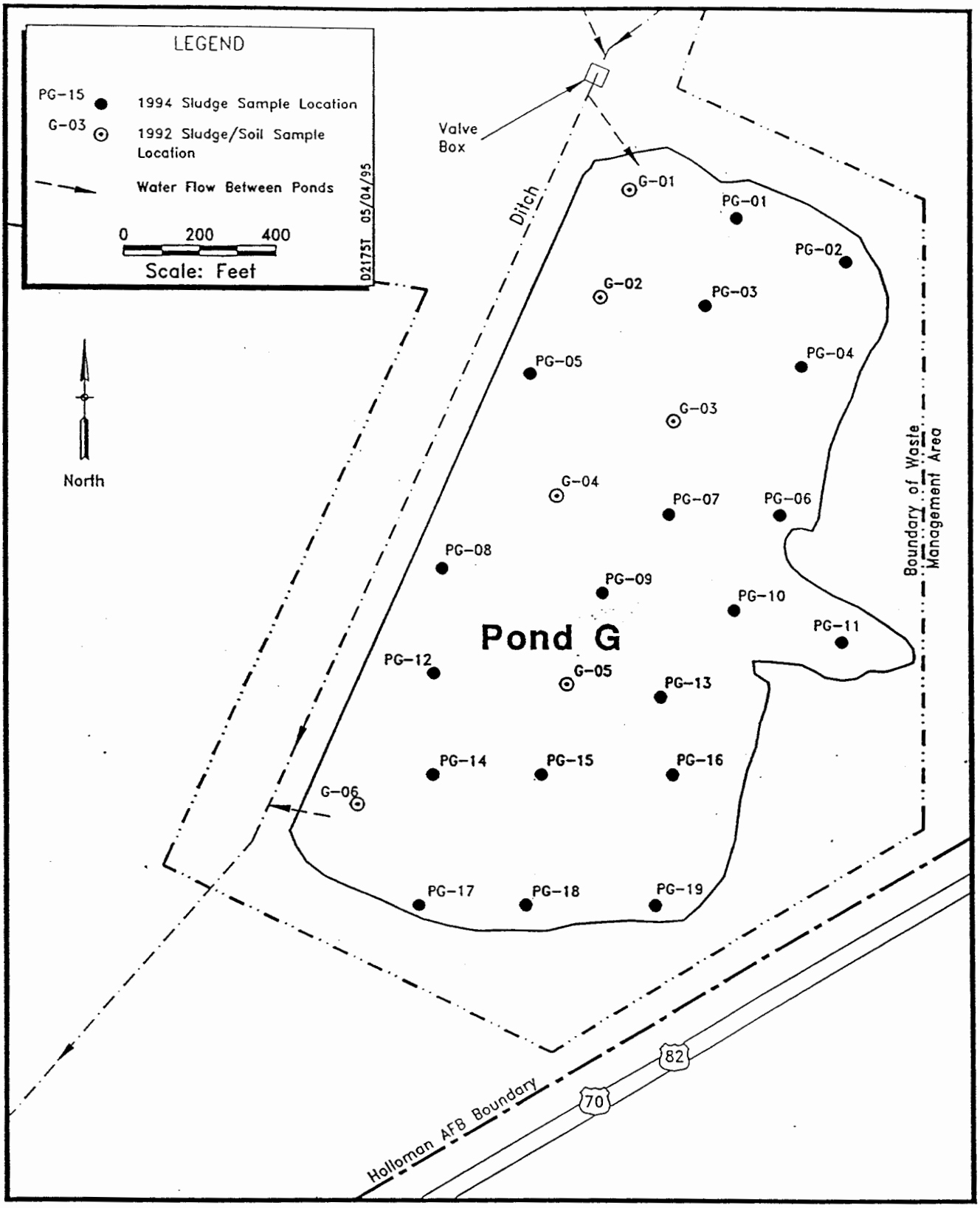

Figure A-11. Pond G Sludge and Soil Sample Locations

Groundwater

Table A-9
Analytical Summary For Groundwater Through 1993

Analyte	Groundwater			
	Hits	Median	Maximum	Location
E130.2 - Hardness (mg/L)				
Hardness, as CaC03	13/13	12000	20000	MWS-05 [93]
E160.1 - Total Dissolved Solids (mg/L)				
Total dissolved solids	13/13	35000	55000	MWS-05 [93]
SW6010 - Metals (mg/L)				
Antimony	4/13	<1.0	<1.0	MW-17 [93]
Barium	13/13	0.042 @	0.58	MW-16 [93]
Beryllium	8/13	0.00035 @	0.0036 @	MW-16 [93]
Cadmium	12/13	0.011 @	0.019 @	MW-17 [93]
Chromium	6/13	<0.01	0.043 @	MW-16 [93]
Cobalt	5/13	<0.01	0.04 @	MW-16 [93]
Copper	2/13	<0.02	<0.02	MW-16 [93]
Nickel	4/13	<0.02	<0.02	MW-16 [93]
Thallium	12/13	0.26 @	0.47 @	MW-11 [93]
Tin	9/13	0.021 @	0.73 @	MW-15 [93]
Vanadium	12/13	0.014 @	0.091 @	MW-16 [93]
Zinc	12/13	0.011 @	0.16	MW-16 [93]
SW7060 - Arsenic (mg/L)				
Arsenic	5/13	<0.016	0.032 @	MW-16 [93]
SW7421 - Lead (mg/L)				
Lead	2/13	<0.006	0.014 @	MW-16 [93]
SW7470 - Mercury (mg/L)				
Mercury	8/13	0.00001	0.00003	MW-18 [93]
SW7740 - Selenium (mg/L)				
Selenium	6/13	<0.01	0.044 @	MWD-05 [93]
SW7841 - Thallium (mg/L)				
Thallium	5/13	<0.01	<0.02	MWD-04 [93]
SW8080 - Organochlorine Pesticides and PCBs (µg/L)				
Aldrin	7/43	<0.0095	0.097 C	MW-03 [92]
alpha-BHC	19/43	<0.00975	0.1 X	MW-04 [93]
beta-BHC	17/43	<0.0096	0.03 X@	MW-13 [93]
delta-BHC	13/43	<0.0096	0.049 G	MW-16 [93]
gamma-BHC	17/43	<0.0096	0.15 G	MW-05 [93]
alpha-Chlordane	16/43	<0.0095	0.062 X	MW-02 [93]
gamma-Chlordane	24/43	<0.0097	2.7 G	MW-05 [93]
4,4'-DDD	8/43	<0.0096	0.047 @	MW-04 [93]
4,4'-DDE	8/43	<0.0095	0.026 X@	MW-05 [93]
4,4'-DDT	12/43	<0.019	0.24 C	MW-03 [92]
Dieldrin	13/43	<0.0096	0.25 C	MW-03 [92]
Endosulfan I	6/43	<0.0095	0.054 X	MW-05 [93]

Table A-9
(Continued)

Analyte	Groundwater			
	Hits	Median	Maximum	Location
Endosulfan II	11/43	<0.029	0.067 @	MW-03 [93]
Endosulfan Sulfate	24/43	0.033 JX	<0.05	MW-08 [92]
Endrin	23/43	<0.0097	0.28 C	MW-03 [92]
Endrin Aldehyde	16/43	<0.019	0.077 GB@	MW-03 [93]
Heptachlor	24/43	<0.0095	0.082 C	MW-03 [92]
Heptachlor epoxide	24/43	<0.0095	1.2 G	MW-08 [93]
Isodrin	12/43	<0.0096	0.068 X	MW-05 [93]
Kepone (Mirex)	3/43	<0.0095	0.99 X	MW-18 [93]
Methoxychlor	3/43	<0.048	0.21 G@	MW-03 [93]
SW8270 - Semivolatile Organic Compounds (mg/L)				
Cyclohexene	3/13	<0.0058	0.012	MW-13 [93]
bis(2-Ethylhexyl)phthalate	5/13	<0.0095	<0.0097	MW-14 [93]
SW9012 - Total Cyanide (mg/L)				
Cyanide	15/15	0.0043 @	0.0097 @	MW-11 [93]
SW9030 - Sulfides (mg/L)				
Sulfide	6/13	<1.0	<1.0	MWS-05 [93]

Hits = Frequency of detection (i.e. 1/15 means 1 out of 15 samples reported a detected concentration)
NA = Not applicable, or not analyzed
ND = Not detected
[92] = Year that the sample reporting the maximum value was collected
< = Value reported after < is the reporting limit

Legend for Analytical Flags:
X - Qualitative confirmation of analyte on both columns. Quantification differed by a factor of two or more between columns. Value determined by the first column is reported.
@ - Measured result is less than five times the detection limit
C - Presence and quantitation of the analyte confirmed by second column analysis
D - Secondary dilution required for this analyte
J - Detected below the method detection limit
B - Analyte detected in laboratory blank analysis, no blank subtraction performed
G - Indicates an estimated GC value due to interference.

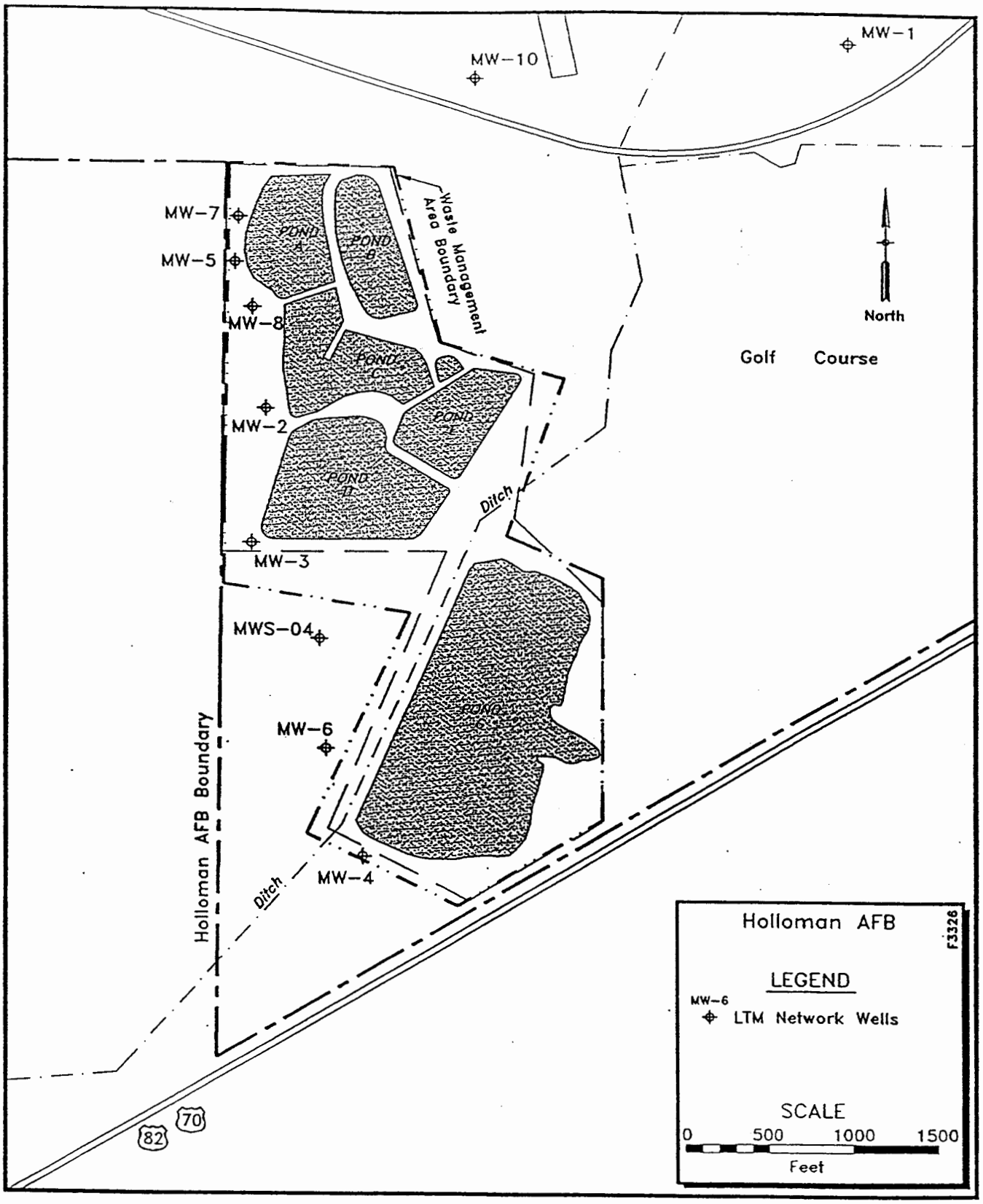

Figure A-12. Groundwater Sample Locations

Table A-10
Analytical Summary for Groundwater
1995 Long-term Groundwater Monitoring Program

Analyte	Hits	Median	Maximum	Location
Organochlorine Pesticides - SW8081 (μg/L)				
Aldrin	0/10	NA	ND (0.0035)	NA
Chlordane	0/10	NA	ND (0.046)	NA
4,4'-DDD	3/10	ND (0.0054)	0.0229	MW-04 [95]
4,4'-DDE	1/10	ND (0.0049)	0.119 P	MW-05 [95]
4,4'-DDT	0/10	NA	ND (0.0066)	NA
Dieldrin	5/10	ND (0.0048)	0.071 P	MW-05 [95]
Endosulfan I	0/10	NA	ND (0.003)	NA
Endosulfan II	2/10	ND (0.0067)	0.0254 P	MW-07 [95]
Endosulfan Sulfate	1/10	ND (0.0162)	0.0185 B	MW-01 [95] Upgradient Well
Endrin	6/10	<DL (0.0128)	0.0199 BP	MW-03 [95]
Endrin Aldehyde	0/10	NA	ND (0.0108)	NA
Heptachlor epoxide	4/10	ND (0.0092)	0.0647 P	MW-05 [95]
Isodrin	6/10	0.0108	0.0671 P	MW-08 [95]
Methoxychlor	0/10	NA	ND (0.0431)	NA
Toxaphene	0/10	NA	ND (0.0903)	NA
alpha-BHC	1/10	ND (0.0022)	0.0115	MW-03 [95]
beta-BHC	0/10	NA	ND (0.0131)	NA
delta-BHC	5/10	ND (0.0025)	0.249 P	MW-04 [95]
gamma-BHC	0/10	NA	ND (0.0018)	NA
Metals (mg/L)				
Antimony	1/10	<DL (0.0041)	0.0838	MW-06 [95]
Barium	10/10	0.0204	0.0448	MW-01 [95] Upgradient Well
Beryllium	5/10	<DL (0.0002)	0.0009	MW-10 [95] Upgradient Well
Cadmium	0/10	NA	<DL (0.0046)	NA
Chromium	5/10	<DL (0.0005)	0.0189	MW-03 [95]
Cobalt	7/10	0.0046	0.0234	MW-06 [95]

Table A-10
(Continued)

Analyte	Hits	Median	Maximum	Location
Copper	0/10	NA	<DL (0.135)	NA
Nickel	9/10	0.0122	<DL (0.058)	MW-06 [95]
Silver	3/10	<DL (0.011)	<DL (0.0222)	MW-06 [95]
Tin	5/10	0.0021 J	0.0045	MW-04 [95]
Vanadium	10/10	0.0183	0.105	MW-01 [95] Upgradient Well
Zinc	0/10	NA	<DL (0.26)	NA
Arsenic	5/10	0.0197	0.0816	MW-02 [95]
Lead	10/10	0.0059 S	0.0204 S	MWS-04 [95]
Mercury	0/10	NA	<DL (28E-06)	NA
Selenium	9/10	0.029 S	0.0721 S	MW-01 [95] Upgradient Well
Thallium	4/10	<DL (0.0012)	0.0037 S	MW-05 [95]

P = The analyte concentration was not confirmed. The results from the primary and secondary GC columns differed by greater than a factor of 3.
B = The analyte was detected in the blank within 10 times the concentration reported in the field sample.
S = The analyte concentration was obtained using the Method of Standard Addition.
ND = Not detected.
<DL = Detected below detection limit.

APPENDIX B

October 1994 Field Sampling Plan with Addendum

RCN 670-008-03-11

FIELD SAMPLING PLAN

SEWAGE LAGOONS AND LAKES CLOSURE PROJECT

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Omaha District
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Revision 0, 14 October 1994
Revision 1, 26 October 1994

TABLE OF CONTENTS

Page

1.0 INTRODUCTION 1-1

1.1 Background 1-1
1.2 Risk Assessment Results 1-3
1.3 Scope 1-3
1.4 Purpose of Investigation 1-3

2.0 SLUDGE AND SOIL SAMPLES 2-1

2.1 Sludge and Soil Sample Locations 2-1
2.2 Sample Collection Techniques 2-1
2.3 Sludge and Soil Sample Analyses 2-5

3.0 SURFACE WATER SAMPLES 3-1

3.1 Surface Water Sample Locations 3-1
3.2 Sample Collection Techniques 3-1
3.3 Surface Water Sample Analyses 3-1

4.0 QUALITY/ASSURANCE QUALITY CONTROL SAMPLES 4-1

5.0 GENERAL INFORMATION AND DEFINITIONS 5-1

5.1 Decontamination Procedures for Sampling Equipment 5-1
5.2 Field Documentation 5-1
5.3 Sample Containers, preservation, and Holding Times 5-1
5.4 List of Equipment, Containers, and Supplies 5-1

6.0 SAMPLE CHAIN OF CUSTODY, PACKAGING, AND TRANPORTATION 6-1

6.1 Chain of Custody 6-1
6.2 Sample Identification 6-4
6.3 Correction to Documentation 6-4
6.4 Sample Handling, Packaging, and Shipping 6-4

7.0 MANAGEMENT OF INVESTIGATION DERIVED WASTE 7-1

7.1 Responsibilities 7-1
7.2 Field Materials 7-1
7.3 Waste Streams 7-1
7.4 Waste Minimization 7-1

APPENDIX A Water Depths and Sludge Thicknesses in Sewage Lagoons and Lakes

APPENDIX B Sample Identification Spreadsheet

LIST OF FIGURES

Page

1-1 Location of Sewage Lakes and Lagoons 1-2

2-1 Sample Locations for the Sewage Lagoons 2-3

2-2 Sample Locations for Lakes Holloman and Stinky 2-4

5-1 A-E Daily Quality Control Report 5-2

6-1 Example Sample Label and Custody Seal 6-2

6-2 Sample Chain-of-Custody Record 6-3

6-3 Sample Chain-of-Custody Addendum 6-5

LIST OF TABLES

Page

1-1 Summary of Constituents With Concentrations Above Action Levels, 1992 1-4

2-1 Number of Sludge and Soil Samples for Sewage Lagoons and Lakes 2-2

2-2 Summary of Target Analytes 2-6

3-1 Number of Surface Water Samples for Sewage Lagoons and Lakes 3-2

5-1 Summary of Sampling And Analysis Requirements 5-4

Section 1
INTRODUCTION

This plan was prepared for sampling sludge, soil, and surface water from the sewage lagoons and lakes at Holloman Air Force Base (AFB), New Mexico, in support of the sewage lagoon closure project. This section presents the background and scope for the sampling program.

1.1 Background

The seven aeration/evaporation lagoons are located in the southwestern corner of the Base, as shown in Figure 1-1. Wastewater generally flows in parallel through Ponds A and B. Then, water flows in series from Pond C into Ponds D, E, F, and G. Discharge from Pond G flows through an open ditch to Lake Holloman. Because of seasonal low evaporation, water from Lake Holloman flows into Lake Stinky during the winter months.

Holloman AFB submitted a Post-Closure Care Permit (PCCP) application for the sewage lagoons in June 1991 to allow continued operation of the lagoons for nonhazardous wastewater treatment prior to final closure as hazardous waste management units. The application addressed Ponds A, B, C, D, E, F, and G, and includes a delay-of-closure plan for these surface impoundments. As a condition for review of the PCCP application, the New Mexico Environment Department (NMED) required that a sampling and analysis program be conducted in all impoundments downstream of Ponds A and B, including Lakes Holloman and Stinky. These requirements, contained in a letter dated 22 May 1991, were intended to demonstrate that hazardous constituents are not present in the sludge and underlying soil at levels that would adversely affect human health and the environment.

A preliminary investigation was conducted in October 1991 to determine the water depths and sludge thicknesses in the sewage lagoons and lakes. The work focused on Ponds C, D, E, F, and G, and Lakes Holloman and Stinky. Appendix A includes a summary of the results.

A more thorough investigation of the sewage lagoons and lakes was conducted in 1992 and is documented in the *Site Characterization Report* (Radian, 1992). Samples were collected from the sludge and underlying soil in the sewage lagoons, lakes, and ditch, and were analyzed for Appendix IX constituents.

The primary contaminants in the sludge and soil samples from the sewage lagoons and lakes were metals and organochlorine pesticides. Metals detected in the soil were below background levels and pesticides were significantly below action levels.

Analytical results suggested that the ditch and lakes may be affected by a source of contaminants other than the wastes historically discharged into the wastewater treatment system. Constituents detected in Lake Stinky were not detected in the sewage lagoons, Lake Holloman, or the ditch. Also, concentrations of organochlorine pesticides detected in ditch samples from a location upstream of the sewage lagoons were higher than concentrations of the same pesticides detected in ditch samples from locations downstream of the sewage lagoons.

Analytical results were compared with proposed Resource Conservation and Recovery Act (RCRA) Subpart S risk-based action levels (40 CFR Part 264, Subpart S, Section 264.521 [proposed 27 July 1990, 55 *Federal Register* 30798 et seq.]). A summary of the results above action levels is presented in Table 1-1.

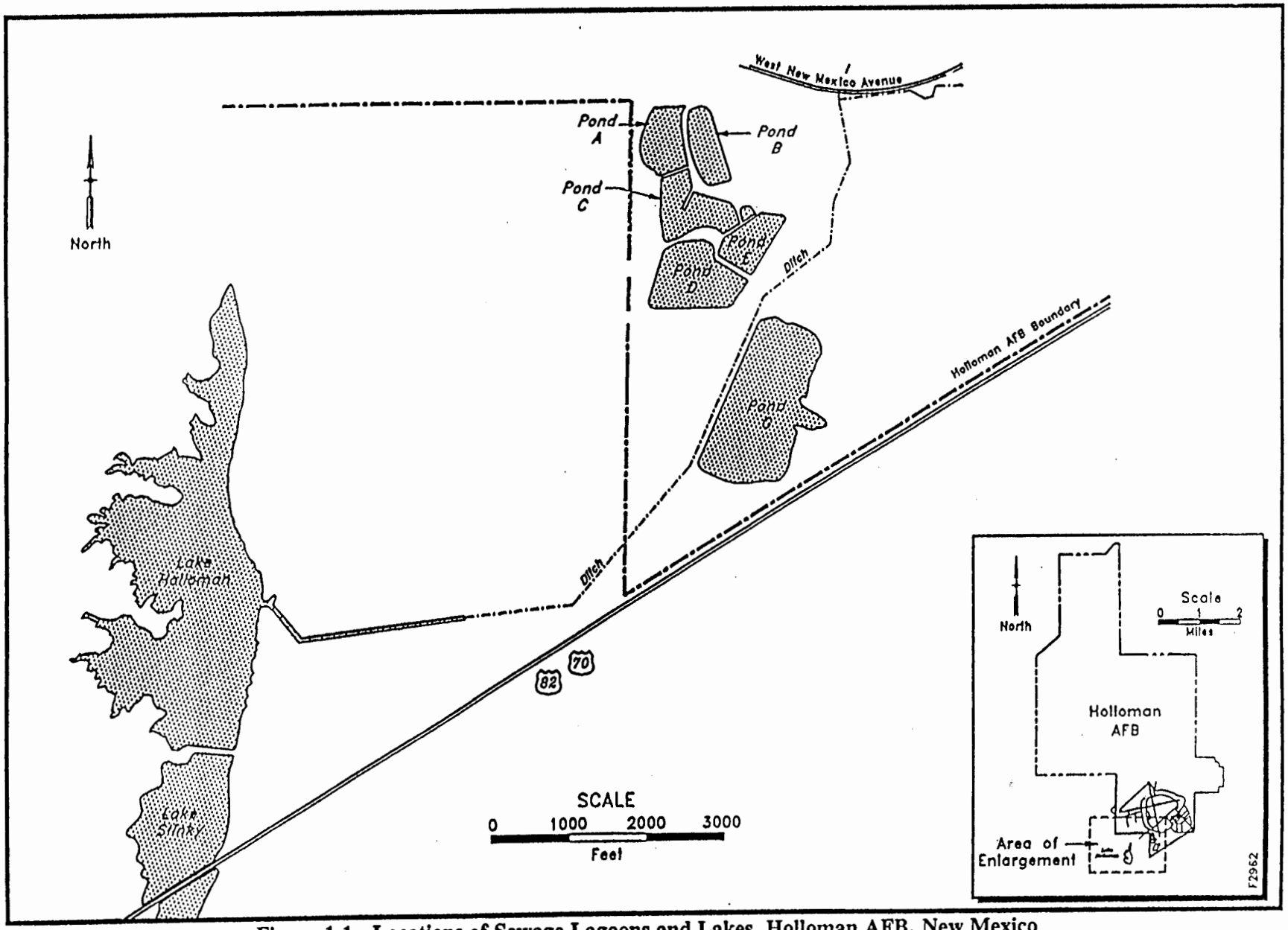


Figure 1-1. Locations of Sewage Lagoons and Lakes, Holloman AFB, New Mexico

Table 1-1
Summary of Constituents With Concentrations Above Action Levels, 1992

Location	Constituent	Sample Interval
Pond C	None	NA
Pond D	None	NA
Pond E	4,4'-DDD	Sludge
Pond F	4,4'-DDD	Sludge
Pond G	Beryllium	Sludge
	4,4'-DDD	Sludge
Lake Holloman	Dieldrin	Sludge
	Isodrin	Sludge and soil (0 to 1 ft bgl)
Lake Stinky	None	NA
Ditch from Pond G to Lake Holloman	Beryllium	Soil (0 to 1 ft bgl)

Note: Several constituents were not detected, and their reporting limits exceed the action levels. Some of these constituents include antimony, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and 2,3,7,8-TCAA.

NA = Not applicable.
bgl = Below ground level.

1.2 Risk Assessment Results

The risk assessment completed for the sewage lagoons and lakes (*Risk Assessment—Sewage Lagoons and Lakes Investigation*, Radian, 1993) suggested the possibility of unacceptable health risks for the ditch connecting Pond G with Lake Holloman based on a single analytical result for heptachlor epoxide. Although the measured result was fairly high, the result was not confirmed by the analytical method (i.e., second column confirmation by gas chromatography [GC] for EPA Method 8080). This suggests that the compound measured may have been an interferant rather than heptachlor epoxide itself. Risk assessments typically include results with some uncertainty to avoid underestimating risk; therefore, the unconfirmed result was included in the risk assessment as recommended by U.S. Environmental Protection Agency (EPA) guidance. This may have resulted in an overestimate of the risk of exposure at the ditch. Holloman AFB has committed to resampling and reanalyzing the soil from the ditch to clarify the previous result.

Possible adverse health effects were also suggested as a result of organolead concentrations in surface water in Pond G and Lake Holloman. The organolead results were up to 100 times higher than total lead results obtained. However, this may primarily reflect measurement variability for the two analytical techniques because all of the lead results are near the detection limits. Total lead was measured using graphite furnace atomic absorption (GFAA) spectroscopy; whereas organolead was measured using flame atomic absorption (FAA) spectroscopy. Detection limits for total lead were substantially lower than for organolead because spectral interferences are minimized in GFAA analysis. As described above, the organolead results were included in the risk assessment, even though there were uncertainties, to ensure that risk would not be underestimated. Holloman AFB has committed to resampling surface water to clarify the significance of the previous lead results.

1.3 Scope

The proposed sampling and analytical program will complement the 1992 sampling results and define more precisely the extent of contamination in Ponds C, D, E, and G, and in Lakes Holloman and Stinky. Sludge samples (surface soil samples for Pond D, Lake Stinky, and the ditch) will be collected from the sewage lagoons and lakes at locations determined through geostatistical analysis of existing data. These sludge and soil samples will be analyzed for organochlorine pesticides and metals. Surface water samples will also be collected in Ponds C, D, E, G, Lake Holloman, and the ditch. The surface water samples will be analyzed for total and organic lead. Because Holloman AFB anticipates remediating the entire area of Ponds A, B, and F, additional sampling is not being conducted to determine extent of contamination for those impoundments.

1.4 Purpose of Investigation

The results will be used to resolve and better define risks associated with each lagoon and lake due to uncertainties found in previous investigations. The results of this investigation will also be used in conjunction with previous investigation results to drive the decisions for closure alternatives and requirements.

Section 2
Sludge and Soil Samples

This section discusses the sludge and soil sampling locations, sample methodology, and sample analyses. At locations where the surface water will also be sampled, the surface water sample will be collected first, before disturbing the sludge or soil. This is to minimize the amount of suspended solids in these samples. Appendix B contains a detailed breakdown of all sampling locations and media, with their respective analyses.

2.1 Soil and Sludge Sample Locations

A total of 98 locations will be sampled for soil and sludge. The total number of samples, including 18 QA/QC samples and six Missouri River Division (MRD) duplicates, is 122. Prior to sampling, the sample locations will be surveyed by Southwest Engineering Inc. The surveyors will mark each sampling point. Underwater locations will be marked with a floating buoy positioned by a leader and anchor. Locations not underwater will be marked with a stake.

Samples for analyses of sludge will be collected from Ponds C, E, G, and Lake Holloman. Samples for analyses of surface soil (0 to 1 ft below ground level [bgl]) will be collected from Pond D, Lake Stinky, and the ditch from Pond G to Lake Holloman, since previous sampling indicated that little to no sludge exists in these areas. No sampling will be conducted in Ponds A, B, and F. Table 2-1 shows the numbers and depths of samples for the sewage lagoons, the lakes, and the ditch. Sample locations are shown in Figures 2-1 and 2-2. Appendix A gives the water and sludge levels in each of the lagoons and lakes as determined in the 1991 investigation.

2.2 Sample Collection Techniques

Sludge samples will be collected from a floating vessel by using a stainless steel sludge sampler (Arts Manufacturing Supply [AMS] or similar) or a PVC syringe. In areas where the sludge is too thin to sample, a stainless steel auger will be used to collect a soil sample from the 0 to 1 foot interval. The AMS sludge sampler takes 3" samples and is equipped with a butterfly valve to prevent sample escape. The PVC syringe utilizes a suction to retrieve and prevent escape of the sample.

The sampling vessel will be a flat bottomed aluminum boat with an open sampling port constructed in the center. The vessel will be equipped with outriggers to enhance stability during sampling. The vessel will be propelled with an electric trolling motor if this does not disturb the sludge and water samples. If necessary, the vessel will be manually propelled with oars.

The sampling vessel will be positioned over the sample location marker buoys. Sludge thickness and water depth will be measured using a sounding device (optimal method to be determined in the field). The sampling device will be lowered through the sample port to the top of the sludge or soil surface, and the sample withdrawn and brought on board to be composited in a stainless steel bowl. There, the entire sample interval will be homogenized and placed in precleaned bottles. At some locations, more than one sludge core may be collected to provide sufficient volume for all required analyses.

Considerable preparation and preplanning is necessary to minimize the time the field crew

Table 2-1
Number of Sludge and Soil Samples for Sewage Lagoons and Lakes

Location	Surface Area (Acres)	Number of Additional Soil and Sludge Samples	Matrix
Pond C	12	13	Sludge
Pond D	18	10	Soil (0 to 1 ft bgl)
Pond E	8	16	Sludge
Pond G	40	19	Sludge
Lake Holloman	166	25	Sludge
Lake Stinky	38	11	Soil (0 to 1 ft bgl)
Ditch from Pond G to Lake Holloman	NA	4	Soil (0 to 1 ft bgl)
Total	282	98	- -

Note: Sludge samples will be collected from the entire depth of the sludge.

NA = Not available.
bgl = Below ground level.

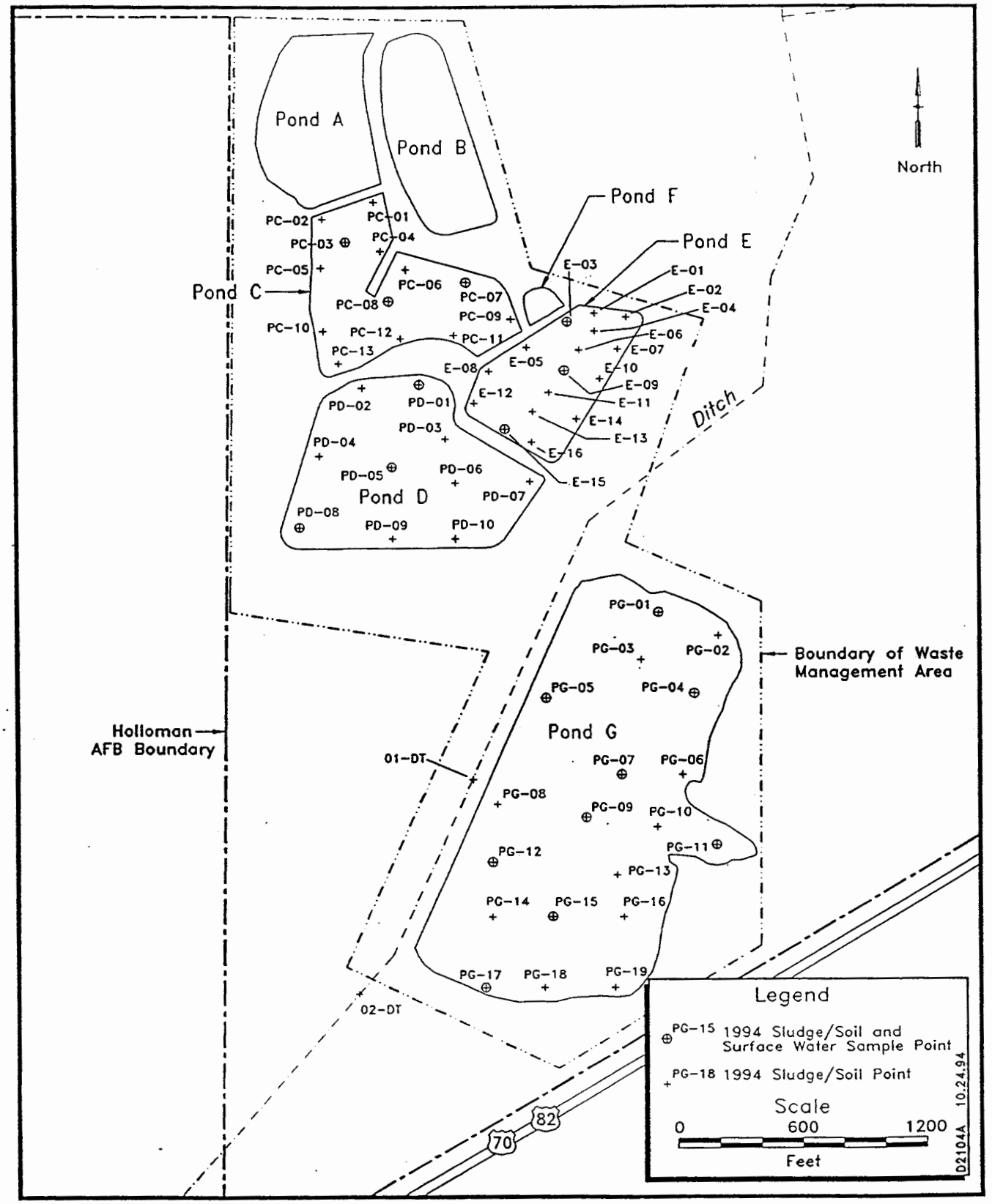


Figure 2-1. Sample Locations for the Sewage Lagoons

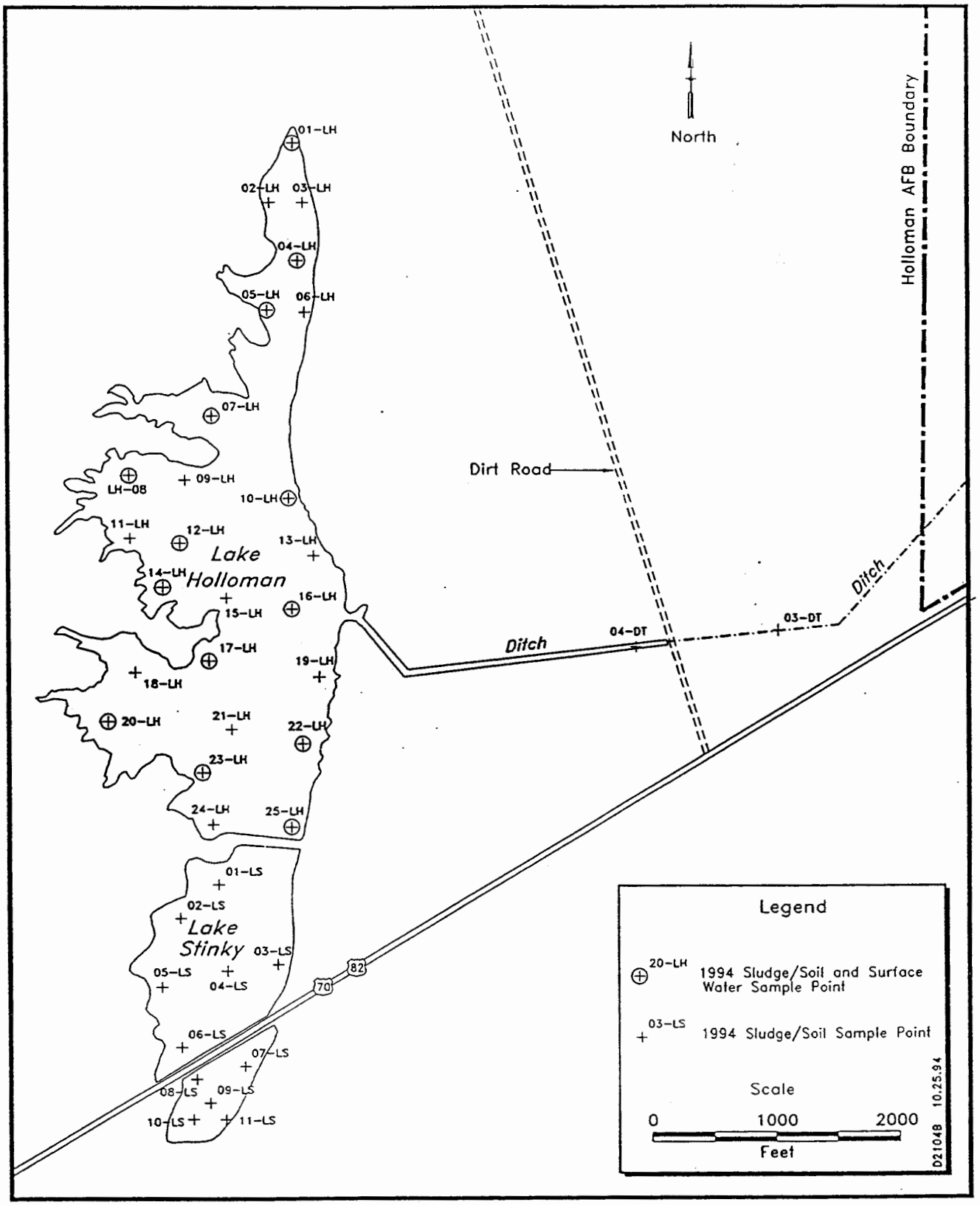


Figure 2-2. Sample Locations for Lakes Holloman and Stinky

spends in the sampling vessel. Such preparation includes prelabeling of sample containers and the use of a checklist to ensure that all needed equipment is on board the sampling vessel. The field crew must wear personal floatation devices (PFDs) whenever they are in the floating vessel as defined in the Site Safety and Health Plan.

2.3 Sludge and Soil Sample Analyses

Sludge and soil samples will be analyzed for organochlorine pesticides and metallic constituents (40 CFR, Part 264). EPA SW846 methods will be used for these constituents. Samples for analysis by method SW8270 (semivolatiles) will also be collected and extracted, but will only be analyzed to confirm any positive detections of isodrin or heptachlor epoxide in the SW8080 analyses. In addition, 37 soil and sludge samples from selected locations in Ponds C, G and Lake Holloman will be analyzed for kepone, since kepone was detected in these impoundments. Table 2-2 lists the target analytes for this sampling effort.

Sample analyses by methods SW6010, SW7060, SW7421, SW7471, SW7740, SW8080, and SW8270 will be performed by Quanterra Inc. The thallium concentration in the soil and sludge will be analzed by SW6010-trace method. These analyses will also be performed by Quanterra Inc. The kepone analyses will be performed by Midwest Research Institute (MRI). Additional information on these laboratories is located in Section 6.4. The analytical procedures and the Data Quality Objectives are described in the Sewage Lagoons and Lakes Closure Project *Quality Assurance Project Plan (QAPP)*, October, 1994.

Table 2-2
Summary of Target Analytes

Organochlorine Pesticides (Method 8080 [a])		Metals (Method 6010 [a])	
Aldrin		Antimony	
alpha-BHC		Arsenic	(SW7060)
beta-BHC		Barium	
delta-BHC		Beryllium	
gamma-BHC		Cadmium	
alpha-Chlordane		Chromium	
gamma-Chlordane		Cobalt	
4,4'-DDD		Copper	
4,4'-DDE		Lead	(SW7421)
4,4'-DDT		Mercury	(SW7471)
Dieldrin		Nickel	
Endosulfan I		Organolead	(Quanterra SOP)
Endosulfan II		Selenium	(SW7740)
Endosulfan sulfate		Silver	
Endrin		Thallium	(SW6010-Trace)
Endrin aldehyde		Tin	
Heptachlor		Vanadium	
Heptachlor epoxide	(SW8080, 8270 if needed)	Zinc	
Isodrin	(SW8080, 8270 if needed)		
Kepone	(MRI SOP)		
Methoxychlor			
Toxaphene			

[a] Unless otherwise noted.

Section 3
SURFACE WATER SAMPLES

This section discusses the locations of surface water samples to be taken and the sampling procedure to be used. Appendix B contains a detailed breakdown of all sampling locations and media, with their respective analyses.

3.1 Surface Water Sample Locations

Surface water samples will be collected from Ponds C, D, E, and G, Lake Holloman and the ditch. Table 3-1 gives the number of samples to be collected from each. The surface water samples will be collected from locations throughout the lagoons as shown in Figures 2-1 and 2-2. Before the sampling program begins, these locations will be surveyed and marked with a floating buoy positioned by a leader and anchor.

The surface water samples will be collected at the same location as the soil and sludge samples. Surface water samples will be collected *prior* to collecting sludge and soil samples to reduce the risk of agitated materials (soil and sludge) being collected in the water samples. The water sample will be collected prior to setting the vessel anchor to reduce/prevent agitation of the soil and sludge prior to collecting the water sample.

3.2 Surface Water Sample Collection Techniques

Surface water samples will be collected by a small Teflon® bailer. Since the bailer size is smaller than the required total sample volume, each sample will be composited from approximately four bailer samples using a clean, four-liter glass container. The sample will then be split into aliquots and placed in precleaned bottles for analyses. All sample handling activities will be accomplished with minimum contact using decontaminated gloves.

3.3 Surface Water Analyses

Surface water samples will be analyzed for organolead and total lead. Quanterra Inc. will perform both of these analyses.

Table 3-1
Number of Surface Water Samples for Sewage Lagoons and Lakes

Location	Surface Area (Acres)	Number of Surface Water Sample Locations
Pond C	12	3
Pond D	18	3
Pond E	8	3
Pond G	40	9
Lake Holloman	166	14
Lake Stinky	38	0
Ditch from Pond G to Lake Holloman	NA	3
Total	282	35

Note: Sludge samples will be collected from the entire depth of the sludge.

NA = Not available.
bgl = Below ground level.

Section 4
QUALITY CONTROL SAMPLES

A field quality assurance/quality control (QA/QC) program will be used to ensure that data quality objectives are met. Sample collection error will be controlled through the use of standard sample collection methods and field logbooks. Natural matrix errors will be estimated by standard QA/QC methods such as matrix spikes. Field duplicates will be collected to determine field sampling precision and accuracy. The following paragraphs discuss the field QA/QC samples for analytical soil samples, and their collection frequency and procedures.

QC Split Samples—QA and QC split samples (duplicates) will be collected for all analyses at a rate of 5 percent. The soil will be homogenized and divided equally among all containers for both normal and duplicate samples.

Matrix Spike and Matrix Spike Duplicate (MS/MSD)—QC MS/MSD samples will be collected at a rate of 5 percent for each analysis. Additional volume may be necessary for sludge samples.

QA/MRD Duplicate Samples—QA Duplicate samples to be analyzed by the USACE MRD laboratory will be collected for all analyses at the rate of 5 percent for each analyte.

Appendix B contains a detailed breakdown of all QA/QC samples by location and media. No equipment blanks will be collected for the project.

Section 5
GENERAL INFORMATION AND DEFINITIONS

This section discusses miscellaneous practical information that the field team will need to carry out this investigation.

5.1 Decontamination Procedures for Sampling Equipment

To ensure that the sampling equipment and the samples are not contaminated or cross-contaminated by materials and equipment used in the course of the investigation, the following procedures will be employed to decontaminate all sampling equipment between and before use:

- Wash with ALCONOX® detergent;
- Rinse with potable water;
- Rinse with reagent grade isopropanol;
- Triple rinse with deionized water; and
- Allow to air dry for 10 to 15 minutes.

5.2 Field Documentation

A field log book will be kept by the Field Team Leader (FTL). The field log book will serve primarily as a daily log of activities carried out during the investigation. Other observations may be included as the situation dictates for a thorough record to reconstruct the events concerning all field activities. The field log book is a bound book with sequentially numbered pages and with a unique document control number.

Field Activities will be photographed by the FTL with 35mm color slides. At a minimum, photos of each site will be taken before and after the field investigation.

The FTL will also complete A-E Daily Quality Control Reports (A-E DQCR), shown in Figure 5-1, at the end of each day. These reports will be sent to the USACE-PM and the BEC on a weekly basis.

5.3 Sample Containers, Preservation, and Holding Times

The sample containers, preservation measures, and holding times for the sludge, soil, and surface water analyses to be conducted are summarized in Table 5-1. All containers used for chemical analyses will be pre-cleaned by the supplier, I-Chem or Eagle-Picher, in accordance with EPA protocol. The sample label will be affixed to the bottle with the field sample number and the other required information in indelible ink (see Section 6.2). All soil, sludge, and surface water samples collected for organic chemical analysis will be chilled to approximately 4°C with regular ice in a plastic bag during collection and shipment. The samples will be stored upright in a durable ice chest. Sufficient packing material (e.g., vermiculite) will be used to separate the bottles, filling any voids.

5.4 List of Equipment, Containers, and Supplies

Implementation of the field activities will require specific equipment, containers, and supplies for the collection of field samples as summarized below.

Sampling Equipment

- Stainless steel hand auger;
- AMS sludge sampler;
- PVC sludge syringe;
- Teflon® bailers;
- Stainless steel compositing bowls and sampling equipment;
- Aluminum flat bottom boat with outriggers.

A-E DAILY QUALITY CONTROL REPORT

Date_____

Day	S	M	T	W	TH	F	S

COE Project Manager_____
Project_____
Job No._____
Contract No._____

SUB-CONTRACTORS ON SITE:
EQUIPMENT ON SITE:
WORK PERFORMED (INCLUDING SAMPLING):

Figure 5-1. A-E Daily Quality Control Report

Project_____ Report No._____

Job No._____ Date_____

QUALITY CONTROL ACTIVITIES (INCLUDING FIELD CALIBRATIONS):
HEALTH AND SAFETY LEVELS AND ACTIVITIES:
PROBLEMS ENCOUNTERED/CORRECTIVE ACTION TAKEN:
SPECIAL NOTES:
TOMORROW'S EXPECTATIONS:

BY_____ TITLE_____

Figure 5-1. (Continued)

Table 5-1
Summary of Sample Containers, Preservative, and Holding Time Requirements

Reference Method	Parameter	Media	Container Type, No. and Volume [a]	Preservation and Storage Requirements	Maximum Holding Time (Preparation)	Maximum Holding Time (Analysis)
SW-846:6010	Metals	Soil/Sludge	Wide mouth glass jar 250ml (1)	Cool at 4°C	6 Months	6 Months
SW-846:8080	Organochlorine Pesticides	Soil/Sludge	Wide mouth glass jar 250ml (1)	Cool at 4°C	14 Days	40 Days
SW-846:8270	Semivolatile Organics	Soil/Sludge	Wide mouth glass jar 250ml (1)	Cool at 4°C	14 Days	40 Days
	Kepone	Soil/Sludge	Wide mouth glass jar 250ml (1)	Cool at 4°C	14 Days	40 Days
	Organolead	Surface Water	Amber glass jar 1 L (3 for normal, 4 extra for MS/MSDs)	Cool at 4°C, no headspace	14 Days	40 Days
SW-846:7421	Total Lead	Surface Water	Polyethylene 500 ml	Cool at 4°C, pH<2 with HNO_3	6 Months	6 Months

[a] Extra sample must be collected for matrix spike/matrix spike duplicate analysis.

Sampling Bottles and Shipping Materials

- 250 mL wide-mouth glass with Teflon cap;
- 1 L amber glass with Teflon cap;
- 500 mL plastic;
- Bottle mesh;
- Plastic freezer bags;
- Ice chests; and
- Packaging and shipping materials.

Decontamination Equipment

- ALCONOX® soap;
- Reagent grade water;
- Squirt bottles;
- Plastic sheeting;
- Deionized water; and
- General decontamination equipment (scrubbing utensils, paper towels, etc...)

Miscellaneous Field Gear, Chemicals, and Instrumentation

- Protective gloves;
- Saranex-coated Tyvek® and Tyvek coveralls;
- Full-face air purifying respirators (Scott) with organic vapors cartridges;
- First aid kit;
- Eye wash;
- Tape measure;
- Sounding device; and,
- HNO_3 (AR Select).

Section 6
SAMPLE SHIPPING

Sample custody procedures for this project will emphasize careful documentation of sample collection and transfer data. Elements to ensure good sample custody and sample tracking are briefly discussed in this section.

6.1 Chain of Custody

To ensure that all of the important information pertaining to each sample is recorded, the following documentation procedures will be executed. Preformatted field data and sample custody forms will be used to document the relevant information for each sample taken. A master sample inventory will be maintained on site for all samples collected. Sample chain of custody involves documenting the handling of a sample from the time of collection to the time of final disposition. Procedures used to accomplish custody control include sample labels, custody seals, chain-of-custody forms, shipment and transfer of custody, and laboratory custody.

Sample Labels

A sample label, shown in Figure 6-1, will be affixed to all sampling containers submitted for laboratory analysis. Sample labels identify the sample by documenting the sample type, sampler(s) initials, sampling locations, depth, time, and date. The unique number assigned to each sample is also noted on the sample label. Indelible ink will be used to complete all sample labels. All samples shipped to MRD laboratory will also be labeled with "LIMS No. 1619."

Custody Seals

Custody seals, shown in Figure 6-1, will be affixed to coolers to indicate tampering.

Chain-of-Custody Records

A chain-of-custody form, shown in Figure 6-2, will be used to record the number of samples collected and the corresponding laboratory analyses; indelible ink will be used. Information on this form includes time and date of sampling, sample number, type of sample, sampler's name, preservatives used, and any special instructions. Samples collected for matrix spike/matrix spike duplicate analysis will be identified on the chain-of-custody form. A copy of the chain-of-custody form will be retained by the sampler, and will be maintained in a file of field documentation.

Transfer of Custody and Shipment

Chain-of-custody forms are printed on three-part NCR (no carbon required) paper and distributed in the following manner (or internal copies are made and sent to appropriate individuals):

- **First Copy**—Sent to the laboratory with samples. This copy is retained by the laboratory when analyses are completed and the sample is disposed of.
- **Second Copy**—Sent to the laboratory with the samples. Returned to the QA Coordinator with the laboratory analytical report.
- **Third Copy**—Retained by the Field Team Leader to be placed in the project file to document the existence of the sample.

Laboratory Custody Procedures

Each laboratory conducting analyses for this program will be required to use the described chain-of-custody forms or an equivalent to document the handling of each sample. Exception will be made only if the laboratory has

ATTENTION:
BEFORE OPENING
NOTE IF CONTAINER WAS
TAMPERED WITH.

CUSTODY # _____

ATTENTION:
BEFORE OPENING
NOTE IF CONTAINER WAS
TAMPERED WITH.

8-90-12898

Field Number _____
Sample Type: _____
Client: _____
Location: _____
Preservative: _____
Sampler: _____
Date: _____
Comment: _____

6-89-31426

Figure 6-1. Example Sample Label and Custody Seal

RADIAN CORPORATION

Chain of Custody Record

Page _____ of _____

PROJECT

SITE

COLLECTED BY *(Signature)*

FIELD SAMPLE I.D	SAMPLE MATRIX	DATE/TIME	NO. OF CONTAINERS	ANALYSES								REMARKS	SAM ID NO. *(for lab use only)*

REMARKS	RELINQUISHED BY:	DATE	TIME

RECEIVED BY:	DATE	TIME	RELINQUISHED BY:	DATE	TIME	RECEIVED BY:	DATE	TIME	RELINQUISHED BY:	DATE	TIME

LAB USE ONLY

RECEIVED FOR LABORATORY BY:	DATE	TIME	AIRBILL NO.	OPENED BY:	DATE	TIME	TEMP°C	SEAL #	CONDITION

REMARKS:

Figure 6-2. Sample Chain-of-Custody Record

an internal sample tracking system that satisfactorily documents continuous chain-of-custody. The laboratory will also be required to return a copy of the chain-of-custody form after receipt of samples. Upon receipt by the laboratory, sample integrity will be inspected and documented on a Chain-of-Custody Addendum (Figure 6-3). Sample temperatures will be checked and recorded, evidence of other preservative techniques will be reviewed, physical condition of each sample container will be checked, custody seals and chain-of-custody records will be reviewed for consistency, and freight bill identification numbers will be recorded. If any indication of a lack of sample integrity is found, the field task leader will be contacted to discuss implementation of corrective actions.

6.2 Sample Identification

All samples will be assigned a field sample number at the time of collection and a sample control number upon receipt by the laboratory. The field sample number will be recorded in the Sample Inventory, listed on the chain of custody, and on the attached sample label. QA duplicate samples, shipped to MRD for analysis, will be given the same field ID number as the field sample it duplicates. A unique sample control number will be assigned to each individual sample when it is received by the laboratory. A label bearing the sample control number will be affixed to each container. The sample control number will remain with the sample throughout the analysis and data entry procedures. The final report will contain a listing of the field sample numbers and the corresponding laboratory sample control numbers.

6.3 Correction to Documentation

Corrections made to laboratory data or chain-of-custody forms and related documents will be made by drawing a single line through the incorrect section and the corrected entry added. A brief explanation for the change along with the date the change was made should be recorded. Any corrections will be initialled and dated by the author of the change.

6.4 Sample Handling, Packaging, and Shipping

The FTL is responsible for ensuring that samples are properly packaged and shipped to the laboratory. All pertinent Department of Transportation (DOT) shipping regulations will be followed. Packaging and shipping requirements are discussed in this section for soils, sludge, and surface water samples. Procedures for notifying laboratories about incoming shipments are also discussed.

Samples

Soil and water samples will be kept cool with conventional ice in a plastic bag during collection and shipment. The samples will be stored upright in a durable ice chest. Sufficient packing material (e.g., vermiculite) will be used to separate the bottles, filling any intervening voids. Fresh ice will be placed in the cooler prior to shipment to ensure the samples are correctly preserved.

The ice will be placed above and around the top of the sample containers. The remaining space will be filled with additional packing material. The chain-of-custody form will be sealed in a plastic Zip-loc® bag and affixed to the top lid of the cooler. The cooler will be secured by completely wrapping it with strapping tape around both ends. If there is a drain on the cooler, it will be taped shut. The cooler will be labeled with "This Side Up" arrows on two opposing sides. A minimum of two custody seals will also be affixed to coolers to indicate tampering. These seals shall be signed and dated.

CUSTODY NUMBER: 93-0009

Chain-of-Custody Addendum

Received by: _____ Work Order(s): _____

Date: _____ _____

Unpacked Date: _____ _____

_____

Number of Outer Containers Received with Chain-of-Custody: _____ Client Code: _____

(Check the appropriate answer. Add comments or explanations as needed.)

Present	_____ Yes	_____ No
Custody Number	_____ #	_____ No
Container Sealed with Tape	_____ Yes	_____ No
Seal is Intact	_____ Yes	_____ No

If seal is not intact, list airbill number of that container(s).

_____

Sample Temperature Upon Arrival: By: _____ Pyrometer # _____

The temperature of the container(s) is: (acceptable tolerance 2-6°C)

1___°C 2___°C 3___°C 4___°C 5___°C 6___°C 7___°C

When samples are received not requiring cooling: _____ NA

If the temperature(s) are outside the acceptable range of 2-6°C

Client Services was notified: (_____ CSC) _____ Yes

OK to analyze samples: _____ Yes _____ No

If samples not listed below were within the acceptable temperature tolerance of 2-6°C. Samples affected and their temperatures.

Sample ID	Temperature (°C)	Sample ID	Temperature (°C)	Sample ID	Temperature (°C)

Figure 6-3. Sample Chain-of-Custody Addendum

Condition of Bottles/Containers By: _____ (Comment any problems)

Bottles received match COC _____ Yes _____ No

Bottles received intact _____ Yes _____ No

Comments: _____

_____

_____

pH of Samples/Preservation By: _____ (Comment any problem)

Acid preserved samples are <2 pH (as indicated by * on COC) _____ Yes _____ No

Base preserved samples are >12 pH (as indicated by # on COC) _____ Yes _____ No

Water samples for cyanide checked (as indicated by √ on COC) _____ Yes _____ No

Water sulfide samples appear to be preserved with zinc acetate _____ Yes _____ No

_____ NA

If pH/preservation is ouside acceptable limits, Client Services was notified

(_____ CSC) _____ Yes Adjust _____ Yes _____ No

Sample id's and pH of samples received outside of acceptable pH range. All other samples not listed are at the appropriate pH.

Sample ID	pH	Sample ID	pH	Sample ID	pH	Sample ID	pH

Comments: _____

_____

Shipping Documentation

Freightbill is available and attached to chain-of-custody.

_____ Yes _____ No

Other Comments: _____

_____

_____

Client chain-of-custody is signed/dated with time by sample control as received, with the sample control addendum number noted in the comments section.

_____ Yes _____ No

Sample Control Addendum Verified by: _____ **Date:** _____

Figure 6-3. (Continued)

Samples will be shipped to the laboratory by overnight courier on a daily basis. If the laboratory makes provisions for Saturday delivery, samples may be shipped on Friday. Otherwise, samples taken on Friday, Saturday, and Sunday will be stored in the field trailer (@ 4°C) for shipment on the following Monday. The laboratories will be contacted on Friday to inform them of Saturday or Tuesday delivery and will be made aware of hold time requirements.

Laboratory Shipping Information

All sample analyses for soil, groundwater, and surface water except for the kepone analyses and the MRD duplicates will be conducted by Quanterra Inc. at the following address:

Quanterra, Inc.
4955 Yarrow St.
Arvada, CO 80002
Attn: Kevin McHugh
(303) 421-6611 (phone)
(303) 431-7171 (fax)

Samples for kepone analyses will be shipped to Midwest Research Institute at the following address:

Midwest Research Institute
425 Volkar Blvd.
Kansas City, MO 64110
Attn: Gregory
(816) 753-7600

If Saturday delivery is necessary, the Federal Express label should include the note "Hold for pickup at Jefferson St. Station."

External QA Samples required by the USACE Missouri River Division Laboratory will be shipped to the following address:

U.S. Army Engineer Division, Missouri River Division Laboratory
Attn: CEMRD-ET-LC (Laura Percifield)
420 South 18th Street
Omaha, NE 68102
(402) 444-4314

LIMS No. 2997 must be printed on all labels and chain-of custody forms sent to the USACE MRD Laboratory. Samples may be shipped to USACE MRD Laboratory for Saturday *morning* delivery.

Section 7
Management of Investigation Derived Waste

The purpose of this section is to establish procedures for handling the waste generated during the field investigation. The procedures established provide instructions for classifying and handling the various wastes expected to be generated during soil, sludge and surface water sampling, and decontamination of field equipment.

7.1 Responsibilities

Field personnel are responsible for utilizing appropriate work practices and following good housekeeping practices to minimize waste generation and to maintain proper waste segregation. During the course of the investigation, the contractor will segregate and characterize each waste that is generated. Wastes will then be disposed of appropriately.

7.2 Field Materials

Alconox and isopropanol will be used in decontamination, and will be stored in the field vehicles and field trailer. Nitric acid will be used for sample preservation and will be stored in the sample preparation and shipping area of the field trailer. Material Safety Data Sheets (MSDSs) for these items are included in the Site Health and Safety Plan (SSHP).

7.3 Waste Streams

Two waste streams will exist in this field program, equipment waste and decontamination waste.

Equipment Waste

Equipment waste includes expendable or non-repairable sampling equipment, disposable supplies, and personal protective equipment (PPE). It is estimated that no more than one 30-gallon trash bag of equipment waste, mostly PPE, will be generated per day. This waste will be managed in accordance with the *Remedial Compliance Plan* dated October 1994 for Holloman AFB investigations.

Decontamination Waste

Decontamination waste consists of wastewater generated while decontaminating sampling equipment. Decontamination water generated at the site will be discharged in the sewage lagoons.

7.4 Waste Minimization

A primary goal of this plan is to minimize, to the extent practical, the volume of waste which must be generated and stored, and the amount of material which must be removed from the site for disposal. In order to minimize the volume of wastes, the following general rules should be applied:

- Do not contaminate materials unnecessarily;
- Decontaminate and reuse material and equipment when practical; and
- Utilize volume reduction techniques when practicable.

APPENDIX A

Water Depths and Sludge Thicknesses in Sewage Lagoons
(Measured October 1991)

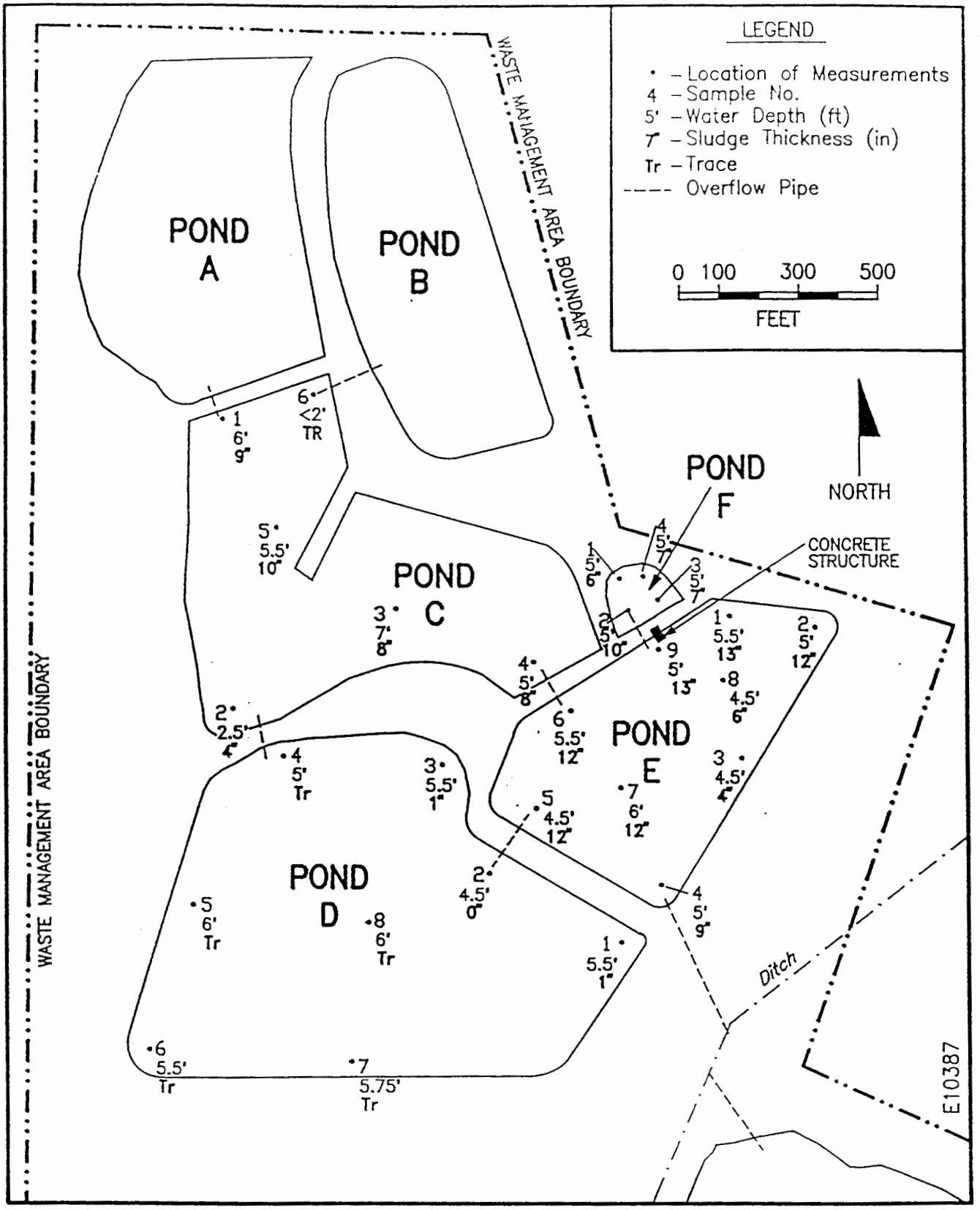


Figure 1. Sample Locations--Ponds C, D, E, and F

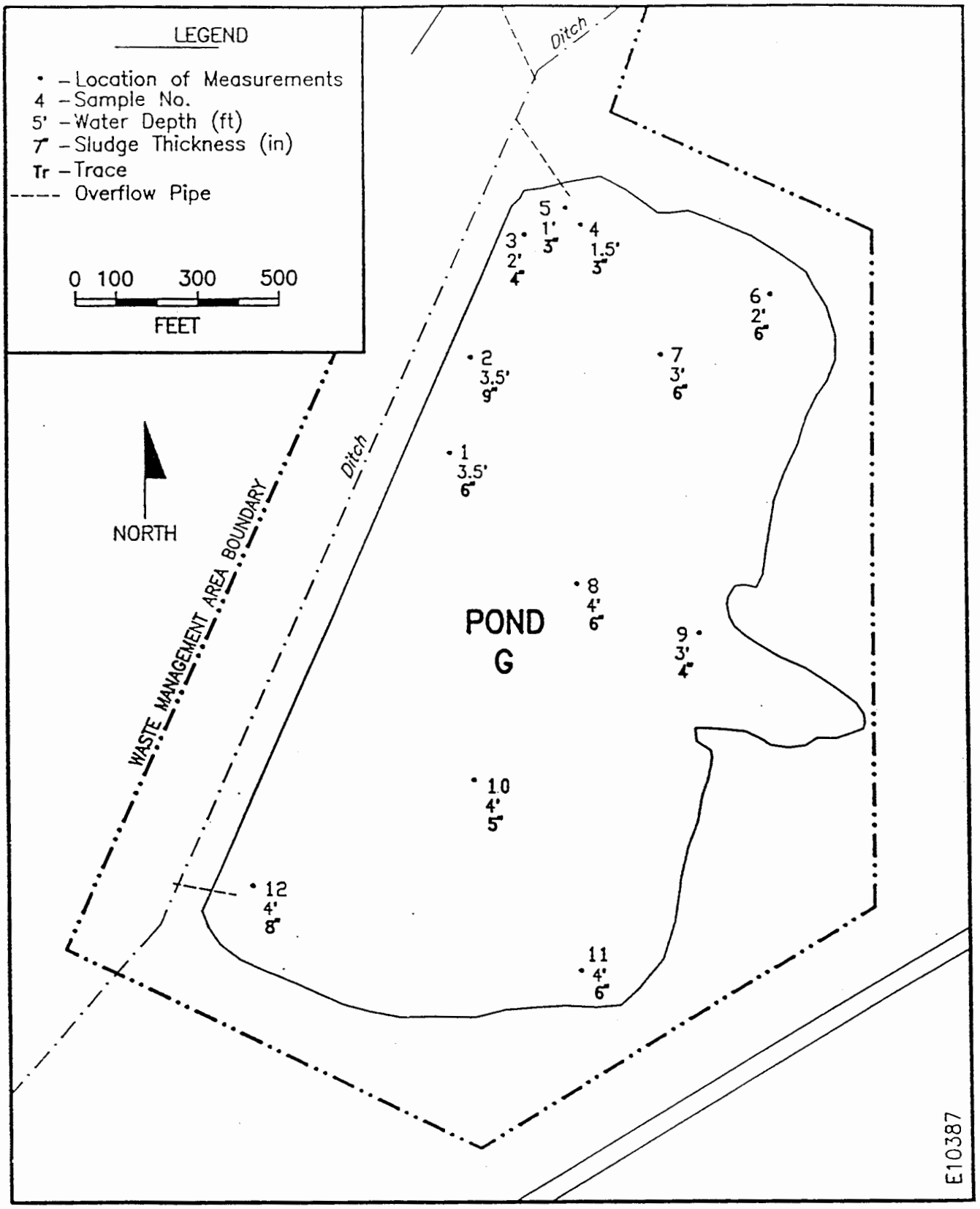


Figure 2. Sample Locations--Pond G

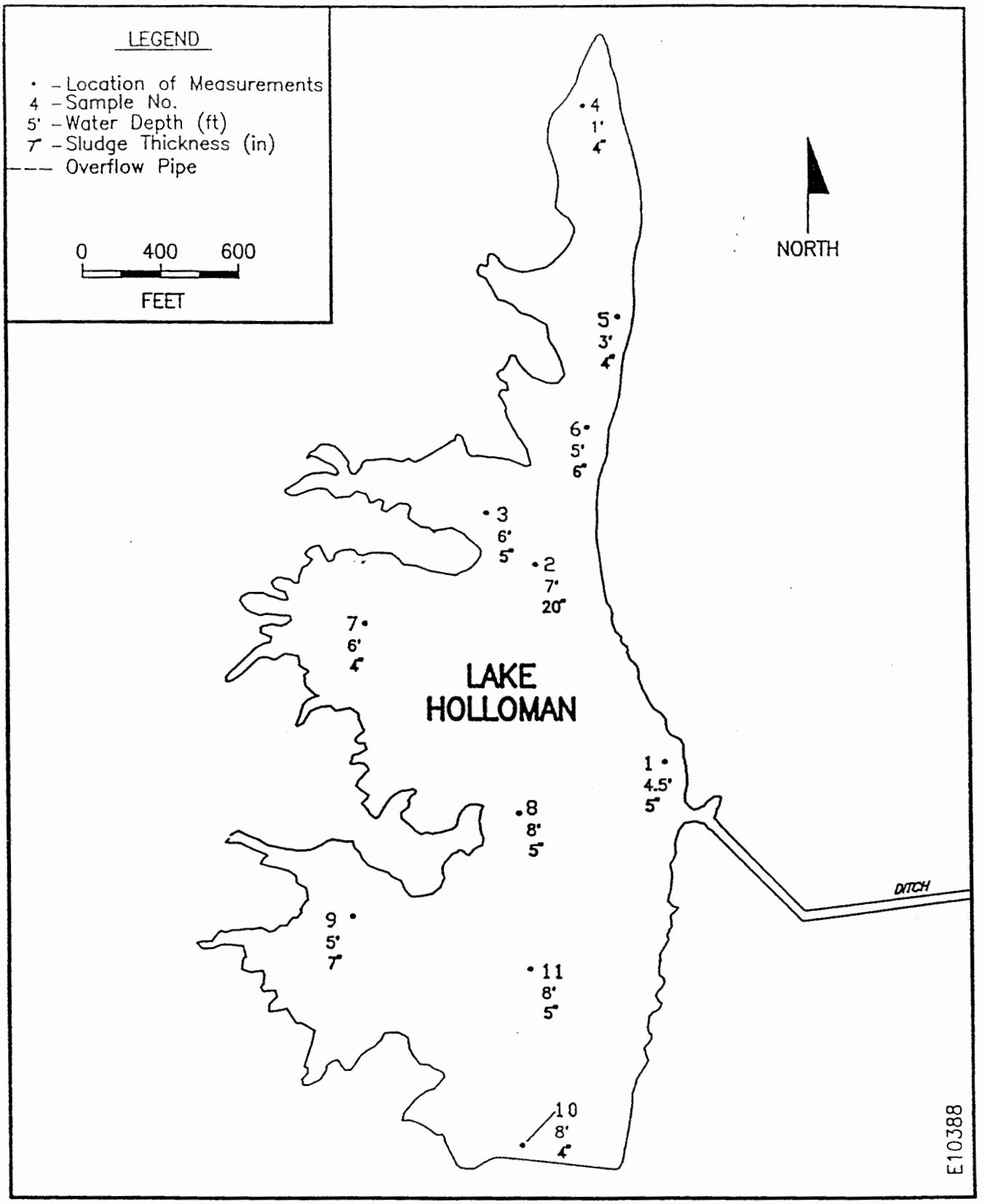


Figure 3. Sample Locations--Lake Holloman

APPENDIX B

Sample Identification Spreadsheet

Holloman Lakes and Lagoons
Sample Summary

10/25/94 Rice
Filename: Smplid.wk3

IDENTIFICATION										ANALYSES					
Location	Year	Site	Media	Loc	Type Sample	Method	Notes	Northing	Easting	8080	8270	Metals	Kepone	Organolead	Total Lead
Pond C	94	PC	SL	01	01					1	1	1	1		
Pond C	94	PC	SL	02	01					1	1	1			
Pond C	94	PC	SL	03	01					1	1	1	1		
Pond C	94	PC	SL	04	01					1	1	1			
Pond C	94	PC	SL	05	01					1	1	1	1		
Pond C	94	PC	SL	06	01					1	1	1	1		
Pond C	94	PC	SL	06	21		Duplicate			1	1	1			
Pond C	94	PC	SL	06	QA1		MRD Dup			1	1	1			
Pond C	94	PC	SL	07	01					1	1	1			
Pond C	94	PC	SL	07	01		MS/MSD			2	2	2			
Pond C	94	PC	SL	08	01					1	1	1	1		
Pond C	94	PC	SL	09	01					1	1	1			
Pond C	94	PC	SL	10	01					1	1	1	1		
Pond C	94	PC	SL	11	01					1	1	1	1		
Pond C	94	PC	SL	12	01					1	1	1			
Pond C	94	PC	SL	13	01					1	1	1	1		
										17	17	17	8	0	0

IDENTIFICATION										ANALYSES					
Location	Year	Site	Media	Loc	Type Sample	Method	Notes	Northing	Easting	8080	8270	Metals	Kepone	Organolead	Total Lead
Pond C	94	PC	WS	03	01	B								1	1
Pond C	94	PC	WS	07	01	B								1	1
Pond C	94	PC	WS	08	01	B								1	1
										0	0	0	0	3	3

IDENTIFICATION										ANALYSES					
Location	Year	Site	Media	Loc	Type Sample	Method	Notes	Northing	Easting	8080	8270	Metals	Kepone	Organolead	Total Lead
ond D	94	PD	S	01	01	HA				1	1	1			
Pond D	94	PD	S	02	01	HA				1	1	1			
Pond D	94	PD	S	03	01	HA				1	1	1			
Pond D	94	PD	S	04	01	HA				1	1	1			
Pond D	94	PD	S	04	21	HA	Duplicate			1	1	1			
Pond D	94	PD	S	04	QA1	HA	MRD Dup			1	1	1			
Pond D	94	PD	S	05	01	HA				1	1	1			
Pond D	94	PD	S	06	01	HA				1	1	1			
Pond D	94	PD	S	07	01	HA				1	1	1			
Pond D	94	PD	S	08	01	HA				1	1	1			
Pond D	94	PD	S	08	01	HA	MS/MSD			2	2	2			
Pond D	94	PD	S	09	01	HA				1	1	1			
Pond D	94	PD	S	10	01	HA				1	1	1			
										14	14	14	0	0	0

IDENTIFICATION										ANALYSES					
Location	Year	Site	Media	Loc	Type Sample	Method	Notes	Northing	Easting	8080	8270	Metals	Kepone	Organolead	Total Lead
Pond D	94	PD	WS	01	01	B								1	1
Pond D	94	PD	WS	05	01	B								1	1
Pond D	94	PD	WS	08	01	B								1	1
										0	0	0	0	3	3

Holloman Lakes and Lagoons
Sample Summary

10/25/94 Rice
Filename: Smplid.wk3

IDENTIFICATION										ANALYSES					
					Type	Sample									
Location	Year	Site	Media	Loc	Sample	Method	Notes	Northing	Easting	8080	8270	Metals	Kepone	Organolead	Total Lead
Pond E	94	PE	SL	01	01					1	1	1			
Pond E	94	PE	SL	02	01					1	1	1			
Pond E	94	PE	SL	03	01					1	1	1			
Pond E	94	PE	SL	04	01					1	1	1			
Pond E	94	PE	SL	04	21		Duplicate			1	1	1			
Pond E	94	PE	SL	04	QA1		MRD Dup			1	1	1			
Pond E	94	PE	SL	05	01					1	1	1			
Pond E	94	PE	SL	06	01					1	1	1			
Pond E	94	PE	SL	07	01					1	1	1			
Pond E	94	PE	SL	08	01					1	1	1			
Pond E	94	PE	SL	08	01		MS/MSD			2	2	2			
Pond E	94	PE	SL	09	01					1	1	1			
Pond E	94	PE	SL	10	01					1	1	1			
Pond E	94	PE	SL	11	01					1	1	1			
Pond E	94	PE	SL	12	01					1	1	1			
Pond E	94	PE	SL	13	01					1	1	1			
Pond E	94	PE	SL	14	01					1	1	1			
Pond E	94	PE	SL	15	01					1	1	1			
Pond E	94	PE	SL	16	01					1	1	1			
										20	20	20	0	0	0

IDENTIFICATION										ANALYSES					
					Type	Sample									
Location	Year	Site	Media	Loc	Sample	Method	Notes	Northing	Easting	8080	8270	Metals	Kepone	Organolead	Total Lead
Pond E	94	PE	WS	03	01	B								1	1
Pond E	94	PE	WS	09	01	B								1	1
Pond E	94	PE	WS	15	01	B								1	1
										0	0	0	0	3	3

Holloman Lakes and Lagoons
Sample Summary

10/25/94 Rice
Filename: Smplid.wk3

IDENTIFICATION										ANALYSES					
Location	Year	Site	Media	Loc	Type Sample	Sample Method	Notes	Northing	Easting	8080	8270	Metals	Kepone	Organolead	Total Lead
Pond G	94	PG	SL	01	01					1	1	1	1		
Pond G	94	PG	SL	02	01					1	1	1			
Pond G	94	PG	SL	03	01					1	1	1	1		
Pond G	94	PG	SL	04	01					1	1	1	1		
Pond G	94	PG	SL	04	21		Duplicate			1	1	1	1		
Pond G	94	PG	SL	04	QA1		MRD Dup			1	1	1	1		
Pond G	94	PG	SL	05	01					1	1	1			
Pond G	94	PG	SL	06	01					1	1	1			
Pond G	94	PG	SL	07	01					1	1	1	1		
Pond G	94	PG	SL	08	01					1	1	1	1		
Pond G	94	PG	SL	09	01					1	1	1			
Pond G	94	PG	SL	10	01					1	1	1	1		
Pond G	94	PG	SL	11	01					1	1	1	1		
Pond G	94	PG	SL	12	01					1	1	1	1		
Pond G	94	PG	SL	13	01					1	1	1	1		
Pond G	94	PG	SL	13	01		MS/MSD			2	2	2	0		
Pond G	94	PG	SL	14	01					1	1	1			
Pond G	94	PG	SL	15	01					1	1	1	1		
Pond G	94	PG	SL	16	01					1	1	1			
Pond G	94	PG	SL	17	01					1	1	1	1		
Pond G	94	PG	SL	18	01					1	1	1			
Pond G	94	PG	SL	19	01					1	1	1	1		
										23	23	23	14	0	0

IDENTIFICATION										ANALYSES					
Location	Year	Site	Media	Loc	Type Sample	Sample Method	Notes	Northing	Easting	8080	8270	Metals	Kepone	Organolead	Total Lead
Pond G	94	PG	WS	01	01	B								1	1
Pond G	94	PG	WS	04	01	B								1	1
Pond G	94	PG	WS	04	EB1	B	Eqp Blank							1	1
Pond G	94	PG	WS	05	01	B								1	1
Pond G	94	PG	WS	07	01	B								1	1
Pond G	94	PG	WS	07	21	B	Duplicate							1	1
Pond G	94	PG	WS	07	QA1	B	MRD Dup							1	1
Pond G	94	PG	WS	09	01	B								1	1
Pond G	94	PG	WS	11	01	B								1	1
Pond G	94	PG	WS	11	01	B	MS/MSD								2
Pond G	94	PG	WS	12	01	B								1	1
Pond G	94	PG	WS	15	01	B								1	1
Pond G	94	PG	WS	17	01	B								1	1
										0	0	0	0	12	14

Holloman Lakes and Lagoons
Sample Summary

10/25/94 Rice
Filename: Smplid.wk3

IDENTIFICATION										ANALYSES					
Location	Year	Site	Media	Loc	Type Sample	Method	Notes	Northing	Easting	8080	8270	Metals	Kepone	Organolead	Total Lead
Lake Holloman	94	LH	SL	01	01					1	1	1	1		
Lake Holloman	94	LH	SL	02	01					1	1	1			
Lake Holloman	94	LH	SL	03	01					1	1	1	1		
Lake Holloman	94	LH	SL	04	01					1	1	1	1		
Lake Holloman	94	LH	SL	04	21		Duplicate			1	1	1	1		
Lake Holloman	94	LH	SL	04	QA1		MRD Dup			1	1	1	1		
Lake Holloman	94	LH	SL	05	01					1	1	1	1		
Lake Holloman	94	LH	SL	06	01					1	1	1			
Lake Holloman	94	LH	SL	07	01					1	1	1	1		
Lake Holloman	94	LH	SL	08	01					1	1	1	1		
Lake Holloman	94	LH	SL	09	01					1	1	1			
Lake Holloman	94	LH	SL	10	01					1	1	1	1		
Lake Holloman	94	LH	SL	11	01					1	1	1			
Lake Holloman	94	LH	SL	12	01					1	1	1	1		
Lake Holloman	94	LH	SL	13	01					1	1	1			
Lake Holloman	94	LH	SL	13	01		MS/MSD			2	2	2			
Lake Holloman	94	LH	SL	14	01					1	1	1	1		
Lake Holloman	94	LH	SL	15	01					1	1	1			
Lake Holloman	94	LH	SL	16	01					1	1	1	1		
Lake Holloman	94	LH	SL	17	01					1	1	1	1		
Lake Holloman	94	LH	SL	18	01					1	1	1			
Lake Holloman	94	LH	SL	19	01					1	1	1			
Lake Holloman	94	LH	SL	20	01					1	1	1	1		
Lake Holloman	94	LH	SL	21	01					1	1	1			
Lake Holloman	94	LH	SL	22	01					1	1	1	1		
Lake Holloman	94	LH	SL	23	01					1	1	1	1		
Lake Holloman	94	LH	SL	24	01					1	1	1			
Lake Holloman	94	LH	SL	25	01					1	1	1	1		
										29	29	29	17	0	0

IDENTIFICATION										ANALYSES					
Location	Year	Site	Media	Loc	Type Sample	Method	Notes	Northing	Easting	8080	8270	Metals	Kepone	Organolead	Total Lead
Lake Holloman	94	LH	WS	01	01	B								1	1
Lake Holloman	94	LH	WS	04	01	B								1	1
Lake Holloman	94	LH	WS	04	EB1	B	Eqp Blank							1	1
Lake Holloman	94	LH	WS	05	01	B								1	1
Lake Holloman	94	LH	WS	07	01	B								1	1
Lake Holloman	94	LH	WS	07	21	B	Duplicate							1	1
Lake Holloman	94	LH	WS	07	QA1	B	MRD Dup							1	1
Lake Holloman	94	LH	WS	08	01	B								1	1
Lake Holloman	94	LH	WS	10	01	B								1	1
Lake Holloman	94	LH	WS	12	01	B								1	1
Lake Holloman	94	LH	WS	14	01	B								1	1
Lake Holloman	94	LH	WS	16	01	B								1	1
Lake Holloman	94	LH	WS	17	01	B								1	1
Lake Holloman	94	LH	WS	20	01	B								1	1
Lake Holloman	94	LH	WS	22	01	B								1	1
Lake Holloman	94	LH	WS	22	01	B	MS/MSD							0	2
Lake Holloman	94	LH	WS	23	01	B								1	1
Lake Holloman	94	LH	WS	25	01	B								1	1
										0	0	0	0	17	19

Holloman Lakes and Lagoons
Sample Summary

10/25/94 Rice
Filename: Smplid.wk3

NOTE: Lake Stinky Sampled for Soil Only

IDENTIFICATION										ANALYSES					
Location	Year	Site	Media	Loc	Type Sample	Method	Notes	Northing	Easting	8080	8270	Metals	Kepone	Organolead	Total Lead
Lake Stinky	94	LS	S	01	01					1	1	1			
Lake Stinky	94	LS	S	02	01					1	1	1			
Lake Stinky	94	LS	S	03	01					1	1	1			
Lake Stinky	94	LS	S	04	01					1	1	1			
Lake Stinky	94	LS	S	04	21		Duplicate			1	1	1			
Lake Stinky	94	LS	S	04	QA1		MRD Dup			1	1	1			
Lake Stinky	94	LS	S	05	01					1	1	1			
Lake Stinky	94	LS	S	06	01					1	1	1			
Lake Stinky	94	LS	S	06	01		MS/MSD			2	2	2			
Lake Stinky	94	LS	S	07	01					1	1	1			
Lake Stinky	94	LS	S	08	01					1	1	1			
Lake Stinky	94	LS	S	09	01					1	1	1			
Lake Stinky	94	LS	S	10	01					1	1	1			
Lake Stinky	94	LS	S	11	01					1	1	1			
										15	15	15	0	0	0

IDENTIFICATION										ANALYSES					
Location	Year	Site	Media	Loc	Type Sample	Method	Notes	Northing	Easting	8080	8270	Metals	Kepone	Organolead	Total Lead
Ditch	94	DT	S	01	01	HA				1	1	1			
Ditch	94	DT	S	02	01	HA				1	1	1			
Ditch	94	DT	S	03	01	HA				1	1	1			
Ditch	94	DT	S	04	01	HA				1	1	1			
										4	4	4	0	0	0

IDENTIFICATION										ANALYSES					
Location	Year	Site	Media	Loc	Type Sample	Method	Notes	Northing	Easting	8080	8270	Metals	Kepone	Organolead	Total Lead
Ditch	94	DT	WS	01	01	B								1	1
Ditch	94	DT	WS	03	01	B								1	1
Ditch	94	DT	WS	04	01	B								1	1
										0	0	0	0	3	3
								Grand Totals		**122**	**122**	**122**	**39**	**41**	**45**

Legend
SL - Sludge Sample
S - Soil Sample
WS - Surface Water Sample
PC - Lagoon C
LH - Lake Holloman
DT - Ditch
01-Sample Type - Normal
21-Sample Type - Duplicate
QA1 - Sample Type - MRD Sample
EB1 - Sample Type - Equipment Blank

NOTE: The MS/MSD samples include 1 MS and 1 MSD.
The Grand Totals include the MS/MSD and MRD samples.

Addendum to Field Sampling Plan (FSP)
Holloman Air Force Base
Sewage Lagoons and Lakes Closure Project
Additional Sampling

March 1995

2.4 Additional Sludge Sampling Locations

In order to resolve recent agency concerns, provide data that will enhance the corrective measures study, and to assist in future remediation at the site, additional sludge samples will be collected from Ponds A, B, C, and D. These activities will occur at a later date relative to the sampling activities described in Sections 2.1 and 3.1.

A total of 25 locations will be sampled for sludge in Ponds A, B, C, and D. The total number of samples, including four QA/QC samples and three Missouri River Division (MRD) duplicates, is 32. Prior to sampling, the locations in Ponds A and B will be surveyed by Southwest Engineering Inc. The surveyors will mark each sampling point with a floating buoy positioned by a leader and anchor (all locations are underwater). Previously sampled locations in Ponds C and D will be resampled; therefore, no additional surveying in these impoundments is required.

Table 2-3 shows the numbers and types of samples to be collected in each impoundment. Sample locations are given in Figure 2-3. Appendix C contains a detailed breakdown of all sampling locations and media, with their respective analyses.

Sludge Sample Analyses

All analyses will be performed using SW846 methods. Sludge samples in Ponds A, B, and C will be analyzed for toxicity characteristic leachate procedure (TCLP, SW1311) metals, and total and reactive sulfides. Additionally, Ponds A and B will be analyzed for polychlorinated biphenyls (SW8080). Sludge samples in Pond D will be analyzed for total metals, and organochlorine pesticides (SW8080). Also, samples from Pond D will be collected and extracted for analysis by method SW8270 (semivolatiles), but will only be analyzed to confirm any positive detections of isodrin or heptachlor epoxide in the SW8080 organochlorine pesticides analyses.

All analyses will be performed by Quanterra Inc. The analytical procedures are described in the Sewage Lagoons and Lakes Closure Project *Quality Assurance Project Plan (QAPP)*, October, 1994, and in the addendum to the QAPP, March 1995.

Table 2-3
Sewage Lagoons Closure Project Modification Sample Location and Analyses

Method	Pond A	Pond B	Pond C	Pond D	Duplicates*	Total
Total Metals	--	--	--	6	1	7
TCLP Metals	6	6	6	--	2	20
8270 Extraction				6		6
8270 Analysis	--	--	--	3		3
8080	6	6	--	6	3	20
Sulfides (Total and Reactive)	6	6	6		2	20

* Duplicates do not include MS/MSDs or MRD duplicates.

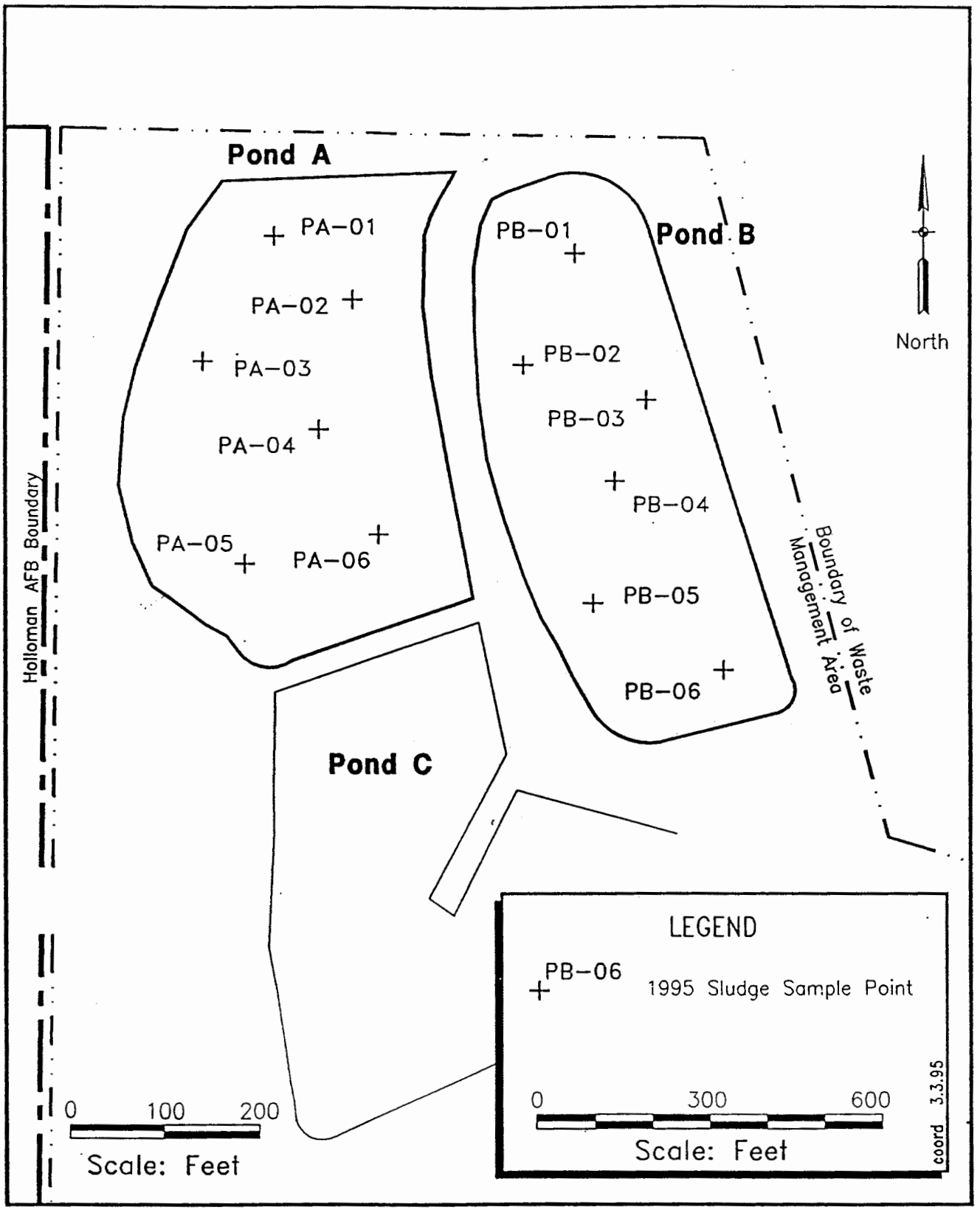


Figure 2-3. Additional Sewage Lagoons Sample Locations for March 1995 Investigation

APPENDIX C

Additional Sampling (March 1995) Identification Spreadsheet

Holloman Lakes and Lagoons
Sample Summary Modified for 3/95 Sampling Effort

02/28/95 Rice
Filename: Holloman\lagoons\fsp\ModSmpid.wk

IDENTIFICATION

Location	Year	Site	Media	Loc	Type Sample	Sample Method	Notes	Northing	Easting	ANALYSES 8080	8270	Metals	TCLP Metals	Tot. & Reac. Sulfides
Pond A	95	PA	SL	01	01					1			1	1
Pond A	95	PA	SL	02	01					1			1	1
Pond A	95	PA	SL	03	21		Duplicate			1			1	1
Pond A	95	PA	SL	03	QA1		MRD Dup			1			1	1
Pond A	95	PA	SL	03	01					1			1	1
Pond A	95	PA	SL	04	01					1			1	1
Pond A	95	PA	SL	04	01		MS/MSD			2			2	2
Pond A	95	PA	SL	05	01					1			1	1
Pond A	95	PA	SL	06	01					1			1	1
										10	0	0	10	10

Location	Year	Site	Media	Loc	Type Sample	Sample Method	Notes	Northing	Easting	ANALYSES 8080	8270	Metals	TCLP Metals	Tot. & Reac. Sulfides
Pond B	95	PB	SL	01	01					1			1	1
Pond B	95	PB	SL	02	01					1			1	1
Pond B	95	PB	SL	03	01					1			1	1
Pond B	95	PB	SL	03	21		Duplicate			1			*	*
Pond B	95	PB	SL	03	QA1		MRD Dup			1			1	1
Pond B	95	PB	SL	04	01					1			1	1
Pond B	95	PB	SL	05	01					1			1	1
Pond B	95	PB	SL	06	01					1			1	1
										8	0	0	7	7

Location	Year	Site	Media	Loc	Type Sample	Sample Method	Notes	Northing	Easting	ANALYSES 8080	8270	Metals	TCLP Metals	Tot. & Reac. Sulfides
ond C	95	PC	SL	01	01								1	1
ond C	95	PC	SL	03	01								1	1
Pond C	95	PC	SL	03	21		Duplicate						1	1
Pond C	95	PC	SL	03	QA1		MRD Dup						1	1
Pond C	95	PC	SL	05	01								1	
Pond C	95	PC	SL	07	01								1	1
Pond C	95	PC	SL	07	01		MS/MSD						2	2
Pond C	95	PC	SL	08	01								1	1
Pond C	95	PC	SL	10	01								1	1
Pond C	95	PC	SL	11	01									1
										0	0	0	10	10

Location	Year	Site	Media	Loc	Type Sample	Sample Method	Notes	Northing	Easting	ANALYSES 8080	8270	Metals	TCLP Metals	Tot. & Reac. Sulfides
Pond D	95	PD	SL	01	01					1	1	1		
Pond D	95	PD	SL	02	01					1	1	1		
Pond D	95	PD	SL	03	01					1	1	1		
Pond D	95	PD	SL	03	01		MS/MSD			2	2	2		
Pond D	95	PD	SL	04	01					1	1	1		
Pond D	95	PD	SL	04	21		Duplicate			1	1	1		
Pond D	95	PD	SL	04	QA1		MRD Dup			1	1	1		
Pond D	95	PD	SL	05	01					1	1	1		
Pond D	95	PD	SL	06	01					1	1	1		
										10	10	10		

Legend
SL - Sludge Sample
PC - Lagoon C
D - Lagoon D (See Note 3)
01-Sample Type - Normal
-Sample Type - Duplicate
A1 - Sample Type - MRD Sample
EB1 - Sample Type - Equipment Blank
* Duplicate sample on PB-03 will only be duplicated for 8080 analysis.

NOTE:
1) The MS/MSD samples include 1 MS and 1 MSD.
2) The Grand Totals include the MS/MSD and MRD samples.

APPENDIX A

Analytical Summary of Sewage Lagoons Investigations

Appendix A

Analytical Summary of Sewage Lagoons Investigations

This appendix summarizes the analytical results from all surface water, sludge, and soil investigations conducted at the Holloman AFB sewage lagoons between 1990 and 1995. The data collected in Ponds A and B during 1988 to define the extent of PCB concentrations greater than 25 ppm is not included in this summary because the sludge was removed in 1990 and many of the 1988 sample locations were within the area of removal. Therefore, the 1988 data is no longer representative of the sludge currently in Ponds A and B.

The *Site Characterization Report* (Radian and Foster Wheeler, June 1995) presents a summary of data collected by individual investigations in Appendices A through F.

Table A-1 outlines the media analyzed, and the analyses performed for all surface water, sludge, soil, sediment, and groundwater investigations for 1990 to 1995. The remainder of this appendix presents an analytical summary of all groundwater, surface water, sludge, and soil investigations conducted at the sewage lagoons between 1990 and 1995. Results are provided by pond, media, analyses, and constituent. In addition, Figures A-1 through A-11 show the location of sludge and soil samples collected from each sewage lagoon. Figure A-12 shows the groundwater monitoring locations.

Tables A-2 through A-8 summarize the analytical data for surface water, sludge, and soil samples. Table A-9 summarizes groundwater assessment monitoring data collected from 1992 and 1993 for the sewage lagoons. Table A-10 summarizes the results of the 1995 long-term groundwater monitoring program. Each table provides the frequency of detection, the median concentration, the maximum concentration, and the sample location, along with year, for maximum detections. Analytical flags are also presented with the data. The flags may vary depending on the laboratory used, and therefore a summary of the analytical flags is presented as follows:

1990 Sampling Event

B	=	Parameter was also detected in the blank sample; result is uncorrected
C	=	Confirmed on second column or by GC/MS
G	=	Indicates an estimated GC value due to interference
h	=	Sample analyzed 4 days past allowable holding time
J	=	Result is less than the method specified detection limit. These results should be considered approximate.
@	=	Result is less than five times the method detection limit. Studies have shown that the uncertainty of the analysis will increase exponentially as the MDL is approached. These results should be considered approximate.
X	=	Not confirmed on second column

1992 and 1993 Sampling Events

X	=	Qualitative confirmation of analyte on both columns. Quantification differed by a factor of two or more between columns. Value determined by the first column is reported.
@	=	Measured result is less than five times the detection limit
C	=	Presence and quantitation of the analyte confirmed by second column analysis
D	=	Secondary dilution required for this analyte
J	=	Detected below the method detection limit
B	=	Analyte detected in laboratory blank analysis, no blank subtraction performed
G	=	Indicates an estimated GC value due to interference

Alternative AF2 -- Containment, Backfill to Top of Berms

Reference	Title of Action	Unit Cost				Unit	Quantity	Cost per Category			TOTAL COST
		Material	Equipment	Labor	Total			Material	Equipment	Labor	
c1	Excavate and move borrow material		3.42	1.62	5.04	cy	1,219,000	0	4,168,980	1,974,780	$6,143,760
c2	Borrow and haul topsoil				8.00	cy	62,000	NA[1]	NA[1]	NA[1]	$496,000
d	Common earth backfill		1.51	1.02	2.53	cy	1,280,000	0	1,932,800	1,305,600	$3,238,400
e	Fine grading and seeding	0.21	1.01	0.21	1.43	sy	372,000	78,120	375,720	78,120	$531,960
	TOTAL COST							78,120	6,477,500	3,358,500	$10,410,120

Unit costs are taken from Means 1996 Site Work and Landscape Cost Data

c1 = 5 cy wheel loader, twelve 20 cy dump trailers, 4 mile round trip -- 12.1-614-7600
c2 = Phone estimate from Frank Denton of Tommy Blankenship Construction
Laluz, NM -- 6 June 1996
d = 300-hp dozer and roller compactor, 300' haul, 8" lifts, 2 passes -- 12.1-724-3300
e = Fine grading and seeding -- 022-286-1000
NA[1] = No cost breakdown was provided by vendor.

ITEM	
Total Earthwork Costs (subcontractor)	$10,410,120
Total Earthwork Cost	$10,410,120
Prime Contractor O&P (20%)	$2,082,024
Bonding and Insurance (3%)	$312,304
Design (10%)	$1,041,012
Small Tools (2%)	$208,202
Prime Contractor	
(4 men @ $35/hr for 360 days)	$403,200
Schedules (0.25%)	$26,025
Submittals (1%)	$104,101
Field and Laboratory Testing (2%)	$208,202
Permitting and Legal (2%)	$208,202
Mobilization/Demobilization (5%)	$520,506
Total Site Construction Costs	$15,523,899
New Mexico Gross Receipt Taxes (6.25%)	$970,244
TOTAL SITE REMEDIATION	**$16,494,143**

Alternative AF3 -- Containment, Restore to Natural Contours

Reference	Title of Action	Unit Cost				Unit	Quantity	Cost per Category			TOTAL COST
		Material	Equipment	Labor	Total			Material	Equipment	Labor	
b	Move on-site cut to fill		2.35	1.26	3.61	cy	205,000	0	481,750	258,300	$740,050
c	Common earth backfill		1.51	1.02	2.53	cy	205,000	0	309,550	209,100	$518,650
d	Fine grading and seeding	0.21	1.01	0.21	1.43	sy	542,000	113,820	547,420	113,820	$775,060
	TOTAL COST							113,820	1,338,720	581,220	$2,033,760

Unit costs are taken from Means 1996 Site Work and Landscape Cost Data

b = 3 cy wheel loader, five 16 cy dump trailers, 1 mile round trip -- 12.1-614-6200
c = 300-hp dozer and roller compactor, 300' haul, 8" lifts, 2 passes -- 12.1-724-3300
d = Fine grading and seeding -- 022-286-1000

ITEM	
Total Earthwork Costs (subcontractor)	$2,033,760
Total Earthwork Cost	$2,033,760
Prime Contractor O&P (20%)	$406,752
Bonding and Insurance (3%)	$61,013
Design (10%)	$203,376
Small Tools (2%)	$40,675
Field Supervision (4 men @ $35/hr for 120 days)	$134,400
Schedules (0.25%)	$5,084
Submittals (1%)	$20,338
Field and Laboratory Testing (2%)	$40,675
Permitting and Legal (2%)	$40,675
Mobilization/Demobilization (5%)	$101,688
Total Site Construction Costs	$3,088,436
New Mexico Gross Receipt Taxes (6.25%)	$193,027
TOTAL SITE REMEDIATION	**$3,281,464**

Addition of 6" Stone Rip-Rap for Channel Erosion Control

Reference	Title of Action	Unit Cost				Unit	Quantity	Cost per Category			TOTAL COST
		Material	Equipment	Labor	Total			Material	Equipment	Labor	
a	Load and Haul 6" Rip-Rap				16.25	cy	370	NA[1]	NA[1]	NA[1]	$6,013
a	Place Rip-Rap in Channel				8.00	cy	370	NA[1]	NA[1]	NA[1]	$2,960
											$0
											$0
											$0
	TOTAL COST										$8,973

a = Phone estimate from Gary Bridges of Danley Construction Laluz, NM -- 6 June 1996
Estimated area of rip-rap is 100' X 200' X 1/2'

NA[1] = No cost breakdown was provided by vendor.

ITEM	
Total Earthwork Costs (subcontractor)	$8,973
Total Earthwork Cost	$8,973
Prime Contractor O&P (20%)	$1,795
Bonding and Insurance (3%)	$269
Design (10%)	$897
Small Tools (2%)	$179
Schedules (0.25%)	$22
Submittals (1%)	$90
Field and Laboratory Testing (2%)	$179
Permitting and Legal (2%)	$179
Mobilization/Demobilization (5%)	$449
Total Site Construction Costs	$13,033
New Mexico Gross Receipt Taxes (6.25%)	$815
TOTAL SITE REMEDIATION	**$13,847**

Addition of Automatic Sprinkler System

Reference	Title of Action	Unit Cost				Unit	Quantity	Cost per Category			TOTAL COST
		Material	Equipment	Labor	Total			Material	Equipment	Labor	
a	Install Automatic Sprinkler System	74,000		42,200	116,200	ea	2	148,000	0	84,400	$232,400
											$0
											$0
											$0
											$0
	TOTAL COST										$232,400

Unit costs are taken from Means 1996 Site Work and Landscape Cost Data

a = Fully automatic system covering 30 acres -- 028-104-0100

ITEM	
Total Earthwork Costs (subcontractor)	$232,400
Total Earthwork Cost	$232,400
Prime Contractor O&P (20%)	$46,480
Bonding and Insurance (3%)	$6,972
Design (10%)	$23,240
Small Tools (2%)	$4,648
Schedules (0.25%)	$581
Submittals (1%)	$2,324
Field and Laboratory Testing (2%)	$4,648
Permitting and Legal (2%)	$4,648
Mobilization/Demobilization (5%)	$11,620
Total Site Construction Costs	$337,561
New Mexico Gross Receipt Taxes (6.25%)	$21,098
TOTAL SITE REMEDIATION	**$358,659**

Annual Operation and Maintenance Costs

Reference	Title of Action	Unit Cost				Unit	Quantity	Cost per Category			TOTAL COST
		Material	Equipment	Labor	Total			Material	Equipment	Labor	
	Maintain Sprinkler System (5% of installation cost)	3,700.00		2,110.00	5,810.00	ea	2	7,400	0	4,220	$11,620
e	Fine grading and seeding (1% of 60 acre area)	0.21	1.01	0.21	1.43	sy	4,940	1,037	4,989	1,037	$7,064
g	Water Charges	6.90				1000 cf	5,663	39,073	0	0	$39,073
											$0
											$0
	TOTAL COST							47,511	4,989	5,257	$57,758

Unit costs are taken from Means 1996 Site Work and Landscape Cost Data

e = Fine grading and seeding -- 022-286-1000
g = City of Alamogordo charges $6.90 per 1,000 cf of water. Assume 1/2 of an inch of water weekly over 60 acre area.

ITEM	
Total Annual Costs	$57,758
New Mexico Gross Receipt Taxes (6.25%)	$3,610
Site Construction Costs	$61,367
TOTAL O&M ANNUAL EXPENSES	**$61,367**

Net Present Value

Assume 5% discount value for 30 years
$61,000 X 15.372 = $940,000

Water for 3-Months to Establish Vegetation

Reference	Title of Action	Unit Cost				Unit	Quantity	Cost per Category			TOTAL COST
		Material	Equipment	Labor	Total			Material	Equipment	Labor	
a	Water Truck Rental		1250		1250	month	3	0	3,750	0	$3,750
g	Water Charges	6.90				1000 cf	1,307	9,017	0	0	$9,017
											$0
											$0
											$0
	TOTAL COST							9,017	3,750	0	$12,767

Unit costs are taken from Means 1996 Site Work and Landscape Cost Data

a = ChemicalSpreader Rental 016-440-1000

g = City of Alamogordo charges $6.90 per 1,000 cf of water. Assume 1/2 of an inch of water weekly over 60 acre area (12 Weeks)

ITEM	
Total System Costs (subcontractor)	$12,767
Total Cost	$12,767
Mobilization/Demobilization (5%)	$638
Total Site Construction Costs	$13,405
New Mexico Gross Receipt Taxes (6.25%)	$838
TOTAL SITE REMEDIATION	**$14,243**

Annual Operation and Maintenance Costs (No Watering)

Reference	Title of Action	Unit Cost				Unit	Quantity	Cost per Category			TOTAL COST
		Material	Equipment	Labor	Total			Material	Equipment	Labor	
e	Fine grading and seeding (1% of 60 acre area)	0.21	1.01	0.21	1.43	sy	2,904	610	2,933	610	$4,153
											$0
											$0
	TOTAL COST										$4,153

Unit costs are taken from Means 1996 Site Work and Landscape Cost Data

e = Fine grading and seeding -- 022-286-1000

ITEM	
Total Annual Costs	$4,153
New Mexico Gross Receipt Taxes (6.25%)	$260
Site Construction Costs	$4,412
TOTAL O&M ANNUAL EXPENSES	**$4,412**

APPENDIX C

Corrective Measures Study

DCN 96-612-001-24-01

CORRECTIVE MEASURES STUDY

SEWAGE LAGOONS CLOSURE PROJECT
HOLLOMAN AIR FORCE BASE, NM

Prepared for:

49 CES/CEV
Holloman Air Force Base, NM

and

HQ ACC/CEVR
Langley Air Force Base, VA

Prepared by:

Radian International, LLC
8501 North Mopac Boulevard
Austin, Texas 78720-1088
512/454-4797

Under Contract No. DACW45-91-D-0018

U.S. Army Corps of Engineers
Omaha District
Omaha, Nebraska

June 1996
Revised November 1996

TABLE OF CONTENTS

Page

1 INTRODUCTION 1-1

1.1 Regulatory Background 1-1
1.2 Stakeholders Closure Meeting 1-1
1.2.1 Items Discussed 1-1
1.2.2 Incorporation of Discussion Items into the CMS 1-3
1.3 Approach to Closure 1-3
1.4 Purpose of CMS 1-4

2 DESCRIPTION OF CURRENT CONDITIONS 2-1

2.1 Areas and Volumes of the Sewage Lagoons and Sludge Depths 2-1
2.2 Topography 2-1
2.3 Geology and Soils 2-1
2.4 Surface Water Hydrology 2-2
2.5 Regional Groundwater Hydrology 2-2
2.6 Local Groundwater Hydrology 2-4
2.7 Groundwater Quality 2-4
2.8 Nature and Extent of Contamination 2-6
2.8.1 Sludge 2-6
2.8.2 Soil 2-8
2.8.3 Surface Water 2-8
2.8.4 Groundwater 2-8
2.9 Risk Assessment Results 2-9
2.9.1 Human Health Site-Specific Risk Assessments 2-9
2.9.2 Ecological Risk Assessment 2-10

3 CLOSURE OBJECTIVES AND CLOSURE CRITERIA 3-1

3.1 Closure Objectives 3-1
3.2 Closure Criteria 3-1
3.3 Discussion of Potentially Relevant Requirements 3-1
3.3.1 FFCA 3-1
3.3.2 RCRA 3-1
3.3.3 CERCLA 3-2
3.3.4 State of New Mexico Hazardous Waste Regulations 3-2
3.3.5 State and Federal Water Quality Regulations 3-2
3.3.6 Human Health Standards 3-2
3.3.7 Wetlands 3-2

TABLE OF CONTENTS (CONTINUED)

Page

4 TECHNOLOGY SCREENING AND ALTERNATIVES DEVELOPMENT 4-1

4.1 Development and Screening of Closure Actions 4-1
4.1.1 Development of Potential Closure Actions 4-1
4.1.2 Screening of Closure Actions 4-1
4.2 Screening of Technologies 4-3
4.3 Development of Closure Alternatives for Ponds A Through F 4-3
4.3.1 Alternative AF1: No Action 4-3
4.3.2 Alternative AF2: Containment—Backfill to Top of Berms 4-3
4.3.3 Alternative AF3: Containment—Restore to Natural Contours 4-4
4.4 Development of the Closure Alternative for Pond G—Alternative G1: No Action 4-4

5 EVALUATION OF CLOSURE ALTERNATIVES 5-1

5.1 Closure Objectives and Criteria 5-1
5.2 Evaluation Criteria 5-1
5.2.1 Technical 5-1
5.2.2 Environmental 5-2
5.2.3 Human Health 5-2
5.2.4 Institutional 5-2
5.3 Evaluation of Alternatives for Ponds A through F 5-2
5.3.1 Alternative AF1: No Action 5-2
5.3.2 Alternative AF2: Containment—Backfill to Top of Berms 5-4
5.3.3 Alternative AF3: Containment—Restore to Natural Contours 5-5
5.4 Evaluation of Alternatives for Pond G 5-6
5.4.1 Alternative G1: No Action 5-6
5.5 Cost Estimates 5-7
5.5.1 Addition of Erosion Control 5-7
5.5.2 Addition of a Sprinkler System 5-7

6 RECOMMENDATION AND JUSTIFICATION OF THE CLOSURE ALTERNATIVES . . . 6-1

6.1 Recommended Alternative for Ponds A Through F 6-1
6.1.1 Technical 6-1
6.1.2 Environmental 6-1
6.1.3 Human Health 6-1
6.1.4 Institutional 6-1

TABLE OF CONTENTS (CONTINUED)

Page

6.1.5 Cost 6-1
6.1.6 Recommended Alternatives 6-2
6.2 Recommended Alternative for Pond G 6-2

7 REFERENCES 7-1

ATTACHMENT A: Conceptual Design Calculations
ATTACHMENT B: Cost Calculations

LIST OF FIGURES

Page

1-1 Comparison of RCRA Corrective Action and IRP Phases 1-5

2-1 Stratigraphic Fence Diagram 2-3

2-2 Groundwater Contour Map 2-5

4-1 Alternative AF2: Final Contours—Backfill to Top of Berms 4-5

4-2 Typical Cross Section—Alternative AF2: Backfill to Top of Berms 4-6

4-3 Alternative AF2: Final Contours—Restore to Natural Contours 4-7

4-4 Typical Cross Section—Alternative AF3: Restore to Natural Contours 4-8

LIST OF TABLES

1-1 Overview of Significant Project Activities 1-2

1-2 Comparison of Key CMS Components with Key CERCLA FS Components 1-6

2-1 Summary of Areas and Volumes for the Sewage Lagoons 2-2

5-1 Summary of Evaluation of Alternatives 5-3

5-2 Summary of Costs for Each Alternative 5-7

6-1 Comparison of Alternatives Against Evaluation Criteria 6-2

LIST OF ACRONYMS

µg/kg	micrograms/kilograms
ACLs	alternative concentration levels
AFB	Air Force Base
BCP	Base Comprehensive Plan
bgl	below ground level
BHC	hexachlorocyclohexane
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CMS	Corrective measures study
DDD	p,p'-Dichlorodiphenyl dichloroethane
DDE	p,p'-Dichlorodiphenyl dichloroethylene
DDT	p,p'-Dichlorodiphenyl trichloroethane
DERA	Defense Environmental Restoration Account
DOC	dissolved organic carbon
DoD	Department of Defense
EPA	Environmental Protection Agency
FFCA	Federal Facilities Compliance Agreement
FS	feasibility study
ft	feet
gal.	gallon(s)
HHSs	Human Health Standards
HWMUs	hazardous waste management units
in.	inch(es)
IRP	Installation Restoration Program
LTM	Long-term Monitoring
MCLs	maximum contaminant levels
mg/L	milligrams per liter
mg/kg	milligrams per kilograms
MSGP	Multi-Sector General Permit
NCP	National Contingency Plan
NM WQCC	New Mexico Water Quality Control Commission
NMED	New Mexico Environment Department
NPDES	National Pollutant Discharge Elimination System
PCBs	polychlorinated biphenyls
RCRA	Resource Conservation and Recovery Act
SMCLs	secondary maximum contaminant levels
TC	toxicity characteristic
TCLP	toxicity characteristic leaching procedure
TDS	total dissolved solids
TOC	total organic carbon
TSCA	Toxic Substances Control Act
USDA	United States Department of Agriculture

LIST OF ACRONYMS (CONTINUED)

USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UTL	upper tolerance limit
WWTP	wastewater treatment plant
yd^3	cubic yard(s)

Section 1
INTRODUCTION

This corrective measures study (CMS) has been prepared as a component of the *Sewage Lagoons Closure Plan* (Radian and Foster Wheeler, 1996c) for Holloman Air Force Base (AFB). It supports the closure plan by providing a more detailed explanation of how the closure alternative was selected and why it was chosen over other alternatives. This CMS describes the current conditions (Section 2), presents the closure objectives (Section 3), describes the screening of technologies and the development of alternatives for closure of the sewage lagoons (Section 4), evaluates the alternatives on the basis of standard evaluation criteria (Section 5), and recommends the most appropriate alternatives for closure (Section 6).

1.1 Regulatory Background

Until July 1996, Holloman AFB operated seven sewage lagoons (Ponds A through G) as part of a system to treat domestic and industrial wastewater. Table 1-1 presents an overview of significant regulatory activities for these sewage lagoons.

The U.S. Environmental Protection Agency (EPA) Region VI informed the Base in 1987 that the facility had lost interim status to operate its surface impoundments on 8 November 1985. Afterwards, EPA Region VI, Holloman AFB, and the New Mexico Environment Department (NMED) signed a Federal Facilities Compliance Agreement (FFCA) in December 1988. Through a series of meetings between EPA Region VI, NMED, and Holloman AFB during January 1991, it was agreed that the Base would pursue closure supported by a site-specific demonstration (i.e., a risk assessment).

The sewage lagoons are regulated under the Resource Conservation and Recovery Act (RCRA) as hazardous waste management units (HWMUs). The sewage lagoons are also included in the Installation Restoration Program (IRP), which follows the provisions under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Consequently, investigation and remediation activities at the sewage lagoons must comply with CERCLA as well as RCRA. To date, over $10 million have been spent characterizing the sewage lagoons and removing sludge contaminated with polychlorinated biphenyls (PCBs) from Ponds A and B.

1.2 Stakeholders Closure Meeting

A stakeholders closure meeting was held for the sewage lagoons on 3 April 1996. Representatives from EPA Region VI, NMED, Holloman AFB, the U.S. Fish and Wildlife Service (USFWS), and the Audubon Society participated in the meeting, the purpose of which was to discuss issues affecting the closure of the sewage lagoons. The intent was to incorporate the comments and discussions of the meeting into the CMS and the closure plan. The main items discussed at the meeting are summarized below. The incorporation of the input from the meeting is also described.

1.2.1 Items Discussed

The meeting participants generally agreed that the CMS should be streamlined to the extent possible and should focus on reasonable and realistic approaches to closure. It appeared to the participants that closure concentrations could be based on prior sampling at the sewage lagoons and on process knowledge.

Table 1-1
Overview of Significant Project Activities

Date of Activity	Activity Summary
8 November 1985	Interim status units lacking groundwater monitoring program certification lose authorization to operate as HWMUs, triggering closure.
1981-1988	Five nonroutine sampling events conducted. PCBs were contaminant of concern.
20 December 1988	EPA Region VI, NMED, and Holloman AFB sign FFCA to resolve all issues in second Notice of Noncompliance. Major requirements of FFCA were to: 1) develop closure method and have it approved, and 2) develop a groundwater monitoring system and install it.
8 March 1990	Removal of 1316 tons of PCB-contaminated sludge from Pond B completed. Sludge and soil sampled at Pond C.
19 July 1990	Removal of 2588 tons of PCB-contaminated sludge from Pond A completed.
8 May 1991	NMED informed Holloman AFB that closure may be delayed in accordance with new regulations adopted by the state on 13 March 1991.
December 1993	Submitted Draft Risk Assessment for Sewage Lagoons and Lakes, Phase I Groundwater Assessment Monitoring and Phase 2 RFI for Lakes Holloman and Stinky to NMED.
January 1994	Submitted Conceptual Plan for Additional Sampling of Sewage Lagoons and Lakes to NMED.
October 1994	Performed additional sampling of sewage lagoons and lakes.
May 1995	Submitted Closure Plan to NMED.
June 1995	Submitted Site Characterization Report to NMED.
March 1996	Submitted Risk Assessment Addendum to NMED.
June 1996	Submitted CMS and Updated Closure Plan to NMED.
November 1996	Submitted Updated CMS and Closure Plan Revisions to NMED.

FFCA = Federal Facilities Compliance Agreement.
HWMUs = Hazardous waste management units.
NMED = New Mexico Environment Department
PCBs = Polychlorinated biphenyls.

The Base explained that the land use for Ponds A through F is currently industrial, but will be classified as restricted open space after closure because the land is in the runway clear zone. The land use for Pond G is, and will remain, restricted open space. Pond G is an impounded playa lake and, therefore, it is considered Waters of the United States. Also, the lands surrounding Pond G are either jurisdictional wetlands or are in a floodplain.

During the meeting, the participants discussed the possibility that the sewage lagoons could be closed through a risk-based closure.

The alternative for Ponds A through F discussed at the meeting involves installing a soil cover over the dewatered sludge in the sewage lagoons. There are currently no unacceptable risks associated with the sludge; the addition of a soil cover would further reduce currently acceptable risks and add further protection by controlling disease vectors. It was generally agreed that if sufficient soil cover was placed over the sludge, all exposure pathways would be eliminated, and the alternative would meet residential risk levels.

The group discussed the reasons that Pond G should remain open as a habitat for wildlife. The USFWS and the Audubon Society have requested that Holloman AFB continue to supply water to Pond G to maintain the habitat. The environmental assessment for the construction of the new Holloman AFB wastewater treatment plant (WWTP) documents the importance of keeping Pond G open for wildlife habitat (USAF, 1995). Pond G is an impounded playa lake which is Waters of the United States and is associated with jurisdictional wetlands in the area. It was suggested that Pond G should be addressed separately in the discussion of closure alternatives.

Closure objectives and closure criteria were also discussed during the meeting. The closure objectives and closure criteria for the sewage lagoons are presented in Section 3.

1.2.2 Incorporation of Discussion Items into the CMS

The input and comments from the stakeholders closure meeting have been incorporated into this CMS. The risk-based approach to closure is discussed in Section 1.3. As suggested in the 3 April meeting, the CMS process has been streamlined by including only the relevant information. In addition, the closure objectives and closure criteria presented and discussed during the meeting have been incorporated into the CMS without substantive changes. These objectives and criteria follow the RCRA corrective action methodology because the CMS includes an evaluation of closure alternatives.

To focus the CMS, response actions and technologies are screened in Section 4 so that only the practical alternatives for closure are evaluated in Sections 5 and 6. Also, the closure of Pond G is discussed separately from the closure of Ponds A through F in Sections 4 through 6.

1.3 Approach to Closure

The sewage lagoons will be closed in accordance with the closure performance standards for HWMUs listed in 40 CFR Part 265 and the FFCA. Extensive investigations have determined the nature and extent of contamination, and a baseline risk assessment has been performed. These results will be used to demonstrate how the selected closure action will meet the intent of the standards listed in 40 CFR Part 265.

The closure requirements of 40 CFR Sections 265.111 and 265.228 overlap the closure criteria discussed at the stakeholders closure meeting. These are also the waste management standards placed on Holloman AFB by reference in

the FFCA. To meet these requirements for closure, the closure action should accomplish the following:

- Minimize the need for further maintenance;
- Control, minimize, or eliminate, to the extent necessary to protect human health and the environment, postclosure releases to the environment; and
- Remove or decontaminate all wastes.

However, as generally agreed in the stakeholders closure meeting, a risk-based approach to closure is appropriate for the sewage lagoons. Therefore, it will not be necessary for the closure action to meet the third criterion if the sludge in the sewage lagoons does not pose an unacceptable risk and/or the exposure pathways to potential risk are eliminated.

1.4 Purpose of CMS

The objective of this CMS report is to identify, develop, and screen alternatives for closure of the sewage lagoons. The closure of the lagoons is funded by the Defense Environmental Restoration Account (DERA), which is the Department of Defense (DoD) implementation for the "Superfund," and is administered by the IRP. As such, the closure process must meet the requirements of CERCLA and the National Contingency Plan (NCP), under which a feasibility study (FS) is normally conducted to examine alternatives. However, because the sewage lagoons are RCRA-regulated facilities, Holloman AFB will use the equivalent RCRA terminology.

Both the RCRA and IRP programs are ultimately intended to ensure the remediation of contaminated sites that pose an actual or potential threat to human health or the environment. Both programs are implemented through phased approaches to identify, investigate, and remediate sites. A comparison of the phases is presented in Figure 1-1.

The purpose of a CMS and an FS is essentially the same: to identify and develop alternatives for closure or remedial action, to evaluate the alternatives against specified criteria, and to justify and recommend specific alternatives on the basis of the accepted criteria. CMS requirements are based on the *RCRA Corrective Action Plan* (EPA, 1988b); FS requirements are based on the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, 1988a). The format for this document will be consistent with the RCRA CMS requirements, and only RCRA terminology will be used in the document. Table 1-2 provides a cross-reference of applicable FS requirements with sections in the CMS report.

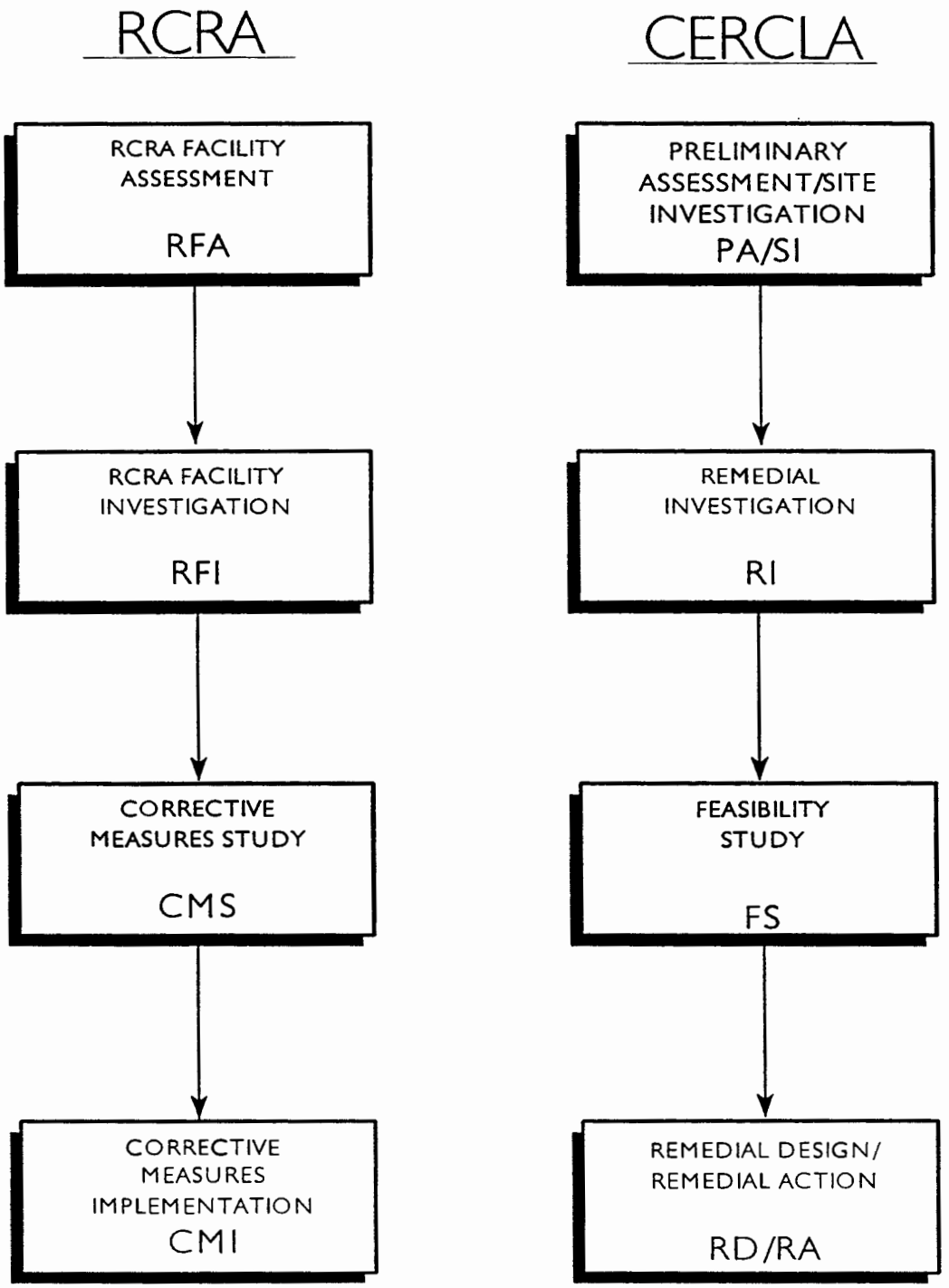


Figure 1-1. Comparison of RCRA Corrective Action and IRP Phases

Table 1-2
Comparison of Key CMS Components with Key CERCLA FS Components

RCRA CMS	CERCLA FS
Description of Current Conditions	Summary of Remedial Investigation
Closure Objectives	Remedial Action Objectives
Screening of Corrective Measures Technologies	Identification and Screening of Technologies
Development of Corrective Measures Alternatives	Development of Remedial Alternatives
Evaluation of Corrective Measures Alternatives • Technical • Environmental • Human Health • Institutional • Cost	Detailed Evaluation of Alternatives • Overall Protection of Human Health and the Environment • Compliance with Applicable or Relevant and Appropriate Requirements (ARARs) • Long-Term Effectiveness/Permanence • Reduction of Toxicity, Mobility, and Volume; Implementability • Short-Term Effectiveness • Cost
Justification and Recommendation of the Corrective Measures	Comparative Analysis and Selection of Preferred Remedial Alternative

Section 2
DESCRIPTION OF CURRENT CONDITIONS

Holloman AFB is situated in south-central New Mexico in the northwest-central portion of Otero County. The Base is located about 75 miles northeast of El Paso, Texas, and about 7 miles west of Alamogordo, New Mexico. The sewage lagoons are located in the southwestern corner of the Base.

The sewage lagoon system consisted of seven aeration/evaporation lagoons. The first three sewage lagoons, Ponds A, B, and C, were aerated. Ponds A and B were generally operated in parallel; occasionally they were operated in sequence to increase residence time. Afterward, the wastewater flowed in series from Pond C through Ponds D, E, and G. Pond F is a sump that recirculated wastewater from Pond E back to the headworks of the system. Discharge from the last sewage lagoon (Pond G) flowed via an open ditch to Lake Holloman.

2.1 Areas and Volumes of the Sewage Lagoons and Sludge Depths

The *Site Characterization Report, Sewage Lagoons Closure Project* (Radian and Foster Wheeler, 1995) summarizes the results of the investigations performed at the Holloman AFB sewage lagoons between 1990 and 1994. Table 2-1 summarizes the estimates of lagoon size and thickness of sludge according to that report. The maximum thickness of the sludge in the sewage lagoons ranges from about 6 in. in Pond F to about 48 in. in Pond E. The total estimated volume of sludge in Ponds A through F is 52,800 yd^3. The sludge, which is primarily the result of domestic wastewater, has a high (55% to 75%) moisture content. When the system was in operation, typical surface water elevations (as compared with mean sea level) ranged from 4037.5 ft in Ponds A and B to 4036.5 ft in Pond E to 4029.9 ft in Pond G.

2.2 Topography

The topography in the region of the southwest portion of Holloman AFB is dominated by the dikes surrounding and dividing the sewage lagoons. In this region, the surface is relatively flat and naturally slopes toward the southwest at less than 0.5% grade. Natural and engineered surface water drainage features circumvent the lagoons and flow directly into Lake Holloman. The main base (developed portion) storm water channel is several feet below grade and runs from northeast to southwest, separating Pond G from Ponds A through F.

The rise of the lagoon dikes over the natural surface features ranges from approximately 1.5 ft on the north end of Ponds A and B to over 10 ft above natural grade on the south end of Pond D.

2.3 Geology and Soils

The soils are either Holloman-Gypsum Land-Yesum, Complex, or Mead silty clay loam soil. The Mead silty clay loam is found in low-lying areas, is less permeable, and sometimes is associated with wetlands, as described in *Soil Survey of Otero County, New Mexico* (USDA Soil Conservation Service, 1981). The surface soils grade into the upper sand unit, which consists of 6 to 40 ft of sand, silt, or silty sand. Clay lenses are common in the upper sand unit. A discontinuous middle clay unit underlies the upper sand. The middle clay is reddish brown with abundant gypsum crystals and ranges from 10 to 40 ft thick where present. A lower sand unit consisting of interbedded sand, clay, and silt lies beneath the middle clay. This unit is lithologically heterogeneous and ranges from 10 to 20 ft thick.

Table 2-1
Summary of Areas and Volumes for the Sewage Lagoons

Sewage Lagoon	Area (acres)	Average Sludge Thickness (ft)	Average Moisture Content of Sludge (%)	Average Water Depth (ft)	Sludge Volume (yd^3)	Total Lagoon Volume (yd^3)
Pond A	10	0.5	70	6.0	8,000	89,000
Pond B	11	0.78	70	6.5	13,800	102,000
Pond C	12	0.88	75	5.4	17,000	88,000
Pond D	18	0.16	70	5.4	4,500	152,000
Pond E	8	0.72	60	4.9	9,200	54,000
Pond F	0.5	0.37	60	5.0	300	3,700
Pond G	39.8	0.38	55	3.4	27,000	219,400

The subsurface conditions at the sewage lagoons were defined by direct sampling and observation of the drilling operations of soil and/or monitor well borings drilled between 1987 and 1993.

The sediments consist of sand, silt, and clay, and are subdivided into six very broadly definable units that appear to be continuous across the site. This interpretation is supported by available data; however, irregularities exist on a smaller scale because of the discontinuous nature of alluvial and lacustrine deposits. Figure 2-1 presents a stratigraphic fence diagram of the sewage lagoons and lakes area.

2.4 Surface Water Hydrology

Holloman AFB is located in the Tularosa Basin, which is a closed basin with no surface water drainage. Lake Lucero, the lowest point in the basin, located approximately 20 miles southwest of Holloman AFB, does not receive surface water from the east side of the Tularosa basin, where Holloman AFB is located.

The Base is crossed by several southwest-trending arroyos that control surface drainage in the undeveloped part of the Base. The arroyos mostly terminate in the gypsum dune fields located in the western portion of the Base.

Most drainage from the main Base (developed portion) runs off through a drainage ditch that bypasses the sewage lagoons and flows to Lake Holloman. The ditch flows most of the year to Lake Holloman. Limited overlap will occur between the wetlands and the ditch.

Lake Holloman and Pond G are impounded playa lakes and are considered Waters of the United States as defined in 40 CFR 122.2. Holloman AFB has submitted a National Pollutant Discharge Elimination System (NPDES) permit application for the new WWTP which will cover the discharge of treated wastewater to Lake Holloman as well as Pond G.

2.5 Regional Groundwater Hydrology

Groundwater occurs in unconfined conditions in the uppermost unconsolidated bolson deposits beneath Holloman AFB. The primary source of recharge for groundwater in the bolson aquifer is percolation of rainfall and stream runoff through the coarse, unconsolidated alluvial fan deposits located near the base of the mountains approximately 10 miles upgradient (east) of

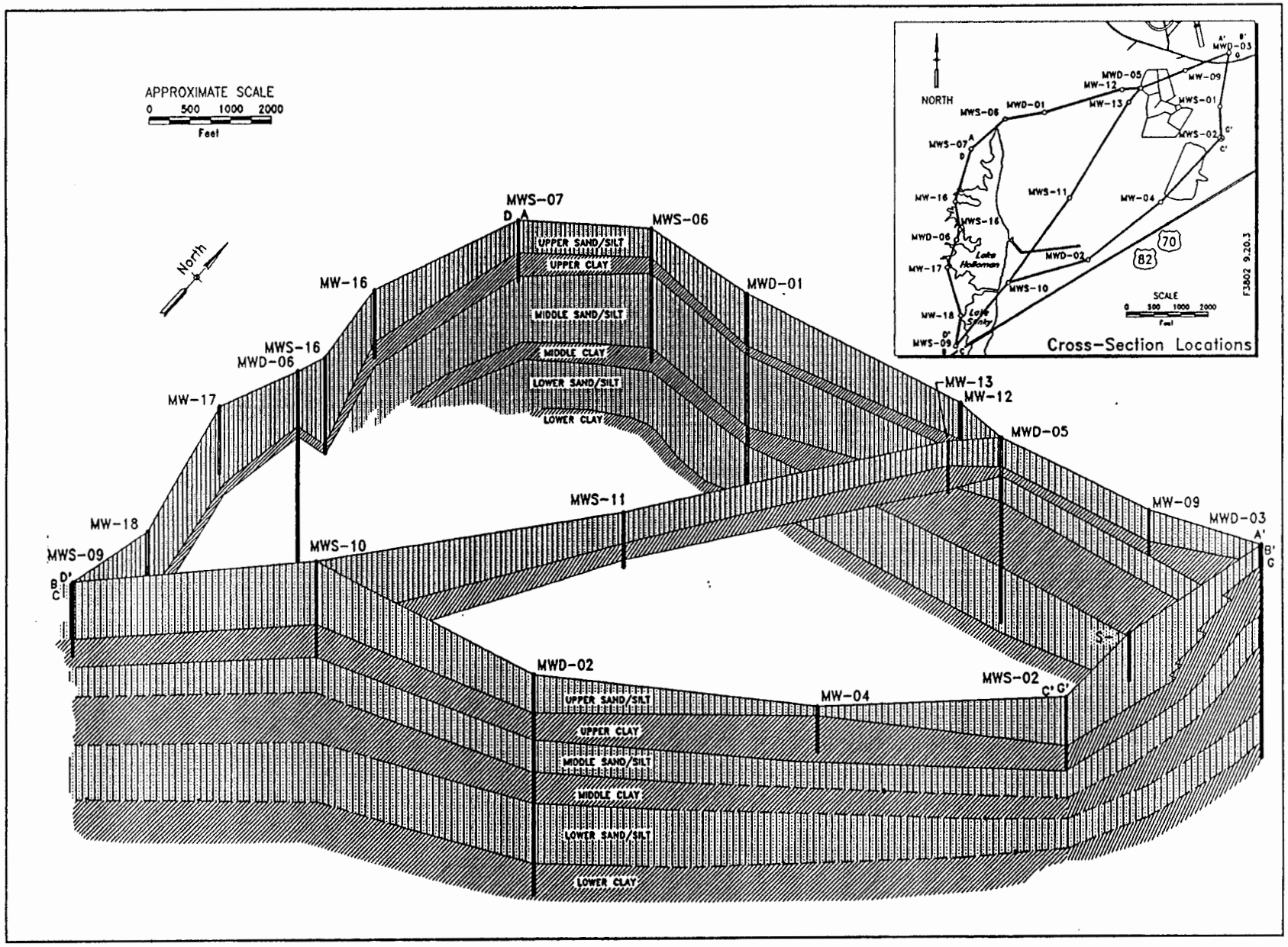


Figure 2-1. Stratigraphic Fence Diagram

Holloman AFB. Groundwater discharge occurs through evapotranspiration or into closed playa lakes such as Lake Lucero, the regional groundwater discharge area.

Regional groundwater flow is to the southwest. Local groundwater flow is seasonally variable and is affected by the relationship between the water table elevation and the elevation of the bottom of the local arroyo channels. In the southeastern portion of the Base, regional groundwater flows to the southwest, following the Dillard Draw surficial drainage system. In the northern portion of the Base, groundwater flows to the west, following the Rita Draw, Malone Draw, and Lost River drainages.

2.6 Local Groundwater Hydrology

The groundwater elevation at the sewage lagoons was surveyed in 1993, 1994, 1995, and 1996 to determine seasonal yearly variation associated with precipitation and evaporation rates at Holloman AFB. As part of that survey, surface water elevations were measured in Ponds A, D, and G and in Lakes Holloman and Stinky to provide data necessary to characterize local relationships between surface water and groundwater. It should be noted that the sewage lagoons created artificial groundwater mounding that is expected to recede after closure. Results of this evaluation are presented in the *Phase I Groundwater Assessment Monitoring Report, Sewage Lagoons and Lakes Investigation* (Radian, 1993). A groundwater contour map is presented in Figure 2-2.

Near the wastewater treatment facility, the depth to groundwater ranges from 2 ft below ground level (bgl) near the sewage lagoons to 13 ft bgl near Lakes Holloman and Stinky. Under an average hydraulic gradient of 0.3, the groundwater flows consistently from the northeast to the southwest. However, surface water in the unlined lakes and lagoons causes groundwater mounding. Immediately to the east of Lakes Holloman and Stinky, groundwater flows to the southeast if the elevation of Lake Holloman surface water is higher than the water table, which occurs most of the time.

According to the *Final Hydrogeologic Investigation Report and Proposed Groundwater Monitoring Plan for the Sewage Treatment Lagoons—Volume 1, Holloman AFB* (Radian, 1989), the geometry of the sediments beneath the sewage lagoons and Lakes Holloman and Stinky is such that no definable lower aquifer boundaries exist.

Several trends in the aquifer in the region at the lagoons were noted from the results of slug tests and pump tests conducted in 1987:

- With increased depth, successive clay and silt units create semiconfining conditions as discussed in the *Long-term Monitoring Plan for the Sewage Lagoons* (Radian, 1995); and
- No evidence of artesian conditions exist in the aquifers below the lagoons.

2.7 Groundwater Quality

Groundwater directly upgradient of the Base (approximately 10 miles) at the recharge zone at the foot of LaLuz canyon is slightly saline, with total dissolved solids (TDS) ranging from 1000 to 3000 mg/L. Groundwater becomes progressively more mineralized as it flows downgradient toward the interior of the basin. This decrease in water quality can be attributed to slow groundwater migration from recharge to discharge areas and the presence of readily soluble minerals in the bolson sediments. TDS exceed 100,000 mg/L in groundwater in some portions of the Tularosa Basin (USGS, 1986).

The groundwater beneath Holloman AFB is designated as unfit for human consumption, based on New Mexico Water Quality Control Commission Regulations (NM WQCC 82-1, as

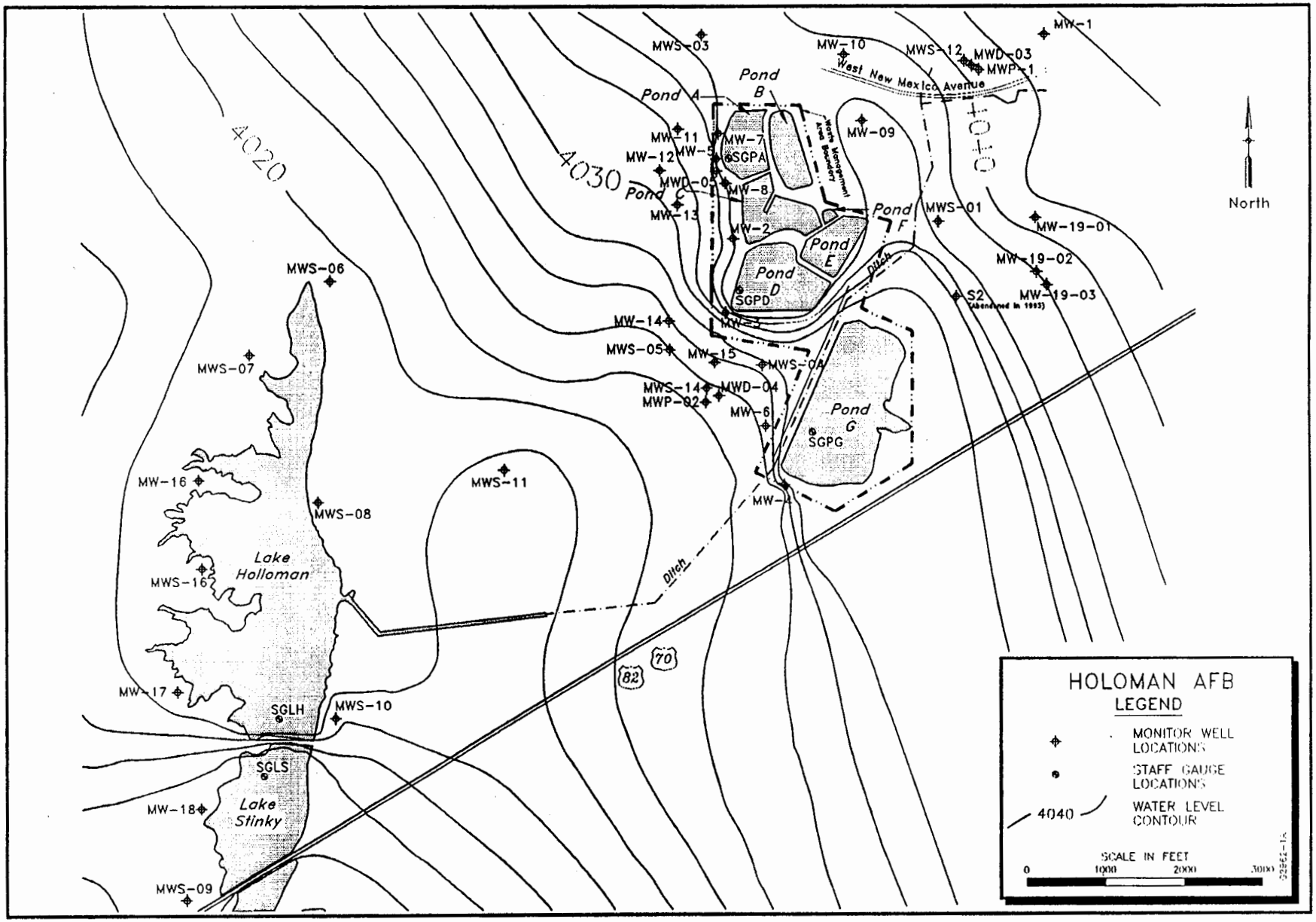


Figure 2-2. Groundwater Contour Map

amended through August 18, 1991 Parts 3-100 through 3-103), because it exceeds New Mexico Human Health Standards (HHSs) for TDS and sulfate. Average values of other groundwater quality parameters measured at Holloman AFB (chloride, fluoride, and nitrate-nitrite) also exceed HHSs and, except for fluoride, also exceed federal primary and secondary drinking water maximum contaminant levels (MCLs; SMCLs). Water quality parameters reflect the fact that the groundwater in this area is not potable under natural conditions.

Although EPA guidelines for groundwater classification (*Guidelines for Groundwater Classification Under the EPA Groundwater Protection Strategy* [EPA, 1986]) are not recognized by the State of New Mexico, the EPA guidelines classify the groundwater beneath Holloman AFB as a Class III B aquifer. Class III groundwater, characterized by having a TDS concentration greater than 10,000 mg/L, is not considered a source or a potential source of drinking water. Class III B groundwater is characterized by a low degree of interconnection to adjacent surface waters or groundwater of a higher class. The average measured TDS value of groundwater at Holloman AFB is greater than 10,000 mg/L, as reported in the *Site Characterization Report, Sewage Lagoons Investigation* (Radian, 1992). Because the Tularosa Basin is a closed basin, its groundwater does not discharge or connect to any adjacent aquifers. Adjacent surface waters include groundwater surfacing in Malone Draw and Lakes Holloman and Stinky. The TDS concentration in Lake Holloman ranges from a winter low of 12,400 mg/L to a summer high of 17,000 mg/L (Cole et al., 1981); therefore, groundwater at Holloman AFB is not interconnected with surface water of a higher class. In the 1993 investigation, TDS concentrations were found to range from 11,000 to 12,000 mg/L in Lake Holloman and were 14,000 mg/L in Lake Stinky.

2.8 Nature and Extent of Release

The historical data summarized in this section are sufficient to demonstrate that the contaminants associated with the sewage lagoons are relatively immobile and are decreasing in concentration. As explained in the *Site Characterization Report, Sewage Lagoons Closure Project* (Radian and Foster Wheeler, 1995), and summarized later in this section, the concentrations of DDT and its derivatives have decreased by approximately one order of magnitude between 1992 and 1994, and are anticipated to continue to decrease. Because the Base has also demonstrated that hazardous constituents have not entered the lagoons since the 1980s, additional sampling is not needed to determine whether or not additional constituents have entered the sewage lagoons since the most recent investigation. Therefore, closure will be based on the results of the previous investigation, and no future investigation or monitoring of the site will be necessary after closure.

2.8.1 Sludge

Sludge samples were collected from the sewage lagoons in 1990 and 1992-1995. Summaries of the analytical results of these investigations are contained in Section 5 of the *Site Characterization Report, Sewage Lagoons Closure Project,* (Radian and Foster Wheeler, 1995). Because of the apparent differences in the character of the sludge contained in Ponds A and B compared with that contained in Ponds C through G, the overall conclusions for these sewage lagoons are discussed separately.

Ponds A and B

Sludge from Ponds A and B has been investigated primarily for PCBs. Sludge found to have PCB concentrations above the Toxic Substances Control Act (TSCA) action level of 25 mg/kg in Ponds A and B during the 1988 investigation was removed in 1990. Subsequent to the sludge removal, confirmation sampling was

performed in 1990 to determine the effectiveness of the removal. The confirmation sampling, along with the 1994 investigation of Ponds A and B, confirmed that sludge PCB concentrations were below the TSCA action level. These investigations also indicated that metal concentrations in the sludge are below the toxicity characteristic (TC) regulatory levels and that the sludge is not characteristically hazardous due to reactivity (i.e., it contains less than 500 mg/kg of reactive sulfides). In addition, metals concentrations are below pollutant concentrations for land-applied sludge in 40 CFR Part 503.13.

Ponds C, D, E, F, and G

Sludge in Ponds C, D, E, F, and G was investigated in 1990 (Pond C only), 1992, and 1994. The sludge was analyzed for Appendix IX constituents in 1990 and 1992. These investigations indicated that organochlorine pesticides and metals were the primary constituents in the sludge. Therefore, the 1994 investigation focused on these constituents.

The only organochlorine pesticides that have been detected above their reporting limits in all of the investigations are 4,4'-DDD and 4,4'-DDE. The concentrations of 4,4'-DDD and 4,4'-DDE, as well as the other constituents that were sporadically detected, have decreased over time.

The investigations also show that 4,4'-DDT, gamma-chlordane, and delta-BHC were detected in the sludge during one or more sampling events. However, these constituents were not detected in all of the investigations, and also appear to have decreased over time. Generally, concentrations of 4,4'-DDT have decreased from concentrations of approximately 100 µg/kg in 1992 to approximately 10 µg/kg in 1994. Concentrations of gamma-chlordane have decreased to either nondetect or to below the reporting limit.

These reductions in 4,4'-DDT, 4,4'-DDD, and 4,4'-DDE can be explained as occurring by both biological and physical phenomena. Biologically, 4,4-DDT can be reduced to 4,4'-DDD and eventually to 4,4'-DDE by anaerobic bacteria as described in *Microbial Ecology* (Atlas and Bartha, 1987). Bacteria use the energy associated with the contaminant's chemical bonds for growth and reproduction. Physically, dechlorination of 4,4'-DDE may result through photolysis as described in *Abiotic Transformations in Water, Sediments, and Soil* (Wolfe, Mingelgrin, and Miller, 1990). Also, the sludge that has been deposited since the 1980s has not contained these constituents, because the Base has taken actions to prevent the discharge of chemicals into the wastewater system.

The 1994 investigation showed that the toxicity characteristic leaching procedure (TCLP) concentrations for all metals were well below the TC regulatory levels. Therefore the sludge is not considered TC hazardous. The 1994 investigation also indicated that the Pond C sludge is not characteristically hazardous due to reactivity. The maximum potential TCLP concentrations for samples from Ponds D, E, and G were calculated by dividing the total concentrations by 20 and comparing the value with TC regulatory levels, as per guidance in Method 1311 TCLP (40 CFR Part 261, Appendix II). Using this approach, referred to as the "20 times rule," it was determined that Ponds D, E, and G do not contain metal constituents in concentrations that could potentially exceed the TC regulatory levels. Therefore, no samples from these sewage lagoons were analyzed for TCLP because the sludge does not have the potential to be TC hazardous. In addition, metals concentrations are below the pollutant concentrations for land-applied sludge, as defined in 40 CFR Part 503.13, which indicate that the metals would not cause an unacceptable risk even if the sludge was spread on the land surface.

Sludge samples collected in 1994 from Ponds C and G were analyzed for kepone because a previous investigation indicated that it may be

present in the sewage lagoons. Eight samples from Pond C and 12 samples from Pond G were analyzed for kepone. Only one sample from each of the two sewage lagoons contained a detectable concentration of kepone. However, the results were below the 70-μg/kg reporting limit.

2.8.2 Soil

Soil samples were collected from Ponds A, B, and C in 1990, and from Ponds C, D, E, F, and G in 1992. Similar to those found in the sludge, the constituents found in the soil were generally limited to organochlorine pesticides and metals. However, the concentrations in soil were significantly lower than those in sludge. 4,4'-DDD and 4,4'-DDE were detected in Ponds C, D, E, F, and G but not in Ponds A and B. Other organochlorine pesticides detected in the soil include 4,4'-DDT, gamma-chlordane, beta-BHC, gamma-BHC, delta-BHC, aldrin, endosulfan sulfate, endosulfan II, and heptachlor epoxide, but many of these constituents were detected below their reporting limits during one or more investigations. The concentrations of these constituents are typically at least one order of magnitude lower in the soil than in the sludge.

A comparison of the results of inorganic analyses for soil samples indicates that several of the metals were detected at concentrations above the 1993 background upper tolerance limit (UTL). However, calculations of the maximum possible TCLP concentrations, according to the "20 times rule," indicate that none of the metals exceed TC regulatory levels.

2.8.3 Surface Water

Surface water samples were collected from the sewage lagoons in 1990, 1993, and 1994 (Pond B in 1990 only). Summaries of the analytical results of these investigations are presented in Section 5 of the *Site Characterization Report, Sewage Lagoons Closure Project* (Radian and Foster Wheeler, 1995). The results of the 1990 and 1993 investigations indicated that metals were the primary constituents of concern in the surface water and organochlorine pesticides existed in parts per trillion range. The 1990 investigation also found unconfirmed concentrations of organic lead; concentrations of organic lead exceeded those for total lead, and similar concentrations were detected in the equipment rinsate samples. In the 1994 investigation, organic lead was not detected even though a methodology with a lower detection limit was used, which indicates that the 1990 results for organic lead were not reliable. All constituents above reporting limits in the surface water are below MCLs.

2.8.4 Groundwater

A groundwater detection monitoring system was installed as part of the FFCA requirement and for the RCRA compliance. Background concentrations were developed on an accelerated schedule and collected during August, September, November, and December 1989. Semiannual monitoring sampling continued in January and July 1990 (a resample was also collected in September 1990), and January 1991. Detection monitoring indicated a potential release of TOC downgradient of Ponds A and B. Therefore, assessment monitoring was required.

As part of assessment monitoring, samples were collected in September 1991 from the monitor well network and analyzed for Appendix IX organic constituents and total organic carbon (TOC). Results of this sampling indicated the presence of primarily organochlorine pesticides. TOC and dissolved organic carbon (DOC) were also detected in several samples. Results showed no strong correlation between the presence of TOC/DOC and waste-specific organic contaminants. TOC can reasonably be present as a result of biological activity (e.g., decomposing organic matter) occurring in the domestic wastewater treatment system.

Subsequent discussion of the Appendix IX sampling results with NMED concluded that

organochlorine pesticides were the only contaminants of concern, and that confirmation sampling should be conducted to confirm the presence of these constituents in the groundwater. The confirmation sampling was conducted in February 1992 for SW-846 Method 8080 compounds. Results of the confirmation sampling indicated that two organochlorine pesticides, alpha-BHC and delta-BHC, are present in the groundwater in monitor wells MW-5 and MW-7 respectively. Therefore, an investigation of the extent was required downgradient of MW-5, MW-7, and MW-03. Analytical results are presented in *Results of Confirmation Sampling and Comparison to Appendix IX Sampling, Assessment Monitoring Program*, (Radian, 1992a).

The extent of contamination was defined in the subsequent investigation and results are documented in the *Groundwater Assessment Monitoring Report* (Radian, 1993). Holloman has subsequently initiated a long-term monitoring program for the lagoons. The *Long-term Monitoring Plan* (Radian, 1995) (LTM Plan) and *Long-term Monitoring Report* (Radian, 1996) document the plan and the results, respectively. All concentrations are below health-based levels presented in the LTM Plan.

2.9 Risk Assessment Results

A risk assessment for each sewage lagoon was prepared in 1993 (Radian, 1993) on the basis of existing data. Biological tissue samples were collected in 1993; however, these samples were not available at the time the 1993 risk assessment was prepared. Because several uncertainties existed in the analytical data that were used to estimate risks in the 1993 risk assessment, an additional investigation was conducted at the sewage lagoons in 1994. The risk assessment was updated in a March 1996 addendum using the results of the 1994 investigation, the biota data, and the supportable data from previous investigations.

The exposure scenarios evaluated in the risk assessment addendum for the sewage lagoons included the following:

1) Current on-site worker (chronic and subchronic) for Ponds A through G;

2) Current/Future recreational—Hunters (chronic and subchronic) for Pond G only; and

3) Current/Future Trespasser—Teenager (subchronic) for Pond G only.

2.9.1 Human Health Site-Specific Risk Assessments

The EPA Superfund site remediation goal set forth in the National Contingency Plan established cancer risks of 10^{-4} to 10^{-6} as acceptable levels for known or suspected carcinogens. This range is designed to protect human health. For noncarcinogens, there may be potential for noncancer effects when the hazard index exceeds 1.

Cancer risk estimates for the lagoons are below or well within the acceptable risk range of 10^{-4} to 10^{-6} established by the EPA. The estimated noncancer hazard index at all sites and for all exposure scenarios is less than 1. It should be noted that arsenic concentrations in the soil beneath the sewage lagoons are within the background range expected, and are below the UTL of 6.88 mg/kg for arsenic in soil at Holloman AFB. However, even the background concentration of arsenic at Holloman AFB has the potential to cause some risk for a residential scenario.

exposure pathways could be controlled by covering the sludge in the sewage lagoons with a minimum 12 in. soil cover. Because the land use in that area is restricted by its location in the runway clear zone, and because the sludge would not provide sufficient structural stability, no residences will be constructed in the area.

2.9.2 Ecological Risk Assessment

Ponds A through F were not evaluated in the ecological risk assessment because they will be closed and will not serve as a habitat for aquatic wildlife. Pond G was the only sewage lagoon included in the ecological risk assessment because it is an important wildlife habitat that the stakeholders have suggested should remain open.

DDT and its derivative, DDE, were the only constituents found to have the potential to cause adverse effects in Pond G. These constituents are no longer used at the Base. Furthermore, the concentrations of DDT in the sewage lagoons decreased by an order of magnitude between 1992 and 1994, as is documented in the *Site Characterization Report* (Radian and Foster Wheeler, 1995). It is unlikely that the survivorship and productivity of the aquatic food chains are threatened. For instance, it has been determined that DDT concentrations detected in the tissue of waterfowl from Pond G are unlikely to cause concentrations in eggs that would be detrimental to reproductive success (Foster Wheeler, 1996).

Because only slight ecological risks were indicated in the risk assessment for Pond G, and because Pond G is an important wildlife habitat, there does not appear to be a need to conduct closure activities at this lagoon. Furthermore, the results of the *Biological Resources Report* (Radian and Foster Wheeler, 1996a), which was prepared to assess the effects of closing the sewage lagoons to selected threatened or endangered animal and plant species, indicate that activities such as sludge removal would be disruptive to the wildlife that use Pond G as habitat.

Section 3
CLOSURE OBJECTIVES AND CLOSURE CRITERIA

The closure objectives focus on preventing exposure to the sludge in the sewage lagoons. As discussed in the stakeholders closure meeting, the closure of Ponds A through F will be considered and evaluated separately from Pond G, because Pond G is an important wildlife habitat and the stakeholders are interested in keeping it open. As described in the *Long-term Monitoring Plan* (Radian, 1995) and discussed in Section 2, groundwater contamination is not a problem. Furthermore, the groundwater at Holloman AFB is designated as unfit for human consumption, based on the NM WQCC regulations, because it exceeds New Mexico HHSs for TDS and sulfate. Restoration of groundwater is not considered necessary or a closure objective.

3.1 Closure Objectives

The closure objectives for the sewage lagoons include the following:

- Ensure the protection of human health and the environment at the sewage lagoons after closure;
- Provide an adequate habitat for the wildlife associated with the sewage lagoons; and
- Ensure that closure eliminates disease vectors (e.g., mosquito habitats) and odors that may be associated with the sewage lagoons and that the closure is aesthetically suitable.

3.2 Closure Criteria

The closure criteria for the sewage lagoons include the following:

- Protect human health and the environment;
- Control or eliminate the source of contamination;
- Comply with applicable waste management standards; and
- Prevent human exposure to constituents in soil and/or sludge that would lead to an unacceptable risk for a exposure scenario.

These criteria follow the RCRA corrective action methodology. The results of the *Risk Assessment Addendum* (Radian and Foster Wheeler, 1996b), which are discussed in Section 2.9, support the closure of the sewage lagoons under these criteria.

3.3 Discussion of Potentially Relevant Requirements

This section provides a brief overview of the federal and state requirements and guidance documents that may apply to the closure of the Holloman AFB sewage lagoons. Each regulation and guidance document cited below is discussed individually as it may apply to the lagoons. A description of the overall approach to closure incorporating all of these regulations is presented in Section 1.3.

3.3.1 FFCA

Holloman entered into a FFCA with EPA and NMED on 20 December 1988. Violation Number 10 listed on this FFCA is "Failing to submit for approval an adequate closure plan for hazardous waste surface water impoundments," referring to the lagoons. This is the only open violation remaining in the FFCA. To comply with the FFCA, Holloman AFB must certify the completion of closure of the lagoons with NMED.

3.3.2 RCRA

The sewage lagoons are regulated as RCRA HWMUs. The classification as a HWMU is based on the contention by EPA Region VI and NMED that the sewage lagoons allegedly received

listed hazardous wastes after the applicable date of the substantive RCRA rules (19 November 1981). Because of this classification, the closure of the sewage lagoons falls under regulation 40 CFR Part 265. A 6 April 1994 letter from NMED initially indicated that 40 CFR Part 264 should be applied, but NMED clarified during the stakeholders closure meeting in April 1996, that closure is regulated under Part 265.

3.3.3 CERCLA

The CERCLA requirements apply to the sewage lagoons at Holloman AFB because they are identified by the Air Force as an IRP site. The IRP was established to investigate potential former waste sites at DoD installations and to comply with the provisions of CERCLA. Consequently, all of the activities for investigation and remediation of the lagoons must be consistent with the provisions of CERCLA and the NCP.

The lagoons are currently at the RCRA corrective action equivalent of the FS stage of the CERCLA process, having met all recommended milestones up to this point. Holloman AFB is submitting this CMS to satisfy the FS portion of CERCLA guidance which, as stated previously, is compatible with RCRA corrective action guidance.

3.3.4 State of New Mexico Hazardous Waste Regulations

Title 20 Chapter 4 Part 1 of New Mexico's state regulations adopts federal regulations as promulgated in 40 CFR Parts 261 through 281 with few exceptions noted. Therefore, complying with the federal regulations for hazardous waste will meet the requirements of the State of New Mexico.

3.3.5 State and Federal Water Quality Regulations

The discharge to Pond G—the only sewage lagoon that will remain open—will be regulated under the NPDES permit for the new WWTP, which will be in operation by the fall of 1996. Surface water quality for the entire sewage lagoons area will be regulated under the Basewide NPDES storm water permit. In the 29 September 1995 *Federal Register*, the EPA released the final Multi-Sector General Permit (MSGP) for Industrial Activities. The permit lists industry-specific requirements for effluent limitations, storm water pollution prevention plans, and monitoring requirements. Holloman AFB will implement the requirements listed in the MSGP Sector L (Landfills and Land Application Sites) as part of their storm water NPDES compliance activities. (*Federal Register*, September 29, 1995, Volume 60, No. 189, Book 2, Section VIII.L)

3.3.6 Human Health Standards

Any remediation-related activities conducted at the sewage lagoons would require compliance with the requirements in 29 CFR Section 1910.120. These regulations require that personnel receive appropriate training for working at sites where there is the potential for hazardous materials or conditions to be present. These regulations also require the use of personal protective equipment to prevent exposure to hazardous materials.

3.3.7 Wetlands

Ponds A through F are constructed facilities that are not Waters of the United States. Pond G is considered Waters of the United States, but it is currently exempt from Section 404 of the Clean Water Act because it is part of the existing wastewater treatment system. Pond G will be a receiving water for the new WWTP after closure is complete. The discharge from the new WWTP will be required to be an NPDES-permitted outfall for the new WWTP. Any dredging or backfilling would require a Clean Water Act Section 404 permit.

Section 4
TECHNOLOGY SCREENING AND ALTERNATIVES DEVELOPMENT

It is the intent of this document to present a focused discussion of the identification of applicable closure actions and technologies and the development of appropriate alternatives. It is not the intent of this document to review an exhaustive list of technologies that have little or no applicability to this site. As suggested by NMED in the stakeholders closure meeting and generally agreed by the other participants, the CMS will focus on practical alternatives that meet the objectives for closure of the sewage lagoons.

4.1 Development and Screening of Closure Actions

This section of the CMS focuses on the development of appropriate closure actions for the sewage lagoons. The results of the risk assessment indicate no unacceptable risks to human health and the environment, and any currently acceptable risks can be further reduced by eliminating the exposure pathways. On the basis of the risk assessment results, alternatives that involve treatment of the sludge are not required. Alternatives are developed that have the potential to meet the closure objectives by 1) ensuring the protection of human health and the environment, 2) providing an adequate wildlife habitat, and 3) ensuring that closure controls disease vectors and is aesthetically suitable.

4.1.1 Development of Potential Closure Actions

Holloman AFB has decided that Ponds A through F will be removed from service. The alternatives for closing Ponds A through F will center on how to remove them from service in such a way that the closure objectives and criteria can be met.

It has also been decided that Pond G will remain in use because it is a wetland as well as an important ecological habitat. The risk assessment results (Radian and Foster Wheeler, 1996b) indicated that no unacceptable human health or ecological risks are associated with Pond G. There is a slight potential for black-necked stilts to have increased levels of DDE in their tissues; however, the *Site Characterization Report* (Radian and Foster Wheeler, 1995) has shown that concentrations of DDT and its derivatives are decreasing rapidly. On the other hand, the results presented in the *Biological Resource Report* (Radian and Foster Wheeler, 1996a) indicated that adverse effects would likely be associated with removal of sludge from Pond G. On the basis of the stakeholders concerns for keeping Pond G open, the low constituent concentrations, and the absence of unacceptable risk, closure actions involving excavation of sludge are not carried forward for Pond G.

Closure actions that could be considered include the following:

- No action;
- Institutional action;
- Containment;
- In situ treatment;
- Excavation and disposal; and
- Excavation, treatment, and disposal.

4.1.2 Screening of Closure Actions

These closure actions have been screened to represent those that are most appropriate for the given site conditions and closure objectives. The screening criteria include the consideration of the following:

- Site characteristics;
- Waste characteristics;
- Technology limitations; and
- Cost.

No Action

This closure action involves no actions other than removing Ponds A through F from service. It may also involve some type of environmental monitoring. This closure action will not, by itself, meet the third objective: "Ensure that closure eliminates disease vectors (e.g., mosquito habitats) and odors that may be associated with the sewage lagoons and that closure is aesthetically suitable." The no action closure action is retained for further consideration to provide a baseline with which the other closure actions can be compared.

Institutional Action

This closure action provides some type of access restriction such as land use restrictions or deed restrictions. It may also involve some type of environmental monitoring. This closure action will not, by itself, meet the third objective: "Ensure that closure eliminates disease vectors (e.g., mosquito habitats) and odors that may be associated with the sewage lagoons and that closure is aesthetically suitable." Institutional actions are retained, however, to be used in conjunction with other closure actions.

Containment

Containment involves the prevention or minimization of potential risk to human health and the environment by eliminating the exposure pathway. Containment will also prevent or minimize the release of contaminants from the site through surface water or wind erosion. This action is appropriate for consideration because of the low concentrations of constituents and the absence of unacceptable risk at the site. It is also cost effective and effective in controlling disease vectors. The containment action is retained for further consideration for Ponds A through F. It is not retained for Pond G, because of the importance of keeping that lagoon open.

In Situ Treatment

In situ treatment allows treatment of the affected sludge and sediments without excavation of the contaminated media. This could include such technologies as physical treatment, chemical treatment, thermal treatment and biological treatment. In situ treatment would not alone meet the closure objectives and would have to be used in combination with another action such as containment. There is no unacceptable risk at the site, and the levels of constituents are too low to justify treatment, which is an expensive action. Treatment would not provide any added value. Treatment would be used only to address disease vectors, which is not part of RCRA requirements. Since containment alone appears to meet the closure objectives, in situ treatment is eliminated from further consideration because it does not provide added risk reduction or other benefits.

Excavation and Disposal

Excavation and disposal could involve excavating the contaminated sludge and then disposing of the material at an approved facility. The contaminated material could also be excavated from one lagoon and placed in another lagoon to consolidate the material. Off-site disposal would cause significant logistical problems because up to 3000 20-cubic-yard truckloads of sludge from Ponds A through F might potentially require disposal. It would be expensive to excavate and dispose of the material in a permitted facility. Land disposal restrictions would have to be met. Because there is no unacceptable risk at the site, there would be no added value for this action. Therefore, excavation and disposal as a closure action will be retained only to the extent that the sludge could be relocated and consolidated within a lagoon or from one lagoon to another.

Excavation, Treatment, and Disposal

Excavation, treatment, and disposal would involve excavating the contaminated sludge as discussed above and would include an additional step of treating the contaminated material prior to disposal. Treatment could include physical, chemical, thermal, or biological technologies. There is no unacceptable risk at the site, and the

levels of constituents are too low to justify treatment, which is an expensive action. Treatment would be used only to address disease vectors, which is not part of RCRA requirements. This action would not provide any added value. Disposal, which could be either on site or off site, would have to comply with land disposal restrictions. Off-site disposal would cause significant logistical problems because up to 3000 20-cubic-yard truckloads of sludge from Ponds A through F might potentially require disposal. This closure action is eliminated from further consideration since it is very expensive and does not provide any advantage to this site, given the contaminants and site conditions.

4.2 Screening of Technologies

Appropriate technologies that support the remaining closure actions and that will help meet the closure objectives include the following:

Institutional Action

- Land use restrictions.

Containment

- Soil cover.

Excavation and Disposal

- Excavation of sludge; and
- Disposal of sludge in one of the other lagoons or in another area of the same lagoon.

The technologies listed above are considered viable technologies to use in the development of alternatives. These technologies individually may not meet the closure objectives but, when combined with other technologies, will form alternatives that do meet the closure objectives and criteria.

4.3 Development of Closure Alternatives for Ponds A Through F

The following sections describe the closure alternatives that have been developed using the technologies described above and represent the range of alternatives that were developed to meet the closure objectives. The evaluation of these alternatives is presented in Section 5.

4.3.1 Alternative AF1: No Action

This alternative is included to provide a baseline against which other alternatives can be compared as required by the CMS guidance. The no action alternative consists of removing Ponds A through F from service and letting the water infiltrate and evaporate naturally.

4.3.2 Alternative AF2: Containment—Backfill to Top of Berms

This alternative involves draining the water from the lagoons, dewatering the sludge to the extent that it has sufficient structural stability to support the backfill, and then backfilling the lagoons to the top of the existing berms.

The first step involved with implementing this alternative is to shut off the influent to Ponds A and B and to redirect this flow to the new WWTP. This step has already been accomplished. The water in Ponds D, E, and F has been pumped to Ponds A and B, and the water in Ponds A, B, and C is being allowed to infiltrate and evaporate naturally. It is estimated that in November 1996 the lagoons contained approximately 60,000,000 gal. of surface water and that it will take over 6 months for this water to infiltrate and evaporate. A discussion of this calculation is included in Attachment A. Holloman AFB will explore options for removing the water from Ponds A, B, and C more quickly.

Once the surface water has been removed, the sludge will be dewatered. Natural evaporation will play an important part in the sludge dewatering. Current data indicate that the sludge thicknesses in Ponds A through F range from 2 to 48 in. Mixing and turning the sludge with dozers will help with the natural dewatering process. This process can be expedited by mixing soil with the

sludge. If necessary, soil or commercial chemical additives may be mixed with the sludge to reduce odors. Considerations will be given to applying such techniques to all the sludge in Ponds A through F as well as selective use of such techniques depending on the thickness and nature of the sludge (e.g., Ponds A and B only).

Ponds A through F will be backfilled once the sludge is dewatered sufficiently. Clean soil from other locations on the Base will be trucked to the site and placed in the lagoons. This soil will be spread and compacted using standard backfilling techniques and standard earth-moving equipment. The finished surface of the compacted backfill will be graded to provide for adequate drainage. Finally, 6 in. of topsoil will be applied and the area will be vegetated. It is estimated that approximately 1,200,000 yd^3 of backfill and 62,000 yd^3 of topsoil will be required. These calculations are included in Attachment A. Care will be taken to minimize erosion and to control dust during closure activities.

The final contours for Alternative AF2 are shown in Figure 4-1. Typical sections of the backfilled lagoons are shown in Figure 4-2.

Once the closure is completed, the land use for the lagoon area will be restricted open space. The area will be fenced and will remain a restricted area since it is in a designated runway clear zone. This land use cannot be changed unless the potential risks associated with the new land use are reevaluated and the land use designation is changed in the Base Comprehensive Plan (BCP).

Long-term operation and maintenance could involve regrading because of settlement or erosion, and reseeding areas as required. Storm water in this area would be monitored as specified. It may be necessary to provide a system to water the vegetative cover.

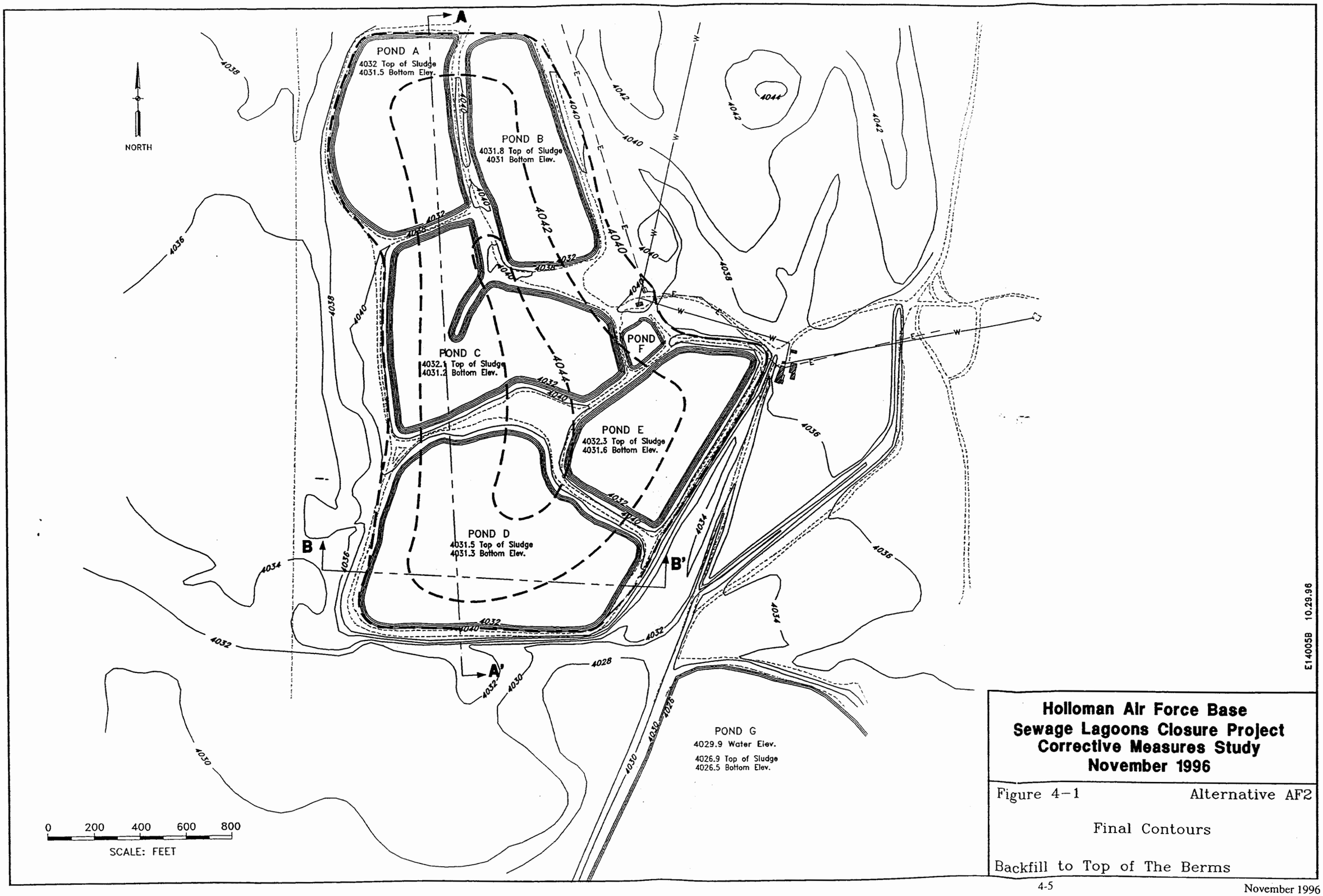
4.3.3 Alternative AF3: Containment—Restore to Natural Contours

Alternative AF3 is similar to Alternative AF2 except that the berms elevated above grade around the lagoons will be removed and placed in the lagoons as a soil cover so that the site can be restored to the approximate natural contours, as shown in Figures 4-3 and 4-4. Although the area will be graded and seeded, topsoil will not be required. It is estimated that approximately 200,000 yd^3 of soil will need to be excavated from the berms and placed in the lagoons. Additional fill material from off site may be needed, especially if the construction for some areas requires a certain type of material (e.g., crushed concrete) that is not available on site. The contours in the final design may differ slightly from those shown in Figures 4-3 and 4-4. The final design may also consider the use of riprap or geotextile products for erosion control.

4.4 Development of the Closure Alternative for Pond G—Alternative G1: No Action

Pond G is an important wildlife habitat that the stakeholders generally agreed should remain open. Because the risk assessment results have indicated no unacceptable human health or ecological risks, only the no action alternative has been developed for Pond G. The evaluation of this alternative is presented in Section 5.

The no action alternative consists of shutting off the influent to Ponds A and B, which effectively shuts off flow to Pond G. A pipeline from the new WWTP will be installed by July 1997 that will pump effluent from the WWTP to Pond G. This will ensure that Pond G continues to receive water and will continue to provide the ecological habitat that it does currently.



Holloman Air Force Base
Sewage Lagoons Closure Project
Corrective Measures Study
November 1996

Figure 4-1 Alternative AF2

Final Contours

Backfill to Top of The Berms

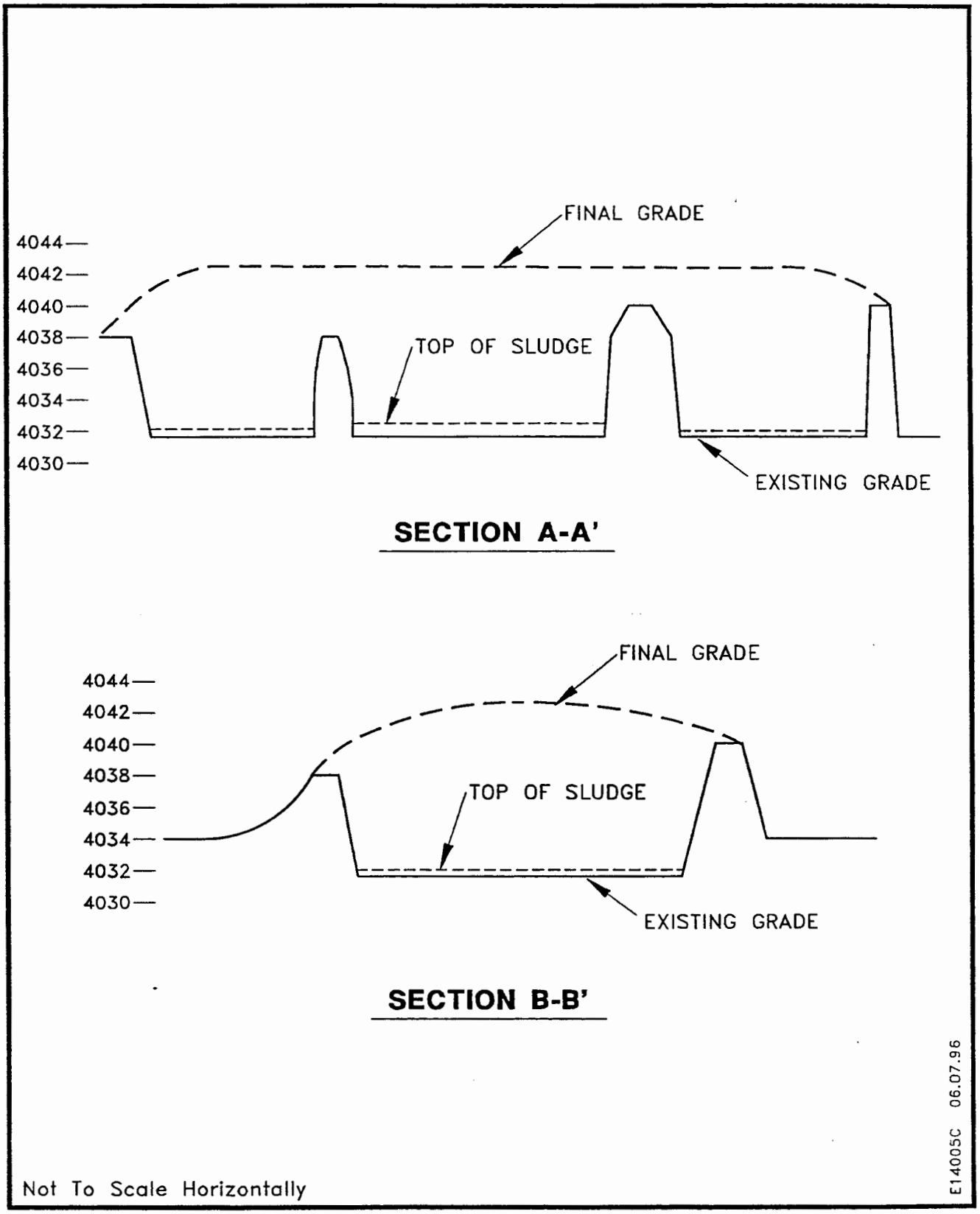
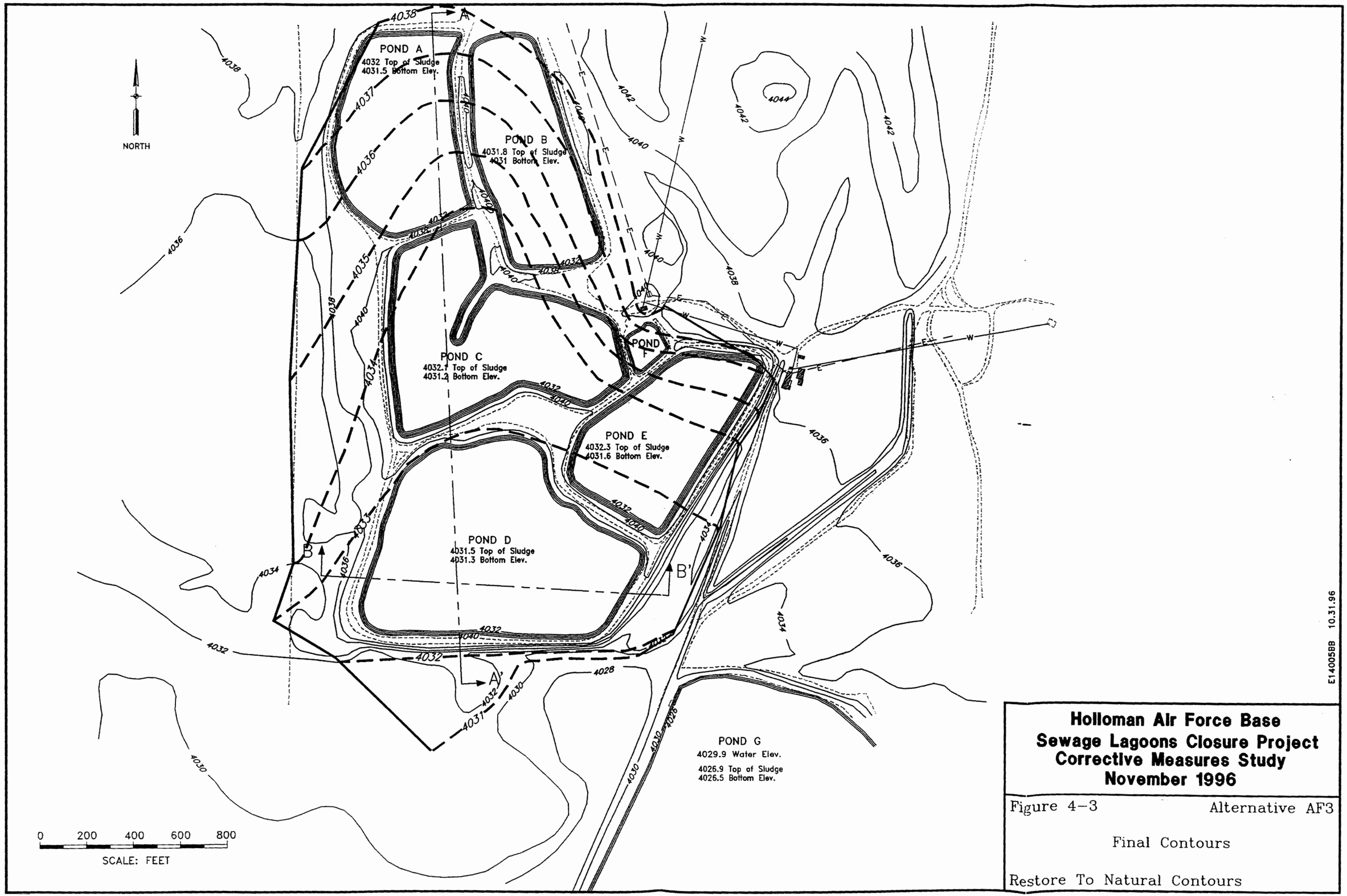


Figure 4-2. Typical Cross Sections—Alternative AF2: Backfill to Top of Berms



Holloman Air Force Base
Sewage Lagoons Closure Project
Corrective Measures Study
November 1996

Figure 4-3 Alternative AF3

Final Contours

Restore To Natural Contours

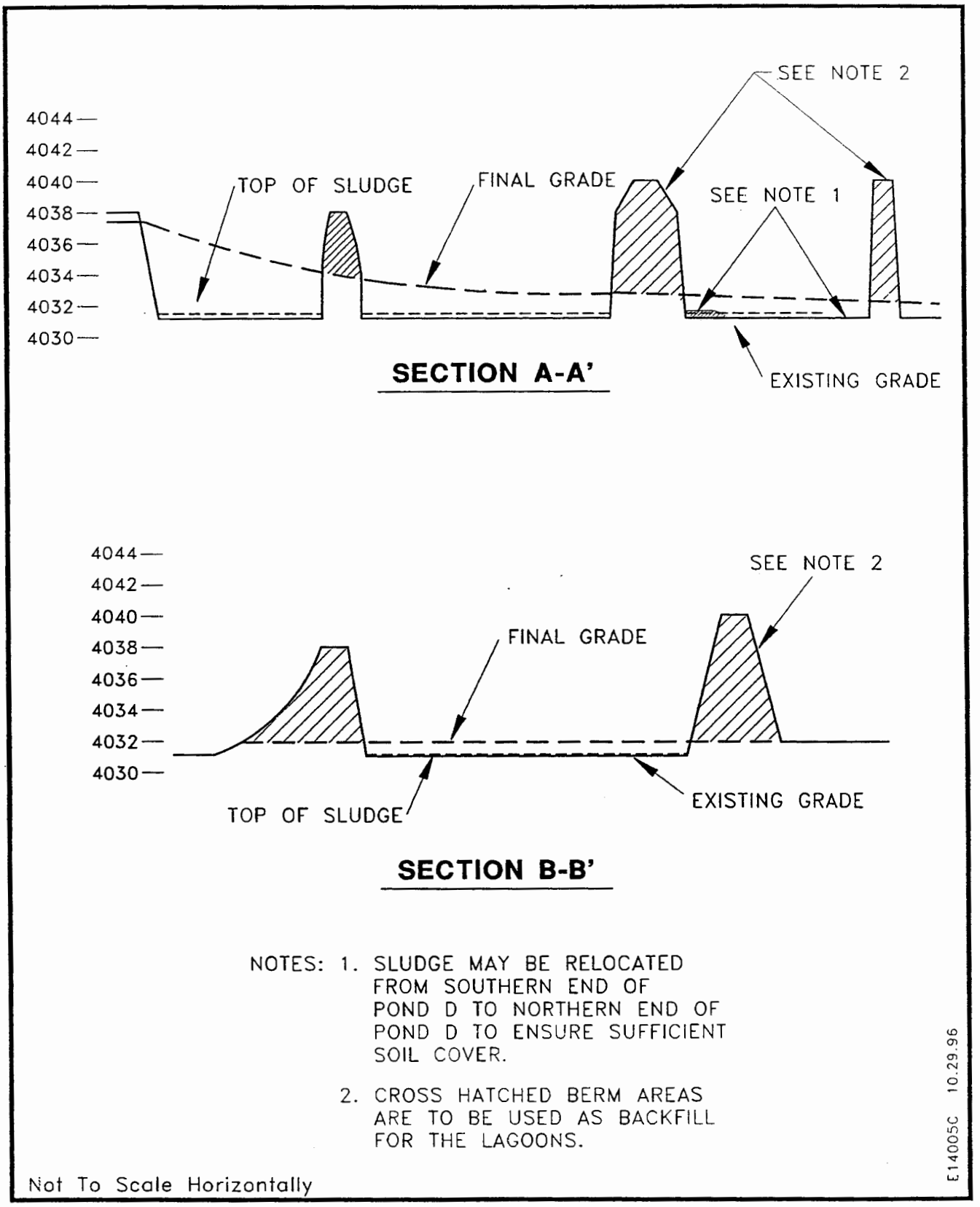


Figure 4-4. Typical Cross Sections—Alternative AF3: Restore to Natural Contours

Section 5
EVALUATION OF CLOSURE ALTERNATIVES

This section provides a focused evaluation of the ability of the closure alternatives developed in Section 4 to meet the closure objectives and closure criteria that were discussed in Section 3 of this report.

5.1 Closure Objectives and Criteria

As stated in Section 3, the closure objectives for the sewage lagoons include the following:

- Ensure the protection of human health and the environment at the sewage lagoons after closure;
- Provide an adequate habitat for the wildlife associated with the sewage lagoons; and
- Ensure that closure eliminates disease vectors (e.g., mosquito habitats) and odors that may be associated with the sewage lagoons and that the closure is aesthetically suitable.

The closure criteria for the sewage lagoons include the following:

1) Protect human health and the environment;

2) Control or eliminate the source of contamination;

3) Comply with applicable waste management standards; and

4) Prevent human exposure to constituents in soil and/or sludge that would lead to an unacceptable risk

5.2 Evaluation Criteria

Each of the alternatives is evaluated on the basis of its ability to meet the above closure criteria in accordance with preestablished evaluation criteria. The evaluation is based on technical, environmental, human health, and institutional criteria.

5.2.1 Technical

The technical evaluation involves considering the performance, reliability, implementabilty, and safety of each alternative.

Performance

Performance is a measure of the effectiveness and useful life of the alternative. Effectiveness is evaluated in terms of the ability of the alternative to perform its intended functions, such as containment or isolation of the sludge. Useful life is defined as the length of time that the level of effectiveness can be maintained.

Reliability

Reliability is a measure of the operation and maintenance requirements and the demonstrated and expected reliability of the alternative. Operation and maintenance requirements include the frequency and complexity of necessary operation and maintenance. The availability of labor and materials to meet the requirements also are considered. Demonstrated and expected reliability is a measure of the potential risk and the effect of failure of the alternative to perform as intended to meet the closure criteria. It includes an evaluation of whether the technologies have been used effectively under similar conditions.

Implementability

Implementability is a measure of the constructibility and the total length of time required to achieve a given level of response.

Constructibility includes internal conditions such as depth to groundwater, location of the facility, and availability of fill material. It also includes external factors that affect the implementability such as the need for special permits and the availability of equipment. Time requirements include the time to implement the alternative as well as the time required to actually see any beneficial results from the alternative.

Safety

Safety is a measure of threats to the safety of nearby communities or the environment as well as threats to the safety of workers during the implementation of the alternative.

5.2.2 Environmental

This criterion will include an evaluation of the short- and long-term beneficial and adverse effects of the alternative, any adverse effects on environmentally sensitive areas, and an analysis of measures to mitigate adverse impacts.

5.2.3 Human Health

This criterion will include an evaluation of how well the alternative mitigates short- and long-term potential exposure to any residual contamination and protects human health during and after implementation of the alternative.

5.2.4 Institutional

This criterion will evaluate how well the alternative addresses the relevant institutional needs, including the effects of federal, state, and local environmental and public health standards, regulations, guidance, advisories, ordinances, or community relations on the design, operation, and timing of each alternative.

5.3 Evaluation of Alternatives for Ponds A through F

This section provides an evaluation of each of the alternatives for Ponds A through F using the criteria described above. The performance of each alternative according to the evaluation criteria is presented in Table 5-1.

5.3.1 Alternative AF1: No Action

The no action alternative consists of letting the water in Ponds A through F infiltrate and evaporate naturally.

Technical

The evaluation of this alternative, based on the technical criteria, is as follows:

Performance—The no action alternative would not isolate the sludge. As a result, it would not meet closure objectives, would not control or eliminate the source of contamination, and would not prevent human or ecological exposure to constituents in the sludge and/or soil.
there is no unacceptable risk for an industrial or restricted open space scenario,

Also, it would not control the disease vectors or odor problems associated with leaving the sludge exposed.

Reliability—There would be no operation and maintenance requirements associated with the no action alternative. Since no action would be taken, there are no reliability issues.

Implementability—This alternative is readily implementable since the only action that would be taken would be to allow the water in Ponds A through F to infiltrate and evaporate naturally. The time to implement the alternative would be short.

Safety—This alternative would not fully comply with the evaluation criteria for safety to the environment, because it would not limit potential exposure pathways. It would allow the potential for wildlife and workers to be exposed to the sludge because the water that currently covers the sludge would drain off and the sludge would be

Table 5-1
Summary of Evaluation of Alternatives

Evaluation Criteria	Alternative AF1 No Action	Alternative AF2 Containment: Backfill to top of Berms	Alternative AF3 Containment: Restore to Natural Contours	Alternative G1 No Action
Technical				
Performance	Would not isolate sludges. Would not control disease vectors or odors.	Would contain and isolate sludges. Would control disease vectors and odors.	Would contain and isolate sludges. Would control disease vectors and odors.	Would isolate sludges. Would control disease vectors and odors.
Reliability	No operation and maintenance requirements.	Risk of failure is low. O&M requirements could be relatively high because of potential erosion problems. Labor and materials are readily available.	Risk of failure is low. O&M requirements are significantly lower than for AF2. Labor and materials are readily available.	No operation and maintenance requirements.
Implementability	Readily implementable.	Readily constructable. Equipment readily available. 1.2 million yd^3 of off-site backfill is required. Construction time is reasonable.	Readily constructable. Equipment readily available. Significantly less off-site backfill is required than for AF2. Construction time is reasonable.	Readily implementable.
Safety	Does not limit exposure pathways. Does not control disease vectors or odors.	Potential exposure to sludge during implementation. Eliminates exposure pathways. Controls disease vectors and odors.	Potential exposure to sludge during implementation. Eliminates exposure pathways. Controls disease vectors and odors.	No threats to safety of nearby communities or the environment.
Environmental	Could allow direct or indirect exposure to sludge.	Eliminates exposure pathways.	Eliminates exposure pathways.	Will preserve an important biological resource.
Human Health	Does not limit exposure pathways. No unacceptable risk. Does not control disease vectors or odors.	Eliminates exposure pathways to disease vectors. No unacceptable risk.	Eliminates exposure pathways to disease vectors. No unacceptable risk.	No unacceptable risk.
Institutional	Does not comply with closure requirements. Complies with state and federal water quality regulations.	Complies with 40 CFR Part 265.111. Complies with NM hazardous waste regulations. Complies with state and federal water quality regulations. Complies with worker safety standards.	Complies with 40 CFR Part 265.111. Complies with NM hazardous waste regulations. Complies with state and federal water quality regulations. Complies with worker safety standards.	Complies with 40 CFR Part 265.111. Complies with state and federal water quality regulations. Must continue to meet NPDES permit requirements.

exposed. It would not control disease vectors or odor problems.

Environmental

There would be the potential for direct or indirect exposure to constituents in the sludge, because the water would be drained off and the sludge would be left exposed.

Human Health

The no action alternative would leave contaminated sludge exposed at the site. It would not control disease vectors or odors. This alternative would not meet the closure objectives. However, it should be noted that the results of the risk assessment indicate that the constituent concentrations in sludge and soil would not pose an unacceptable risk to human health. The alternative would result in an acceptable risk within the 10^{-4} to 10^{-6} range. Also, the potential for exposure is likely to be relatively low, because the site is fenced and is a restricted area in the runway clear zone.

Institutional

This alternative does not adequately address institutional needs. It does not satisfy the closure criteria.

It would comply with state and federal water quality regulations.

5.3.2 Alternative AF2: Containment—Backfill to Top of Berms

This alternative involves draining the water from the lagoons, dewatering the sludge, and then backfilling the lagoons to the top of the existing berms.

Technical

The evaluation, based on the technical criteria, is as follows:

Performance—This alternative would be effective in its ability to perform its intended function of containing and isolating the sludge. It would also control disease vectors and odors. The components of this alternative would have an unlimited useful life.

Reliability—The risk of potential failure for this alternative to perform its intended function would be low. The operation and maintenance requirements would include periodic inspection and maintenance of the vegetative cover to identify and/or address any erosion of the backfill. The relatively steep slopes could cause erosion problems and require substantial maintenance. Monitoring of the storm water runoff would have to be carried out under the storm water regulations in Sector L of the multi-sector general permit (MSGP) (*Federal Register*, 29 Sept., 1995) and under the pollution prevention program. Labor and materials would be readily available to meet these requirements. The use of a soil cover to eliminate exposure pathways has been demonstrated to be reliable under similar conditions. Therefore, this alternative is expected to be reliable.

Implementability — This alternative would be easily implementable. The water should infiltrate and evaporate naturally from the lagoons. The sludge should dry quickly by natural processes in the desert environment. This could be expedited by turning it with standard earth-moving equipment or by adding stabilization agents such as soil, lime, cement, or fly ash. Standard earth moving equipment could be used to backfill the area. This alternative would require a large amount of off-site backfill (approximately 1.2 million yd^3). No special permits would be required. Beneficial results from implementing this alternative would be apparent immediately upon completion of the backfilling and placement of the final cover.

Safety—Potential safety issues during the implementation of this alternative, other than standard construction-related safety issues, would include the potential exposure to the sludge during the dewatering process and the initial backfilling of the lagoons. The potential risk would result largely from disease vectors. These potential safety issues will be addressed by restricting access to the area by maintaining fences around the area; by ensuring that workers are properly trained, wear appropriate personal protective equipment (PPE) in accordance with the regulations in 29 CFR 1910.120 and are vaccinated for the Hepatitis-B virus; and by implementing dust control measures to prevent dust from blowing off site.

Environmental

The long-term beneficial effects would include the containment of and elimination of potential exposure pathways to the sludge by placing a soil cover at least 12 in. thick over the dewatered sludge in the sewage lagoons.

Human Health

Because the installation of a soil cover would eliminate potential exposure pathways, this alternative would be effective in mitigating any long-term potential exposure to the contaminated sludge and would protect human health. The provision of access restrictions (e.g., restricting the land use in the BCP, fencing, etc.) would further ensure that humans could not come into contact with the sludge

Short-term potential health risks during implementation should be minimal and could be addressed by developing a site-specific health and safety plan to address the safety considerations listed in Section 5.3.2.1.

Institutional

This alternative would meet the requirements for closure by ensuring that potential exposure pathways would be eliminated. This alternative meets closure requirements of 40 CFR Parts 265.111 and 265.228, which require that the closure accomplish the following:

- Minimize the need for further maintenance;
- Control, minimize, or eliminate, to the extent necessary to protect human health and the environment, postclosure releases to the environment; and
- Remove or decontaminate all wastes.

By covering the sludge and restricting the use of the land after closure, the alternative meets the first two criteria. Meeting the third criterion will not be necessary because it has been established that the sludge in the sewage lagoons does not pose an unacceptable risk. This alternative will minimize risk, eliminate future releases, and require little future maintenance. It will also comply with state and federal water quality regulations, as well as with the worker safety standards in 29 CFR 1910.120.

5.3.3 Alternative AF3: Containment—Restore to Natural Contours

Alternative AF3 is similar to Alternative AF2, with one exception: the elevated dikes around the south and west sides of lagoons would be removed, and the resulting excavated soil would be placed in the lagoons as a soil cover so that the site could be restored to the approximate natural contours. The major difference would be the amount of backfill and the location of the final contours. Both alternatives would provide a minimum of 12 in. of soil cover over the sludge in the lagoons. Alternative AF3 would perform as well against the evaluation criteria as AF2. In fact, its performance would be superior, because it would require significantly less off-site backfill material and less labor. Alternative AF3 would also be more sustainable. There would be fewer erosion problems because it would include removing the portions of the berms that are above grade and it would restore the area to the

approximate natural drainage. Because the two alternatives are so similar, the evaluation of Alternative AF3 is not repeated here.

5.4 Evaluation of Alternatives for Pond G

Only one alternative—the no action alternative—has been developed for the closure of Pond G. This alternative would meet the closure objectives and the closure criteria by doing the following:

- Ensuring the protection of human health and the environment;
- Providing adequate habitat for the wildlife associated with the sewage lagoons;
- Ensuring that closure eliminates disease vectors and odors and that the closure is aesthetically suitable; and
- Preventing human exposure to constituents in soils and/or sludge that would lead to an unacceptable risk.

5.4.1 Alternative G1: No Action

The no action alternative consists of shutting off the influent to Ponds A and B, which effectively shuts off flow to Pond G. A pipeline from the new WWTP will be installed by July 1997 that will pump treated wastewater from the new WWTP to Pond G. This will ensure that Pond G receives water (not wastewater as before, but treated effluent via an NPDES permitted outfall) and will continue to provide the ecological habitat that it does currently.

Technical

The technical evaluation criteria are as follows:

Performance—The no action alternative would perform effectively for the foreseeable future. There are no specific activities associated with the no action alternative, so performance should not be a problem.

Reliability—There are no activities associated with the no action alternative, so reliability is not an issue.

Implementability—There are no construction activities associated with this alternative, so implementability is not an issue.

Safety—There will be no threats to the safety of nearby communities or the environment with the continued operation of Pond G under the no action alternative.

Environmental

Pond G is an important wildlife habitat, as discussed in the *Biological Resources Report* (Radian and Foster Wheeler, 1996a). The no action alternative will preserve this valuable resource by allowing Pond G to serve as a wetland and a wildlife habitat. The results of the ecological risk assessment indicated that no unacceptable risks would be associated with leaving Pond G open. As discussed in the *Biological Resources Report*, it would be beneficial to the bird species in the area to leave Pond G open.

Human Health

The risk assessment results indicated that there are no unacceptable human health risks associated with leaving Pond G open. The short- and long-term exposure to any residual constituents is not a concern.

Institutional

The alternative for Pond G will comply with 40 CFR Part 265.111 in that it will minimize the need for further maintenance. Although there are no unacceptable human health or ecological risks associated with Pond G, this alternative will minimize any releases to the environment by keeping the sludge covered with water while further decreases in constituent concentrations occur. The alternative will comply with the state and federal water quality regulations. It will also have to comply with the requirements for the

NPDES permit for the new WWTP. The stakeholders' concerns for keeping Pond G open as an important wildlife habitat are addressed by this alternative.

5.5 Cost Estimates

The estimated capital costs and the estimated operation and maintenance costs (30-year net present worth) for each of the alternatives are shown in Table 5-2. The cost calculations are presented in Attachment B. These cost estimates are intended to provide an accuracy of +50% to -30%. More accurate cost estimates will be developed after the detailed design is completed.

Table 5-2
Summary of Costs for Each Alternative

Alternative	Capital Cost	Operation and Maintenance Cost
AF1	$0	$0
AF2	$16,490,000	$940,000
AF3	$3,280,000	$940,000
G1	$0	$0

The costs for various process options that may be necessary are listed below.

5.5.1 Addition of Erosion Control

The costs for the addition of rubble to control erosion in the area that is currently the southeast corner of Pond D would add only about $14,000 to the cost of Alternative AF3.

5.5.2 Addition of a Sprinkler System

If necessary, the addition of a sprinkler system to provide water for the vegetative cover for Alternative AF3 would add about $360,000 to the total cost.

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Section 6
RECOMMENDATION AND JUSTIFICATION OF THE CLOSURE ALTERNATIVES

On the basis of the evaluation according to the closure criteria, alternatives for Ponds A through F and for Pond G are recommended. Justification for the recommendations is also provided.

6.1 Recommended Alternative for Ponds A through F

Alternative AF3: Containment—Restore to Natural Contours, is the recommended alternative for closing Ponds A through F.

The justification for the recommendation of Alternative AF3, based on the evaluation criteria discussed in Section 5, is presented below. Table 6-1 presents a comparison of the alternatives' performance against the criteria.

6.1.1 Technical

The technical criteria include performance, reliability, implementability, and safety. As discussed in Section 5, Alternative AF1: No Action was rated lower in each of these areas than the other alternatives. In particular, it would not be fully protective of human health and the environment because it would not eliminate exposure pathways. Alternative AF2: Containment—Backfill to Top of Berm, and Alternative AF3: Containment—Restore to Natural Contours were rated higher than was Alternative AF1 in their ability to meet all of these criteria. Both alternatives would protect human health and the environment by eliminating exposure pathways and controlling any potential disease vectors or odor problems. Alternative AF2 would be less reliable than AF3 because the steeper slopes included in the design may cause higher maintenance requirements due to erosion problems. Alternative AF3 would be more easily implementable because it requires significantly less off-site backfill material.

6.1.2 Environmental

Alternatives AF2 and AF3 were rated equal with respect to the environmental criteria. They were rated higher than the no action alternative, AF1, because they eliminate exposure pathways that could lead to ecological risks.

6.1.3 Human Health

Alternatives AF2 and AF3 were rated equal with respect to the human health criteria. They were rated higher than the no action alternative, AF1, because they also eliminate exposure pathways that could lead to other types of risks to human health (e.g., disease vectors).

6.1.4 Institutional

Alternatives AF2 and AF3 were rated equal with respect to the institutional criteria. They were rated higher than the no action alternative, AF1, because they satisfy requirements for closure.

6.1.5 Cost

Alternative AF1, the no action alternative, has no associated cost. The capital and present worth operation and maintenance costs associated with Alternative AF2 were estimated to be $16,490,000 and $940,000, respectively. The capital and present worth operation and maintenance costs for Alternative AF3 were estimated to be $3,280,000 and $940,000, respectively. Alternative AF3 is the least expensive alternative that meets the closure objectives and criteria.

Table 6-1
Comparison of Alternatives Against Evaluation Criteria

Alternative	Technical				Environmental	Human Health	Institutional	Cost
	Performance	Reliability	Implementability	Safety				
AF1	Poor	Excellent	Excellent	Fair	Fair	Fair	Poor	Low
AF2	Excellent	Good	Fair	Good	Excellent	Excellent	Good	High
AF3	Excellent	Excellent	Good	Good	Excellent	Excellent	Good	Moderate
G1	Excellent	Excellent	Good	Good	Good	Good	Good	Low

6.1.6 Recommended Alternatives

A summary of the performance of the alternatives according to the evaluation criteria is presented in Table 5-1. Alternatives AF2 and AF3 were very similar in their performance according to the technical, environmental, human health, and institutional criteria. Alternative AF3 was superior in terms of the technical criteria. It required significantly less material and labor, and the soil cover would be more sustainable because the design does not include as steep of slopes. As seen from the cost estimates, Alternative AF3 is considerably less costly than Alternative AF2. Therefore, since Alternatives AF2 and AF3 perform very similarly in all areas other than cost, Alternative AF3, the least costly of the two, is the recommended alternative.

6.2 Recommended Alternative for Pond G

Alternative G1 was the only alternative evaluated for Pond G. It was found to meet all of the evaluation criteria and to have no cost associated with it. This alternative addresses the stakeholders' concerns for keeping Pond G open as a wetland and as an important wildlife habitat. There are no unacceptable human health or ecological risks associated with leaving the lagoon open. As discussed in the *Biological Resources Report* (Radian and Foster Wheeler, 1996a), the removal of sludge from Pond G is not necessary, and it would result in adverse effects to the wildlife that inhabit the area. Therefore, Alternative G1: No Action, is the recommended alternative for Pond G.

Section 7
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ATTACHMENT A

Conceptual Design Calculations

Calculation of Evaporation and Infiltration Time for Lagoons

An analytical model was used to estimate the time for all of the free standing water to be removed from the lagoons due to natural evaporation and infiltration. The approach used in this modeling is defined in the equation:

$$V(t) = InitialVolumeofLagoons - \sum_t E(t) - \sum_t I(t)$$

Where V(t) is the volume of water contained in the lagoons at time t; E(t) is the amount of water that evaporated during time step t; and I(t) is the amount of water that infiltrated during time step t.

Evaporation was estimated based on the value of 67 inches per year as reported in the *Final Hydrogeologic Investigation Report and Groundwater Monitoring Plan for the Sewage Treatment Lagoons*, Holloman Air Force Base, New Mexico (Radian, 1989). However, this value was reduced by two-thirds to account for the difference in the winter evaproation rate versus the summer rate. The surface area of the lagoons available for evaporation was calculated at every time step based on the dimensions of the lagoons and volume of water. A time step of 1 day was used to calculate the time for the lagoons to dewater. Infiltration was estimated using the Green-Ampt method as described in *The Handbook of Hydrology* (David R. Maidment, 1992). This equation accounts for hydraulic conductivity, wetting front soil suction head, head due to ponded water, porosity, and initial moisture content of the soil. Hydraulic conductivity and porosity were estimated from the *Hydrogeologic Investigation Report* (Radian, 1989). The wetting front soil suction head was estimated based on a table from *The Handbook of Hydrology* (David R. Maidment, 1992). The average head of water in the lagoons was calculated at every time step based on the dimensions of the lagoons and volume of water. Initial soil moisture content was set to 33%, based on the assumption that the porosity was 34% and the soil was over 97% saturated under and around the lagoons.

One simulation was run for Ponds A, B, and C. It was assumed that the lagoons held an average of 6 feet of water. The estimated time to dewater the lagoons from the beginning depth of 6 feet was 179 days. The following page shows the model inputs and output matrix.

Based on historical rainfall data in the *Hydrogeologic Investigation Report* (Radian, 1989), the majority of Holloman AFB's rain falls in the months of July through October. But is is feasible to expect 2-3 inches between December and May. This rainfall will add 3 to 5 days to the numbers estimated by the model. Therefore, with rainfall added into the estimates, the time estimated for the natural removal of the free-standing water in Ponds A, B, and C is approximately 184 days.

In addition to the uncertain rainfall, the hydrogeological parameters of the deeper aquifer were not considered. The hydrogeological parameters used to estimate the infiltration were based on average results of slug tests in the shallow aquifer conducted around the lagoons. Because the deeper aquifer has a lower hydraulic conductivity, the infiltration may be slightly slower than what is estimated by the model. It was determined that the salinity of the water in the lagoons would have very little effect on the evaporation rate based on the book *Hydrology for Engineers* (Linsley, Kohler, and Paulhus, 1986).

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**Parameters used in this run are:
**Initial pond volume=8575199 (ft^3)
**Time step(days) =1
**Depth below surface where infiltration starts(feet) = 0
**Pumping rate(gpm)=0
**Pan evaporation rate(inches/year)=67(1/3) to account for winter evap
**Pan evaporation coefficient(unitless)=1
**hydraulic conductivity(feet/day)=2.83    (=1.00e-3 cm/sec)
**wetting front soil suction head(feet)=0.197
**porosity(unitless)=.34
**initial soil moisture content(unitless)=.33
**# of Days before Pumping Begins=0

**Holloman Lagoon #'s 1-3 with 6' of initial h2o

**update inputs

Input.mat[1,]_c(8575199,1,0,0,67*(1/3),1,2.83,0.197,0.34,0.33,0)

hol.6ft_hol.ba2(Input.mat)
hol.6ft_round(hol.6ft,2)
hol.6ft
```

	Day	Pumped	Evap	Infil	Lake.Vol	Inf.depth	surf	Inf.cum	Avg.head
	1	0	7342.47	41573.76	8575199	2.89	1440000	41573.76	6.00
	2	0	7342.19	41173.11	8526283	5.75	1439946	82746.87	5.97
3	3	0	7341.91	41032.93	8477767	8.60	1439892	123779.80	5.93
4	4	0	7341.64	40960.80	8429393	11.44	1439838	164740.59	5.90
5	5	0	7341.37	40916.46	8381090	14.28	1439784	205657.05	5.87
6	6	0	7341.09	40886.19	8332832	17.12	1439731	246543.24	5.83
7	7	0	7340.82	40864.03	8284605	19.96	1439677	287407.27	5.80
8	8	0	7340.55	40846.97	8236400	22.80	1439624	328254.24	5.76
9	9	0	7340.27	40833.33	8188213	25.63	1439570	369087.57	5.73
10	10	0	7340.00	40822.09	8140039	28.47	1439516	409909.66	5.70
						...			
	Day	Pumped	Evap	Infil	Lake.Vol	Inf.depth	surf	Inf.cum	Avg.head
172	172	0	7295.92	40494.06	372807.44	487.05	1430871	6991284	0.29
173	173	0	7295.65	40492.53	325017.45	489.88	1430818	7031777	0.25
174	174	0	7295.38	40490.99	277229.28	492.71	1430765	7072268	0.22
175	175	0	7295.11	40489.45	229442.91	495.54	1430712	7112757	0.19
176	176	0	7294.83	40487.92	181658.35	498.37	1430658	7153245	0.15
177	177	0	7294.56	40486.38	133875.60	501.20	1430605	7193731	0.12
178	178	0	7294.29	40484.84	86094.66	504.03	1430552	7234216	0.09
179	179	0	7294.02	40483.31	38315.53	506.86	1430499	7274699	0.05

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO.

IGNATURE ROBERT MICHNA DATE 11/1/96 CHECKED DATE

PROJECT HAFB LAGOONS CLOSURE JOB NO.

SUBJECT TOTAL CUT AND FILL SHEET 1 OF 2 SHEETS

TOTALS

RESTORE TO NATURAL CONTOURS

CUT = FILL = 186,233 cy + 10% = 204,856 → 205,000 cy

FILL TO TOP OF BERMS

FILL = 1,163,841 cy + 10% = 1,280,225 → 1,280,000 cy

TOPSOIL = WORKED AREA × 6"

FILL TO TOP OF BERMS

$3,040,000 \frac{6}{12} \div 27 = 56,296$ cy + 10% = 61,926 → 62,000 cy

NOTE: ALL VOLUMES INCREASED BY 10% FOR SCOPE CONTINGENCIES

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO.

SIGNATURE Robert Michna DATE 11/1/96 CHECKED DATE

PROJECT HAFB Lagoons Closure JOB NO.

SUBJECT TOTAL QUANTITIES SHEET 2 OF 2 SHEETS

FILL TO BERMS

	TOTAL FILL (CY)	OFFSITE FILL (CY)	AREA OF GRADING (SY)
Move on-site cut to fill			
Excavate + move borrow		1,219,000	
Borrow + haul topsoil		61,000	
Common earth backfill	1,280,000		
Grade/seed			372,000

RESTORE TO NATURAL CONTOURS

	TOTAL FILL (CY)	OFFSITE FILL (CY)	AREA OF GRADING (SY)
Move on-site cut to fill	205,000	0	
Common earth backfill	205,000	0	
Grade/seed			540,000

NOTE: ALL QUANTITIES INCREASED BY 10% FOR SCOPE CONTINGENCIES

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO.

SIGNATURE SgWest DATE 6/6/96 CHECKED DEF DATE 6/7/96

PROJECT HAFB Lagoons Closure JOB NO.

SUBJECT Fill + Mound SHEET 1 OF 6 SHEETS

HAFB Lagoons Closure
OPTION: Fill to Berms + Mound to Drain

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO.

SIGNATURE SmWL DATE 6/6/96 CHECKED REF DATE 6/7/96

PROJECT HAFB Lagoons Closure JOB NO.

SUBJECT Fill + mound SHEET 2 OF 6 SHEETS

Alternative AF2 → Backfill to top of berms
Mound interior to drain off area

Fill → Fill all ponds to 4040 el (vol)
Find vol of mound above 4040 el

Procedure – Pond bottoms ~ 4031.5 – 4037.3 (top of sludge)
Side slopes up from bottom

A_1 Measure bottom area
A_2 Measure area at top of sideslopes
$\frac{A_1 + A_2}{2} \cdot \text{depth} = \text{vol}$

A_3 Measure area of 4040 el around pond
$\frac{A_2 + A_3}{2} \cdot \text{depth} = \text{vol}$

A_1, A_2, A_3 for each pond – total to get ∀ to bring site inside berms to 4040 el. $\Sigma = A_{4040}$. $\Sigma \text{ vol} = V_{4040}$

A_{4040} – Σ of pond vol
A_{4042} – Measure on map
$(A_{4040} + A_{4042}) \div 2 \cdot 2' \ \Delta\text{elev} = V_{4040-4042}$

A_{4044} – Measure on map
$(A_{4042} + A_{4044}) \div 2 \cdot 2' \ \Delta\text{elev} = V_{4042-4044}$

Total fill $= V_{4040} + V_{4040-4042} + V_{4042-4044}$

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO.

SIGNATURE SEWH DATE 6/6/96 CHECKED REF DATE 6/7/96

PROJECT HAFB lagoons Closure JOB NO.

SUBJECT Fill + mound SHEET 3 OF 6 SHEETS

Pond A

Top of sludge = 4032 → A 4032 contour = 429694 ft^2
Top of sideslopes = 4038 → A 4038 contour = 493117 ft^2
Fill to 4040 → A 4040 contour = 547027 ft^2

$V_{4032-4038} = [(429694 + 493117) \div 2 * (4038 - 4032)] \div 27 = 102535$ cy
$V_{4038-4040} = [(493117 + 547027) \div 2 * (4040 - 4038)] \div 27 = 38524$ cy
$\therefore V_{To\ 4040} = 141059$ cy

Pond B

T.O.S. = 4031.8 $A_{4032 (\approx 4031.8)} = 404324\ ft^2$
Top of banks = 4038 $A_{4038} = 459819\ ft^2$
Fill to 4040 $A_{4040} = 612036\ ft^2$

$V_{4031.8-4038} = [(404324 + 459819) \div 2 \cdot (4038 - 4031.8)] \div 27 = 99216$ cy
$V_{4038-4040} = [(459819 + 612036) \div 2 \cdot (4040 - 4038)] \div 27 = 39698$ cy
$\therefore V_{To\ 4040} = 138915$ cy

Pond C

T.O.S. = 4032.1 $A_{4032.1} = 561297\ ft^2$
Top of banks = 4040 $A_{4040} = 680216\ ft^2$

$V_{4032.1-4040} = (561297 + 680216) \div 2 \cdot (4040 - 4032.1)] \div 27 = 181629$ cy

$V_{To\ 4040} = 181629$ cy

RADIAN CORPORATION

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PROJECT HAFB Lagoons Closure JOB NO.

SUBJECT Fill + mound SHEET 4 OF 6 SHEETS

Pond D

T.O.S = 4031.5 $A_{4031.5 (\sim 4032)} = 827676\ ft^2$

Top of banks = 4040 $A_{4040} = 1911712\ ft^2$

$$V_{4031.5-4040} = [(827676 + 911712) \div 2 \cdot (4040 - 4031.5)] \div 27 = 273792\ cy$$

Pond E

T.O.S = 4032.3 $A_{4032.3 (\sim 4032)} = 371027\ ft^2$

Top of banks = 4040 $A_{4040} = 442378\ ft^2$

$$V_{4032.3-4040} = [(371027 + 442378) \div 2 \cdot (4040 - 4032.3)] \div 27 = 115985\ cy$$

Pond F

Bottom elev ~ 4036 $A_{4036} = 28540$

Top of banks = 4038 $A_{4038} = 31712$

Fill to 4040 elev $A_{4040} = 63423$

$$V_{4036-4038} = [(28540 + 31712) \div 2 \cdot (4038 - 4036)] \div 27 = 2232\ cy$$

$$V_{4038-4040} = [(31712 + 63423) \div 2 \cdot (4040 - 4038)] \div 27 = 3523\ cy$$

$$\therefore V_{To\ 4040} = 5755\ cy$$

$\therefore$ Total V fill ponds to 4040 = 857134 cy

RADIAN CORPORATION

CALCULATION SHEET

CALC. NO.

SIGNATURE StayWet DATE 6/6/96 CHECKED REF DATE 6/7/96

PROJECT HAFB Lagoons Closure JOB NO.

SUBJECT Fill + mound SHEET 5 OF 6 SHEETS

Fill 4040 → Final contours

$A_{4040} = 3713441\ ft^2$
$A_{4042} = 2032721\ ft^2$
$A_{4044} = 329802\ ft^2$

$V_{4040-4042} = [(3713441 + 2032721) \div 2 \cdot (4042-4040)] \div 27 = 212821\ cy$

$V_{4042-4044} = [(2032721 + 329802) \div 2 \cdot (4044-4042)] \div 27 = 87501\ cy$

Assume ridge at ~4045 along peak for drainage
Assume A 4045 = 15000 ft²

$V_{4044-4045} = [(329802 + 15000) \div 2 \cdot (4045-4044)] \div 27 = 6385$

Total

$V_{To\ 4040} = 857134\ cy$

∴ Total Fill = 857134 + 212821 + 87501 + 6385
= 1,163,841 cy (in place)

Sewage Lagoons Closure

Alternative AF3--Containment, Restore to Natural Contours

Volume Calculations Using the Average End Area Method

RADIAN INTERNATIONAL LLC

CALCULATION SHEET

CALC. NO. _____

NATURE [signature] DATE 10/28/96 CHECKED ESM DATE 10/30/96

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 1 OF 7 SHEETS

All following cross sections

horizontal scale → 1" = 400'
vertical scale → 1" = 8'

$1 in^2 = 400 \cdot 8 = 3200 sf$

3200 is multiplication factor on x-section measurements to calculate ft^2.

From section	To section	Distance in (ft)
A	B	236
B	B1	69
B1	C	142
C	C1	58
C1	D	255
D	E	69
E	F	65
F	G	182
G	H	138
H	I	156
I	J	73
J	K	102
K	L	109
L	M	385
M	N	80

HJP-3 38778.fh5

RADIAN INTERNATIONAL LLC

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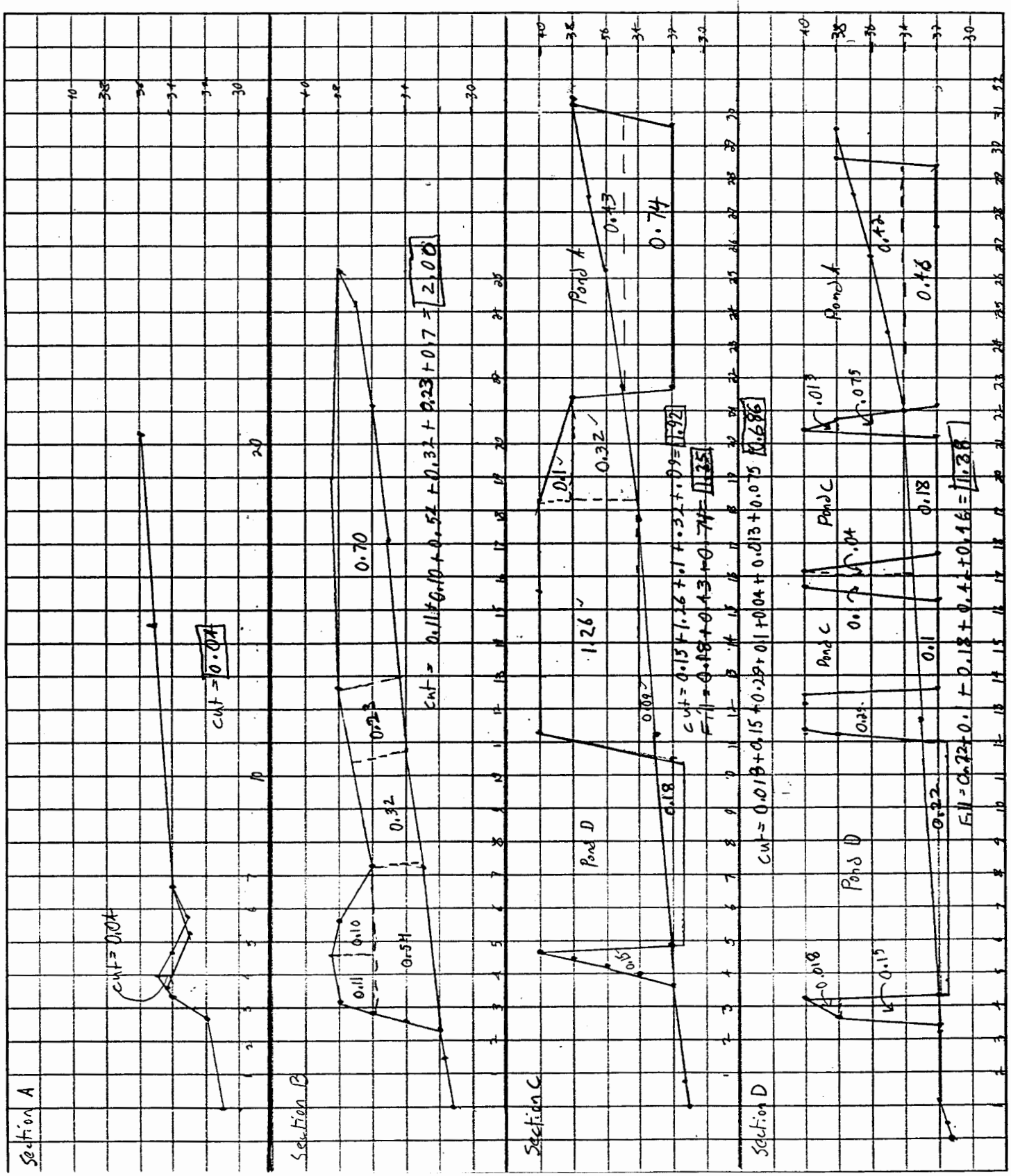
SIGNATURE [signature] DATE 10/28/96 CHECKED RJM DATE 10/30/96

PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 2 OF 7 SHEETS



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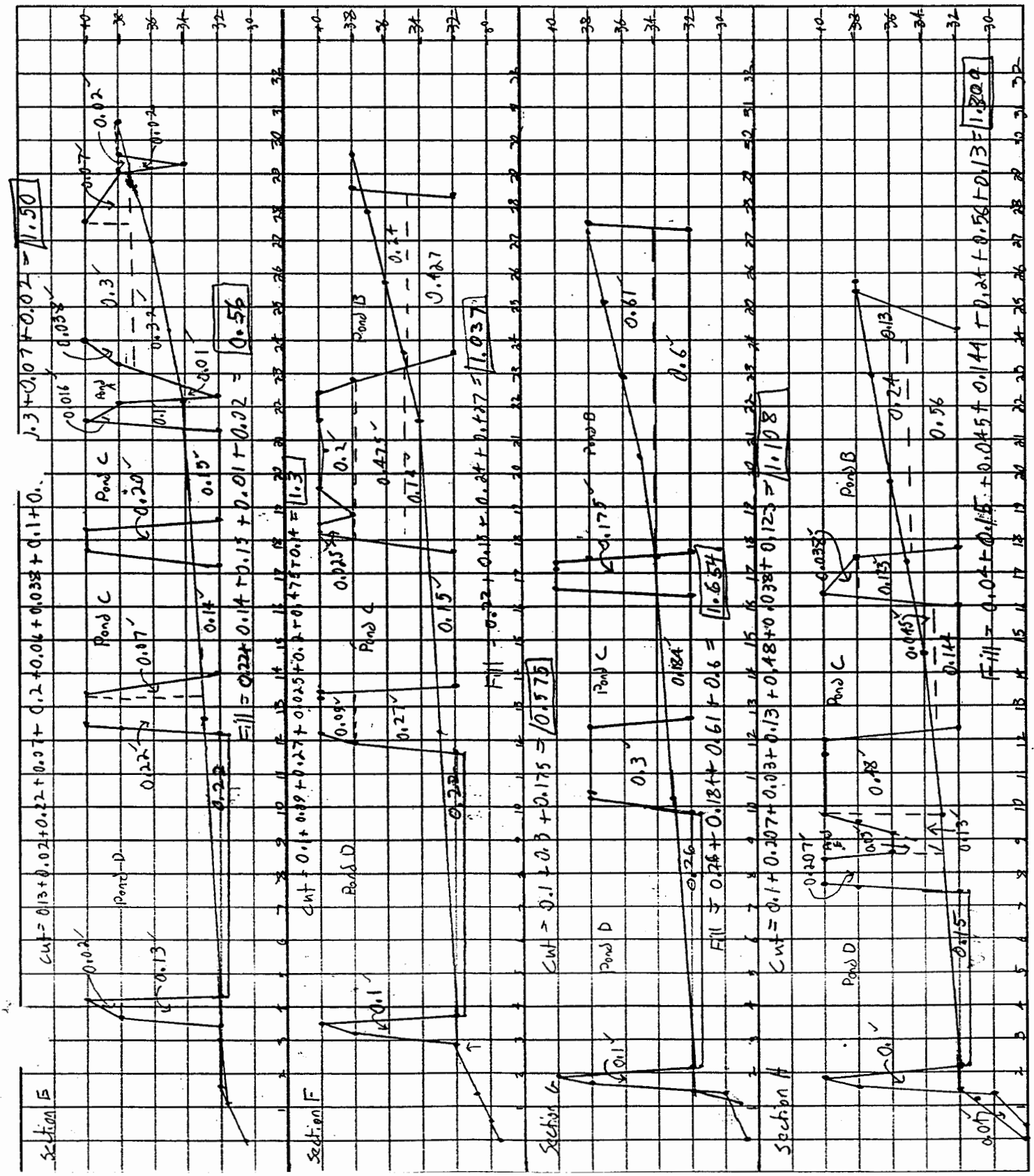
PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 3 OF 7 SHEETS



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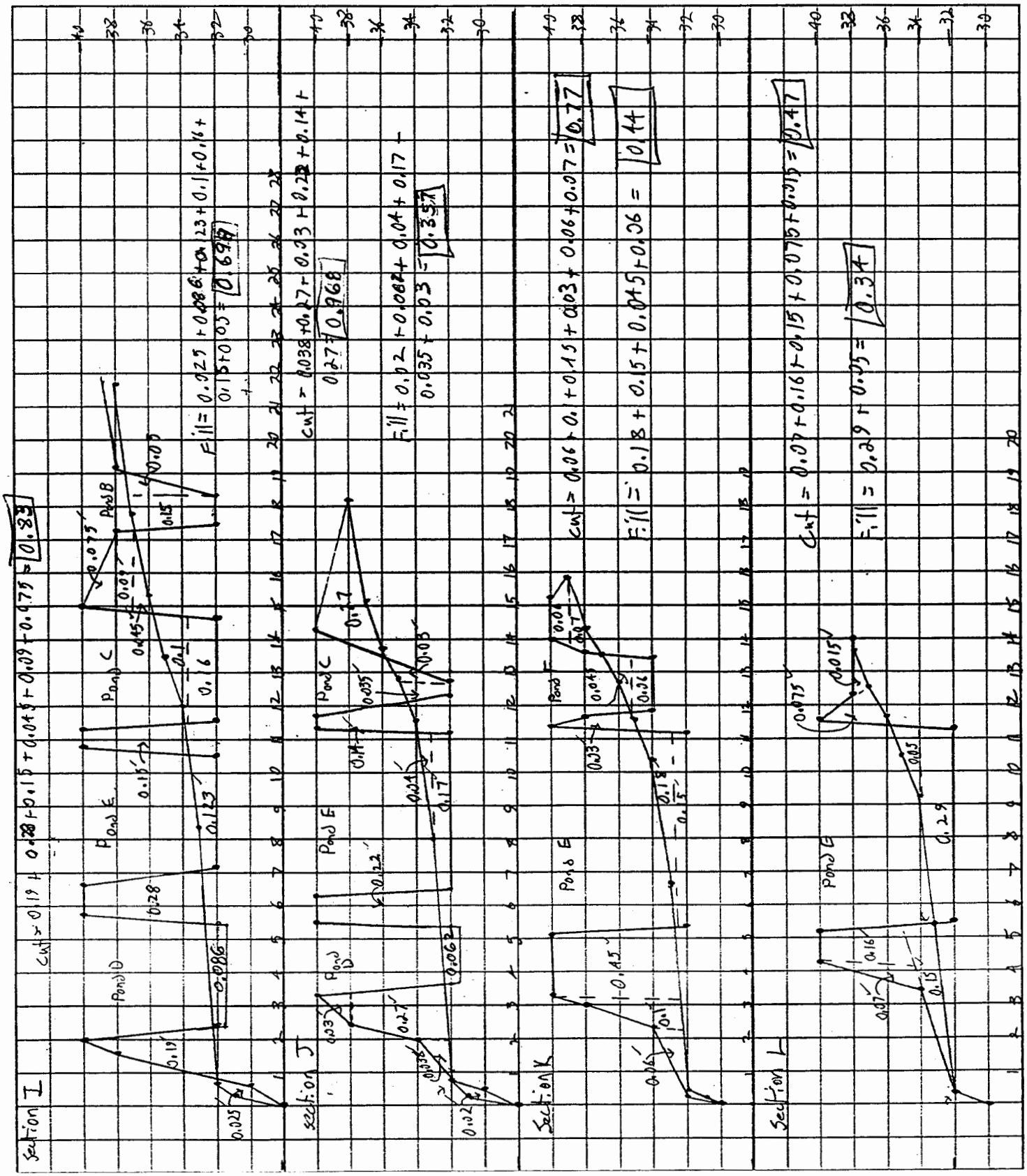
PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 4 OF 7 SHEETS



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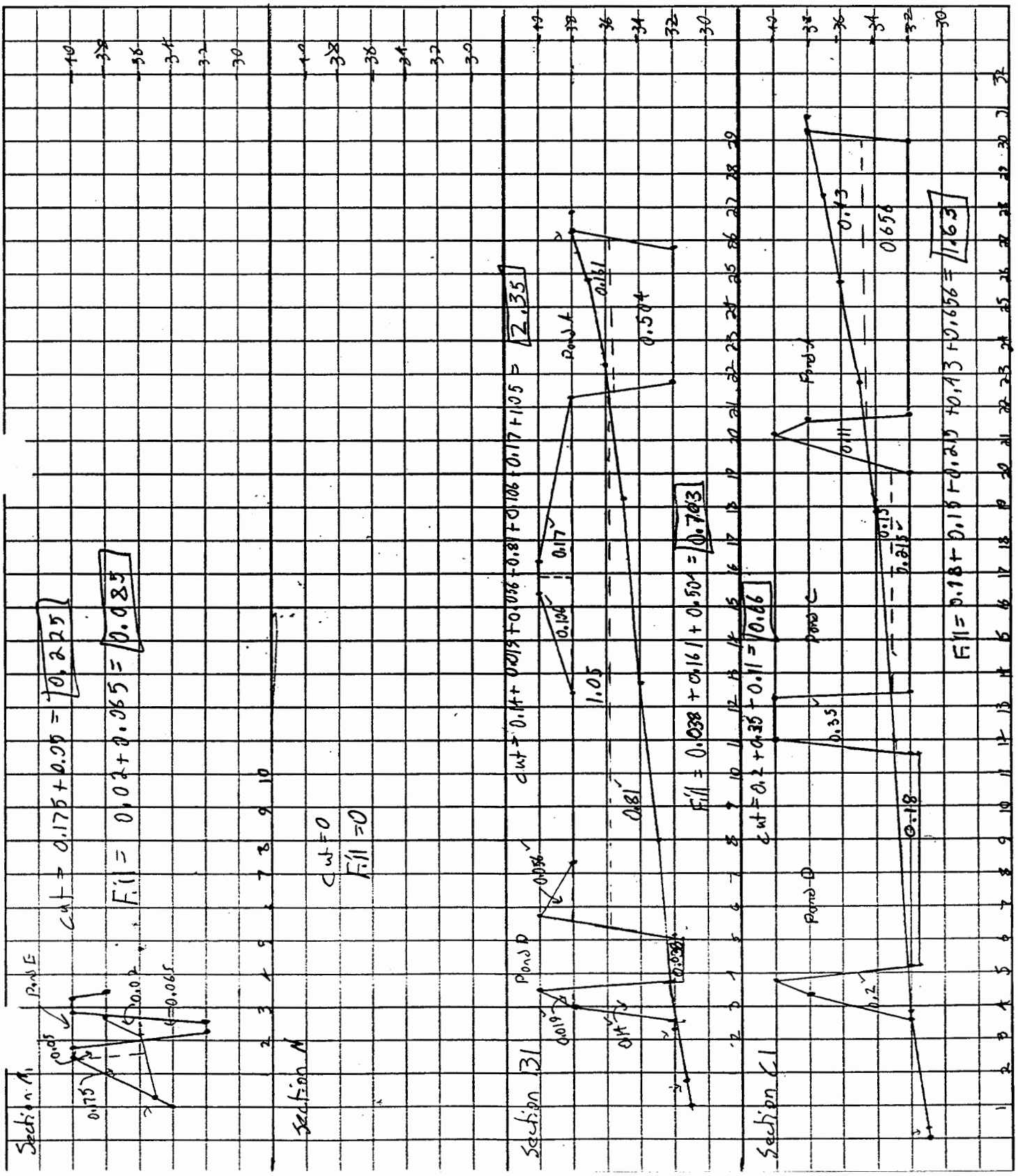
PROJECT _____ JOB NO. _____

SUBJECT _____ SHEET 5 OF 7 SHEETS



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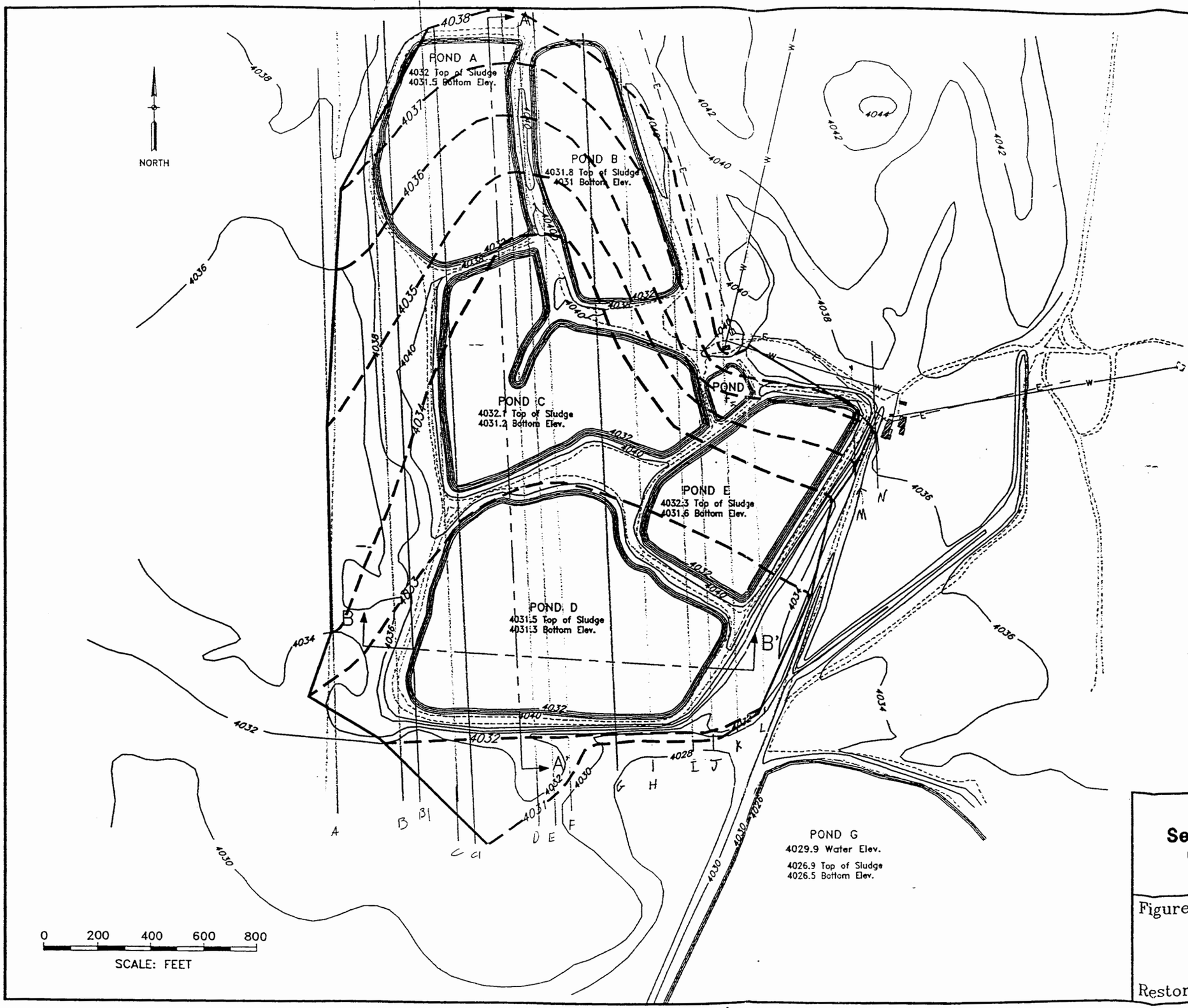
Alternative AF3--Restore to Natural Contours

Section Number	Cut Calculations						Fill Calculations					
	Distance X	(first cut +	second cut /	2) x	Scale Factor =	Total (cf)	Distance X	(first fill +	second fill /	2) x	Scale Factor =	Total (cf)
A-B	236	0.04	2	2	3200	770,304	236	0	0	2	3200	0
B-B1	69	2	2.35	2	3200	480,240	69	0	0.703	2	3200	77,611
B1-C	142	2.35	1.92	2	3200	970,144	142	0.703	1.35	2	3200	466,442
C-C1	58	1.92	0.66	2	3200	239,424	58	1.35	1.63	2	3200	276,544
C1-D	255	0.66	0.686	2	3200	549,168	255	1.63	1.38	2	3200	1,228,080
D-E	69	0.686	1.5	2	3200	241,334	69	1.38	0.56	2	3200	214,176
E-F	65	1.5	1.3	2	3200	291,200	65	0.56	1.037	2	3200	166,088
F-G	182	1.3	0.575	2	3200	546,000	182	1.037	1.654	2	3200	783,619
G-H	138	0.575	1.108	2	3200	371,606	138	1.654	1.309	2	3200	654,230
H-I	156	1.108	0.83	2	3200	483,725	156	1.309	0.694	2	3200	499,949
I-J	73	0.83	0.968	2	3200	210,006	73	0.694	0.357	2	3200	122,757
J-K	102	0.968	0.77	2	3200	283,642	102	0.357	0.44	2	3200	130,070
K-L	109	0.77	0.47	2	3200	216,256	109	0.44	0.34	2	3200	136,032
L-M	385	0.47	0.225	2	3200	428,120	385	0.34	0.085	2	3200	261,800
M-N	80	0.225	0	2	3200	28,800	80	0.085	0	2	3200	10,880
Total Cubic Feet						6,109,970						5,028,278
Total Cubic Yards						226,295						186,233
											+10% Scope Contingency	18,623
												204,856

Difference = 21,439 Cubic Yards Additional Cut Material Available

Sheet 7/7



TOTAL WORKED AREA

≈491,000SY

E14005BB 10.24.96

Holloman Air Force Base
Sewage Lagoons Closure Project
Corrective Measures Study
November 1996

Figure 4-3 Alternative AF3

Final Contours

Restore To Natural Contours

ATTACHMENT B

Cost Calculations

APPENDIX D

List of Reports Prepared Regarding the Sewage Lagoons at Holloman AFB

APPENDIX D
List of Reports Prepared Regarding the Sewage Lagoons at Holloman AFB

REPORT TITLE	DESCRIPTION	DATE
Evaluation for Hazardous Waste at Holloman AFB Sewage Treatment Plant	EP toxicity results of November 1981 water and sludge samples collected from the sewage lagoons and Lake Holloman	January 1982
Report to USEPA Regarding Holloman Air Force Base Lagoons and T-38 Washrack Oil-Water Separator	Analytical results of sludge and wastewater samples collected from Ponds A and B.	December 22, 1983
Sewage Lagoon Test Results	Analytical results of sludge and wastewater samples	UBTL/March 1985
Evaluation for 129 Priority Pollutants, Holloman AFB Sewage Ponds	During December 1984 HAFB collected sludge and wastewater samples from Ponds A, B, and C and analyzed for the 129 priority pollutants, heavy metals and pesticides and EP toxicity. Analytical methods used included EPA methods 624, 625, and 608, cyanides, and total phenols.	Holloman AFB Bioenvironmental Engineering Services/March 1986
Analytical Summary of Holloman Air Force Base Delisting Assessment, Holloman, New Mexico	Analytical results of December 1984 sampling event and a July 1987 sampling event that collected one sludge and one water sample from each sewage lagoon, Lake Holloman, and Lake Stinky. Appendix IX constituents were analyzed during the July 1987 event.	Wadsworth/ALERT Laboratories/August 18, 1987
Draft Quality Control Summary Report (A-E QCSR) for Additional Sampling Hazardous Waste Sewage Sludge Removal	Defines extent of PCB, organic constituents, and metals contamination in Ponds A (45 locations) and B (40 locations) and along the periphery of each lagoon (4 samples each). Analytical results of sewage sludge for metals, Methods 8240, 8270, 8080, cyanide, and EP toxicity. Samples were collected between August 22 and September 8, 1988.	Radian/January 1989
Hydrogeologic Investigation Report and Groundwater Monitoring Plan for the Sewage Treatment Lagoons	Results of hydrogeologic investigation and proposed monitoring system.	Radian/July 1989
Data Quality Control Summary Report for Additional Groundwater Samples from the First Groundwater Sampling Round	Results of groundwater monitoring.	Radian/November 1989
Letter to USACE summarizing sampling activities conducted in March 1990 for Ponds B and C	Analytical results of sludge and soil collected from Pond C.	Radian letter report April 1990

List of Reports Prepared Regarding the Sewage Lagoons at Holloman AFB

(Continued)

REPORT TITLE	DESCRIPTION	DATE
Background Contamination Indicator Parameters Summary Statistics for Upgradient Wells and Comparison with Data for the Third Semi-annual Groundwater Sampling Episode, Sewage Treatment Lagoons Monitoring Wells	See title for description	IT Corp./June 1991
Fourth semiannual groundwater sampling report	Results of groundwater sampling from July 15-19, 1991	IT Corp./ October 1991
Background Contamination Indicator Parameters Summary Statistics for Upgradient Wells and Comparison with Data for the Fourth Semi-annual Groundwater Sampling Episode, Sewage Treatment Lagoons Monitoring Wells	See title for description	IT Corp./October 1991
Groundwater Assessment Monitoring Plan for the Sewage Treatment Lagoons	Describes groundwater monitoring procedures for the Phase I Assessment	Radian/September 1991
Conceptual Plan for Sludge and Soil Sampling	Describes alternate plan for sampling each sewage lagoon to support the PCCP application.	Radian/November 1991
A-E Sampling and Quality Control Summary Report for Appendix IX Groundwater Sampling, Assessment Monitoring Program	Analytical results of assessment monitoring program conducted between September 1991 and April 1992	Radian/April 1992
Results of Confirmation Sampling and Comparison to Appendix IX Sampling, Assessment Monitoring Program, Holloman AFB, NM	Results of confirmation sampling to determine the presence of organochlorine pesticides in the groundwater. Sampling was performed in February 1992.	Radian/April 1992
Hazardous Waste Sewage Sludge Removal Lab Results	Results of sludge sampling on October 9, 1990	WT Environmental Consultants/ May 1992
Sampling and Quality Control Summary Report (A-E SQCSR), Sewage Lagoon Investigation	Appendix IX analytical results of sludge and soil collected in the Ponds C, D, E, G, ditch, and Lakes Holloman and Stinky during the Spring of 1992. Sludge and soil samples were also analyzed for organophosphorus pesticides, chlorinated herbicides, PCBs, dioxins and furans.	Radian/August 1992

List of Reports Prepared Regarding the Sewage Lagoons at Holloman AFB

(Continued)

REPORT TITLE	DESCRIPTION	DATE
Project Assessment Report, Sewage Lagoons and Lakes, Closure Project	Provides historical background of regulatory issues, and investigates from the early 1980s through 1995.	Radian and Foster Wheeler, March 1995
Long-term Monitoring Plan for the Sewage Lagoons	Outlines the current groundwater monitoring program for the sewage lagoons.	Radian, April 1995
Annual Sampling Reports, Sewage Lagoons Long-term Groundwater Monitoring Program	Presents the results of the 1995 groundwater monitoring program for the sewage lagoons.	Radian, February 1996
Risk Assessment Report	Updates risk values for human health using the data collected during 1994 and 1995. Completely redoes the ecological risk assessment using biological sample data collected.	Radian and Foster Wheeler, March 1996
Site Characterization Report	Provides results and conclusions of data collected during 1994 and 1995. Describes trend in data from previous investigations.	Radian and Foster Wheeler, June 1996
Biological Resources Report	Describes effects that different closure alternatives could have on the ecosystem provided by the sewage lagoons and lakes.	Radian and Foster Wheeler, June 1996
Corrective Measures Study	Provides an evaluation of several closure alternatives, defines the closure objective and criteria, and proposes a conceptual design for closure of the sewage lagoons.	Radian, June 1996

DCN 95-670-008

RISK ASSESSMENT ADDENDUM

SEWAGE LAGOONS CLOSURE PROJECT
HOLLOMAN AIR FORCE BASE, NM

Draft Final

Prepared for:

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Holloman Air Force Base, NM

and

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Delivery Order 02, WAD 05 with:

U.S. Army Corps of Engineers
Omaha District
Omaha, Nebraska

March 1996

TABLE OF CONTENTS

Page

EXECUTIVE SUMMARY ES-1

ES.1 Human Health Risk Assessment ES-5
ES.1.1 Site-Specific Risk Assessments ES-5
ES.1.2 Updated Exposure Assumptions for the Human Health Risk Assessment .. ES-6
ES.2 Ecological Risk Assessment ES-8

1 INTRODUCTION AND BACKGROUND 1-1

1.1 Human Health Risk Evaluation Criteria 1-3
1.2 1993 Human Health Risk Assessment 1-3
1.2.1 1993 Baseline Risk Assessment 1-3
1.2.2 1993 Site-Specific Risk Assessments 1-6
1.2.3 Resolution of Uncertainties Associated with the 1993 Risk Assessment 1-6
1.3 1993 Ecological Risk Assessment 1-7
1.3.1 Summary of 1993 Ecological Risk Estimates 1-8
1.3.2 Uncertainties Associated with the 1993 Ecological Risk Assessment 1-9
1.4 Human Health Risk Assessment Update 1-9
1.5 Ecological Risk Assessment Update 1-11

2 DATA EVALUATION FOR THE HUMAN HEALTH RISK ASSESSMENT 2-1

2.1 Ponds A and B 2-1
2.2 Pond D 2-1
2.3 Pond F 2-1
2.4 All Other Sites 2-1

3 METHODOLOGY FOR THE HUMAN HEALTH RISK ASSESSMENT 3-1

3.1 Selection and Calculation of Risks For New COPCs 3-1
3.2 Risk Ratio Method 3-5
3.3 Calculation of Updated Risk Estimates 3-6

4 HUMAN HEALTH RISK ASSESSMENT UPDATE SUMMARY 4-1

4.1 Updated Risk Assessment Assumptions 4-1
4.1.1 Updated Exposure Scenarios Evaluated 4-1
4.1.2 Toxicity Values 4-2
4.2 Summary of the Updated Risk Estimates for the Sewage Lagoons and Lakes 4-2
4.3 Pond A 4-3
4.4 Pond B 4-6
4.5 Pond C 4-6
4.6 Pond D 4-10
4.7 Pond E 4-10

TABLE OF CONTENTS (Continued)

Page

4.8 Pond F 4-10
4.9 Risk Estimates for Ingestion of Waterfowl from Pond G, the Ditch, Lake Holloman, and Lake Stinky 4-13
4.10 Pond G 4-17
4.11 The Ditch 4-17
4.12 Lake Holloman 4-20
4.13 Lake Stinky 4-20
4.14 Conclusions 4-22

5 METHODOLOGY FOR THE ECOLOGICAL RISK ASSESSMENT 5-1

5.1 Assessment and Measurement Endpoints and the Quotient Method 5-1
5.2 Ecological Characterization 5-3
5.3 Identification of Chemicals of Potential Ecological Concern 5-5
5.4 Exposure Assessment 5-7
5.4.1 Selection of Measurement Endpoints 5-8
5.4.2 Uncertainty Factors 5-8
5.4.3 Ecological Quotients for the Indicator Species 5-12
5.5 Toxicity Assessment 5-15
5.5.1 Selection of Measurement Endpoints 5-15
5.5.2 Uncertainty Factors 5-15
5.5.3 Ecological Quotients for the Assessment Endpoint Species 5-16

6 RESULTS AND CONCLUSIONS OF THE ECOLOGICAL RISK ASSESSMENT 6-1

6.1 Summary of Results 6-1
6.2 Waterfowl 6-2
6.3 Mosquito Fish 6-3
6.4 Constituents Not Evaluated 6-4
6.5 Summary of Conclusions 6-5
6.6 Uncertainty Assessment 6-6

7 REFERENCES 7-1

APPENDIX A: Chemicals of Potential Concern and Supporting Statistical Data
APPENDIX B: Summary Tables for Determination of COPCs
APPENDIX C: Raw Data
APPENDIX D: Analytical Results and QA/QC of Biological Data
APPENDIX E: Risk-Based Screening Tables
APPENDIX F: Site-Specific Human Health Risk Assessments
APPENDIX G: Risk Summary Tables
APPENDIX H: Toxicity Profiles

LIST OF FIGURES

Page

ES-1 Location of the Sewage Lagoons at Holloman AFB ES-2

1-1 Location of the Sewage Lagoons at Holloman AFB 1-2

2-1 Decision Flow Chart for Determining COPCs for the Risk Assessment Addendum 2-3

3-1 Decision Flow Chart for Determining New COPCs and Calculating Risk Ratios for the Risk Assessment Addendum 3-2

5-1 Methodology for Ecological Risk Assessment 5-4

5-2 Trophic Levels of the Sewage Lagoons and Lakes 5-9

LIST OF TABLES

Page

ES-1 Summary of Sewage Lagoons and Lakes Investigations ES-3

ES-2 Biological Samples Collected in 1993 ..... ES-4

ES-3 Summary of Human Health Risk Assessment Results ES-7

ES-4 Summary of Ecological Risk Assessment Results, Chemicals That Have Potential to Cause Adverse Effects to Ecology Surrounding the Sewage Lagoons and Lakes ES-9

1-1 Summary of Sewage Lagoons and Lakes Investigations 1-4

1-2 Biological Samples Collected in 1993 1-5

2-1 Summary of the Data Sets Available to Determine COPCs for the Risk Assessment Addendum 2-2

2-2 COPCs for the Risk Assessment Addendum 2-5

3-1 Summary of the New COCs Identified 3-3

3-2 Risk Ratios for the Human Health Risk Assessment 3-7

4-1 Summary of the Updated Risk Estimates 4-3

4-2 Summary of the Updated Risk Assessment Results Pond A 4-7

4-3 Summary of the Updated Risk Assessment Results Pond B 4-8

4-4 Summary of the Updated Risk Assessment Results Pond C 4-9

4-5 Summary of the Updated Risk Assessment Results Pond D 4-11

4-6 Summary of the Updated Risk Assessment Results Pond E 4-12

LIST OF TABLES (Continued)

Page

4-7 Comparison of Health Risk Estimates from the Ingestion of Ducks Based on Actual Tissue Samples and Modeled Tissue Values 4-15

4-8 Comparison of Contaminant Levels Found in Duck Tissue and Modeled Estimates with Allowable Residue Levels in Foods 4-16

4-9 Summary of the Updated Risk Assessment Results Pond G 4-18

4-10 Summary of the Updated Risk Assessment Results The Ditch 4-21

4-11 Summary of the Updated Risk Assessment Results Lake Stinky 4-22

5-1 Samples Collected for the Ecological Risk Assessment 5-6

5-2 Constituents Eliminated from the Risk Evaluation 5-6

5-3 Intake Equation and Parameters for Avian Assessment Endpoint Species 5-14

5-4 Critical Effects for COECs at Holloman AFB 5-17

6-1 Summary of Ecological Quotients 6-2

6-2 Uncertainties in the Ecological Risk Assessment 6-7

LIST OF ACRONYMS

AFB	Air Force Base
AWQC	Ambient Water Quality Criteria
BCF	Bioconcentration factor
BEHP	Bis(2-ethylhexyl)phthalate
BRA	Baseline risk assessment
CMS	Corrective measures study
COC	Chemical of Concern
COEC	Chemical of Ecological Concern
COPC	Chemical of potential concern
COPEC	Chemical of potential ecological concern
EPA	U.S. Environmental Protection Agency
EQ	Ecological hazard quotient
ERA	Ecological risk assessment
FWS	U.S. Fish and Wildlife Service
GC	Gas chromatography
GC/MS	Gas chromatography/mass spectroscopy
HCB	Hexachlorobenzene
HI	Hazard index
HSDB	Hazardous Substances Data Base
HSWA	Hazardous and Solid Waste Amendments
HWMR	Hazardous Waste Management Regulations
HWMUs	Hazardous waste management units
IRIS	Integrated Risk Information System
LC_{50}	Median lethal concentration
LD_{50}	Median lethal dose
LOAEL	Lowest observable adverse effect level
ND	Not detected
NMED	New Mexico Environment Department
PCBs	Polychlorinated biphenyls
PPE	Personal protective equipment

LIST OF ACRONYMS (Continued)

RCRA	Resource Conservation and Recovery Act
RTECS	Registry of Toxic Effects of Chemical Substances
SCR	Site Characterization Report
SWMU	Solid waste management unit
TCLP	Toxicity characteristic leaching procedure
TDS	Total dissolved solids
TEF	Toxicity equivalency factor
UCL	Upper confidence limit
UF	Uncertainty factor
UTL	Upper tolerance limit

EXECUTIVE SUMMARY

This report evaluates the current and future risks to human health and the environment potentially associated with the sewage lagoons and lakes at Holloman Air Force Base (AFB), New Mexico. These include seven sewage lagoons (referred to as Ponds A through G), the ditch from Pond G to Lake Holloman, Lake Holloman, and Lake Stinky (see Figure ES-1).

The risk assessment has been prepared to support Sections 4.3 and 6.4 of the *Sewage Lagoons Closure Plan* (Radian and Foster Wheeler, 1995b). The information in this risk assessment addendum will be used to guide decisions regarding the closure of the sewage lagoons and lakes. Closure of the sewage lagoons is under the authority of the New Mexico Environment Department (NMED), New Mexico Hazardous Waste Management Regulations (HWMR-7), Part V, 40 CFR 264. The ditch and the two lakes are classified as solid waste management units (SWMUs) and will be monitored, if necessary, under the Hazardous and Solid Waste Amendments (HSWA) corrective action program. Currently, the ditch and Lake Holloman are designated as SWMU 139, and Lake Stinky is SWMU 140. Monitoring of these SWMUs, if necessary, will be performed in accordance with Holloman AFB's Resource Conservation and Recovery Act (RCRA) permit. When the new wastewater treatment system begins operating, the outfalls to Pond G and Lake Holloman will be regulated under a Clean Water Act NPDES permit.

A risk assessment for each of the sewage lagoons and lakes was prepared in December 1993 (Radian, 1993a) on the basis of data collected through 1993. Biological tissue samples were collected in 1993 (for birds, insects, fish, vegetation, benthic organisms, and salamanders), but the analytical results from these data were not available at the time the 1993 risk assessment report was prepared. In the absence of these data, some of the ecological and human health risks were estimated using uptake models which were based on soil/sediment and surface water data.

Several uncertainties were identified in the analytical data that were used to estimate risks for both human and ecological receptors in 1993. These uncertainties included 1) unconfirmed detections of heptachlor epoxide in sludge; 2) suspect detections of organic lead, at amounts greater than total lead concentrations, in surface water; and 3) estimated chemical concentrations in waterfowl.

To address the uncertainties with the soil, sludge, and surface water data, a sampling plan (one component of the *Project Plans*) was developed (Radian and Foster Wheeler, 1994). A geostatistical analysis was used for the sampling plan to determine the appropriate number and the optimum location of samples to be collected. An investigation that followed the sampling plan was implemented in 1994 and 1995 (referred to as the 1994 investigation in this addendum). In addition, analytical methodologies were reviewed and selected to address the analytical uncertainties that were identified in the 1993 risk assessment.

This risk assessment addendum uses the results of the 1994 investigation along with the supportable data from previous investigations. Tables ES-1 and ES-2 summarize the data that have been collected. Table ES-1 presents the data collected for surface water, sludge, sediment, and soil, and Table ES-2 presents the biological data collected.

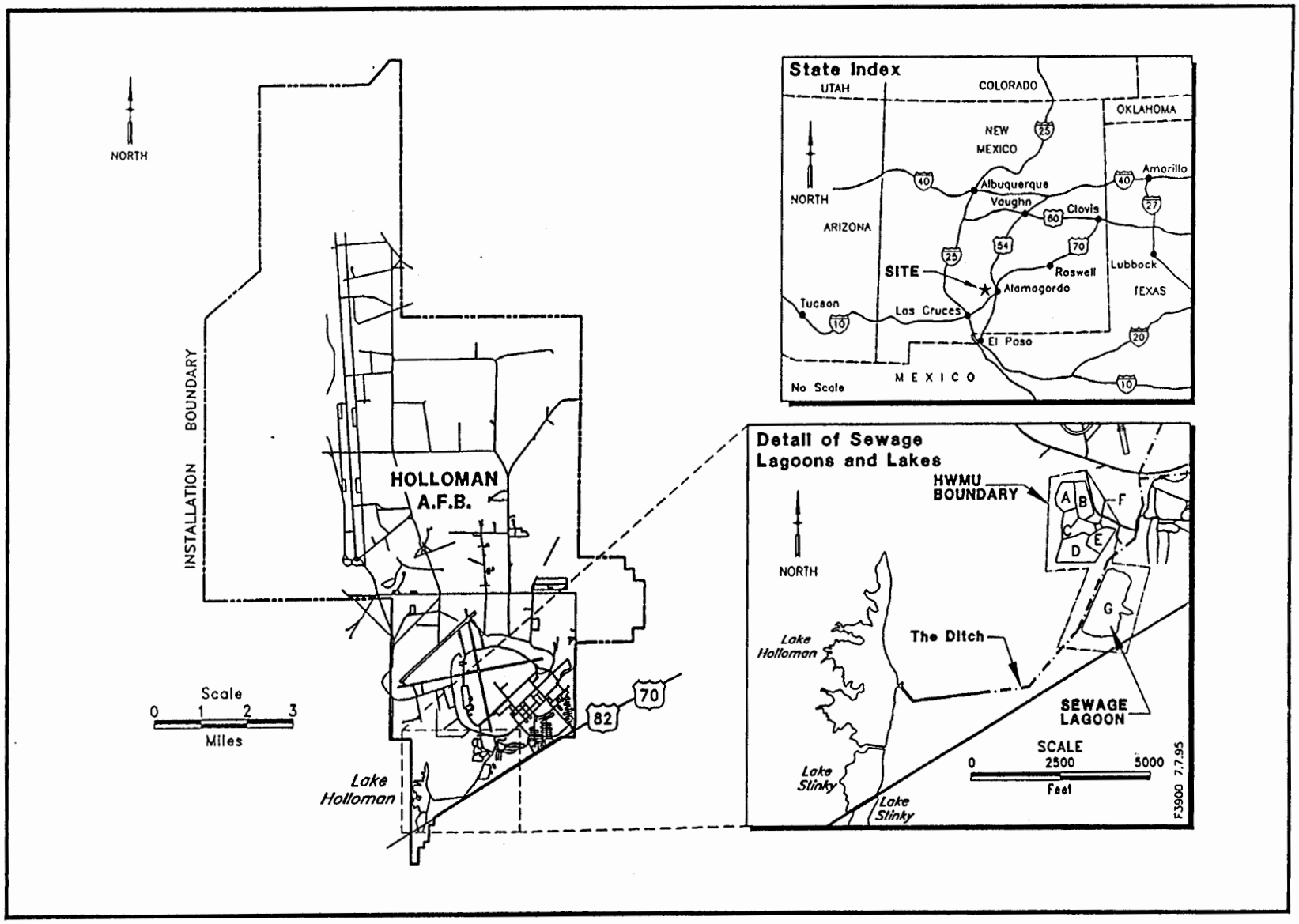


Figure ES-1. Location of the Sewage Lagoons at Holloman AFB

Table ES-1
Summary of Sewage Lagoons and Lakes Investigations

Medium	Year	Number of Sample Locations[a]										Analyses Performed
		Pond A	Pond B	Pond C	Pond D	Pond E	Pond F	Pond G	The Ditch	Lake Holloman	Lake Stinky	
Surface Water	1990	--	5	5	5	5	--	5	--	6	--	Semivolatiles, Organochlorine Pesticides, PCBs, and Metals
	1993	1	1	--	1	1	1	1	1	3	2	Organochlorine Pesticides
	1994/ 1995	--	--	3	3	3	--	9	3	14	--	Total, and Organic Lead
Sludge	1990	28[b]	37	6	--	--	--	--	--	--	--	Ponds A, B, and C - PCBs; Pond C - VOCs, Semivolatiles, Chlorinated Herbicides, Organochlorine Pesticides, and Metals
	1992	--	--	6	--	5	2	6	--	7	--	Appendix IX Constituents
	1994/ 1995	6	6	13[c]	16	16	--	19[d]	--	25	--	Ponds A and B - PCBs; Ponds A, B, and C - TCLP Metals, and Total and Reactive Sulfides; Ponds C, D, E, and G - Organochlorine Pesticides and Metals; Ponds C and G - Kepone
Sediment[e]	1993	1	--	--	--	1	--	--	--	--	--	Semivolatiles, Organochlorine Pesticides, and Metals
Soil	1990	8	6	6	--	--	--	--	--	--	--	Ponds A and B - Appendix IX Constituents; Pond C - VOCs, Semivolatiles, Chlorinated Herbicides, Organochlorine Pesticides, PCBs, and Metals
	1992	--	--	8	9	8	1	8	4	9	6	Appendix IX Constituents

[a] This table presents the number of sample locations and not the number of samples collected. At some locations multiple samples were collected.
[b] Originally 25 sludge samples were collected during the 1990 investigation. One sample had questionable data, and three additional samples were collected to verify or disprove the questionable data. Therefore, a total of 28 sludge samples were collected in 1990.
[c] Six samples were analyzed for TCLP metals and for sulfides; eight were analyzed for kepone.
[d] Twelve samples were analyzed for kepone.
[e] For purposes of characterizing the sewage lagoons, the sediment samples were considered as sludge samples. The sediment samples were near surface composite samples collected as part of the biota sampling to correlate constituents found in benthic organisms with the environment in which they lived.

PCBs = Polychlorinated biphenyls.
TCLP = Toxicity characteristic leaching procedure.
VOCs = Volatile organic compounds.
-- = Not sampled.

Table ES-2
Biological Samples Collected in 1993

Site	Biological Samples					
	Algae-Benthos	Insects-Invertebrates	Fish (*Gambusia*)	Salamander	Black-Necked Stilt	Mallard
Pond A	(a)	(b)				
Pond B						
Pond C	(a)	(b)			3	
Pond D						
Pond E	(a)					
Pond F						
Pond G	(a)	(b)	(c)	4		1
Ditch	(a)	(b)	(c)			
Lake Stinky	(a)	(b)				
Lake Holloman	(a)		(c)			

(a) Numerous microscopic algae and benthic organisms were present in each sample taken. It is not possible to quantify the exact number of organisms per sample.

(b) Various insects and invertebrates were collected from these locations. Sampling records estimate the number of organisms to be greater than 100 per sample.

(c) Fish samples (gambusia) at each impoundment consisted of greater than 40 fish per sample. These fish were approximately 1 inch long on average.

This addendum is not intended to replace the 1993 human health risk assessment report for the sewage lagoons and lakes (Radian, 1993a). Rather, its purpose is to update the 1993 report by recalculating the human health risk estimates using supplemental data collected between 1993 and 1995. However, the ecological risk assessment presented in this addendum does replace the 1993 version because biological data were available to calculate risks instead of relying on the modeled estimates that were used primarily in 1993. In this addendum, biota samples of benthic organisms and insects were used to model food uptake to higher trophic levels. These modeled values and the tissue samples of higher trophic level organisms were used to draw conclusions concerning ecological risk.

ES.1 Updated Human Health Risk Assessment

Site-specific risk assessments were updated for each component of the sewage lagoons and lakes. These site-specific risk assessments are presented in Section 4 and Appendix F of this addendum.

Four of the five exposure scenarios identified in the 1993 risk assessment were used to estimate the health risks associated with human exposure to site-related contaminants in this addendum. These scenarios, and the sites where they were evaluated, are presented below.

1) **Current On-site Worker (chronic and subchronic).** This exposure scenario was evaluated at Ponds A through G and the ditch. It addressed the exposure pathways associated with normal maintenance and operations at the sewage lagoons and the ditch.

2) **Current/Future Recreational—Hunters (chronic and subchronic).** This scenario was evaluated at Pond G, the ditch, and the lakes for both children and adults.

3) **Current/Future Trespasser—Teenager (subchronic).** This exposure scenario was evaluated only at Pond G because Ponds A through F are securely fenced, and Ponds A through F will be removed from active service in the future.

4) **Future Beef Consumer—Agricultural (chronic).** This exposure scenario was evaluated only at Lake Stinky. The other impoundments are within the confines of Holloman AFB where grazing of livestock is not permitted due to lack of water and because of conflicts with wildlife management objectives.

The Future On-site Worker scenario, evaluated at Ponds A through F in the 1993 risk assessment, was not evaluated in this addendum. Holloman AFB will ensure that OSHA health and safety requirements are implemented during closure activities, thereby precluding exposure to hazardous constituents.

ES.1.1 Site-Specific Risk Assessments

For each carcinogenic chemical of concern (COC), the incremental probability that an individual will develop cancer over a lifetime was estimated from projected intake levels and cancer potency factors. The USEPA Superfund site remediation goal set forth in the National Contingency Plan (NCP) established cancer risks of 1E-4 (1 in 10,000) to 1E-6 (1 in a million) as acceptable levels for known or suspected carcinogens. This range is designed to be protective of human health. For risk management decisions, a cancer risk of 1E-6 is considered a level of negligible risk and is the point of departure for determining remedial goals. As cancer risk estimates increase above 1E-6, so too does the level of concern for human health. Since these cancer risk estimates are generally upper-bound values, it is not likely that the "true risk," resulting from actual exposure, will be exceeded.

For noncarcinogenic COCs it is assumed there is an exposure level below which it is unlikely that adverse health effects will occur

(even for sensitive populations such as children). To characterize adverse noncarcinogenic health effects, comparisons were made between projected chemical intake and the toxicity of a given chemical. This relationship is referred to as the hazard quotient. For noncarcinogens then, there may be concern for potential noncancer effects when the hazard quotient (for individual chemicals) or hazard index (the sum of multiple hazard quotients) exceeds 1. In general, the greater the value above 1, the greater level of concern.

The updated cancer risk and noncancer hazard estimates are listed in Table ES-3 for each site at the sewage lagoons and lakes. As shown in this table, cancer risk estimates are well within the acceptable risk range of 1E-06 to 1E-04 established by the USEPA. Cancer risk estimates are greater than 1E-6, only in the reasonable maximum exposure case, at Ponds A, B, and G, the ditch, and both lakes. Cancer risk estimates are less than 1E-6 at Ponds C, D, E, and F in all exposure scenarios. The estimated noncancer hazard index at all sites, for all exposure scenarios, is less than 1.

Ponds A and B

The reasonable maximum cancer risk estimates at Ponds A and B are associated primarily with worker exposure to sludge. Although these estimates are 2E-6, they are well within the acceptable levels for cancer effects established by EPA. Additionally, potential health risks will be mitigated once these sewage lagoons are removed from active service.

Pond G, the Ditch, Lake Holloman, and Lake Stinky

The reasonable maximum cancer risk estimate is 6E-6, well within the acceptable risk range established by EPA for remediation goals, at each of these sites and is based on the ingestion of waterfowl in the adult recreational (hunter) scenario. The data used to estimate cancer risk for this scenario came from the breast tissue of one duck that was caught while flying over Pond G. Although this data set is limited, the risks estimated from it were also compared to the risks estimated in 1993 which were based on modeled duck tissue data. In general, the risk estimates were similar for the two data sets, actual tissue data and modeled tissue data, and indicated that PCBs were the primary COCs. Although PCBs are the primary cancer risk drivers for this scenario, the only known source of these PCBs will be eliminated once Ponds A through F are removed from active service.

Because both data sets resulted in cancer risk estimates greater than 1E-6, chemical concentrations in duck tissue, actual and modeled, were also compared to federal and/or state tolerance levels for chemical residues in foods. This comparison indicated that the residue levels in duck tissue (actual and modeled) were 5 to 500 times lower than the tolerance levels established for commonly eaten foods such as eggs, fish, and commercial poultry. Since hunters were assumed to ingest the breast meat of 3 to 6 ducks in one year, it is likely that the allowable tolerance levels for commonly eaten foods could also apply to the ducks caught at Holloman AFB. Therefore, these tolerance levels suggest that the chemical residues in ducks taken from the sewage lagoons and lakes are not of concern to hunters who ingest them.

ES.1.2 Updated Exposure Assumptions for the Human Health Risk Assessment

At the time the 1993 risk assessment was being prepared, the disposition of the sewage lagoons and lakes was uncertain and the extent of contamination at these sites had not been fully defined. Based on that understanding of the sewage lagoons and lakes, a number of assumptions were made when selecting the potential exposure scenarios for the sewage lagoons and lakes. These assumptions often erred in favor of selecting the most conservative

Table ES-3
Summary of Human Health Risk Assessment Results

Site	Human Health Risk Estimates				Exposure Scenario Associated with Health Risks	Comments
	Noncancer Hazard		Cancer Risk			
	AVG	RM	AVG	RM		
Pond A	< 1	< 1	< 1E-6	2E-6	Cancer risk estimates are based entirely on dermal contact with Aroclor-1254, in sludge, for the Current Onsite Worker Scenario.	Risks are well within EPA's acceptable levels established for carcinogens and will be mitigated once this sewage lagoon is removed from active service. Planned for closure.
Pond B	< 1	< 1	< 1E-6	2E-6	Cancer risk estimates are based entirely on dermal contact with sludge for the Current On-site Worker Scenario. Aroclor-1254 contributes 76% to the overall risk estimate, with 4,4'-DDE, benzo[a]pyrene, and chlordane accounting for 19% of this estimate.	Risks are well within EPA's acceptable levels established for carcinogens and will be mitigated once this sewage lagoon is removed from active service. Planned for closure.
Pond C	< 1	< 1	< 1E-6	< 1E-6	NA	Planned for closure.
Pond D	< 1	< 1	< 1E-6	< 1E-6	NA	Planned for closure.
Pond E	< 1	< 1	< 1E-6	< 1E-6	NA	Planned for closure.
Pond F	< 1	< 1	< 1E-6	< 1E-6	NA	Planned for closure.
Pond G The Ditch Lake Holloman Lake Stinky	< 1	< 1	< 1E-6	6E-6	Cancer risk estimates are based entirely on the ingestion of waterfowl hunted at these sites in the Adult Recreational Scenario. PCBs (36%), 4,4'-DDE (23%), oxychlordane (18%), dieldrin (15%), gamma-Chlordane (4%), and 4,4'-DDD (3%) are the primary risk drivers for this scenario.	The cancer risk estimates for Pond G, the Ditch, and the Lakes are identical and are discussed here collectively. These risk estimates are well within EPA's acceptable levels established for known or suspected carcinogens. The levels of pesticide and PCB residues in duck tissue used to estimate these risks are 5 to 500 times lower than federal and/or state tolerance levels for these residues in commonly eaten foods. As such, these allowable tolerance levels could also apply to the ducks hunted at Holloman AFB. See Section 4.9 of this addendum for a complete discussion of these tolerance levels.

AVG = Average Exposure Case
RM = Reasonable Maximum Exposure Case

exposure scenarios (i.e., scenarios that would be the most protective of human health). With greater understanding of the sewage lagoons and lakes, and the closure plan being developed for it, it is clear that the future onsite worker scenario should be eliminated, the future beef consumer scenario should be evaluated only at Lake Stinky, and the current/future recreational scenario will consider exposure to hunters only because the only risks identified in 1993 were for ingestion of waterfowl. The rationale for eliminating and updating these exposure scenarios in this addendum is provided below.

Future On-site Worker

While it is accurate to assume that the on-site worker scenario will exist when Ponds A through F are being removed from active service, it is inaccurate to assume that these workers will be exposed to site-related contaminants. During closure operations, all workers will be required to wear personal protective equipment (PPE) and will be properly decontaminated before leaving the work area. By implementing these and other OSHA health and safety measures, the potential health risks associated with this exposure scenario will be eliminated.

Future Beef Consumer

In the future beef consumer scenario, it was assumed that children and adults were exposed to chemicals in groundwater and lake water by consuming cattle that had ingested the groundwater or lake water directly, or had grazed on grasses irrigated by these waters. This exposure scenario is not likely to happen since the groundwater in this area of the Tularosa Basin is not potable due to the naturally high levels of total dissolved solids (TDS). The high salinity associated with this groundwater also precludes its use as a drinking water source for livestock. Moreover, the land surrounding the sewage lagoons and lakes is managed by Holloman AFB which does not allow cattle to graze north of Highway 70. However, in the event that grazing should occur south of Highway 70 (the southern portion of Lake Stinky) the future beef consumer scenario was evaluated at Lake Stinky.

Current/Future Recreational—Hunter

In the 1993 risk assessment, the current/future recreational scenario was evaluated for both birdwatchers and hunters at Pond G, the ditch, and the lakes. The risk estimates generated in 1993 for this scenario indicated that ingestion of waterfowl, caught at these sites and ingested by hunters, was the primary pathway of exposure for both children and adults. Because the risks associated with bird watching were overshadowed by the risks estimates for hunters (i.e., from ingesting waterfowl), exposure to birdwatchers was eliminated in the recreational scenario for this addendum.

Additionally, the number of ducks taken by hunters (and ingested) per year was updated for this exposure scenario. In the 1993 risk assessment, the ingestion rates for hunters, the number of ducks eaten per year, were based on data from the Colorado Division of Wildlife for the average number of ducks harvested by hunters per year.

In this addendum, more appropriate ingestion rates were adopted for duck hunters in the State of New Mexico. These ingestion rates are based on the 1994 statewide average number of ducks harvested per year by active adult hunters (FWS, 1995).

A detailed discussion of these ingestion rates is presented in Section 4.1.1 of this addendum.

ES.2 Ecological Risk Assessment

Ponds A through F were not evaluated in the new ecological risk assessment (ERA) because they are planned to be closed and will no longer

serve as a habitat for aquatic wildlife. Specific ERAs for Pond G, the ditch, Lake Holloman, and Lake Stinky as well as an overall evaluation of the sewage lagoons and lakes is presented in Sections 5 and 6 of the risk assessment addendum.

The potential for adverse ecological effects was evaluated using a combination of basic uptake modeling from lower trophic levels to higher trophic levels, and actual biological tissue sample data taken from the sewage lagoons and lakes. The potential for adverse effects was estimated by comparing chemical concentrations in the media at these sites with safe concentrations determined from literature studies. Adverse effects were defined as attributes that may threaten the survivorship and productivity of the aquatic food chain.

DDT and its derivatives, DDD and DDE, were the only constituents found to have the potential to cause adverse effects in the sewage lagoons and lakes. Table ES-4 provides a summary of the species and locations where DDT and its derivatives could potentially result in an adverse effect. These constituents are no longer used at the Base and should be decreasing to a level that poses no risk to the aquatic ecosystem. The concentrations of DDT in the sewage lagoons decreased by an order of magnitude between 1992 and 1994, as is documented in the *Site Characterization Report* (Radian and Foster Wheeler, 1995d). It is unlikely that the survivorship and productivity of the aquatic food chains are threatened.

Table ES-4
Summary of Ecological Risk Assessment Results, Chemicals that Have Potential to Cause Adverse Effects to Ecology Surrounding the Sewage Lagoons and Lakes

Analyte	Pond G (Fish)	The Ditch (Fish)	Black-necked Stilt [a] (Body Burden)	Mallard [a] (Body Burden)
DDD	X	X		
DDE	X	X	X	X
DDT		X		

[a] Stilt and mallard EQs are not based on impoundment-specific samples but are intended to represent waterfowl present at the lakes and lagoons. None of the impoundment-specific EQs for waterfowl modeled from the food source data exceeded 1.0.

Section 1
INTRODUCTION AND BACKGROUND

In support of Sections 4.3 and 6.4 of the Sewage Lagoons Closure Plan (Radian and Foster Wheeler, 1995b), the information in this risk assessment addendum will be used to guide decisions regarding the closure of Holloman Air Force Base's (AFB's) sewage lagoons. This addendum identifies the chemicals of concern that pose potential human health or environmental risk and provides a quantitative measure of these potential risks; however, it does not provide cleanup standards for reducing these risks. The results of this risk assessment addendum may be used in the corrective measures study (CMS) to develop appropriate cleanup standards based on expected future land use.

The sewage lagoons and lakes system is composed of seven sewage lagoons (referred to as Ponds A through G), Lake Holloman, the ditch between Pond G and Lake Holloman, and Lake Stinky (see Figure 1-1). Closure of the sewage lagoons is under the authority of the New Mexico Environment Department (NMED), New Mexico Hazardous Waste Management Regulations (HWMR-7), Part V, 40 CFR 264. NMED has classified the sewage lagoons as hazardous waste management units (HWMUs) and as such they must be closed as Resource Conservation and Recovery Act (RCRA) hazardous waste units. The ditch and the two lakes are classified as solid waste management units (SWMUs) and will be monitored, if necessary, under the Hazardous and Solid Waste Amendments (HSWA). Currently, the ditch and Lake Holloman are designated as SWMU 139 and Lake Stinky is SWMU 140. Monitoring of these SWMUs, if necessary, will be performed in accordance with Holloman AFB's RCRA permit. Because of the interrelation of the sewage lagoons and lakes in respect to the ecology and the potential for human exposure, this addendum evaluates both the sewage lagoons and lakes. The history of the sewage lagoons and lakes is fully documented in the *Project Assessment Report* (Radian and Foster Wheeler, 1995a).

A risk assessment for each of the sewage lagoons and lakes on the basis of data collected through 1993 was presented to NMED in December 1993 (Radian, 1993a). Biological tissue samples were collected in 1993 (for birds, insects, fish, vegetation, benthic organisms, and salamanders), but the analytical results from these samples were not available at the time the 1993 risk assessment report was prepared. In the absence of these data, some of the ecological and human health risks were estimated with basic uptake models using soil/sediment and surface water data only. Several uncertainties were identified in the analytical data used to estimate risks for both human and ecological receptors. These uncertainties included 1) unconfirmed detections of heptachlor epoxide in the sludge; and 2) suspect detections of organic lead at concentrations greater than total lead in the surface water.

To address the uncertainties with the soil, sludge, and surface water data, a sampling plan (one component of the *Project Plans*) was developed (Radian and Foster Wheeler, 1994). Geostatistical analysis was used for the sampling plan to determine the appropriate number and the optimum location of samples to be collected. An investigation that followed the sampling plan was implemented in 1994 and 1995 (referred to as the 1994 investigation in this addendum). In addition, analytical methodologies were reviewed and selected to address the analytical uncertainties that were identified in the 1993 risk assessment.

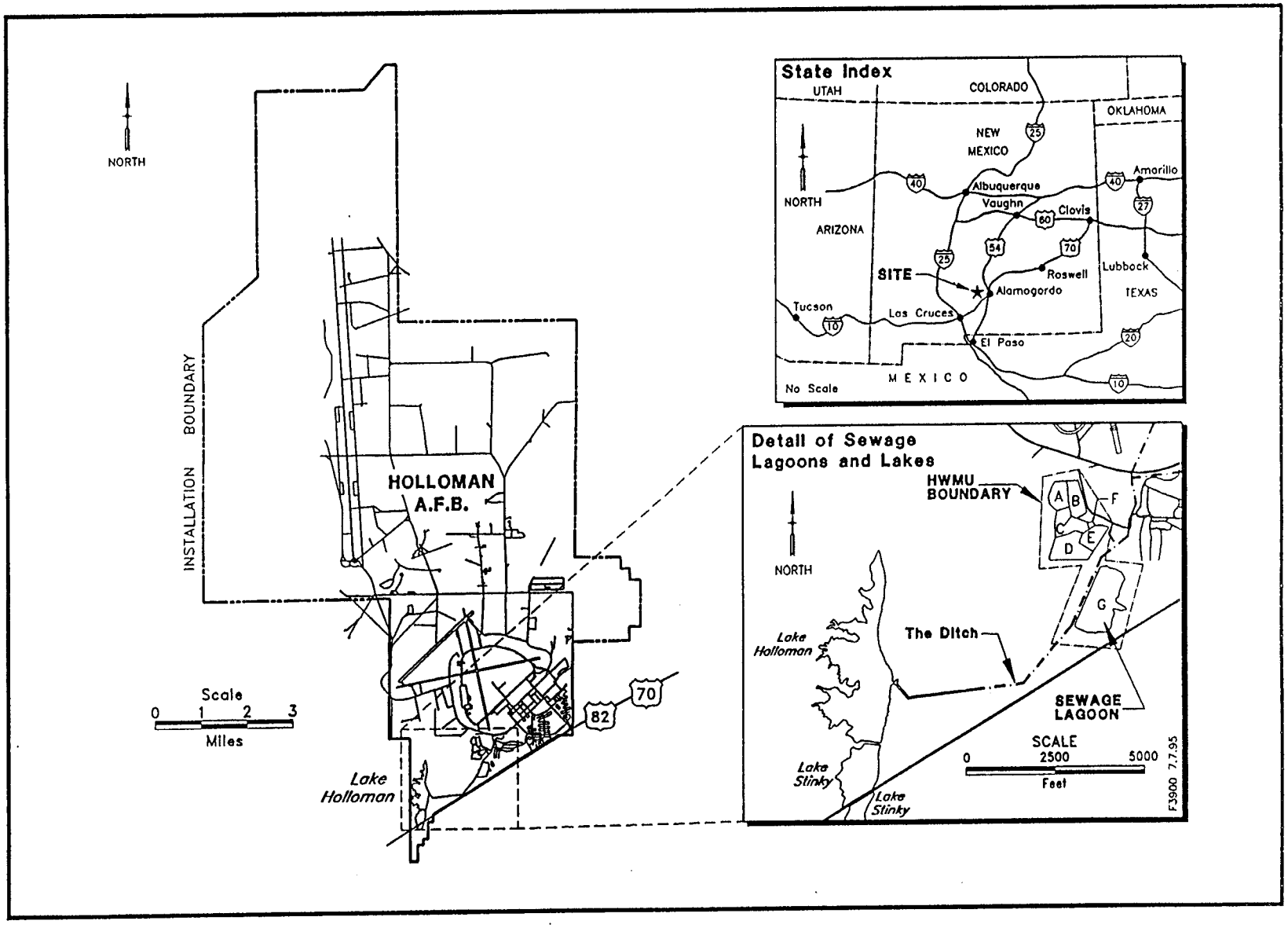


Figure 1-1. Location of the Sewage Lagoons at Holloman AFB

This risk assessment addendum uses the results of the 1994 investigation along with the supportable data from previous investigations. Tables 1-1 and 1-2 summarize the data. Table 1-1 lists the data for surface water, sludge, sediment, and soil, and Table 1-2 lists the biological data collected in 1993. This addendum is not intended to replace the 1993 human health risk assessment report for the sewage lagoons and lakes (Radian, 1993a). Rather, its purpose is to update the 1993 report by recalculating the human health risk estimates using supplemental data collected between 1993 and 1995. However, the ecological risk assessment presented in this document does replace the 1993 version because biological data were available to use instead of the modeled estimates in 1993.

1.1 Human Health Risk Evaluation Criteria

For each carcinogenic chemical of concern (COC), the incremental probability that an individual will develop cancer over a lifetime was estimated from projected intake levels and cancer potency factors. The USEPA Superfund site remediation goal set forth in the National Contingency Plan (NCP) establishes cancer risks of 1E-4 (1 in 10,000) to 1E-6 (1 in a million) as acceptable levels for known or suspected carcinogens. This range is designed to be protective of human health. For risk management decisions, a cancer risk of 1E-6 is considered a level of negligible risk and is a point of departure for determining remedial goals. As cancer risk estimates increase above 1E-6, so too does the level of concern for human health. Since these cancer risk estimates are generally upper-bound values, it is not likely that the "true risk," resulting from actual exposure, will be exceeded.

For noncarcinogenic COCs it is assumed there is an exposure level below which it is unlikely that adverse health effects will occur (even for sensitive populations such as children). To characterize adverse noncarcinogenic health effects, comparisons were made between projected chemical intake and the toxicity of a given chemical. This relationship is referred to as the hazard quotient. For noncarcinogens then, there may be concern for potential noncancer effects when the hazard quotient (for individual chemicals) or hazard index (the sum of multiple hazard quotients) exceeds 1. In general, the greater the value above 1, the greater level of concern.

These criteria were used to evaluate the potential health risks for the sewage lagoons and lakes in the 1993 risk assessment and for this updated risk assessment.

1.2 1993 Human Health Risk Assessment

The 1993 risk assessment evaluated cancer risks and noncancer hazards at Holloman AFB under two conditions. The first condition, a baseline risk assessment (BRA), assumed that homes would be built on top of the sewage lagoons (Ponds A through G) with little or no remedial activities. In addition to the exposure pathways considered in this scenario, it was also assumed that groundwater would be used as a potable water source. This BRA is discussed in Appendix L of the 1993 risk assessment report (Radian, 1993a).

Under the second condition, each sewage lagoon, each lake, and the drainage ditch between Pond G and Lake Holloman, was evaluated separately in a site-specific risk assessment. Unlike the BRA, the site-specific assessments did not evaluate the residential exposure scenarios. The site-specific risk assessments are discussed in detail in Sections 2 through 12, Volume I, of the 1993 risk assessment report (Radian, 1993a).

1.2.1 1993 Baseline Risk Assessment

The BRA was initially performed to determine if health risks would exist under very conservative assumptions (i.e., a residential setting without prior site cleanup). If human health risk

Table 1-1
Summary of Sewage Lagoons and Lakes Investigations

Medium	Year	Number of Sample Locations[a]										Analyses Performed
		Pond A	Pond B	Pond C	Pond D	Pond E	Pond F	Pond G	The Ditch	Lake Holloman	Lake Stinky	
Surface Water	1990	--	5	5	5	5	--	5	--	6	--	Semivolatiles, Organochlorine Pesticides, PCBs, and Metals
	1993	1	1	--	1	1	1	1	1	3	2	Organochlorine Pesticides
	1994/ 1995	--	--	3	3	3	--	9	3	14	--	Total, and Organic Lead
Sludge	1990	28[b]	37	6	--	--	--	--	--	--	--	Ponds A, B, and C - PCBs; Pond C - VOCs, Semivolatiles, Chlorinated Herbicides, Organochlorine Pesticides, and Metals
	1992	--	--	6	--	5	2	6	--	7	--	Appendix IX Constituents
	1994/ 1995	6	6	13[c]	16	16	--	19[d]	--	25	--	Ponds A and B - PCBs; Ponds A, B, and C - TCLP Metals, and Total and Reactive Sulfides; Ponds C, D, E, and G - Organochlorine Pesticides and Metals; Ponds C and G - Kepone
Sediment[e]	1993	1	--	--	--	1	--	--	--	--	--	Semivolatiles, Organochlorine Pesticides, and Metals
Soil	1990	8	6	6	--	--	--	--	--	--	--	Ponds A and B - Appendix IX Constituents; Pond C - VOCs, Semivolatiles, Chlorinated Herbicides, Organochlorine Pesticides, PCBs, and Metals
	1992	--	--	8	9	8	1	8	4	9	6	Appendix IX Constituents

[a] This table presents the number of sample locations and not the number of samples collected. At some locations multiple samples were collected.
[b] Originally 25 sludge samples were collected during the 1990 investigation. One sample had questionable data, and three additional samples were collected to verify or disprove the questionable data. Therefore, a total of 28 sludge samples were collected in 1990.
[c] Six samples were analyzed for TCLP metals and for sulfides; eight were analyzed for kepone.
[d] Twelve samples were analyzed for kepone.
[e] For purposes of characterizing the sewage lagoons, the sediment samples were considered as sludge samples in the 1993 data set. The sediment samples were near surface composite samples collected as part of the biota sampling to correlate constituents found in benthic organisms with the environment in which they lived.

PCBs = Polychlorinated biphenyls.
TCLP = Toxicity characteristic leaching procedure.
VOCs = Volatile organic compounds.
-- = Not sampled.

Table 1-2
Biological Samples Collected in 1993

Biological Samples						
Site	**Algae-Benthos**	**Insects-Invertebrates**	**Fish (*Gambusia*)**	**Salamander**	**Black-Necked Stilt**	**Mallard**
Pond A	(a)	(b)				
Pond B						
Pond C	(a)	(b)			3	
Pond D						
Pond E	(a)					
Pond F						
Pond G	(a)	(b)	(c)	4		1
Ditch	(a)	(b)	(c)			
Lake Stinky	(a)	(b)				
Lake Holloman	(a)		(c)			

(a) Numerous microscopic algae and benthic organisms were present in each sample taken. It is not possible to quantify the exact number of organisms per sample.

(b) Various insects and invertebrates were collected from these locations. Sampling records estimate the number of organisms to be greater than 100 per sample.

(c) Fish samples at each impoundment consisted of greater than 40 fish per sample. These fish were approximately 1 inch long on average.

estimates from the BRA were negligible, further evaluation of the sewage lagoons and lakes would not be required. Results of the BRA indicated cancer risk estimates exceeded 1E-6 for all the sewage lagoons at Holloman AFB. At Ponds A, B, and E, cancer risk estimates were greater than 1E-4. At Ponds C, D, F, and G, cancer risk estimates were greater than 1E-6 but less than 1 E-4. Since cancer risk estimates were not negligible in the BRA, further evaluation of the sewage lagoons and lakes was required (i.e., performing site-specific risk assessments).

It is assumed that the residential conditions of the BRA would still show risk, so for this addendum the BRA risks were not reevaluated. The exclusion of the BRA is discussed in Section 1.4 of this addendum. A detailed summary of the risk estimates for the BRA is provided in Appendix L of the 1993 risk assessment report (Radian, 1993a).

1.2.2 1993 Site-Specific Risk Assessments

Individual site-specific human health risk assessments were performed for all sewage lagoons, the ditch, and the lakes. The purpose of these risk assessments was to adequately characterize the potential risks associated with each site on the basis of the exposure conditions thought to be the most likely to occur. The exposure scenarios evaluated for these risk assessments are described in Section 4 and Appendix F of this addendum. The 1993 risk estimates for each sewage lagoon, the ditch, and the lakes are presented in Appendix F of this addendum.

Cancer risks exceeded 1E-6 for at least one scenario at all sites except at Ponds C, D, and F, and noncancer hazard estimates exceeded 1 for at least one scenario at all sites except Ponds D and F. The health risk estimates for many of these sites were based primarily on the suspect analytes heptachlor epoxide and/or organic lead. However, the actual presence of both analytes was questionable, which added a great deal of uncertainty to the health risk estimates. The uncertainty associated with these suspect chemicals is discussed in Section 1.2.3 of this addendum.

1.2.3 Resolution of Uncertainties Associated with the 1993 Risk Assessment

Several uncertainties were identified in the analytical data that were used to estimate risks for both human and ecological receptors. These uncertainties included 1) unconfirmed detections of heptachlor epoxide in sludge, and 2) suspect detections of organic lead above total lead concentrations in surface water.

Heptachlor Epoxide

In the 1993 risk assessment, heptachlor epoxide was the primary risk driver at Ponds A and E and contributed significantly to cancer risks at the ditch and Lake Stinky. The risk at each of these sites was based on a single sample in which heptachlor epoxide was tentatively identified in analysis by EPA Method 8080 (an unconfirmed hit). In this method, samples are analyzed on two columns containing different packing materials, which cause each target analyte to be detected at different retention times. Compounds which coelute with the target compound on one column will not coelute with that same target compound on the second column. When an analyte is detected on both columns, its presence is considered confirmed. However, if the analyte is detected on one column, but not on the other, the detection is likely to be a false positive. When samples were analyzed by EPA Method 8080, heptachlor epoxide was detected only on the first column and was never confirmed on the second column. In the absence of second column confirmation, the validity of these data was questionable. It was determined that the presence of heptachlor epoxide could not be confirmed since EPA Method 8080 could not clearly resolve the heptachlor epoxide detections.

To confirm or disprove the presence of heptachlor epoxide at these sites, additional sampling was performed during a subsequent investigation in 1994. Samples were analyzed again using EPA Method 8080, but any samples that indicated heptachlor epoxide on one column only were then analyzed by gas chromatography/ mass spectroscopy (GC/MS) using EPA Method 8270. For 17 samples of 105 collected, heptachlor epoxide was reported on the first column but not on the second using the GC methodology. Fourteen (14) of these samples with unconfirmed detections (i.e., all samples with unconfirmed detections of 10 μg/kg or higher) were analyzed by GC/MS, and the results of this analysis indicated that heptachlor epoxide was not present in the sewage lagoons, the ditch, or the lakes. Since heptachlor epoxide was not detected at these sites, and GC/MS is a much more reliable analytical tool than GC alone, heptachlor epoxide is no longer considered a chemical of potential concern (COPC) at these sites. Therefore, heptachlor epoxide does not contribute to cancer or noncancer risks at Pond A, Pond E, the ditch, or Lake Stinky.

Organic Lead

In the 1993 risk assessment, organic lead in surface water was a noncancer risk driver at Pond G and Lake Holloman. The presence of organic lead in these surface water samples was also in question. A great deal of uncertainty surrounded this analyte for the following reasons:

1) There is no indication that organic lead is related to past waste disposal activities or current practices for sewage treatment;

2) Sample concentrations for organic lead exceeded those for total lead; and

3) Analytical results for equipment rinsate samples also indicated similar concentrations of organic lead.

To address the uncertainties surrounding these results, additional surface water samples were collected from Ponds C, D, E, and G, the ditch, and Lake Holloman in 1994 and analyzed by a method that allowed a lower detection limit than was previously used in 1993. The analytical results of these samples indicated that organic lead was not detected at these sites. This sampling event was conducted to confirm the presence or absence of organic lead in the sewage lagoons and lakes. Since organic lead was not detected during the 1994 sampling event, the risks previously associated with this analyte are no longer considered valid.

1.3 1993 Ecological Risk Assessment

The 1993 ecological risk assessment evaluated risk at each sewage lagoon, the ditch and the lakes individually. The indicator species, which were chosen to be representative of other species in the area, included fish and mallard at all of the sites; killdeer at Ponds A, B, and E, and the ditch; and mergansers at Pond G, Lake Holloman, and the ditch.

Risk was estimated by calculating an ecological hazard quotient (EQ), which is the ratio of the observed or estimated contaminant concentrations to the safe benchmark concentration for a specific species. Ecological hazard indices were then calculated for the birds by summing the EQs for each indicator species at each impoundment. The ecological hazard index was used in estimating the potential for adverse effects on the indicator species within the sewage lagoons and lakes. The hazard index was not calculated for the fish, because it was assumed that the fish would spend their entire life in a single impoundment as opposed to the birds which are likely to use all sewage lagoons and lakes for food and cover. Analysis of the biological samples had not been completed at the time of the 1993 report; thus only a fraction of the data for benthic organisms and invertebrates was used. Uptake

from surface water and sediment/sludge was used to model the remaining pathways.

1.3.1 Summary of 1993 Ecological Risk Estimates

Ponds A through D

The 1993 ecological risk assessment at Ponds A, B, C, and D indicated that birds (mallards and killdeer) subsisting on the sewage lagoons and lakes are not likely to be at risk. Although fish were not found in any of these sewage lagoons, the EQ showed that risk to fish was theoretically possible. The fish results were based entirely on water contaminant concentrations. All of these sewage lagoons are planned for closure and will no longer be wet habitat for wildlife or contribute risk to the ecosystem.

Pond E

The 1993 ecological risk assessment at Pond E indicated that mallards were not likely to be at risk. For killdeer living near Pond E, however, adverse effects were possible on the basis of the calculated EQ. Although fish were not found in Pond E, adverse effects are theoretically possible solely on the basis of contaminant concentrations in surface water. Pond E is planned to be closed and will no longer be a wildlife habitat or contribute risk to the ecosystem.

Pond F and the ditch

The 1993 ecological risk assessment for Pond F and the ditch indicated that no adverse effects were expected for any of the indicator species or the species they represent. Pond F is planned to be closed.

Pond G

The 1993 ecological risk assessment (ERA) concluded that bird species using Pond G were not likely to be at risk. The EQs for both mallards and mergansers indicated that risk to these species was insignificant. The EQs for fish indicated that adverse effects may be possible; however, it was noted that Pond G has a fish population of *Gambusia* which were introduced to control the mosquito population. Further evaluation, based upon analysis of fish tissue samples, was recommended.

Lake Holloman

Mallards, mergansers and fish were evaluated in the 1993 ecological risk assessment. Acceptable EQs were found for mallards and mergansers under average conditions. The reasonable maximum EQ was slightly elevated for the mallards. EQ values for fish were also slightly elevated. However, on the basis of the large population of fish (*Gambusia*) in Lake Holloman, it was concluded that the EQs were unlikely to represent significant risk.

Lake Stinky

The 1993 ecological risk assessment for Lake Stinky evaluated risks to fish and mallards. EQ values were in the acceptable range for both species. The reasonable maximum EQ for mallards was slightly elevated, but it was concluded that this was unlikely to represent significant risk. Fish EQs were below the acceptable limit for both the average and the reasonable maximum scenarios. Additionally, Lake Stinky is dry most of the time and does not support populations of fish and mallards on a continuous basis.

The 1993 ecological risk assessment concluded that additional biological sampling was needed to validate the modeling results and determine which chemicals, if any, were being bioaccumulated up the food chain. Additional sampling and evaluation were required to make recommendations concerning the future of the individual impoundments and the system as a whole. Overall, the 1993 ecological risk assessment concluded that mergansers were not likely to be at risk, whereas the potential for risk existed for mallards, killdeer, and fish.

1.3.2 Uncertainties Associated with the 1993 Ecological Risk Assessment

Uncertainty was noted in the 1993 ERA for sampling and analysis, the toxicity assessment, and the exposure assessment. Sampling uncertainty resulted from difficulties in extracting benthic organisms from the substrate at several locations. It was also noted that, in general, obtaining a representative biota sample is difficult.

The quality assurance/quality control (QA/QC) analysis noted several data limitations that resulted in adjusting concentrations that may have been biased low. Results that may have been biased high were not adjusted, possibly causing risks to be overestimated for 4,4'-DDD, 4,4'-DDE, bis(2-ethylhexyl)phthalate, dioxins, and furans. Uncertainty in the toxicity assessment was due to the absence of the most sensitive toxicity endpoints for some of the chemicals in some species. Toxicity data had to be extrapolated between species causing additional uncertainty.

Uncertainty in the exposure assessment resulted from the assumptions used to determine the intake rates and ingestion fractions. In some cases, surrogate values had to be used, and in other cases values such as the exposure duration had to be estimated.

Because bioaccumulation factors were not used in the food uptake model for birds, the possibility exists that risks to birds were underestimated for certain chemicals in the model. It was concluded that including these factors would have grossly overestimated risk. Tissue samples were expected to validate the results of the model.

1.4 Human Health Risk Assessment Update

As a general rule, the assumptions used in this addendum reflect the same methodology and rationale used in the 1993 risk assessment. The exceptions to these assumptions are listed below.

1) **Toxicity values for PCBs have been updated.** In the 1993 risk assessment report (Radian 1993a), cancer and noncancer toxicity values for PCBs were based on their relative potency compared to that of 2,3,7,8-TCDD. Toxicity values for PCBs were calculated by multiplying the chemical-specific toxicity equivalency factor (TEF) by the toxicity value of 2,3,7,8-TCDD. The TEF values used in this calculation were obtained from EPA (EPA, 1989a).

In this addendum, toxicity values for PCBs have been updated to reflect EPA's current position on PCB potency in humans. Although EPA still considers certain PCBs to have dioxin-like properties, they have not assigned new TEFs for these PCBs. EPA further states, "In the case of PCBs, research on the applicability of the TEF approach is ongoing but there is not yet any formal EPA policy" (EPA, 1994a). Currently the EPA provides cancer and noncancer toxicity values for PCBs through the Integrated Risk Information System (IRIS) (EPA, 1995a). IRIS lists a cancer potency value for "PCBs" in general, and non-cancer values for certain PCB mixtures (also called aroclors). For cancer risk estimates, all PCBs were evaluated using the same (and the only) toxicity value presented in IRIS. Likewise, noncancer hazards for all PCBs were estimated using the most health protective value of any aroclor mixture listed in IRIS.

2) **The 1993 BRA is not updated.** The baseline risk assessment (BRA), one component of the 1993 risk assessment report (Radian 1993a), does not accurately reflect the human health risk associated with the sewage lagoons. The BRA assumed that remediation of the sewage lagoons (Ponds A through G) would not occur and that homes would be built directly on top of these sites. Because these exposure conditions are very conservative, the BRA can be viewed as a screening tool to determine if health risks are

present at a site. Moreover, it is unlikely that homes will ever be built on the sewage lagoons, because:

- The soils at these sites are unsuitable for constructing buildings;
- The groundwater beneath Holloman AFB is unfit for human consumption and is too high in total dissolved solids (TDS > 10,000 mg/L basewide) for use in backyard gardens;
- This land is likely to become open space or be used for industrial purposes;
- The sewage lagoons are located at the end of the runway clear zone;
- The installation of sewage lines and a potable water source to support these homes would be too costly for prospective developers; and
- The area is inundated with wetlands and floodplains, making the area unsuitable for residential building.

On the basis of these considerations, the residential land use assumption is not included as a component of the updated risk assessment for the sewage lagoons and lakes.

3) **Actual duck tissue data are used to estimate health risks to hunters.** In the 1993 report, health risks for hunters that ingested waterfowl caught from the sewage lagoons and lakes were estimated using data from a model that predicted chemical levels in duck tissue. Modeled tissue data were used in 1993 because actual tissue samples were not available. Subsequent to the 1993 report, several attempts were made to collect actual duck tissue samples from the sewage lagoons and lakes. However, only one duck was collected, while flying over Pond G, to assess risks for this exposure scenario.

In this addendum, the data used to estimate health risks for hunters came from the breast tissue of the one duck that was caught while flying over Pond G. Because this data set is limited, the risks estimated from the breast tissue of this duck will also be compared to the risks estimated in 1993 (which were based on modeled duck tissue data). This comparison will be made in order to correlate the COCs for each data set and their resultant health risk estimates.

4) **Arsenic removed as a COPC at the lakes.** In the 1993 risk assessment, cancer risks from arsenic exceeded 1E-6 at both lakes based on the inhalation of wind-blown dust from Lake Stinky. In the summer months, part of Lake Stinky dries up. When this occurs it was assumed that COPCs in lake bed soils and sediments, once covered by water, could become suspended in the air and be dispersed over both Lakes Holloman and Stinky. Arsenic was detected only in the surface soil at Lake Stinky. The mean and reasonable maximum exposure concentrations of arsenic in these soils were 2.7 and 3.4 mg/kg, respectively.

Results from the 1993 risk assessment indicated that the estimated cancer risk from inhaled soil-bound arsenic exceeded 1E-6. However, the site-background upper tolerance limit (UTL) for this analyte is reported as 6.88 mg/kg in the 1993 *Base-Wide Background Study* (Radian, 1993b). Since arsenic has been detected in the soil at Lake Stinky at concentrations below the background UTL, it is unlikely that the cancer risks estimated for the lakes could be distinguished from those that would occur due to the natural levels of arsenic. On the basis of this rationale, arsenic has been removed as a COPC at both lakes for all soil related pathways.

5) **Heptachlor epoxide and organic lead are no longer COPCs.** As stated in Section 1.1.2 of this addendum, these two analytes are not COPCs at any of the sewage lagoons, the ditch, or the lakes. Because there are no risks associated

with these analytes, they are no longer considered in this addendum.

6) **The Future On-site Worker scenario is not evaluated.** This exposure scenario was evaluated at Ponds A through F in the 1993 risk assessment to account for chemical exposure to workers during closure activities at these sewage lagoons. However, protection of workers during remediation or closure activities associated with Ponds A through F will be accomplished using standard OSHA health and safety requirements.

7) **The Future Agricultural (Beef Consumer) scenario is evaluated only at Lake Stinky.** Although the Future Beef Consumer scenario was evaluated at Ponds A through G and Lakes Holloman and Stinky in the 1993 risk assessment, this scenario is only evaluated at Lake Stinky in this addendum. Currently, cattle are not permitted to graze in the area of the sewage lagoons and lakes with the possible exception of the lower portion of Lake Stinky (south of highway 70). Because current grazing restrictions are likely to remain the same in the future, Lake Stinky is the only viable source of chemical uptake for cattle.

8) **Current/Future Recreational scenario is updated to evaluate hunters only.** In the 1993 risk assessment, the current/future recreational scenario was evaluated for both birdwatchers and hunters at Pond G, the ditch, and the lakes. The risk estimates generated in 1993 for this scenario indicated that ingestion of waterfowl, caught at these sites and ingested by hunters, was the primary pathway of exposure for both children and adults. Because the risks associated with bird watching were overshadowed by the risks estimates for hunters (i.e., from ingesting waterfowl), exposure to birdwatchers was eliminated in the recreational scenario for this addendum.

Additionally, the number of ducks taken by hunters (and ingested) per year was updated for this exposure scenario. In the 1993 risk assessment, the ingestion rates for hunters, the number of ducks eaten per year, were based on data from the Colorado Division of Wildlife for the average number of ducks harvested by hunters per year.

In this addendum, more appropriate ingestion rates were adopted for duck hunters in the State of New Mexico. These ingestion rates are based on the 1994 statewide average number of ducks harvested per year by active adult hunters (FWS, 1995).

A detailed discussion of these ingestion rates is presented in Section 4.1.1 of this addendum.

1.5 Ecological Risk Assessment Update

The assumptions used in this addendum to estimate ecological risks reflect a similar methodology and rationale used in the 1993 risk assessment. However, ecological risks were completely reevaluated using biological data that were not available for the 1993 ERA. The assumptions made for the ERA in this addendum are listed below.

1) Tissue samples from several different species collected around the sewage lagoons and lakes have been analyzed since the 1993 risk assessment report. Benthic organisms and insects were used to model food uptake to higher trophic levels. These modeled values and the tissue samples from higher trophic level organisms were used to draw conclusions concerning ecological risk.

2) The equations used to model concentrations in the indicator species have been modified in several ways. The most significant modification is the inclusion of uptake from sediment in several of

the models. This modification was included to provide a more realistic estimate of the contaminant concentrations in the models and address concerns regarding this pathway. Other modifications include adjustments to the parameters used in the models such as body weight, fractions ingested of various food sources, and the amount of time spent at each body of water. These adjustments were modified to reflect the most current data and are presented in Section 5.

3) The new wastewater treatment plant will continue to supply water to Pond G, the ditch, Lake Holloman and Lake Stinky, and continue supporting the habitat similar to current conditions. Only these areas were evaluated in the ecological risk assessment. Ponds A through F will not receive water and therefore will not be able to continue to provide the same type of habitat as currently exists. Because the sewage lagoons will likely be closed in place, the wastes will not be left exposed to nature. By focusing on the areas that will remain open, a more accurate portrayal of the effects to the habitat is possible.

(4) Because ecological risk assessment is a rapidly evolving field, there have been many new studies and papers published since the 1993 risk assessment report. For this reason, the measurement endpoints used in this addendum have been updated to reflect the most current available literature, allowing for more realistic and accurate ecological quotients.

5) Ecological quotients were not summed for the indicator species in this assessment because measurement endpoints were based on population effects that can be caused by a number of different mechanisms. Specific chemicals that contributed to potential adverse effects were addressed individually for each indicator species.

Section 2
DATA EVALUATION FOR THE HUMAN HEALTH RISK ASSESSMENT

This section summarizes the data evaluation process used to determine the human health chemicals of potential concern (COPCs) for the risk assessment addendum. Additional sludge, soil, and surface water samples were collected from the sewage lagoons and lakes during the 1994 investigation (samples were collected in 1994 and 1995 under this same investigation) and reported in the *Site Characterization Report* (SCR) (Radian and Foster Wheeler, 1995d). The objective of the data evaluation process was to use the data from the 1994 investigation to augment the existing data sets (used in the 1993 risk assessment) and confirm the validity of outlying data points. A complete discussion of the sludge, soil, and surface water data collected during the 1994 investigation is contained in the SCR. For a discussion of the process used to determine the 1993 COPCs, please refer to the 1993 risk assessment report (Radian, 1993a). The only biological data collected for estimating human health risks in this addendum was the breast tissue from a single duck that was shot at Pond G in 1993.

Table 2-1 summarizes the data sets evaluated in determining COPCs in this addendum for each of the sewage lagoons, the ditch, and the lakes.

Once the new data from the 1994 investigation were compiled, COPCs were determined statistically for each site and each exposure medium. These COPCs were then combined, when appropriate, with the COPCs reported in the 1993 risk assessment report (Radian, 1993a) to generate a list of COPCs for this addendum. Figure 2-1 is a flow diagram of the data set combination and selection process used to identify the updated COPCs for each sewage lagoon, the ditch, and the lakes. A complete discussion of the statistical methods used in deriving the updated COPCs and their exposure concentrations is provided in Appendices A through D of this addendum.

Section 3.0 discusses the methodology used in selecting the chemicals of concern (COCs) for this addendum.

2.1 Ponds A and B

For these two sewage lagoons, the 1993 and 1995 data sets were used to obtain the updated COPCs. These data were used exclusively since sludge was removed from both sewage lagoons in 1990. Because of this removal action, these data were chosen as the data sets that best represented updated conditions at Ponds A and B.

2.2 Pond D

Data were collected at Pond D in 1994 and 1995. The COPCs for this sewage lagoon were determined in four steps:

1) Determine COPCs for the 1994 data;

2) Determine COPCs for the 1995 data;

3) Combine the 1994 and 1995 COPCs with the COPCs from the 1993 risk assessment; and

4) Generate COPCs from the combined data sets.

2.3 Pond F

Because there were no significant risks estimated for this sewage lagoon in 1993, no new data were collected from any medium. Therefore, no new risks are estimated in this addendum.

Table 2-1
Summary of the Data Sets Available to Determine COPCs for the Risk Assessment Addendum

Site	Media Sampled	Year Data Set Collected					
		1988	1990	1992	1993	1994	1995
Pond A [a]	Sludge	x	x		x		x
	Soil		x				
	Surface Water				x		
Pond B [a]	Sludge	x	x				x
	Soil		x				
	Surface Water		x		x		
Pond C	Sludge		x	x		x	x [b]
	Soil		x				
	Surface Water		x			x	
Pond D	Soil			x			
	Sludge					x	x
	Surface water		x		x	x	
Pond E	Soil			x			
	Sludge			x	x	x	
	Surface water		x		x	x	
Pond G	Soil			x			
	Sludge			x		x	
	Surface Water		x		x	x	
	Water Fowl [c]				x		
The Ditch	Soil			x	x	x	
	Surface water				x	x	
	Water Fowl [c]				x		
Lake Holloman	Soil			x			
	Sludge			x		x	
	Surface water		x		x	x	
	Water Fowl [c]				x		
Lake Stinky	Soil			x	x	x	
	Surface Water			x			
	Water Fowl [c]				x		

Note: The groundwater is monitored regularly through the groundwater monitoring network for the sewage lagoons as part of the federal facility compliance agreement (FFCA).

[a] Only 1993 and 1995 data were used to determine COPCs in Ponds A and B because the sludge was removed in 1990.
[b] Sludge samples collected in 1995 were analyzed only for reactive sulfide.
[c] One mallard was caught at Pond G only. The data from this one duck was used for Pond G, the ditch, and Lakes Holloman and Stinky.

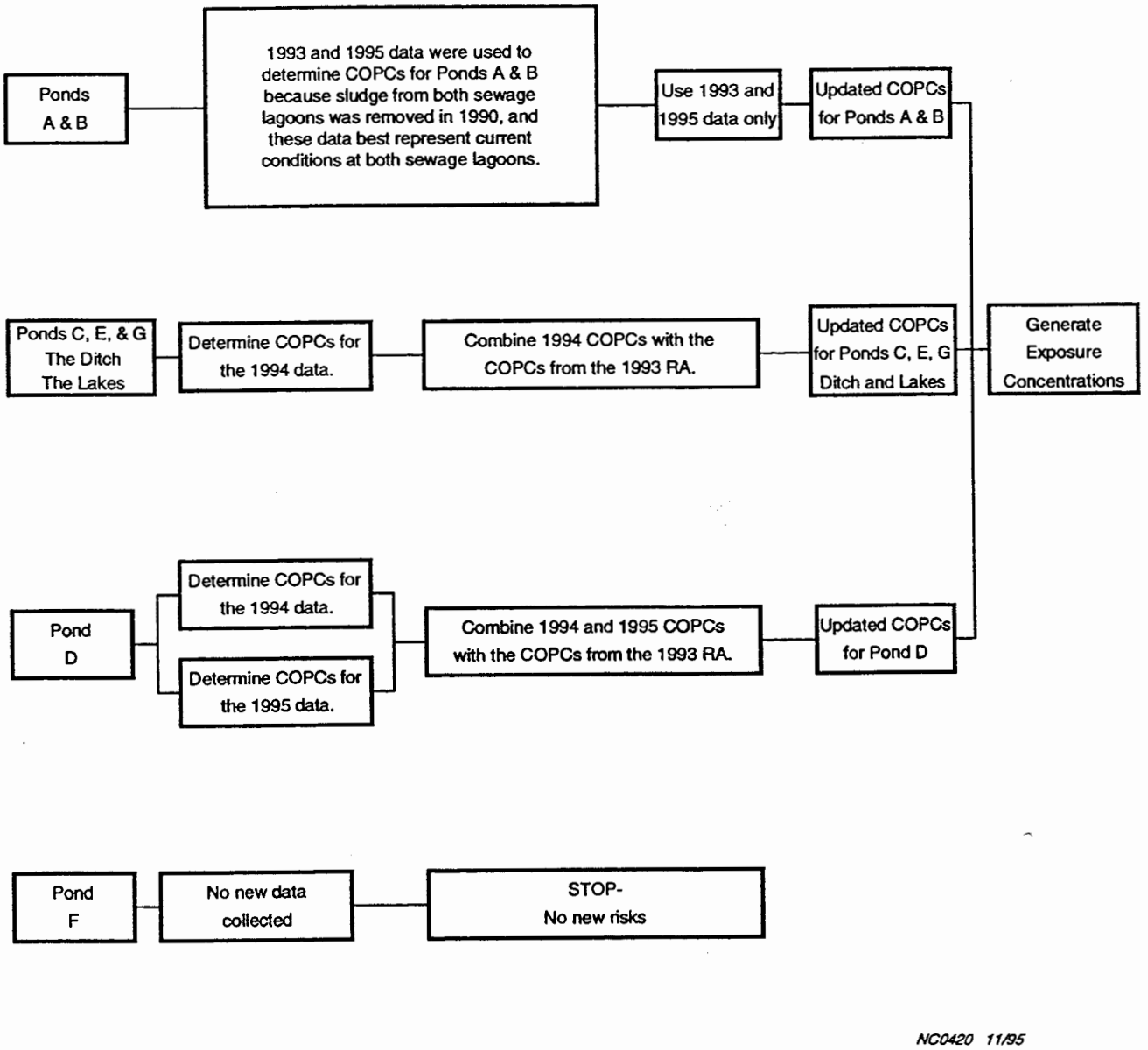


Figure 2-1. Decision Flow Chart for Determining COPCs for the Risk Assessment Addendum

2.4 All Other Sites

At Ponds C, E, and G, the ditch, and the lakes, additional data were collected in 1994. The COPCs were determined in three steps for these remaining sites:

1) Determine COPCs for the 1994 data;
2) Combine the 1994 COPCs with the COPCs from the 1993 risk assessment; and
3) Generate COPCs from the combined data sets.

Table 2-2 lists the updated COPCs for each site, by exposure medium.

Table 2-2
COPCs for the Risk Assessment Addendum

Risk Group	COPCs for the Risk Assessment Addendum		
Pond A	**Sludge** Aroclor-1254 [c] **Soil / Surface Water** No 1994/1995 data collected.		
Pond B	**Sludge** Aroclor-1254 [c] **Soil / Surface Water** No 1994/1995 data collected		
Pond C	**Sludge** Arsenic [a,b] alpha-BHC [a,b] delta-BHC [a,b] gamma-BHC [b] Barium [a,b] Beryllium [a,b] Cadmium [a,b] Chromium [a,b] Cobalt [a,b] **Soil** No 1994/1995 data collected. **Surface Water** None.	Copper [a,b] 4,4'-DDD [a,b] 4,4'-DDE [a,b] 4,4'-DDT [a,b] Dieldrin [b] Endosulfan I [a,b] Kepone [b] Lead [a,b] Mercury [a,b]	Nickel [a,b] Selenium [a,b] Silver [a,b] Sulfide, Reactive [c] Sulfide, Total [c] Tin [b] Vanadium [a,b] Zinc [a,b]
Pond D	**Sludge** Aldrin [b] Arsenic [b] alpha-BHC [b] Barium [b] Beryllium [b] Chlordane [b] Chromium [b] **Soil** Arsenic [a] Barium [a] Beryllium [a] Chromium [a] Cobalt [a] **Surface Water** None.	Cobalt [b] Copper [b] 4,4'-DDD [b] 4,4'-DDE [b] 4,4'-DDT [b] Endosulfan II [b] Copper [a] 4,4'-DDD [a] 4,4'-DDE [a] 4,4'-DDT [a] Lead [a]	Lead [b] Nickel [b] Selenium [b] Silver [b] Vanadium [b] Zinc [b] Nickel [a] Selenium [a] Silver [a] Vanadium [a] Zinc [a]

Table 2-2
(Continued)

Risk Group	COPCs for the Risk Assessment Addendum		
Pond E	**Sludge**		
	Arsenic [a,b]	Copper [a,b]	Nickel [a,b]
	alpha-BHC [b]	4,4'-DDD [a,b]	Selenium [a,b]
	delta-BHC [b]	4,4'-DDE [a,b]	Silver [a,b]
	gamma-BHC [b]	4,4'-DDT [a,b]	Thallium [b]
	Barium [a,b]	Dieldrin [b]	Tin [a,b]
	Beryllium [b]	Lead [a,b]	Vanadium [a,b]
	Chromium [a,b]	Mercury [a,b]	Zinc [a,b]
	Cobalt [b]		
	Soil		
	No 1994/1995 data collected.		
	Surface Water		
	None.		
Pond F	**Sludge / Soil / Surface Water**		
	None		
Pond G	**Sludge**		
	Arsenic [a,b]	Copper [a,b]	Lead [a,b]
	alpha-BHC [a,b]	4,4'-DDD [a,b]	Mercury [a,b]
	delta-BHC [b]	4,4'-DDE [a,b]	Nickel [a,b]
	Barium [a,b]	4,4'-DDT [a,b]	Selenium [a,b]
	Beryllium [a,b]	Dieldrin [b]	Silver [b]
	Chlordane [b]	Heptachlor epoxide [b]	Vanadium [a,b]
	Chromium [a,b]	Kepone [b]	Zinc [a,b]
	Cobalt [a,b]		
	Soil / Surface Water		
	No 1994/1995 data collected.		
The Ditch	**Sludge**		
	NA		
	Soil		
	Aldrin [a,b]	Cobalt [a,b]	Lead [a,b]
	Arsenic [a,b]	Copper [a,b]	Methoxychlor [b]
	delta-BHC [a,b]	4,4'-DDD [a,b]	Nickel [a,b]
	gamma-BHC [a,b]	4,4'-DDE [a,b]	Selenium [a,b]
	Barium [a,b]	4,4'-DDT [a,b]	Silver [a,b]
	Beryllium [a,b]	Dieldrin [b]	Vanadium [a,b]
	Chlordane [b]	Endosulfan Sulfate [b]	Zinc [a,b]
	Chromium [a,b]	Endrin [b]	
	Surface Water		
	None		

Table 2-2
(Continued)

Risk Group	COPCs for the Risk Assessment Addendum		
Lake Holloman	**Sludge**		
	Arsenic [a,b]	Chromium [a,b]	Kepone [b]
	alpha-BHC [a,b]	Cobalt [a,b]	Lead [a,b]
	delta-BHC [a,b]	Copper [a,b]	Nickel [a,b]
	gamma-BHC [a,b]	4,4'-DDD [a,b]	Selenium [a,b]
	Barium [a,b]	4,4'-DDE [a,b]	Silver [b]
	Beryllium [b]	4,4'-DDT [a,b]	Thallium [b]
	Cadmium [b]	Dieldrin [a,b]	Vanadium [a,b]
	Chlordane [b]	Isodrin [b]	Zinc [a,b]
	Soil		
	No 1994/1995 data collected.		
	Surface Water		
	None.		
Lake Stinky	**Sludge**		
	NA		
	Soil		
	Aldrin [a,b]	Chromium [a,b]	Heptachlor [b]
	Arsenic [a,b]	Cobalt [a,b]	Heptachlor epoxide [b]
	alpha-BHC [a,b]	Copper [b]	Nickel [a,b]
	delta-BHC [a,b]	4,4'-DDD [b]	Selenium [a,b]
	gamma-BHC [a,b]	4,4'-DDT [b]	Vanadium [a,b]
	Barium [a,b]	Dieldrin [b]	Zinc [a,b]
	Beryllium [a,b]	Endrin [a,b]	
	Surface Water		
	No 1994/1995 data collected.		

[a] Analyte was identified as a COPC during the 1993 risk assessment
[b] Analyte was identified as a COPC based on the 1994 data.
[c] Analyte was identified as a COPC based on the 1995 data.

Note 1: Groundwater data were not collected during the 1994 and 1995 sample collection efforts. See the 1993 risk assessment report for groundwater conclusions (Radian, 1993a). Also, "Soil" includes both surface and subsurface soil.

Note 2: For a complete list of the analytes identified as COPCs in the 1993 risk assessment, refer to Appendix A, Table A-2.

NA = Not applicable. No data collected for this medium at the indicated site.
None = No COPCs for this medium at the indicated site.

Section 3
METHODOLOGY FOR THE HUMAN HEALTH RISK ASSESSMENT

Two approaches were used to estimate human health risks for each sewage lagoon, the ditch, and the lakes. First, risks were estimated for all analytes detected during the 1994 investigation that were not chemicals of concern (COCs) in the 1993 risk assessment. These analytes are referred to as the "New COCs". Second, risk estimates were recalculated for the analytes considered as COCs in both the 1993 risk assessment and this addendum. For these COCs, the recalculation of risk was based on the relative change in exposure concentration that occurred between the 1994 investigation and the 1993 risk assessment. Figure 3-1 illustrates the data selection process and rationale used in calculating risk estimates based on these two approaches.

Section 3.1 discusses the methods used to identify and calculate risks for the new COCs. Section 3.2 describes the *risk ratio method*, by which risks were recalculated using the ratio of the current exposure concentrations and those used in 1993.

3.1 Selection and Calculation of Risks For New COCs

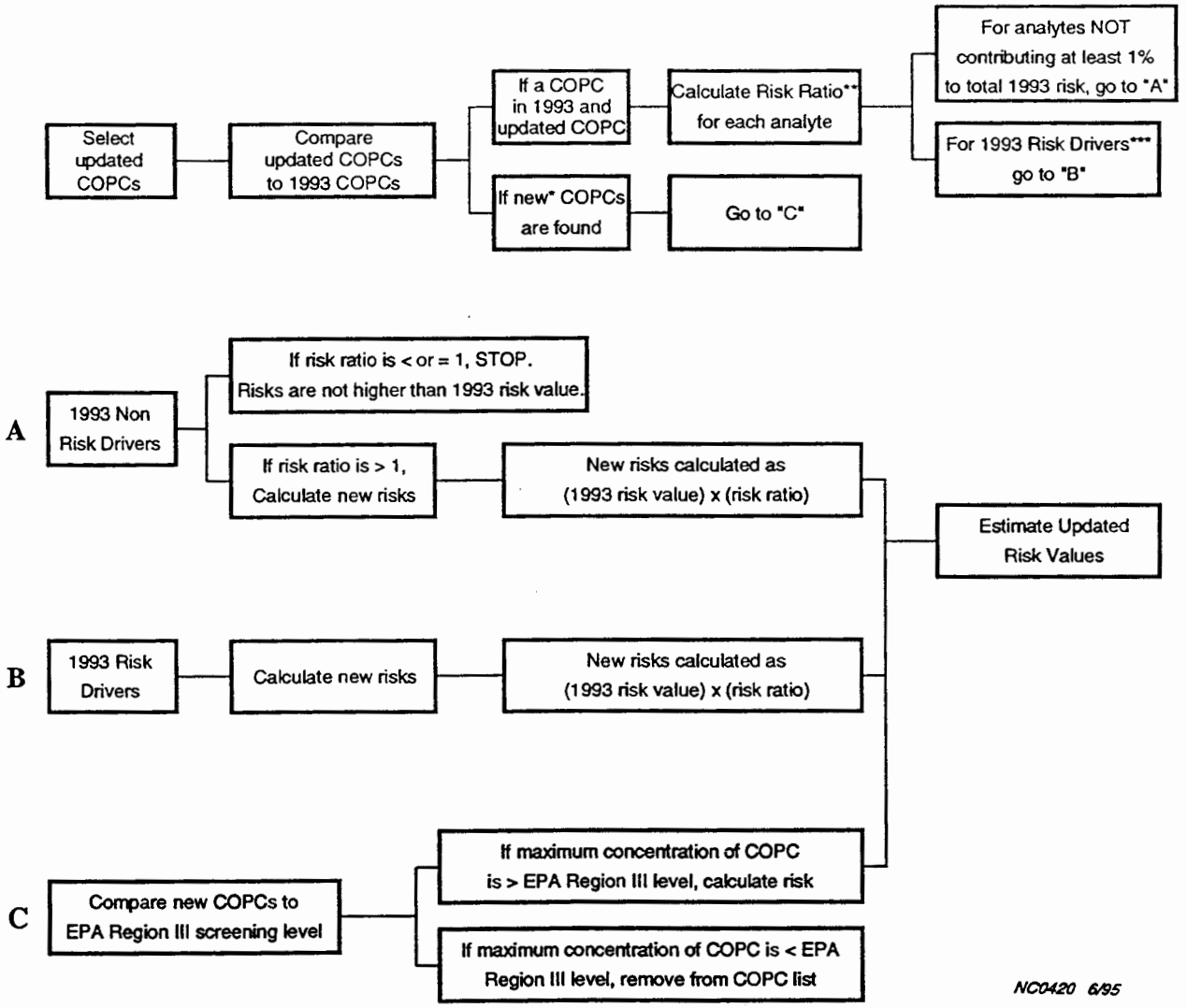
A two-step screening process was used to determine the new COCs. First, all COPCs selected for this addendum were compared, by site and exposure media, with the 1993 COCs for the same site and exposure media. If an analyte was a COPC in both 1993 and this addendum, then it was not considered a new COC (these analytes were evaluated according to the methodology outlined in Section 3.2). If, however, an analyte was not a COC in 1993, but was a COPC for this addendum, then the second step in selecting new COCs was followed.

A risk-based screening methodology was used to select the final list of updated COCs. This screening process followed guidance outlined in EPA's Region III Technical Guidance Manual for Risk Assessment, *Selecting Exposure Routes and Contaminants of Concern by Risk-Based Screening* (EPA, 1993a). This guidance provides the methodology to estimate risk-based screening levels for contaminants that correspond to a systemic noncancer hazard quotient of 0.1 or a lifetime cancer risk of 1E-6, and are based on the conservative algorithms for residential exposure to contaminants in soil and drinking water. An updated COPC was selected as a new COC only when its maximum detected concentration was greater than its corresponding EPA Region III risk-based screening level. Appendix E contains the output tables generated from the risk screening process.

Tables 3-1 list the analytes selected as new COCs for each site, by medium for each sewage lagoon, the ditch and the lakes. Because limited sampling was performed at Ponds A and B, no new COCs were identified during the 1994 investigation. Therefore, these sewage lagoons are not shown in Table 3-1. Pond F is not listed in Table 3-1 because samples were not collected during the 1994 investigation.

For each new COC, cancer and noncancer risk estimates were calculated for the revised exposure scenarios listed in Section 4 of this addendum that included the media where the analyte was detected. These risk estimates were based on the same exposure parameters used in the 1993 risk assessment and are presented individually for each site in Section 4 and Appendix F of this addendum.

Data collected from the breast tissues of one duck caught at Pond G were used to estimate human health risks in place of the modeled data



* *New = All analytes that are updated COPCs, for a given medium, that were not COPCs in 1993 for the same medium.*

** *Risk Ratio = (updated exposure point concentration)/(1993 RA exposure point concentration)*

*** *Risk drivers include: (a) all carcinogenic analytes exceeding 1 E-6 risk; (b) all noncarcinogenic analytes having an HQ > 1; and (c) all analytes > or = 1% of the total estimated cancer risk or noncancer hazard.*

COPCs = Chemicals of Potential Concern.

Figure 3-1
Decision Flow Chart for Determining New COPCs and Calculating Risk Ratios for the Risk Assessment Addendum

Table 3-1
Summary of the New COCs Identified

Analyte	Pond C	Pond D	Pond E	Pond G	The Ditch	Lake Holloman	Lake Stinky
Sludge and Soil [a,b]							
4,4'-DDD							x
4,4'-DDT							x
Aldrin		x					
alpha-BHC	x	x					
Beryllium		x	x			x	
delta-BHC				x			
Dieldrin	x		x	x	x		x
Endosulfan II		x					
Endosulfan sulfate					x		
Endrin					x		
gamma-BHC	x		x				
Heptachlor							x
Kepone	x			x		x	
Methoxychlor					x		
Thallium		x	x			x	
Surface Water							
No new COPCs identified							
Duck Breast Tissue [c]							
2,4'-DDE				x	d	d	d
4,4'-DDD				x	d	d	d
4,4'-DDE				x	d	d	d
4,4'-DDT				x	d	d	d
Antimony				x	d	d	d
Arsenic				x	d	d	d
Cadmium				x	d	d	d
Chromium				x	d	d	d
Dieldrin				x	d	d	d
Endrin				x	d	d	d

Table 3-1
(Continued)

Analyte	Pond C	Pond D	Pond E	Pond G	The Ditch	Lake Holloman	Lake Stinky
Duck Breast Tissue [c] (Continued)							
gamma-Chlordane				x	d	d	d
Heptachlor				x	d	d	d
Hexachlorobenzene				x	d	d	d
Magnesium				x	d	d	d
Mercury				x	d	d	d
Nickel				x	d	d	d
Oxychlordane				x	d	d	d
PCBs (total)				x	d	d	d
Selenium				x	d	d	d
Silver				x	d	d	d
Thallium				x	d	d	d
trans-Nonachlor				x	d	d	d

Note: Ponds A and B are not included because no new COCs were identified in those sewage lagoons.

[a] These COCs were selected using the EPA Region III screening process (EPA, 1993a and 1995b).

[b] For Ponds C, D, E, and G, and Lake Holloman, all COCs were detected in sludge. For the ditch and Lake Stinky, all COCs were detected in soil.

[c] Risk-based concentrations for contaminants in duck tissue are not provided by EPA; therefore, these new COCs were not screened using EPA Region III screening methodology.

[d] The tissue data shown are from one duck taken from Pond G. However, data from this sample were also applied to the ditch and Lakes Holloman and Stinky.

previously used in the 1993 risk assessment (Radian, 1993a). The rationale for excluding these modeled data is discussed in Section 4.9 of this addendum. Because these tissue data were used exclusively to determine COCs, any analyte with a confirmed detection was considered a new COC in duck tissue for this addendum. These new COCs are also listed in Table 3-1.

3.2 Risk Ratio Method

The risk ratio method was used to estimate risks for all analytes that were COCs in 1993 and COPCs in this addendum.

In the 1993 risk assessment, cancer risks and noncancer hazards were estimated for each COC. The magnitude of these risk estimates was directly proportional to the concentration of the COC at a given site. If the concentration of a COC were to change (e.g., due to improved sampling or environmental degradation), then the risk for that COC would also change proportionately (under the same exposure conditions). This concept of proportional change is the basis of the risk ratio method.

The risk ratio represents the change in chemical concentration, or exposure concentration, as reported in the 1993 risk assessment to the exposure concentrations derived from the 1994 investigation (due primarily to the availability of additional data to characterize a site). In this case, the risk ratio represents the updated exposure concentration divided by the 1993 exposure concentration. Mathematically, the risk ratio is expressed as:

Risk Ratio = (Updated ExpCon) / (1993 ExpCon)

where,

ExpCon = Exposure Concentration for each COC

For the 1993 risk assessment and this addendum, the mean concentration, and 95% upper confidence limit for the mean (UCL), were used to estimate risks for the average and reasonable maximum exposure concentrations, respectively.

Since risk and exposure concentration are proportional to one another, an adjusted health risk value for this addendum could be calculated by multiplying the 1993 risk value by the risk ratio. This relationship is represented in the following equation:

Adjusted Risk = (1993 Risk Value) × (Risk Ratio).

For example, assume that in 1993 Chemical A was detected in soil at a concentration of 1 mg/kg and produced a risk value of 10. Then, during the 1994 investigation, the exposure concentration for Chemical A was 2 mg/kg, twice the original concentration. Since risk and exposure concentration are proportional to one another, the resultant risk value for Chemical A would also be twice the 1993 estimate, or 20.

Using the risk ratio method, the adjusted risk for Chemical A would be calculated in two steps:

1) Risk Ratio for Chemical A
= (Updated ExpCon) / (1993 ExpCon)
= (2 mg/kg) / (1 mg/kg)
= 2

2) Adjusted Risk for Chemical A
= (1993 Risk Value) x (Risk Ratio)
= (10) × (2)
= 20

In this simple example, the adjusted risk value represents the updated risk value for Chemical A. In more complex exposure scenarios, such as those evaluated in the 1993 risk assessment, multiple chemicals and multiple exposure media are considered when estimating total risk. Therefore, the adjusted risk value for a

single constituent may only partially contribute to the total risk value in this addendum.

The risk ratio method was used to recalculate cancer risk and noncancer hazard estimates for analytes that were considered COCs in the 1993 risk assessment and COPCs in this addendum for the same exposure media. However, risk estimates were not recalculated for all these analytes. As shown in Figure 3-1, risks were estimated using the risk ratio method for either of two conditions:

1) Risks were recalculated for all analytes having a risk ratio greater than 1.0 (i.e., chemical concentrations increased since 1993).

2) Risk ratios were used to recalculate risks for all COCs that contributed at least 1% to the overall risk value in 1993.

At Ponds A and B only, if an analyte was listed as a COC in sludge in the 1993 risk assessment, but was not detected (ND) in the 1995 sludge samples, a risk ratio of 0.0 was assigned to that analyte. A 0.0 value was assigned to these analytes because sludge, containing PCBs at a concentration greater than 25 mg/kg, was removed from Ponds A and B in 1990, and the 1993 risk estimates for sludge were based on data collected before the 1990 removal action. Therefore, the 1995 data set best represents current conditions in sludge at Ponds A and B.

The risk ratios calculated for each site, by exposure media, are presented in Table 3-2. These ratios were calculated for both the average and reasonable maximum exposure concentration for each COPC (shown in this table as the mean and UCL, respectively).

3.3 Calculation of Updated Risk Estimates

When presenting the overall risk for an exposure scenario in this addendum, the total risk value was calculated as the sum of the following three data sets:

1) The total risk value from the 1993 risk assessment;

2) The total relative change in the 1993 risk value (determined using the risk ratio method); and

3) The risk estimates for all new COCs.

The total relative change in a 1993 risk value was determined as follows:

Relative Change in 1993 Risk
= (Adjusted Risk Value) - (1993 Risk Value).

By summing the 1993 risk value, the total relative change to that value, and the risk estimates for new COCs, an updated risk value is produced that reflects a more current understanding of the contaminant concentrations at the sewage lagoons and lakes since the 1993 risk assessment. A detailed discussion of these calculations, for each site, is presented in Appendix F.

Table 3-2
Risk Ratios for the Human Health Risk Assessment

Site	Analyte (by media)		Risk Ratios		Exposure Concentrations (mg/kg)			
					1993 COCs		Updated COPCs	
			Mean	UCL	Mean	UCL	Mean	UCL
Pond A								
	Sludge							
	Aroclor-1254		0.4	0.5	7.4 E+0	9.0 E+0	2.7 E+0	4.7 E+0
	Aroclor-1260	*a*	0.0	0.0	2.4 E+0	2.8 E+0	ND	ND
Pond B								
	Sludge							
	Aroclor-1254		0.4	0.5	6.0 E+0	7.3 E+0	2.2 E+0	3.7 E+0
	Aroclor-1260	*a*	0.0	0.0	1.6 E+0	1.9 E+0	ND	ND
Pond C								
	Sludge							
	4,4'-DDD		0.5	0.5	2.3 E+0	4.7 E+0	1.2 E+0	2.3 E+0
	4,4'-DDE		0.6	0.5	9.9 E-1	2.2 E+0	5.6 E-1	1.1 E+0
	4,4'-DDT		0.3	0.4	1.7 E-1	2.6 E-1	5.7 E-2	9.6 E-2
	Arsenic		1.0	0.9	1.7 E+0	2.2 E+0	1.7 E+0	2.0 E+0
	Barium		1.0	1.0	9.1 E+1	1.0 E+2	9.2 E+1	1.0 E+2
	Beryllium		0.8	0.8	3.2 E-1	4.2 E-1	2.6 E-1	3.2 E-1
	Cadmium		0.6	0.6	3.9 E+0	5.1 E+0	2.2 E+0	2.8 E+0
	Chromium		0.9	0.8	5.0 E+1	6.9 E+1	4.6 E+1	5.7 E+1
	Cobalt		0.8	0.8	5.3 E+0	6.5 E+0	4.4 E+0	5.2 E+0
	Copper		0.9	0.8	1.0 E+2	1.6 E+2	9.2 E+1	1.2 E+2
	delta-BHC		0.3	0.3	1.5 E+0	3.0 E+0	4.8 E-1	9.6 E-1
	Endosulfan I		0.4	0.4	8.3 E-1	1.7 E+0	3.4 E-1	7.0 E-1
	Lead		0.8	0.7	2.2 E+1	3.2 E+1	1.7 E+1	2.2 E+1
	Mercury		0.6	0.6	9.6 E-1	1.2 E+0	6.0 E-1	7.9 E-1
	Nickel		1.0	1.0	9.6 E+0	1.1 E+1	9.8 E+0	1.1 E+1
	Selenium		0.8	0.7	2.3 E+0	3.4 E+0	1.8 E+0	2.4 E+0
	Silver		0.9	0.8	9.5 E+1	1.5 E+2	8.6 E+1	1.2 E+2
	Vanadium		1.0	1.0	3.2 E+1	3.9 E+1	3.4 E+1	3.8 E+1
	Zinc		0.9	0.8	1.4 E+2	1.9 E+2	1.2 E+2	1.5 E+2

Table 3-2
(Continued)

Site	Analyte (by media)		Risk Ratios		Exposure Concentrations (mg/kg)			
					1993 COCs		Updated COPCs	
			Mean	UCL	Mean	UCL	Mean	UCL
Pond D								
	Sludge							
	4,4'-DDD	*b*	0.6	0.4	2.8 E-2	7.8 E-2	1.8 E-2	3.2 E-2
	4,4'-DDE	*b*	***1.1***	0.8	5.1 E-3	1.2 E-2	5.5 E-3	9.1 E-3
	4,4'-DDT	*b*	***1.5***	***1.3***	8.6 E-3	1.9 E-2	1.3 E-2	2.4 E-2
	Arsenic	*b*	***1.4***	***1.3***	1.2 E+0	1.7 E+0	1.7 E+0	2.1 E+0
	* Barium	*b*	***1.2***	***1.1***	4.4 E+1	5.6 E+1	5.4 E+1	6.2 E+1
	Chlordane	*b,c*	***5.1***	***10.3***	4.5 E-4	4.5 E-4	2.3 E-3	4.6 E-3
	* Chromium	*b*	NA	NA	NA	NA	4.2 E+0	5.3 E+0
	Cobalt	*b*	0.7	0.8	3.4 E+0	3.7 E+0	2.4 E+0	3.0 E+0
	delta-BHC	*b*	0.1	0.1	4.4 E-3	8.2 E-3	5.8 E-4	1.0 E-3
	Endosulfan sulfate	*b*	0.0	0.0	1.1 E-2	2.2 E-2	6.0 E-7	8.0 E-7
	Lead	*b*	0.6	***2.7***	7.1 E+0	2.8 E+0	4.4 E+0	7.6 E+0
	Nickel	*b*	0.4	0.5	7.3 E+0	8.6 E+0	3.2 E+0	4.2 E+0
	* Selenium	*b*	***1.7***	***2.1***	4.4 E-1	4.7 E-1	7.4 E-1	9.8 E-1
	* Vanadium	*b*	***1.6***	***1.5***	1.0 E+1	1.3 E+1	1.7 E+1	2.0 E+1
	* Zinc	*b*	***2.9***	***2.6***	1.1 E+1	1.5 E+1	3.2 E+1	3.9 E+1
Pond E								
	Sludge							
	4,4'-DDD		0.3	0.2	1.0 E+0	2.6 E+0	2.8 E-1	6.1 E-1
	4,4'-DDE		0.3	0.3	3.7 E-1	8.2 E-1	1.1 E-1	2.1 E-1
	4,4'-DDT		0.3	0.4	1.0 E-1	1.3 E-1	3.0 E-2	4.6 E-2
	Arsenic		1.0	1.0	1.8 E+0	2.3 E+0	1.9 E+0	2.3 E+0
	* Barium		***1.1***	***1.0***	7.3 E+1	9.3 E+1	8.2 E+1	9.4 E+1
	alpha-BHC	*b*	0.1	0.1	1.5 E-3	1.6 E-3	1.0 E-4	1.8 E-4
	delta-BHC	*b*	0.2	0.1	5.1 E-3	8.8 E-3	9.2 E-4	1.2 E-3
	Chromium		0.9	0.9	1.9 E+1	2.7 E+1	1.8 E+1	2.4 E+1
	Copper		0.7	0.6	3.7 E+1	5.7 E+1	2.7 E+1	3.4 E+1
	Lead		0.5	0.5	1.2 E+1	1.6 E+1	6.7 E+0	8.5 E+0
	Mercury		0.6	0.6	2.7 E-1	3.9 E-1	1.6 E-1	2.2 E-1
	Nickel		0.8	0.7	6.9 E+0	9.3 E+0	5.7 E+0	7.0 E+0
	Selenium		0.7	0.6	1.5 E+0	2.1 E+0	1.0 E+0	1.3 E+0
	Silver		0.9	0.8	2.2 E+1	3.4 E+1	2.1 E+1	2.9 E+1
	* Tin		***60.9***	NA	2.7 E-1	NA	1.6 E+1	2.3 E+1
	* Vanadium		***1.1***	1.0	2.5 E+1	3.3 E+1	2.8 E+1	3.3 E+1
	Zinc		0.8	0.7	5.4 E+1	7.6 E+1	4.5 E+1	5.5 E+1

Table 3-2
(Continued)

Site	Analyte (by media)		Risk Ratios		Exposure Concentrations (mg/kg)			
					1993 COCs		Updated COPCs	
			Mean	UCL	Mean	UCL	Mean	UCL
Pond G								
	Sludge							
	4,4'-DDD		0.3	0.3	8.3 E-1	1.8 E+0	2.4 E-1	4.5 E-1
	4,4'-DDE		0.4	0.3	1.8 E-1	3.1 E-1	6.4 E-2	9.9 E-2
	4,4'-DDT		0.3	0.3	8.2 E-2	1.2 E-1	2.7 E-2	4.0 E-2
	alpha-BHC		0.2	0.3	4.7 E-2	7.4 E-2	1.1 E-2	2.0 E-2
	Arsenic		***1.3***	***1.1***	2.1 E+0	2.7 E+0	2.6 E+0	3.0 E+0
	Barium		1.0	0.9	8.8 E+1	1.0 E+2	8.4 E+1	9.3 E+1
	Beryllium		0.6	0.5	5.8 E-1	7.7 E-1	3.2 E-1	4.0 E-1
	gamma-BHC	*b*	0.0	0.1	2.0 E-3	2.5 E-3	9.8 E-5	1.4 E-4
	Chromium		0.7	0.7	1.4 E+1	1.7 E+1	9.7 E+0	1.2 E+1
	Chlordane	*d*	0.1	0.1	8.8 E-2	1.8 E-1	8.8 E-3	1.3 E-2
	Cobalt		0.8	0.7	4.4 E+0	5.4 E+0	3.3 E+0	3.9 E+0
	Copper		0.8	0.8	1.9 E+1	2.4 E+1	1.6 E+1	1.9 E+1
	Lead		0.4	0.3	6.5 E+1	1.5 E+2	2.6 E+1	4.5 E+1
	* Mercury		***1.3***	***1.1***	1.4 E-1	2.0 E-1	1.8 E-1	2.1 E-1
	Nickel		0.9	0.8	8.4 E+0	1.0 E+1	7.2 E+0	8.3 E+0
	Selenium		0.9	0.8	1.1 E+0	1.5 E+0	9.6 E-1	1.2 E+0
	Vanadium		0.9	0.8	2.3 E+1	2.8 E+1	2.0 E+1	2.3 E+1
	Zinc		0.9	0.8	4.6 E+1	5.8 E+1	4.1 E+1	4.8 E+1
The Ditch								
	Soil							
	4,4'-DDD		0.9	0.8	5.6 E-2	1.2 E-1	5.1 E-2	9.9 E-2
	4,4'-DDE		0.8	0.7	1.3 E-2	2.8 E-2	1.0 E-2	2.0 E-2
	4,4'-DDT		0.8	0.7	2.0 E-2	4.9 E-2	1.5 E-2	3.6 E-2
	Aldrin		***1.2***	***1.3***	1.4 E-3	1.5 E-3	1.7 E-3	2.0 E-3
	Arsenic		0.9	0.8	3.0 E+0	5.0 E+0	2.7 E+0	4.2 E+0
	* Barium		***1.1***	***1.1***	6.3 E+1	8.1 E+1	7.2 E+1	8.8 E+1
	Beryllium		1.0	1.0	6.7 E-1	7.6 E-1	6.7 E-1	7.6 E-1
	Chlordane	*c*	5.4	7.5	7.5 E-3	1.7 E-2	4.0 E-2	1.3 E-1
	* Chromium		***1.4***	***1.4***	8.7 E+0	1.2 E+1	1.2 E+1	1.6 E+1
	Cobalt		1.0	1.0	4.4 E+0	5.3 E+0	4.5 E+0	5.1 E+0
	* Copper		***1.2***	***1.2***	8.9 E+0	1.1 E+1	1.0 E+1	1.3 E+1
	delta-BHC		0.7	0.7	2.0 E-1	3.5 E-1	1.4 E-1	2.6 E-1
	gamma-BHC		0.7	0.8	2.3 E-3	3.3 E-3	1.7 E-3	2.5 E-3
	Lead		***1.0***	0.9	2.0 E+1	4.0 E+1	2.1 E+1	3.6 E+1
	* Nickel		***1.1***	***1.1***	8.2 E+0	1.0 E+1	9.2 E+0	1.1 E+1
	Selenium		0.3	NA	7.1 E+0	NA	1.8 E+0	4.7 E+0
	* Silver		***2.4***	NA	5.9 E-1	NA	1.4 E+0	2.1 E+0
	* Vanadium		***1.2***	***1.1***	1.7 E+1	2.2 E+1	2.0 E+1	2.4 E+1
	* Zinc		***1.2***	***1.1***	3.1 E+1	4.4 E+1	3.6 E+1	4.7 E+1

Table 3-2
(Continued)

Site	Analyte (by media)	Risk Ratios		Exposure Concentrations (mg/kg)			
				1993 COCs		Updated COPCs	
		Mean	UCL	Mean	UCL	Mean	UCL
Lake Holloman							
	Sludge						
	4,4'-DDD	0.4	0.3	9.0 E-2	2.6 E-1	3.2 E-2	6.8 E-2
	4,4'-DDE	0.4	0.3	1.4 E-2	2.5 E-2	5.3 E-3	8.3 E-3
	4,4'-DDT	0.2	0.3	9.4 E-3	1.3 E-2	2.1 E-3	3.5 E-3
	alpha-BHC	0.2	0.3	5.3 E-3	7.2 E-3	1.2 E-3	1.9 E-3
	Arsenic	0.6	0.5	3.0 E+0	4.3 E+0	1.7 E+0	2.0 E+0
	Barium	0.8	0.7	9.6 E+1	1.4 E+2	7.5 E+1	9.4 E+1
	Chlordane *e*	**1.2**	**1.2**	1.6 E-2	3.5 E-2	1.9 E-2	4.4 E-2
	Chromium	0.6	0.6	1.1 E+1	1.7 E+1	6.8 E+0	9.3 E+0
	Cobalt	0.6	0.6	7.6 E+0	1.2 E+1	4.6 E+0	7.6 E+0
	Copper	0.7	0.6	1.4 E+1	2.1 E+1	9.5 E+0	1.2 E+1
	delta-BHC	0.2	0.2	1.1 E+0	3.0 E+0	2.4 E-1	6.1 E-1
	Dieldrin	0.2	0.2	4.0 E-2	6.8 E-2	9.2 E-3	1.6 E-2
	gamma-BHC	0.2	0.3	6.5 E-3	9.6 E-3	1.5 E-3	2.5 E-3
	Lead	0.5	0.4	1.3 E+1	2.2 E+1	6.2 E+0	8.5 E+0
	Nickel	0.6	0.5	1.2 E+1	1.9 E+1	6.9 E+0	9.4 E+0
	Selenium	0.4	0.4	1.4 E+0	1.9 E+0	5.3 E-1	7.3 E-1
	Vanadium	0.9	0.8	2.1 E+1	3.1 E+1	1.8 E+1	2.5 E+1
	Zinc	0.7	0.6	3.7 E+1	5.6 E+1	2.7 E+1	3.4 E+1
Lake Stinky							
	Soil						
	Aldrin	0.4	0.4	7.5 E-3	1.3 E-2	3.3 E-3	5.9 E-3
	alpha-BHC	0.4	0.4	5.5 E-3	1.0 E-2	2.4 E-3	4.4 E-3
	Arsenic	0.9	0.8	2.7 E+0	3.4 E+0	2.4 E+0	2.7 E+0
	Barium	0.9	0.9	7.2 E+1	8.0 E+1	6.2 E+1	6.9 E+1
	Beryllium	0.7	0.7	6.4 E-1	7.1 E-1	4.3 E-1	5.3 E-1
	Chromium	0.8	0.8	7.0 E+0	9.0 E+0	5.9 E+0	7.2 E+0
	Cobalt	0.8	0.9	3.5 E+0	4.0 E+0	2.9 E+0	3.4 E+0
	delta-BHC	0.4	0.4	8.8 E-1	1.8 E+0	3.7 E-1	7.7 E-1
	Endrin	0.5	0.4	6.4 E-3	1.1 E-2	2.9 E-3	5.0 E-3
	gamma-BHC	0.4	0.4	1.0 E-2	1.9 E-2	4.5 E-3	8.3 E-3
	Nickel	0.9	1.0	6.9 E+0	7.2 E+0	6.1 E+0	7.3 E+0
	Selenium	0.6	0.7	4.5 E-1	5.1 E-1	2.8 E-1	3.6 E-1
	Vanadium	0.9	0.9	1.4 E+1	1.7 E+1	1.2 E+1	1.5 E+1
	Zinc	0.9	0.8	2.3 E+1	3.0 E+1	2.1 E+1	2.5 E+1

a Analyte was not detected (ND) at the site during the 1994 investigation. Previous analytical results were from samples collected prior to a removal action; therefore it was eliminated as a COC in this addendum.

b Ratios calculated from 1993 soil data and 1995 sludge data. Sludge and soil exposures are equivalent.

c Ratios calculated from 1993 soil data for alpha-Chlordane and 1995 sludge data for total Chlordane. Toxicity values for both are equivalent.

d Ratios calculated from 1993 soil data for gamma-Chlordane and 1995 sludge data for total Chlordane. Toxicity values for both are equivalent. Sludge and soil exposures are also equivalent.

e Ratios calculated from 1993 sludge data for gamma-Chlordane and 1995 sludge data for total Chlordane. Toxicity values for both are equivalent.

NA 1993 data were not available for this analyte since it was not a listed COC in 1993.

* Analyte was detected below the EPA Region III screening level in both 1993 and for this addendum; therefore, it was eliminated as a COPC.

COPC = Chemical of Potential Concern COC = Chemical of Concern UCL = Upper Confidence Limit

Section 4
HUMAN HEALTH RISK ASSESSMENT UPDATE SUMMARY

This section presents a summary of the human health risks estimated for the impoundments in the sewage lagoons and lakes. These updated risk estimates were derived, as described in Section 3, using the results of the 1993 human health risk estimates along with additional data collected during the 1994 investigation. An overview of the updated risk assessment assumptions are presented first followed by a summary of the potential risks for the sewage lagoons and lakes. A complete discussion of the calculations used to derive the updated risk estimates is provided in Appendix F of this addendum.

4.1 Updated Risk Assessment Assumptions

In general, health risks to human receptors at a given site are restricted to the contaminants detected at that site. There are, however, two exceptions to this general approach.

The first concerns the current/future recreational scenario at Pond G, the ditch, and the lakes where hunters could ingest waterfowl (ducks) caught at a given site. Since these birds could feed at one or more of these sites, contaminants found in their meat could also be related to all sites. Given the possibility of contaminant uptake from multiple sources, the contaminants detected in the duck taken from Pond G, were used in estimating health risks for all these sites. Therefore, cancer risk and noncancer hazard estimates for this scenario are the same at Pond G, the ditch, and the lakes.

The second exception deals with the inhalation of fugitive dusts and volatile chemicals at Lakes Holloman and Stinky. An air dispersion model was used to estimate contaminant concentrations in air over both lakes. The key assumption used in this model was that the soil from Lake Stinky was the only source from which the contaminants in air originated. This assumption was made because most of Lake Stinky is dry most of the time which exposes the underlying soil. Then, contaminants from the dried portions of the lake bed may become suspended in air through windblown action and disperse over both lakes. Therefore, Lake Stinky is the only contaminant source for airborne matter at both Lakes Holloman and Stinky.

4.1.1 Updated Exposure Scenarios Evaluated

In the 1993 risk assessment report (Radian, 1993a), exposure scenarios at the sewage lagoons and lakes were selected based on historical knowledge of the sites. With a more current understanding of the sewage lagoons and lakes and their future disposition, the exposure scenarios selected for evaluation have been updated.

Four exposure scenarios were evaluated in the risk assessment addendum to estimate cancer risks and noncancer hazards at the sewage lagoons and lakes. These four scenarios, their exposure pathways, and the sites they are associated with are presented below. The rationale for selecting these scenarios and the exposure parameters used to estimate health risks are presented in detail in the 1993 risk assessment report (Radian, 1993a), and remain unchanged with the exception of the current/future recreational scenario.

1) **Current On-site Worker (chronic and subchronic).** This exposure scenario was evaluated at Ponds A through G and the ditch. The exposure pathways associated with this scenario are dermal contact with surface water, soil, sludge, and sediment.

2) **Current/Future Recreational—Hunters (chronic and subchronic).** This scenario was evaluated at Pond G, the ditch, and the lakes for

both children and adults. Children are being evaluated only for ingestion of waterfowl.

Hunters—The exposure pathways associated with these individuals are the following:

- Dermal contact with surface water, soil, sludge, and sediment;
- Ingestion of surface water;
- Ingestion of waterfowl; and
- Inhalation of fugitive dust.

The only exposure parameters changed for the current/future recreational scenario are the ingestion rates for duck hunters. In the 1993 risk assessment, the average and reasonable maximum ingestion rates were 7 and 14 ducks per year, respectively. These ingestion rates were based on the average duck harvest of 7.2 ducks per hunter as reported by the Colorado Division of Wildlife (Colorado Division of Wildlife, 1974).

Because more appropriate duck harvest data exist for the State of New Mexico, these 1993 exposure parameters were updated. In this addendum, ingestion rates for hunters are based on the 1994 statewide average number of ducks harvested per year by active adult hunters (FWS, 1995). Based on the average duck harvest in New Mexico of 3.1 ducks per hunter, the average and reasonable maximum ingestion rate for duck hunters was set at 3 and 6 ducks per year, respectively. The reasonable maximum ingestion rate was conservatively selected as twice the average intake rate since the only duck harvest data available for the State of New Mexico is an annual average value.

3) **Current/Future Trespasser—Teenager (subchronic).** This exposure scenario was evaluated only at Pond G. Although Ponds A through G are fenced (in order to prevent trespassing), Pond G is somewhat isolated from the other sewage lagoons and normal base activity; therefore, it was assumed that trespassers could gain access to Pond G. The exposure pathways associated with this scenario are 1) ingestion of surface water and 2) dermal contact with surface water, soil, sludge, and/or sediment.

4) **Future Beef Consumer—Agricultural (chronic).** This exposure scenario was evaluated only at Lake Stinky. In this scenario, adults and children were assumed to be exposed to site-related constituents by ingesting the meat from cattle that foraged on grasses assumed to be irrigated by groundwater and that directly ingested the surface water at Lake Stinky.

4.1.2 Toxicity Values

Although the human health risks at each site in the sewage lagoons and lakes are evaluated separately in the following subsections, the toxicity values used to estimate cancer and noncancer risks at these sites are the same. The chronic and subchronic toxicity values for all COCs at the sewage lagoons and lakes are presented in Appendix F, Table F-1.

4.2 Summary of the Updated Risk Estimates for the Sewage Lagoons and Lakes

As described in Sections 2 and 3 previously, risk estimates were updated from the 1993 report based on data collected during the 1994 investigation and a better understanding of closure activities expected for the sewage lagoons. Since the 1993 risk assessment was prepared, Holloman AFB has proceeded further with plans for the new wastewater treatment plant. It is now known that Ponds A through F will be removed from service and will no longer be used as impoundments.

Criteria to evaluate the risk estimates were presented previously in Section 1.1. Target values were set at 1E-4 to 1E-6 for known or suspected carcinogens and 1 for noncarcinogens. These benchmark values are designed to protect human health and are used to differentiate between health

risks that are considered acceptable and those that require additional evaluation to determine significance. As mentioned previously in Section 1.1, cancer risk estimates higher than 1E-6 are not necessarily considered unacceptable. Also, given the uncertainty factors used to derive noncancer toxicity values, a hazard index greater than 1 may not indicate a greater chance of developing a health problem than a hazard index of 1, or less than 1.

These target risk values are not, however, necessarily the levels that will be used to define cleanup goals in the corrective measures study work plan. Selection of cleanup goals will also consider the location, accessibility, and closure activities planned.

Table 4-1 presents a summary of the updated average and reasonable maximum risk estimates. These estimates replace those previously presented in the 1993 report. The reasonable maximum cancer risk estimates for Ponds A, B and G, the ditch, and both lakes are greater than 1E-6. The average and reasonable maximum cancer risk estimates at all other sites, and exposure scenarios, are less than 1E-6. Noncancer hazard estimates at all sites, for all exposure scenarios, are less than 1.

The reasonable maximum cancer risk estimate at Ponds A and B is 2E-6 for the current on-site worker scenario. Aroclor-1254 was found in the sludge at both Ponds A and B, and is the primary risk driver at each of the sewage lagoons. At Pond B, 4,4'-DDE and benzo(a)pyrene in the sludge, and chlordane in the surface water also contributed to the overall risk estimate. Since these ponds will be closed once the new wastewater treatment plan initiates service, these risks will no longer apply.

A reasonable maximum cancer risk of 6E-6 was estimated for adult ingestion of waterfowl. This estimate is well within acceptable levels established by EPA for remediation goals and is based on data collected from only one duck breast tissue sample. The risk estimates from this one duck were extrapolated as risks for Pond G, the ditch, and the lakes since the future use of these impoundments in the new wastewater treatment system can still serve as duck habitat. The chemicals driving this risk estimate include PCBs and pesticides. However, it should be noted that although this risk assessment predicted a potential risk from ingesting duck tissue, chemical residues in the duck tissue were detected at levels 5 to 500 times lower than federal and/or state tolerance levels for commonly eaten foods (e.g., eggs, fish, and commercial poultry). For example, the acceptable PCB residue level in commercial poultry established by the Food and Drug Administration (FDA) is 3 mg/kg, and PCB levels found in the duck tissue is 0.006 mg/kg. This comparison suggests that the assumptions used in deriving this risk estimate are very conservative. Since ingestion of ducks caught at Holloman AFB is expected to occur less frequently than ingesting commonly eaten foods, these allowable tolerance levels could also apply to the ducks caught at the sewage lagoons and lakes. These tolerance levels also suggest that the chemical residues in ducks taken from the sewage lagoons and lakes are not of concern to hunters who ingest them.

All other exposure scenarios evaluated at the sewage lagoons and lakes resulted in cancer risk and noncancer hazard estimates less than 1E-6 and 1, respectively.

4.3 Pond A

The only exposure scenario considered at Pond A was the current on-site worker, both chronic and subchronic. This scenario assumes that workers would be exposed to sludge and surface water during routine maintenance activities, at a maximum rate of 12 days per year for 25 years.

Table 4-1
Summary of the Updated Risk Estimates

Exposure Scenario	Risk for Scenario	Average	Reasonable Maximum	Analyte Driving Risk	Primary Exposure Pathway	Comments
POND A						
Current On-site Worker						Risks are well within acceptable levels based on EPA remedial goals . Also, risks will be mitigated once the sewage lagoon is removed from active service.
	Cancer Risk	< 1E-6	***2 E-6***	***Aroclor-1254 (100%)***	Dermal Contact - Sludge	
	Hazard Index	< 1	< 1	NA	NA	
POND B						
Current On-site Worker						
	Cancer Risk	< 1E-6	***2 E-6***	***Aroclor-1254 (76%)*** ***4,4'-DDE (8%)*** ***Benzo[a]pyrene (7%)*** ***Chlordane (4%)***	Dermal Contact - Sludge Dermal Contact - Surface water Dermal Contact - Sludge Dermal Contact - Surface water	Risks are well within acceptable levels based on EPA remedial goals . Also, risks will be mitigated once the sewage lagoon is removed from active service.
	Hazard Index	< 1	< 1	NA	NA	
POND C						
Current On-site Worker						
	Cancer Risk	< 1E-6	<.1E-6	NA	NA	None
	Hazard Index	< 1	< 1	NA	NA	
POND D						
Current On-site Worker						
	Cancer Risk	< 1E-6	< 1E-6	NA	NA	None
	Hazard Index	< 1	< 1	NA	NA	

Table 4-1
(Continued)

Exposure Scenario	Risk for Scenario	Average	Reasonable Maximum	Analyte Driving Risk	Primary Exposure Pathway	Comments
POND E						
Current On-site Worker						
	Cancer Risk	< 1E-6	< 1E-6	NA	NA	None
	Hazard Index	< 1	< 1	NA	NA	
POND F						
Health risks were not estimated in this addendum since the 1993 cancer risks were < 1 E-6 and noncancer hazards were < 1.						
POND G THE DITCH LAKE HOLLOMAN LAKE STINKY						Cancer risk estimates are well within EPA's remedial goals for carcinogens. The levels of pesticide and PCB residues in duck tissue used to estimate these risks are 5 to 500 times lower than Federal and/or State allowable tolerance levels for these chemicals in commonly eaten foods. Therefore, these allowable tolerance levels should also apply to the ducks hunted at Holloman AFB. See Section 4.8.4 for a complete discussion of these tolerance levels. Additionally, the only known source of the PCBs (Ponds A & B) will be eliminated once Ponds A-F are removed from active service.
Current / Future Recreational (hunter) - Adult						
	Cancer Risk	< 1 E-6	*6 E-6*	***PCBs (total) (36%)***	Ingestion - Waterfowl	
				4,4'-DDE (23%)	Ingestion - Waterfowl	
				Oxychlordane (18%)	Ingestion - Waterfowl	
				Dieldrin (15%)	Ingestion - Waterfowl	
				gamma-Chlordane (4%)	Ingestion - Waterfowl	
				4,4'-DDD (3%)	Ingestion - Waterfowl	
	Hazard Index	< 1	< 1	NA	NA	
All Other Exposure Scenarios						
	Cancer Risk	< 1 E-6	< 1 E-6	NA	NA	
	Hazard Index	< 1	< 1	NA	NA	

The cancer risk and noncancer hazard estimates were derived using the 1993 data set combined with data obtained from the 1994 investigation. These data were used exclusively because sludge was removed from the sewage lagoon in 1990. Because of this removal action, these data were chosen as the data sets that best represented current conditions.

Table 4-2 summarizes the cancer and noncancer risk estimates for workers at Pond A. The average cancer risk estimate is well below 1E-6. The reasonable maximum cancer risk estimate is 2E-6 and is driven entirely by dermal exposure to Aroclor-1254 in the sludge. Concentrations of Aroclor-1254 in the sludge ranged from 0.3 to 7.1 mg/kg. Although the reasonable maximum risk estimate is 2E-6, this estimate is well within acceptable levels established by EPA. Moreover, risks from dermal contact with sludge will be mitigated once the new wastewater treatment system begins service and Pond A is removed from active service.

Noncancer hazard estimates are significantly less than 1 for all exposure cases, indicating that adverse health effects are unlikely.

4.4 Pond B

The only exposure scenario considered at Pond B was the current on-site worker, both chronic and subchronic. This scenario assumes that workers would be exposed to sludge and surface water, during routine maintenance activities, at a rate of 12 days per year for 25 years.

The cancer risk and noncancer hazard estimates were derived using the 1993 data set combined with data obtained from the 1994 investigation. These data were used exclusively because sludge was removed from the sewage lagoon in 1990. Because of this removal action, these data were chosen as the data sets that best represented current conditions.

Table 4-3 presents the cancer risk and noncancer hazard estimates for workers at Pond B. The average cancer risk estimate is well below 1E-6. The reasonable maximum cancer risk estimate is 2E-6, well within acceptable levels for carcinogenic effects. This risk is based primarily (76%) on dermal contact with Aroclor-1254 found in the sludge at Pond B. These two analytes account for 83% of the total risk value at Pond B. Benzo(a)pyrene in the sludge, and chlordane and 4,4'-DDE in the surface water contribute another 19% to this total cancer risk estimate. Concentrations of these constituents were:

Aroclor-1254	0.06 to 5.3 mg/kg in sludge
Benzo(a)pyrene	1.3 to 1.9 mg/kg in sludge
Chlordane	0.05 to 0.2 µg/L in surface water
4,4'-DDE	0.015 to 0.4 µg/L in surface water

Although the reasonable maximum cancer risk estimate for workers is slightly above 1E-6, it is well within acceptable levels established by EPA and the risk from dermal contact with sludge will be mitigated once the new wastewater treatment system begins service and Pond B is removed from active service.

Noncancer hazard estimates are less than 1 for all exposure cases, indicating that adverse health effects are unlikely.

4.5 Pond C

The only exposure scenario considered at Pond C was the current on-site worker, both chronic and subchronic. This scenario assumes that workers would be exposed to sludge and surface water during routine maintenance activities, at a maximum rate of 12 days per year for 25 years.

Table 4-4 presents the cancer risk and noncancer hazard estimates at Pond C. All cancer risk and noncancer hazard estimates, including average and reasonable maximum exposure cases,

Table 4-2
Summary of the Updated Risk Assessment Results
Pond A

Exposure Scenario	Risk for Scenario	Average	Reasonable Maximum	Analyte Driving Risk	Primary Exposure Pathway
Current					
On-site Worker					
(chronic)	Cancer Risk				
	93 Results (a)	1 E-7	*5 E-6*	NA	NA
	Risk Ratios (b)	-7 E-8	-3 E-6	NA	NA
	New COPCs	NA	NA		
	Total Risk	3 E-8	*2 E-6*	***Aroclor-1254 (100%)***	Dermal Contact - Sludge
(chronic)	Hazard Index	0.001	0.02	NA	NA
(subchronic)	Hazard Index	0.001	0.02	NA	NA

NA = Not Applicable

(a) Risk values shown here do not present contribution of heptachlor epoxide since it was eliminated as a COC. See the discussion of this analyte in Section 1 of this addendum.

(b) Values shown are the relative change in the 1993 risk value, which are based on the risk ratios. Refer to Table F-4 for a complete listing of these values.

Table 4-3
Summary of the Updated Risk Assessment Results
Pond B

Exposure Scenario	Risk for Scenario	Average	Reasonable Maximum	Analyte Driving Risk	Primary Exposure Pathway
Current					
On-site Worker	Cancer Risk				
(chronic)	93 Results	8E-08	*4 E-6*	NA	NA
	Risk Ratios (a)	-5 E-8	*-2 E-6*	NA	NA
	New COPCs	NA	NA		
	Total Risk	3 E-8	*2 E-6*	***Aroclor-1254 (76%)***	Dermal Contact - Sludge
				4,4'-DDE (8%)	Dermal Contact - Surface water
				Benzo[a]Pyrene (7%)	Dermal Contact - Sludge
				Chlordane (4%)	Dermal Contact - Surface water
(chronic)	Hazard Index				
	93 Results	0.02	0.8	NA	NA
	Risk Ratios (a)	–	–		
	New COPCs	–	–		
	Total Hazard	0.02	0.8		
(subchronic)	Hazard Index				
	93 Results	0.02	0.8	NA	NA
	Risk Ratios (a)	–	–		
	New COPCs	–	–		
	Total Hazard	0.02	0.8		

NA = Not Applicable

(a) Values shown are the "relative change in the 1993 risks" which are based on the Risk Ratios. Refer to Table F-8 for a complete listing of these values.

Table 4-4
Summary of the Updated Risk Assessment Results
Pond C

Exposure Scenario	Risk for Scenario	Average	Reasonable Maximum	Analyte Driving Risk	Primary Exposure Pathway
Current					
On-site Worker					
(chronic)	Cancer Risk				
	'93 Results	2.0 E-9	1.0 E-7		
	Risk Ratios (a)	NA	NA	NA	NA
	New COPCs	4.3 E-11	2 E-9		
	Total	2 E-9	1 E-7		
(chronic & subchronic)					
	Hazard Index				
	'93 Results	3 E-4	2 E-3		
	Risk Ratios (a)	-2 E-6	-4 E-4	NA	NA
	New COPCs	1 E-5	6 E-4		
	Total	0.0003	0.002		

NA = Not Applicable

(a) Values shown are the "relative change in the 1993 risks" which are based on the Risk Ratios. Refer to Table F-13 for a complete listing of these values.

were well below the target risk criteria and can be considered negligible.

Cancer risk estimates in this scenario are based on the sum of the 1993 risk estimates and the new COCs reported in the 1994 investigation. In 1993, cancer risk estimates for both the average and reasonable maximum exposure case were less than 1E-6 as well. The pathway- and chemical-specific cancer risk estimates for the new COCs are listed in Appendix G, Table G-1.

The noncancer hazard estimates for this scenario are based on the sum of the 1993 estimates, the relative change in the 1993 estimates based on the risk ratios, and the results from the new COCs found in the sludge during the 1994 investigation. The pathway- and chemical-specific noncancer hazards for the new COCs are listed in Appendix G, Table G-2.

4.6 Pond D

The only exposure scenario considered at Pond D was the current on-site worker, both chronic and subchronic. This scenario assumes that workers would be exposed to soil, sludge, and surface water, during routine maintenance activities, up to 12 days per year for up to 25 years.

Table 4-5 presents the cancer risk and noncancer hazard estimates at Pond D. All cancer risk and noncancer hazard estimates including average and reasonable maximum exposure cases, were well below target risk criteria and can be considered negligible.

Cancer risk and noncancer hazard estimates in this scenario are based on the sum of the 1993 risk estimates, the relative change in the 1993 estimates based on the risk ratios, and the new COCs found in the sludge during the 1994 investigation. The pathway- and chemical-specific cancer risk estimates for the new COCs are listed in Appendix G, Table G-3, and the noncancer estimates are listed in Table G-4.

4.7 Pond E

The only exposure scenario considered at Pond E was the current on-site worker, both chronic and subchronic. This scenario assumes that workers would be exposed to soil, sludge, and surface water, during routine maintenance activities, up to 12 days per year for 25 years.

Table 4-6 presents the cancer risk and noncancer hazard estimates at Pond E. All cancer risk and noncancer estimates, including average and reasonable maximum cancer exposure cases were lower than target risk criteria.

Cancer risk and noncancer hazard estimates in this scenario are based on the sum of the 1993 risk estimates and the new COCs found in the sludge during the 1994 investigation. The pathway- and chemical-specific cancer risk estimates for the new COCs are listed in Appendix G, Table G-5, and the noncancer hazard estimates are listed in Table G-6.

4.8 Pond F

In the 1993 risk assessment cancer risk and noncancer hazard estimates were less than 1E-6 and 1, respectively, for all exposure scenarios. This pond is relatively small and enough samples had been collected during previous investigations to determine the nature and extent of any contamination; therefore, no additional samples were collected during the 1994 investigation. The human health cancer risk and noncancer hazard estimates were not reevaluated in this addendum since the risk estimates presented in the 1993 risk assessment (Radian, 1993a) were lower than the target risk criteria.

Table 4-5
Summary of the Updated Risk Assessment Results
Pond D

Exposure Scenario	Risk for Scenario	Average	Reasonable Maximum	Analyte Driving Risk	Primary Exposure Pathway
Current					
On-site Worker					
(chronic)	Cancer Risk				
	'93 Results	2 E-10	1 E-8		
	Risk Ratios (a)	-1 E-10	2 E-8	NA	NA
	New COPCs	4 E-12	2 E-11		
	Total	**1 E-10**	**3 E-8**		
(chronic & subchronic)					
	Hazard Index				
	'93 Results	5 E-5	1 E-3		
	Risk Ratios (a)	2 E-7	7 E-4	NA	NA
	New COPCs	3 E-6	4 E-6		
	Total	**5 E-5**	**2 E-3**		

NA = Not Applicable

(a) Values shown are the "relative change in the 1993 risks" which are based on the Risk Ratios. Refer to Table F-18 for a complete listing of these values.

Table 4-6
Summary of the Updated Risk Assessment Results
Pond E

Exposure Scenario	Risk for Scenario	Average	Reasonable Maximum	Analyte Driving Risk	Primary Exposure Pathway
Current					
On-site Worker					
(chronic)	Cancer Risk				
	'93 Results	4 E-8	1 E-7		
	Risk Ratios	NA	NA	NA	NA
	New COPCs	1 E-12	5 E-12		
	Total	4 E-8	1 E-7		
(chronic & subchronic)					
	Hazard Index				
	'93 Results	0.02	0.2		
	Risk Ratios	NA	NA	NA	NA
	New COPCs	5 E-6	2 E-5		
	Total	0.02	0.2		

NA = Not Applicable

4.9 Risk Estimates for Ingestion of Waterfowl from Pond G, the Ditch, Lake Holloman, and Lake Stinky

Human health risks from ingesting waterfowl are presented separately in this subsection, and should be considered when evaluating the risks from exposure to sludge/soil and surface water for Ponds G, the ditch, and Lakes Holloman and Stinky. Those risk evaluations are presented separately in Sections 4.10 through 4.13.

Ducks are commonly found around all the impoundments in the sewage lagoons and lakes. However, Ponds A through F will be removed from service when the new wastewater treatment system begins service and will no longer provide habitat for the waterfowl. In addition, Ponds A through F are located within a fenced area that is manned or locked and hunters are not allowed in this area. For these reasons ingestion of waterfowl was evaluated only for Pond G, the ditch, and Lakes Holloman and Stinky. Since ducks do not live on any one impoundment, the risk estimates for duck ingestion were assumed to apply to each of these impoundments.

A great deal of uncertainty surrounds the data used to estimate health risks from ingesting waterfowl caught at the sewage lagoons and lakes. In the 1993 risk assessment the uncertainty associated with the risk estimates were due to the model used to predict chemical concentrations in duck tissue. In this addendum the uncertainty is primarily associated with the sample size of the duck tissue data collected.

In the 1993 risk assessment, actual duck tissue data were not available to estimate health risks from ingesting waterfowl. In the absence of these data a mathematical uptake model was used to predict chemical concentrations in duck tissue. Although the model provided valuable data that were otherwise not available in 1993, it had limitations. The uncertainties associated with the modeled data are:

- The model is based on an equation that was derived specifically to predict chemical uptake in cattle;
- A "feed-to-meat transfer coefficient" for cattle was used in the uptake equation since these transfer coefficients are not available for waterfowl;
- All chemicals in mallard tissue were estimated to come from the sewage lagoons and lakes assuming 100% of the mallard diet consisted of algae and water from the sewage lagoons and lakes; and
- Analytical results for PCBs, dioxins, and furans may have been biased high due to laboratory contamination as explained in Appendix D of the 1993 risk assessment report (Radian, 1993a).

Because of the uncertainties associated with modeled data, collection of duck tissue samples was conducted. Young-of-year ducks (nestlings/fledglings) were targeted for collection under the assumption that the chemicals found in their tissue would most likely come from the sewage lagoons and lakes. Although several attempts were made to capture ducks for analysis, sample collection was difficult since access to the sites where the ducks resided was limited. The U.S. Fish and Wildlife Service (FWS) was then asked to collect the ducks from the sewage lagoons and lakes. During the one-day sampling period the FWS collected one mallard (shot while flying over Pond G). Independent of this duck sampling event, the FWS had collected mature ducks and other biota samples from Holloman AFB in an earlier investigation (FWS, 1994).

Although the risk assessment data set for ducks was limited (one young-of-year mallard), it was assumed that the previously collected FWS data could also be used to compare chemical

concentrations in duck tissue, thereby providing a more valid data set from which to estimate risks. However, it was later determined that the FWS data could not be used to estimate health risks because (1) the FWS had not intended that the data be collected for use in a risk assessment (i.e., QA/QC methods selected would not be appropriate for risk assessments), and (2) only the liver and kidneys of the FWS duck samples were analyzed for chemical residues. Since the breast tissue of these ducks were not analyzed, exposure to hunters ingesting duck tissue could not be evaluated.

The uncertainties associated with the duck tissue sample data are:

- The sample size was limited;
- The estimated age of the duck caught at Pond G was 9 months. At this age the duck would be a mobile feeder and may not have utilized the sewage lagoons and lakes as its sole food source; and
- Because the duck was not a nestling/fledgling it is not known how long this mallard had resided at Holloman AFB; therefore, it is not known what fraction of the chemical residues detected in the breast tissue can be attributed to the sewage lagoons and lakes.

A comparison of the health risks estimated from actual duck tissue data and the 1993 modeled tissue values is presented in Table 4-7.

Comparison is made because of the numerous uncertainties associated with both the modeled tissue values used to estimate risks in the 1993 risk assessment, and the actual tissue data used to estimate risks in this addendum. In addition to comparing these risk estimates for adults and children, Table 4-7 also allows for a comparison of the COCs that drive the risk estimates based on the two data sets.

The risk estimates derived using the duck tissue data are discussed below for both the adult and child. The 1993 risk assessment report (Radian, 1993a) discusses the results of the modeled tissue risk evaluation.

Adult—The average cancer risk estimate for this scenario is 3E-7 and the reasonable maximum cancer risk estimate is 6E-6. Although the reasonable maximum risk estimate is greater than 1E-06, it is well within the Superfund remedial goal for carcinogens. The pathway- and chemical-specific cancer risk estimates for the new COCs found in the duck tissue are listed in Appendix G, Table G-10.

The average and reasonable maximum noncancer hazard estimates are less than 1 for both the chronic and subchronic exposure cases. The pathway- and chemical-specific noncancer hazard quotients estimated for the new COCs found in the duck tissue are listed in Appendix G, Tables G-11 and G-12 for the chronic and subchronic exposure cases, respectively.

Child—Cancer risks were not estimated for children since these estimates are based on the probability of developing cancer over a lifetime. For both chronic and subchronic exposure, the estimated average and reasonable maximum noncancer hazard index is less than 1. The pathway- and chemical-specific noncancer hazard quotients estimated for the new COCs found in duck tissue are listed in Appendix G, Tables G-13 and G-14 for the chronic and subchronic exposure cases, respectively.

Another reference point to evaluate potential risks from ingestion of waterfowl living around the sewage lagoons and lakes are acceptable residue levels allowed in foods. Table 4-8 compares the concentration levels detected in the duck sample, the concentration predicted to be in duck

Table 4-7
Comparison of Health Risk Estimates from the Ingestion of Ducks Based on Actual Tissue Samples and Modeled Tissue Values

Exposure Scenario	Duck Tissue Estimates		1993 Modeled Tissue Estimates	
	Average	Reasonable Maximum	Average	Reasonable Maximum
Ingestion of Waterfowl—Adult				
Cancer Risk	3E-7	6E-6 Risk Drivers PCBs, total (36%) 4,4'-DDE (23%) Oxychlordane (18%) Dieldrin (15%) gamma-Chlordane (4%) 4,4'-DDD (3%)	1E-7	5E-6 Risk Drivers PCBs (93%)[a] 2,3,7,8-TCDD (3%) HxDBF (3%)
Noncancer Hazard				
- Chronic	0.04	0.3	0.05	0.08
- Subchronic	0.03	0.2	0.0008	0.009
Ingestion of Waterfowl—Child				
Noncancer Hazard				
- Chronic	0.1	0.9	0.04	0.2
- Subchronic	0.08	0.5	0.003	0.03

[a] Risks from PCBs were combined in this table. The penta-, hexa-, and tetrachlorinated isomers contributed 64%, 20%, and 8%, to the total risk estimate, respectively.

HxDBF = Hexachlorodibenzofurans

Table 4-8
Comparison of Contaminant Levels Found in Duck Tissue and Modeled Estimates With Allowable Residue Levels in Foods

Cancer Risk Drivers	Reasonable Maximum Contaminant Concentrations In Duck Tissue (mg/kg)		Tolerance Levels in Foods (mg/kg) [a]
	Actual Tissue Sample	Modeled Estimate	
4,4'-DDD	0.014	0.0003	0.5 eggs [c] 5.0 meat [c]
4,4'-DDE	0.087	0.00024	
Dieldrin	0.0012	1.5E-8	0.3 [d]
gamma-Chlordane [b]	0.0038	–	0.3 [e]
Oxychlordane [b]	0.019	–	
PCBs (total)	0.006	0.00018	3.0 [f]

[a] Tolerance levels shown were obtained from the toxicological profiles prepared by the USEPA, Agency for Toxic Substances and Disease Registry (ATSDR), for each analyte shown.

[b] These analytes were not listed as COPCs in the modeled data.

[c] EPA-recommended action levels for the sum of 4,4'-DDT, 4,4'-DDE, and 4,4'-DDD residues.

[d] State of Wisconsin health standard for sport fish and the State of Illinois action level for food.

[e] FDA maximum residue levels of chlordane (including gamma- and oxychlordane) in fish and rendered animal fat.

[f] FDA residue levels for commercial poultry.

tissue based on the 1993 uptake model, and various federal and state standards for the food industry. This table clearly indicates that the chemical residues detected in duck breast tissue, for the primary COCs, are 5 to 500 times less than the allowable tolerance levels in foods. Additionally, these tolerance levels are established for commonly eaten foods such as eggs, fish, and commercial poultry. Since hunters were assumed to ingest 3 to 6 ducks in one year, it is likely that the allowable tolerance levels shown in Table 4-8 would also apply to the ducks hunted at Holloman AFB. These tolerance levels also suggest that the chemical residues in ducks taken from the sewage lagoons and lakes are not of concern to hunters who ingest them.

4.10 Pond G

The following exposure scenarios were considered at Pond G:

- Current On-site Worker
  - — Chronic
  - — Subchronic
- Current/Future Trespasser
  - — Teenager, 12-15 years old
- Current/Future Recreational—Hunters (chronic and subchronic)
  - — Adult
  - — Child

Table 4-9 presents the cancer risk and noncancer hazard estimates for the on-site worker and trespasser scenarios at Pond G. The current/future recreational scenario was discussed previously in Section 4.9 and should be considered when evaluating the total risks associated with Pond G.

On-site Worker—The cancer risk and noncancer hazard estimates for the on-site worker scenario are well below the target risk criteria. This scenario assumed that workers were exposed to soil, sludge, and surface water, during routine maintenance activities, for up to 12 days per year for 25 years.

Cancer risk estimates are based on the sum of the 1993 risk estimates and the new COCs found in the 1994 investigation. The pathway- and chemical-specific cancer risk estimates for the new COCs are listed in Appendix G, Table G-7. The noncancer hazard estimates are based on the sum of the 1993 estimates, the relative change in the 1993 estimates based on the risk ratios, and the results from the new COCs found in the sludge during the 1994 investigation. The pathway- and chemical-specific noncancer hazard quotients estimated for the new COCs are listed in Appendix G, Table G-8.

Trespasser—Only a subchronic noncancer exposure scenario was evaluated for the current/future teenager trespasser at Pond G. The estimated noncancer hazard indices for this scenario are based entirely on the new COCs found in the sludge during the 1994 investigation. The pathway- and chemical-specific noncancer hazard quotients estimated of the new COCs are presented in Appendix G, Table G-9. The noncancer hazard estimates, both average and reasonable maximum, were well below 1 and can be considered negligible.

4.11 The Ditch

The following exposure scenarios were considered at the ditch:

- Current On-site Worker
  - — Chronic
  - — Subchronic
- Current/Future Recreational—Hunters (chronic and subchronic)
  - — Adult
  - — Child

Table 4-10 presents the cancer risk and noncancer hazard estimates for the current on-site

Table 4-9
Summary of the Updated Risk Assessment Results
Pond G

Exposure Scenario	Risk for Scenario	Average	Reasonable Maximum	Analyte Driving Risk	Primary Exposure Pathway
Current					
On-site Worker					
(chronic)	**Cancer Risk**				
	'93 Results	5 E-10	9 E-9		
	Risk Ratios (a)	NA	NA	NA	NA
	New COPCs	6 E-12	2 E-11		
	Total	5 E-10	9 E-9		
(chronic & subchronic)					
	Hazard Index				
	'93 Results	2 E-5	6 E-5		
	Risk Ratios (a)	3 E-8	1 E-7	NA	NA
	New COPCs	3 E-7	4 E-7		
	Total	0.00002	0.00006		
Current/Future					
On-site Trespasser - Teenager					
(subchronic)	**Hazard Index**				
	'93 Results (b)	NA	NA	NA	NA
	Risk Ratios (a)	NA	NA		
	New COPCs	9 E-8	2 E-7		
	Total	9 E-8	2 E-7		

NA = Not Applicable

(a) Values shown are the "relative change in the 1993 risks" which are based on the risk ratios. Refer to Table F-28 for a complete listing of these values.

(b) Risk in this scenario were from exposure to organic lead, which is no longer a COC at Pond G.

Table 4-10
Summary of the Updated Risk Assessment Results
The Ditch

Exposure Scenario	Risk for Scenario	Average	Reasonable Maximum	Analyte Driving Risk	Primary Exposure Pathway
Current					
On-site Worker					
(chronic)	**Cancer Risk**				
	'93 Results	6 E-8	2 E-7		
	Risk Ratios (a)	1 E-11	2 E-10	NA	NA
	New COPCs	5 E-12	2 E-11		
	Total	6 E-8	2 E-7		
(chronic & subchronic)					
	Hazard Index				
	'93 Results	0.004	0.004		
	Risk Ratios (a)	3 E-6	8 E-6	NA	NA
	New COPCs	5 E-8	7 E-8		
	Total	0.004	0.004		

NA = Not Applicable

(a) Values shown are the "relative change in the 1993 risks" which are based on the risk ratios. Refer to Table F-34 for a complete listing of these values.

worker scenario at the ditch. The current/future recreational scenario was discussed previously in Section 4.9 and should be considered when evaluating the overall risks associated with the ditch.

On-site Worker—The risks evaluated for the current on-site worker assumed that workers are exposed to the soil, sludge, and surface water, during routine maintenance activities, for up to 12 days per year for 25 years. The total cancer risk estimates and the noncancer hazard indices are based on the sum of the 1993 risk estimates, the relative change in the 1993 estimates (based on the risk ratios), and the new COCs found in the 1994 investigation. The pathway- and chemical-specific cancer risk estimates and noncancer hazard indices for the new COCs are listed in Appendix G, Tables G-15 and G-16 respectively. The cancer risk and noncancer hazard estimates for the current on-site worker are lower than the target risk criteria.

Recreational—The current/future recreational risk estimates associated with ingesting ducks were discussed previously in Section 4.9. Although exposure to the new COCs in soil was also evaluated for hunters, this exposure pathway contributed less than 0.1% to the total risk estimates for both children and adults. The pathway- and chemical-specific cancer and noncancer risk summaries for the new COCs are listed in Appendix G, Tables G-17 through G-19, and G-20 and G-21 for adults and children respectively.

4.12 Lake Holloman

The only exposure scenario considered at Lake Holloman was the current/future recreational hunters (chronic and subchronic) for adults and children. The risks associated with ingesting waterfowl for this scenario were previously discussed in Section 4.9. Although exposure to new COCs in sludge were also evaluated for hunters, this exposure pathway contributed less than 0.1% to the total risk estimates for both children and adults. The pathway- and chemical-specific cancer and noncancer risk summaries for the new COCs are listed in Appendix G, Tables G-22 through G-24, and G-25 and G-26 for adults and children respectively.

4.13 Lake Stinky

The following exposure scenarios were considered at Lake Stinky:

- Future Beef Consumer—Agricultural
  - — Adult
  - — Child
- Current/Future Recreational—Hunters (chronic)
  - — Adult
  - — Child

Beef Consumer—Table 4-11 presents the updated cancer risk and noncancer hazard estimates for the future beef consumer scenario at Lake Stinky. This exposure scenario assumes that adults and children were exposed to constituents detected in Lake Stinky by ingesting the meat from cattle that foraged on grasses irrigated by water, and that actually drank water from Lake Stinky. Considering the salinity of the groundwater and the limited time that water is present in Lake Stinky, this is a very conservative scenario.

The cancer risk and noncancer hazard estimates for the future beef consumer scenario are based entirely on the estimates from the 1993 risk assessment. These estimates were not updated because:

- The 1993 cancer and noncancer estimates were negligible;
- Groundwater and surface water were not resampled at Lake Stinky during the 1994 investigation; and
- Chemical residue levels in groundwater and surface water are expected to be less than the levels detected in 1993 since Holloman AFB has established Base-wide

Table 4-11
Summary of the Updated Risk Assessment Results
Lake Stinky

Exposure Scenario	Risk for Scenario	Average	Reasonable Maximum	Analyte Driving Risk	Primary Exposure Pathway
Future Beef Consumer					
Adult	**Cancer Risk**				
	'93 Results	7 E-9	2 E-7		
	Risk Ratios	NA	NA	NA	NA
	New COPCs	NA	NA		
	Total	7 E-9	2 E-7		
	Hazard Index				
	'93 Results	0.0002	0.001		
	Risk Ratios	NA	NA	NA	NA
	New COPCs	NA	NA		
	Total	0.0002	0.001		
Child	**Cancer Risk**	NA	NA	NA	NA
	Hazard Index				
	'93 Results	0.0004	0.003	NA	NA
	Risk Ratios	NA	NA		
	New COPCs	NA	NA		
	Total	0.0004	0.003		

NA = Not Applicable

management strategies that further reduce the introduction of chemicals into the sewage lagoons and lakes. The decrease in constituent levels has been shown over the various investigations of the sewage lagoons and lakes and is demonstrated in the *Site Characterization Report* (Radian, 1995).

Risk estimates for the current/future recreational scenario were discussed previously in Section 4.9. Although exposure to the new COCs in soil were also evaluated for hunters, this exposure pathway contributed less than 0.1% to the total risk estimates for both children and adults. The pathway- and chemical-specific cancer and noncancer risk summaries for the new COCs are listed in Appendix G, Table G-27 through G-29, and G-30 and G-31 for adults and children, respectively.

4.14 Conclusions

Based on the criteria used to evaluate potential adverse health effects to humans, cancer risk and noncancer hazard estimates are within the acceptable levels established by EPA for remediation goals at Superfund sites. The EPA target levels used in this assessment were set at 1E-6 to 1E-4 for known or suspected carcinogens, and a hazard index of 1 for noncarcinogens.

Cancer risk estimates at Ponds C, D, E, and F for all exposure scenarios are less than 1E-6. Similarly, the noncancer hazard index is less than 1 at these sites. Cancer risk estimates are slightly greater than 1E-6 at Ponds A, B, and G, the ditch, and Lakes Holloman and Stinky for the reasonable maximum exposure case only, but are well within the acceptable levels established by EPA.

The reasonable maximum cancer risk estimate at Ponds A and B is 2E-6 for the current on-site worker scenario. Although these estimates are greater than 1E-6, the lower end of the Superfund remedial goal, they are well within acceptable levels established by EPA. These estimates are driven entirely by dermal contact with the analytes detected in the sludge and/or surface water at these sites. These risks, however, will be mitigated once these sewage lagoons are removed from active service.

A reasonable maximum cancer risk of 6E-6 was estimated for adult duck hunters who ingest waterfowl caught at Pond G, the ditch, and the Lakes. PCBs and pesticides are the chemicals of concern driving these risk estimates. However, the chemical residues in the duck tissue (caught at Pond G) were detected at levels 5 to 500 times lower than federal and/or State tolerance levels for commonly eaten foods (e.g., commercial poultry). Even though cancer risk estimates of 6E-6 are within the acceptable levels established by EPA, a comparison with the federal and/or state tolerance levels suggests that the chemical residues in ducks taken from the sewage lagoons and lakes are not of concern to hunters who ingest them.

Section 5
METHODOLOGY FOR THE ECOLOGICAL RISK ASSESSMENT

In the 1993 ecological risk assessment (ERA), the risk to aquatic ecosystem health was modeled based on surface water and sediment samples, because site-specific tissue concentrations were not available. Analysis of body burden tissue and food source samples were subsequently conducted to replace the modeled 1993 ERA with an ERA based on actual body burden data collected from the sewage lagoons and lakes.

The objective of this ERA is to determine whether the contaminants in the sewage lagoons and lakes are having detrimental ecological effects. This ERA examines the following Holloman AFB impoundments: Pond G, the ditch, Lake Holloman, and Lake Stinky. Ponds A through F will be removed from service during closure, and therefore they are not addressed in this report.

This ERA focuses on the correlation of the body burden tissue data with the contaminant intake concentrations modeled from food source samples. It was performed in accordance with the following guidance documents:

- EPA. *Framework for Ecological Risk Assessment.* EPA/630/R-92/001. 1992a.
- EPA. *Risk Assessment Guidance for Superfund, Volume II Environmental Evaluation Manual.* EPA/540/1-89/001. 1989b.
- MITRE Corporation. *General Guidance for Ecological Risk Assessment at Air Force Installations.* 1990.

This ERA is based on the following assumptions:

- Physical conditions of Pond G, the ditch, Lake Holloman, and Lake Stinky will remain constant over time.
- Chemical concentrations based on the most recent investigation of the sewage lagoons and lakes will remain constant over time. This approach is conservative, since chemical concentrations have decreased significantly over time and will likely continue to decrease since that the source of contamination has been eliminated.
- Ponds A through F will undergo closure and will no longer contribute risk to the aquatic ecological system.
- No additional contamination will be added to the sewage lagoons and lakes.
- Only constituents that were detected in the sewage lagoons and lakes investigation are included in the analysis.

5.1 Assessment and Measurement Endpoints and the Quotient Method

An assessment endpoint is a quantifiable expression of the environmental value considered to be at risk. Generally, assessment endpoints have associated target species that are primary ecological receptors at a site. The measurement endpoint is a measurable response to a stressor that can be related to the environmental value chosen as the assessment endpoint (Suter, 1990). For the sewage lagoons and lakes exposure scenarios, assessment endpoints were developed by using the five criteria of Suter (1993):

- Relevance to ecology;
- Quantifiability;
- Accessability to prediction and measurement;
- Susceptibility to contaminants; and
- Relevance to society.

However, the relative weights placed on each of the criteria in selecting endpoints are unique to this site.

Ecological relevance is a primary criterion in selecting an endpoint. The ecological relevance of an assessment endpoint is determined by its importance in maintenance of the viability and production of the ecosystem as a whole. That is, an endpoint will be considered ecologically relevant if it meets other pertinent criteria (discussed below) and if risk to the endpoint significantly affects the integrity of higher levels of ecological organization and functions.

An assessment endpoint must have an unambiguous operational definition. That is, adverse effects to endpoints selected must be quantifiable. Depending on the endpoints selected, quantification of effects may be numerical (e.g., 20% reduction in age-specific reproductive rates) or simply indicators of the direction of change in the assessment endpoint parameter in question (e.g., a decrease in population size). The assessment endpoint chosen for the aquatic ecosystem at Holloman AFB is the decrease in the survivorship and productivity of selected aquatic food chains in the sewage lagoons and lakes. Food chains were selected that represent dominant components of the aquatic system trophic structure that possess a high potential for exposure to contaminants.

Assessment endpoints must be quantifiable responses to exposures to contaminant exposures. Measurement endpoints are the results of studies or tests that quantify these responses. Although investigative field studies using such measurement endpoints as egg hatchability, observed health effects, or population changes would be the best estimate of the selected assessment endpoint, a study of this magnitude is not warranted or feasible at this time based on a review of currently available studies and observations at the site (i.e., inhabitants of the ecosystem appear healthy and unstressed). Instead, an indirect estimate of the potential impact to survivorship and productivity, the assessment endpoint, is made by calculating an ecological quotient (EQ). The EQ is based on the comparison of a dose or intake concentration to the measurement endpoint for each constituent.

EQs are a quantitative method of evaluating ecological effects. The "quotient method" (Barnhouse et al., 1982 and Urban and Cook, 1986) is used to arithmetically compare a measurement endpoint (ME) modified by an uncertainty factor (UF) with the calculated intake concentration (I) for each constituent by calculating an EQ of the general form:

$$EQ = I / (ME \times UF).$$

In general, if an EQ is less than 1.0, an adverse effect to the ecosystem is unlikely to occur. Because conservative assumptions and methodologies are used in the calculations, EQs exceeding 1.0 do not necessarily indicate that an impact is expected to occur, and sometimes may overestimate risk. Each EQ greater than 1.0 is evaluated on a case-by-case basis for bioaccumulation potential, contaminant availability, and ecosystem sensitivity to better evaluate the possibilities and probabilities of the occurrence of adverse effects.

For this ERA, the lowest-observed-adverse-effects-levels (LOAELs) for mortality or reproductive effects were the toxicity data used as measurement endpoints. The LOAEL data were taken from available literature for those species used as assessment endpoint species. When toxicity data were not available for these species, toxicity data were used from surrogate species that are similar physiologically and in life history patterns to the assessment endpoint species. Uncertainty factors were applied to ensure that the measurement endpoints were adequately conservative when surrogate species were used.

Assessment endpoints that meet the susceptibility to contaminants criterion were chosen. The home range size of assessment endpoint species, seasonality, and foraging behavior are among the parameters evaluated to determine susceptibility.

The societal relevance criterion addresses the public's understanding and value of the assessment endpoints. This is a controversial criterion; however, it is a criterion that should be considered because it may strongly influence potential corrective action decisions. The waterfowl
present at the sewage lagoons are of recreational value to birdwatchers and hunters. Fish are of minimal societal value because the only fish present are mosquito fish which were introduced to the sewage lagoons for mosquito control but are too small to be caught for recreational purposes.

5.2 Ecological Characterization

Information on climate, soils, surface water, groundwater, and geology are fully described in the 1993 risk assessment report (Radian, 1993a); however, pertinent information is summarized here. The sewage lagoons and lakes are located in the Tularosa Basin and the biological diversity is characteristic of a desert region. Surface water resources are limited in the Tularosa Basin, owing to high evaporation rates and a low annual rainfall of approximately 7.9 in./year. Because of this, these surface water impoundments may be the most significant aquatic resources within at least a 20-mile radius of the area. Groundwater in the area comes from one of the largest saline saturated zones in the United States. The surface water in the sewage lagoons, the ditch, and the lakes is also saline. Plant and animal life in the area is well documented in the 1993 risk assessment report as well as in the Draft Biological Resources Report (Radian and Foster Wheeler, 1995c).

During the summer of 1991 the U.S. Fish and Wildlife Service (FWS) conducted an investigation at the sewage lagoons and Lake Holloman to determine whether migratory birds were being exposed to organic and inorganic constituents potentially present in the impoundments. Eleven sediment, one surface water, and thirty-five biological samples were collected from various locations within the impoundments. These samples were assayed for various metals, metalloids, and organic compounds. The intent of this investigation was not to collect data for use in an ecological risk assessment, but to provide a preliminary assessment of whether the impoundments were affecting the ecosystem. Because analytical QA/QC documentation is not available, this data will not be included in assessing the ecological risks from the sewage lagoons and lakes. The draft report that presents the data was prepared in January 1994, and is entitled *Preliminary Survey of Contaminants Present in Biota, Pore-Water and Sediments at the Holloman AFB Waste Water Treatment Facility* (FWS, 1994). No specific conclusions were drawn in this report.

To fully characterize risks to the ecosystem, two approaches were used to evaluate the data:

1) Screening evaluation using food uptake modeled from food source samples collected; and

2) Evaluation using body burden tissue data collected by Holloman AFB in 1993.

Figure 5-1 presents a summary of the methodology. The first method uses an uptake model based on concentrations in food sources to determine contaminant concentrations in each of the assessment endpoint species. Contaminant concentrations in food sources, as well as surface water and sludge, are carried through the model

EQ Calculations					
	SALAMANDERS[1]	MERGANSER[2]	MALLARD	SHOREBIRDS	FISH
MODELED	NA	X	X	X (Killdeer)	NA
BIOLOGICAL DATA	X	NA	X	X (Stilt)	X

1. Salamanders not included in trophic structure.
2. Merganser EQ's modeled from modeled fish intake and biological fish data (see below), no tissue data was available.
3. NA - Data not available

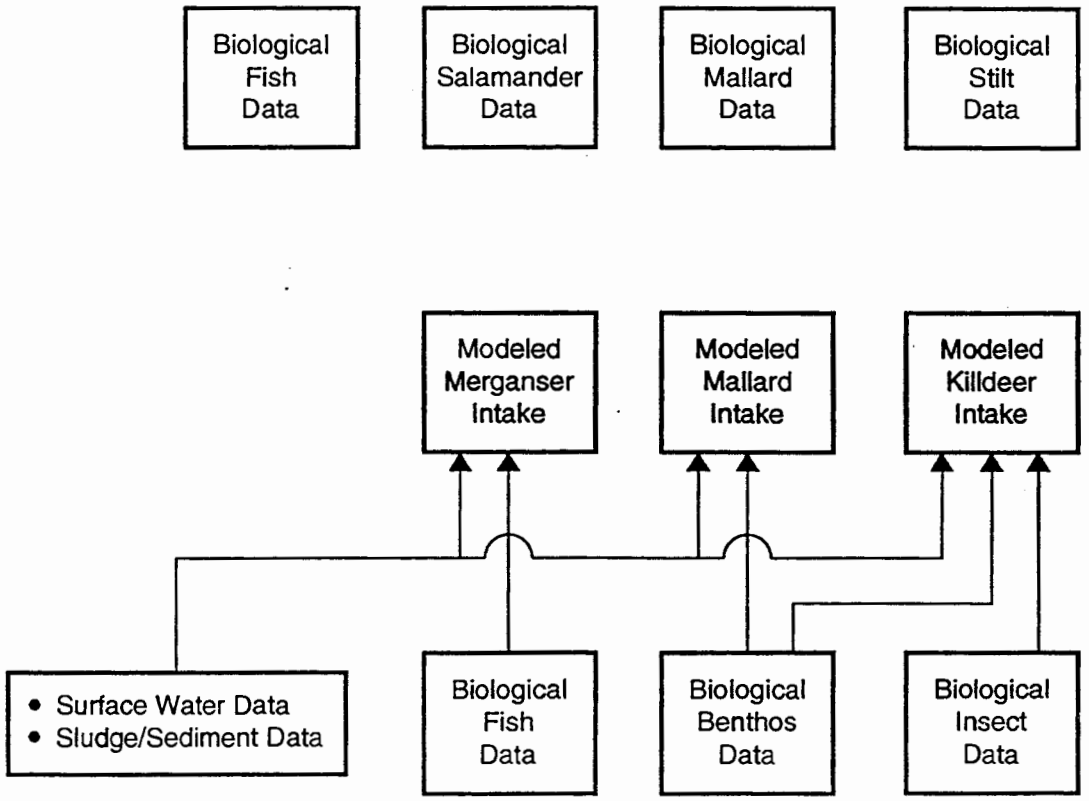


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Figure 5-1. Methodology for Ecological Risk Assessment

and resulting concentrations in the endpoint species are estimated.

The modeled concentrations are then compared with the measurement endpoints. A screening evaluation provides a conservative estimate of potential adverse impacts. Because the screen is very conservative and site-specific tissue concentrations of assessment endpoint species were available, additional evaluation using actual body burden samples was conducted. These data provide tissue concentrations for each of the trophic levels and are considered to be used best as confirmatory evidence for the chemicals of potential ecological concern (COPECs) that were modeled, because of data limitations (i.e., one duck sampled). Concentrations in tissue samples from the different trophic levels provide information concerning the movement of individual contaminants into each segment of the food chain. However, very small sample sizes, as well as uncertainty associated with the analytical data and the representativeness of the samples, suggest that these data are best used in conjunction with the uptake model rather than in place of the model. Both approaches are defined in Section 5.4.3.

5.3 Identification of Chemicals of Potential Ecological Concern

Sampling of surface water, soil, sludge, sediment, and groundwater has been conducted at the sewage lagoons and lakes. Also, biological samples consisting of algae, benthos, insects, fish, grass, salamander, black-necked stilt, and a duck have been collected. Table 5-1 describes the types of site-specific samples collected at each impoundment evaluated in the ERA.

All inorganic constituents (i.e., metals) detected in the soil/sludge and surface water samples were first compared to the previously designated upper tolerance limit (UTL) for soil background concentrations at Holloman AFB and ambient water quality criteria (AWQC), respectively. UTLs are likely conservative for the lakes because inorganic constituents naturally accumulate in playa lakes due to evaporation. If both soil/sludge and surface water samples were analyzed for a constituent, and if the maximum detected concentrations for the constituent in an impoundment were less than the UTL and AWQC, then that constituent was eliminated from further risk evaluation. If surface water was not analyzed for a constituent, the constituent was eliminated if the maximum concentration in soil/sludge was below the background UTL.

Some of the metals that were reported with the biological data received from the laboratory are essential elements and often are naturally present in the soil. Because these essential elements are only harmful in extremely high concentrations, they are not typically carried through a risk evaluation. Also, the focus of the closure investigation for the sewage lagoons and lakes is the Appendix IX constituents (as specified in 40 CFR 265, Appendix IX) previously approved by the New Mexico Environment Department (NMED). Boron, calcium, iron, magnesium, manganese, potassium, silicon, and sodium were not evaluated as part of this ERA because none of these metals are Appendix IX constituents and many of them are also essential elements.

Table 5-2 lists those constituents (with the exception of essential elements) removed from risk evaluation for each of the impoundments. The remaining constituents detected at each impoundment were considered as COPECs and were carried through a screening evaluation to determine the chemical-specific EQs.

For the COPECs detected in nonbiological media, food intake concentrations for birds were modeled from surface water, sediment/sludge, benthos, and insect data (see Figure 5-1). Tables G-32 through G-35 in Appendix G list COPECs

Table 5-1
Samples Collected for the Ecological Risk Assessment

Specimen	Pond G	The Ditch	Lake Holloman	Lake Stinky
Algae/Benthos/Nekton	X	X	X	X
Fish (*Gambusia*)	X	X	X	
Insects/Invertebrates	X	X		X
Widgeon Grass[a]				X
Salamanders	X			
Black-necked stilt[b,c]				
Duck[b]	X			
Surface water	X	X	X	X
Sediment/Sludge	X	X	X	X

[a] Widgeon grass is a pond weed that is normally found in saline waters. It is almost completely submerged under the surface of the water.

[b] These samples are assumed representative for the entire sewage lagoons and lakes because these species are not confined to a single impoundment.

[c] The black-necked stilt was collected from an area around Pond C; however, for this ecological risk assessment it is assumed that these data are representative of all sewage lagoons and lakes.

Table 5-2
Constituents Eliminated From the Risk Evaluation

Constituent	Pond G	The Ditch	Lake Holloman	Lake Stinky	Reason
Arsenic	x		x	x	Background[a]
Boron	x	x	x	x	Not App IX[b]
Cadmium		x			Background[a]
Lead				x	Background[a]
Manganese	x	x	x	x	Not App IX[b]
Selenium	x	x	x	x	Background[a]
Silicon	x	x	x	x	Not App IX[b]
Thallium	x	x	x	x	Background[a]

[a] These constituents were not detected in surface water or sludge/soil at levels greater than background and were subsequently eliminated from further evaluation.

[b] These constituents are not Appendix IX constituents and were subsequently eliminated from the risk evaluation.

and their respective media-specific UCLs for each impoundment.

Some contaminants were detected in the body burden tissue samples that were not identified in the surface water or sediment/sludge at Holloman AFB. Although many of these contaminants were estimated at concentrations below the detection limit, their presence was still investigated. There are several possible explanations for the appearance of these constituents in tissue, but not in environmental media. They include:

- Exposure of the assessment endpoint species to these compounds could have occurred from another source not present at Holloman AFB. However, this is unlikely for the algae and benthic organisms owing to lack of mobility.
- Laboratory analysis of the sludge was difficult because of matrix interferences. Small concentrations of analytes, although detectable by the analytical instrument, were not successfully extracted from the sludge and therefore were not detected. Extraction of analytes from the biological samples was efficient with little matrix interference, therefore presenting a more complete analytical assessment.
- Concentrations of some analytes may have occurred in the biological species analyzed (i.e., through bioconcentration), therefore allowing detection by analytical instruments. Prior to incorporation in the food chain, contaminants in the surface water or sediment, may be at nondetectable levels.

The appearance of these contaminants in biological tissue, but not in surface water or sediment, is most likely a combination of all three of the above factors.

Owing to the small number of samples for some of the media at some of the impoundments (insects at the ditch, benthic organisms at Pond G, mallard tissue samples and widgeon grass), upper confidence levels could not be calculated; maximum detected concentrations were used in these cases. For all other samples, the 95% upper confidence limits were calculated and used in the assessment. Proxy values were calculated for nondetectable concentrations by using a random number between zero and the lesser of the minimum detected concentration or the detection limit as described in "Contaminant Data Containing Concentrations Below the Limit of Detection", *Journal of Air and Waste Management Association*, 1991.

The sampling materials and methods were outlined in the 1993 risk assessment report (Radian, 1993a) for all of the soil and water samples and most of the biological samples, with the exception of stilt, duck, and additional algae and invertebrate samples. The duck was shot with a .22 caliber rifle and the black-necked stilts were captured by placing a net over them. The black-necked stilts were young-of-the-year (less than two weeks old), indicating that they had never lived outside the sewage lagoons and lakes area. The duck was estimated to be approximately 9 months old and may have lived part of its life outside the sewage lagoons and lakes area. Section 5.4.2 describes the habits of mallards.

5.4 Exposure Assessment

This section describes the potential pathways by which wildlife could be exposed to the contamination reported in soil, sludge, sediment, and surface water in and around Pond G, the ditch, Lake Holloman, and Lake Stinky, which are expected to remain in use. The other impoundments will be closed, which will eliminate ecological risk from the impoundments. Assessment endpoint species are selected for

further evaluation on the basis of the ecological significance of local species and the nature of contamination. The exposure assessment presents the methods used to calculate the chemical concentrations in food sources to which the assessment endpoint species may be exposed, or the amount that may enter the animal's body.

5.4.1 Identification of Potential Exposure Pathways

Wildlife can be exposed to the COPECs by the following direct and indirect pathways:

- Incidental ingestion of surface soil, sediment, or sludge;
- Dermal contact with surface soil, surface water, sediment, or sludge;
- Ingestion of contaminated vegetation;
- Ingestion of contaminated surface water; and
- Ingestion of animals that have been exposed to contaminated media.

The main pathways of concern at the sewage lagoons and lakes are ingestion of food, water, and sediment/sludge. Although dermal contact with water and sediment/sludge occurs, the extent is difficult to quantify and the risk is most likely insignificant compared with the ingestion pathway. Volatile compounds were not identified as COPECs, therefore excluding the inhalation pathway.

5.4.2 Selection of Assessment Endpoint Species

Assessment endpoint species were selected because evaluating potential effects on all species that occur in the area is not feasible. The criteria used for selecting assessment endpoint species included:

- Species that regularly occur at Holloman AFB (e.g., killdeer, merganser, black-necked stilt, mallard, mosquito fish);
- Endangered or threatened species;
- Species with economic or recreational value (e.g., mallard); and
- Species whose behavioral patterns or habitat preferences may expose them to COPECs.

Assessment endpoint species were chosen to represent the trophic levels in the aquatic food chain. Figure 5-2 displays the primary food chains seen at the sewage lagoons and lakes. Benthic organisms were used to represent the lowest trophic levels as primary producers. Killdeer, mosquito fish, and mallards represent the primary consumer trophic level. Mergansers represent secondary consumers because they consume mosquito fish that have been exposed to, and fed on, algae, plankton, surface water, and sludge/ sediment.

Because the original source of potential contamination was discharged directly to the sewage lagoons, the aquatic food chains are likely to be more severely impacted than the terrestrial food chains. The *Draft Biological Resources Report* (Radian and Foster Wheeler, 1995c) specifically addresses the threatened or endangered species located in the sewage lagoons and lakes area; therefore no threatened or endangered species were selected for this ERA. The assessment endpoint species chosen represent species directly related to the surface water and sludge/sediment. The home range for each of the assessment endpoint species is considered to be the entire area of the sewage lagoons and lakes that will remain open, because the sewage lagoons and lakes represent a unique habitat in this desert region and because they are all interconnected. The merganser, mallard, killdeer, and mosquito fish were selected as assessment endpoint species for the 1993 ERA (Radian, 1993a) and were retained as the assessment endpoint species in the modeling phase of this ERA. For the body burden aspect, black-necked stilts were used in place of killdeer

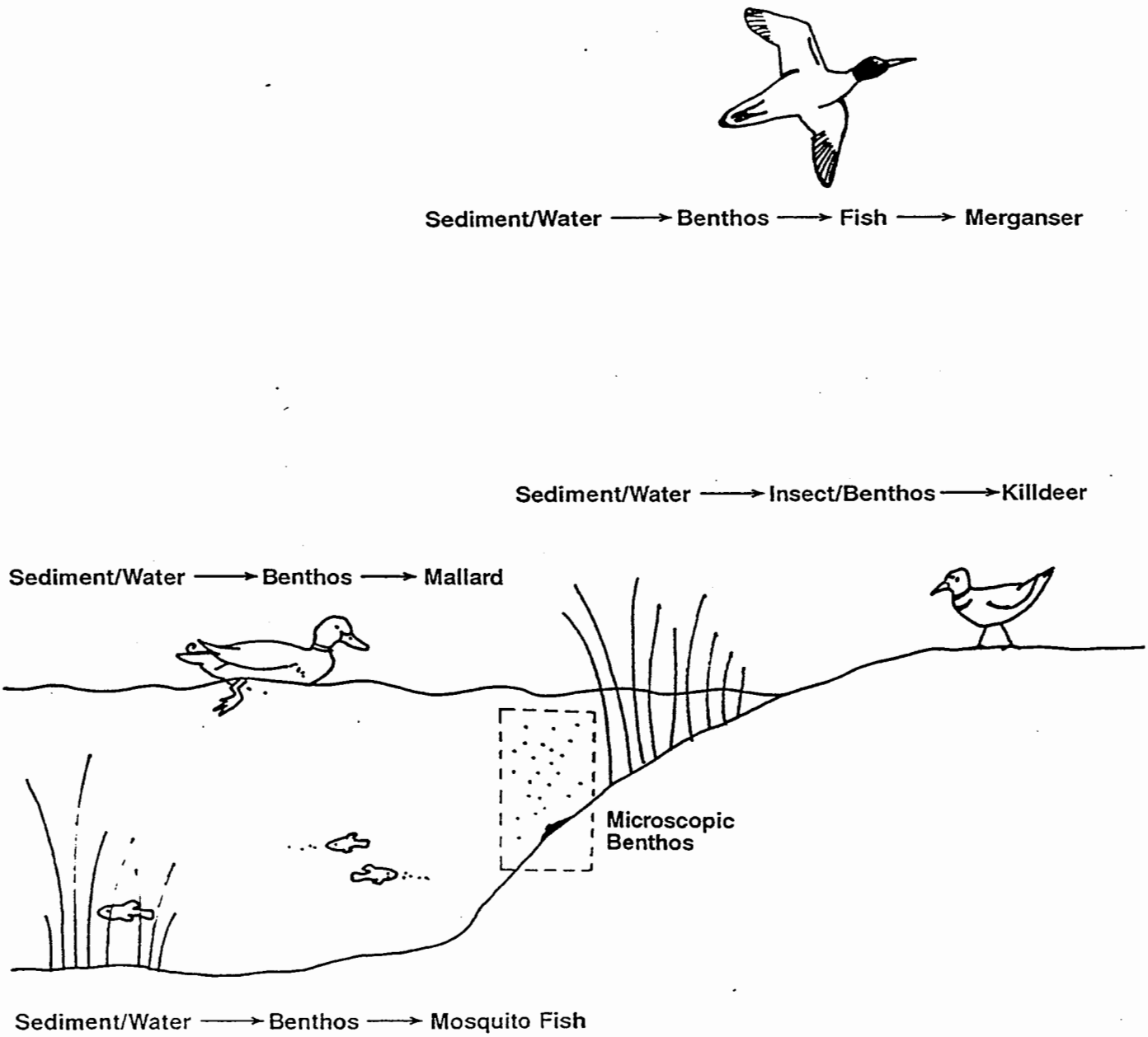

Figure 5-2. Trophic Levels of the Sewage Lagoons and Lakes

because of sample availability; they are considered to be comparable in size and intake. Species-specific information is presented below.

For purposes of this ERA, the home range for waterfowl is assumed to be 240 acres or the area that encompasses Pond G, the ditch, Lake Holloman, and Lake Stinky. This area also represents the foraging range since the sewage lagoons represent a unique habitat in the surrounding desert region. Therefore, in effect, this area would be the home range and foraging range of any water birds inhabiting the area.

Killdeer (*Charadrius vociferus*)

Killdeer, commonly known as plovers, are widely distributed throughout the world. In summer, they frequent sparse bare upland regions, plowed fields and pastureland, and occasionally short-turfed lawns in close proximity to busy roads and buildings. For the rest of the year, they are found along marshy borders of lakes and pools, or along the seashore. Most northern hemisphere plovers migrate southward during the winter, some reaching as far south as Tierra del Fuego, South Africa, and Australia. They are largely insectivorous, eating grass hoppers, beetles, locusts, crane-fly larvae, and caterpillars. They will also eat earthworms, snails, spiders, small crabs, and some vegetable matter. Most of them pick up food at the waterside, either from the surface of the water or mud, or by probing in the mud and sand. All species feed by running in short bursts and darting at the prey.

Killdeer breed during the spring and early summer. Most nest in the open on beaches, grasslands, tundra, gravelly shorelines, or stony deserts. The clutch is four eggs in nearly all northern hemisphere species.

Killdeer were retained as assessment endpoint species for this ERA because of their prevalence throughout Holloman AFB. They are year-round residents and are therefore more likely to be affected by any contamination in the sewage lagoon system. The home range for killdeer varies according to availability of food and water. Because there are no other suitable habitats in the area for killdeer, it is assumed that 100% of their time is spent in the sewage lagoons and lakes. This area is approximately 240 acres. It is unlikely that killdeer spend their entire lifespan at a single impoundment. However, to assess the worst-case scenario, each impoundment is evaluated as an individual system and the risks are evaluated assuming 100% of their food and water is from a single impoundment. The results of this comparison are presented in Section 6.

For the purposes of this assessment, it is assumed that killdeer feed on insects and benthic organisms (Figure 5-1). Concentrations in insects and benthic organisms are used as the starting point for the model. Movement of contaminants up the food chain is modeled using surface water and sediment/sludge as well as insects and benthic organisms to calculate final concentrations in killdeer. Body burden samples of killdeer tissue are not available. Black-necked stilts are used in the place of killdeer to represent the trophic level for the body burden aspect of the ERA.

Black-Necked Stilts (*Himantopus mexicanus*)

The black-necked stilt is a member of the family *Recurvirostridae*. These birds are waders with long legs and slender bills, and feed mainly on insects and crustaceans.

The black-necked stilt is a large slim bird measuring 13-17 inches. The stilt winters mainly south of the United States, but can be found in the west and southeast United States. Likely habitats for the stilt include grassy marshes, mud flats, pools, and shallow lakes (Peterson, 1980).

For this ERA, black-necked stilt body burden tissue samples are used to confirm modeled intake for killdeer.

Mallards (***Anas platyrhynchos***) Surface-feeding ducks are the most familiar ducks of freshwater and saltwater wetlands. They feed by dabbling and tipping up in shallow water, often filtering through soft mud for food. They feed primarily on seeds of aquatic plants and cultivated grains, although they consume aquatic invertebrates, particularly during the breeding season. The mallard feeds mostly on aquatic plants, seeds, and aquatic invertebrates, depending on the season, and forages in ponds and wetlands by dabbling and filtering through sediments (EPA, 1993b). They are generally found in ponds, lakes, and marshes, although semidomestic birds can be found on almost any body of water (Audubon Society, 1977).

Mallards were used as assessment endpoint species in this ERA because of their prevalence at the site. They are also a target of recreational hunters and are thus of recreational value around Holloman AFB.

Adult mallards feed predominantly on vegetative materials. For the modeling aspect of this ERA, it is assumed that they feed 100% on organisms, such as phytoplankton, zooplankton, and mosquito larvae. Biological samples for these organisms were combined to represent the food source for mallards. (For the purposes of this ERA these organisms are combined with benthic organisms.) Because sediments may be a significant source for bioconcentratable chemicals, the intake equation also factors in a fraction of sediment/sludge ingested. The concentrations of COPECs in this combination were used to model uptake through the trophic chain into the mallard. Risks were calculated for each impoundment assuming 100% of their intake from each individual body of water. This conservative estimate of risk better identifies the areas that are contributing to risk from the sewage lagoons and lakes. The home range for mallards varies according to habitat and availability of food and water. It is assumed that 100% of the time spent at Holloman AFB is spent in this area and that mallards spend a maximum of seven months per year at Holloman AFB.

The body burden data for ducks consist of four samples taken from a single mallard. Because the sample size consisted of a single duck that may not have lived its entire life at Holloman AFB, the body burden EQs are most reliable when considered in conjunction with the modeled EQs. These samples were used for comparison with and confirmation of the modeled duck concentrations. The concentrations in duck tissue are not directly comparable to the measurement endpoints. The methodology for converting the tissue concentrations to comparable intakes is presented in Section 5.4.3.

Common Mergansers (***Mergus merganser***)

The common merganser can be found more often than other members of their genus in North America and Eurasia. They are widespread over the Northern Hemisphere, inhabiting Canada and the northern portions of the United States, central California, Arizona, and New Mexico. The common mergansers are the largest of all inland ducks in North America and are usually seen on fresh water, but occasionally locate themselves on the brackish waters of bays and inlets. Mergansers often nest in open cavities of trees near the water, on the ground in bulky masses of weeds, and under low bushes. The nests are lined with weeds, grasses, rootlets, and down from the female's breast. It is in these cavities that usually 9-12 eggs are laid every year during the months of May and June. Mergansers are fish-eating ducks and rarely occur in sizable flocks. They can also feed on crayfish and some amphibians (Ransom, 1981).

Mergansers were chosen as the assessment endpoint species for their trophic level because they have been known to frequent the sewage lagoons and lakes. Mergansers are predators that feed on the mosquito fish (Gambusia) present in the impoundments.

Merganser intake was calculated using actual fish tissue concentrations. Because sediments can be a significant source for bioconcentratable constituents, a factor is included in the equation to account for the fraction of soil/sediment ingested in the diet. The actual home range for the merganser is dependent upon food and water availability. For the ERA, Pond G, the ditch, Lake Holloman, and Lake Stinky (approximately 240 acres total) are considered to be the home range due to the absence of significant additional habitats within approximately 20 miles. EQs for the merganser were calculated for individual impoundments assuming 100% of their food and water intake from each water body, providing a conservative evaluation of impacts. Mergansers are migratory, spending less than seven months at Holloman AFB. Because Lake Stinky dries up each year and supports few fish during the time that it contains water, it was not considered a suitable habitat for mergansers. Therefore, risks to mergansers were not calculated for Lake Stinky. The ditch is also not a suitable habitat for mergansers due to vegetative cover; however, since mosquito fish are present, mergansers were evaluated using data collected from the ditch. Because body burden samples were not collected for the merganser, risk estimates could not be calculated based on tissue concentrations for comparison with the modeling results.

Mosquito Fish *(Gambusia affinis)*

The mosquito fish is a member of the *Poecidliidae* family, which contains live-bearing toothed carps (guppies, mollies, platys, swordtails, and others). These fish are found primarily in the warmer parts of North and South America. *Gambusia affinis* are referred to as mosquito fish because of their habit of feeding on insect larvae close to the water's surface. Mosquito fish from the southern United States were introduced to aid in insect control. Many fish in this order can withstand salt water and are found in estuarine or even marine environments (Bond, 1979).

Mosquito fish were introduced to Pond G and the ditch for mosquito control and have migrated to Lake Holloman. No native fish are present. Mosquito fish are present because of their ability to tolerate the salinity of the water found in these impoundments. They are used in this ERA to represent their trophic level and as the primary food source for the mergansers.

Body burden samples were collected and used to determine COPECs in fish. Because the sample size for fish was larger than the sample size for the bird data, the fish tissue concentrations are considered to provide a more reliable estimate of chemical concentrations in fish due to a more representative sample set. To compare the tissue concentrations in fish with the measurement endpoints that were expressed in daily doses, the measurement endpoints were converted to tissue concentrations by adjusting for bioconcentration. The bioconcentration factors (BCFs) used for each chemical are documented in the spreadsheets in Appendix G and the toxicity profiles in Appendix H.

5.4.3 Quantification of Exposure

This section describes the methods and assumptions used to quantify exposure, using both the body burden data and the modeled uptake. Exposure quantification considers the environmental fate of the contaminants, food chain interactions (including bioaccumulation potential), magnitude and frequency of assessment endpoint species exposure, and seasonal variations. Intake represents the amount of body burden, including intake of each COPEC for each assessment

endpoint species. Daily doses, selected measurement endpoints, and uncertainty factors are presented in Appendix G, Tables G-36 through G-43 for both the body burden data and the uptake models. Measurement endpoints and uncertainty factors are identical for both the body burden samples and the modeled uptake.

Assessment of Body Burden Data

Available toxicological information were obtained from toxicity dose studies. Theoretically, a dose could be converted to a tissue concentration. However, in order to do this, mathematical models for all physiological processes involved in metabolizing and absorbing contaminants into tissues would be required. In the body burden data assessment, tissue concentrations were compared with the measurement endpoints. Because the concentrations in tissue represent the accumulation of contaminants over an entire lifetime, they cannot be directly compared with a dose. However, for comparative purposes only, tissue concentrations were converted to daily intakes by dividing the concentration in the tissue by the estimated lifespan for the species at the time it was sacrificed. Converting a tissue concentration to a daily intake in this manner has a large amount of uncertainty that increases as the age of the animal increases. Therefore this exercise is best performed with very young animals. The mallard was estimated to be nine months old and the stilts were estimated to be approximately two weeks old.

Concentrations in mosquito fish tissue also cannot be directly compared with measurement endpoints. Because measurement endpoints in fish are generally presented as the concentration in water that is likely to cause a given adverse effect in the fish, the endpoints were multiplied by bioconcentration factors (BCFs). BCFs are ratios of the concentration of the chemical in tissue to the concentration in the surrounding media. BCFs vary widely depending largely on the lipid content of the organism, sediment and water properties, and chemical properties. Chemical-specific BCFs were located for each of the COPECs.

Although tissue samples are also available for benthic organisms, insects, salamanders, and widgeon grass, relevant measurement endpoints for direct comparison were not available for these species. The applicable data from these species were used in the overall trophic structure for this ERA as well as in identifying contaminants that may be bioconcentrating in the food chain. The statistical information and results from the analysis of these samples are presented in Appendix G, Tables G-44 through G-47.

Intake Assessment for Modeling Uptake

Table 5-3 presents the intake equation and avian assessment endpoint species-specific factors used for this ERA. To model the movement of chemical concentrations up the food chain, daily food intakes from each of the contaminated food sources and media must be quantified. Intake rates of food sources including benthos, mosquito fish, sludge/sediment, and water were calculated in mg/kg/day for each contaminant of concern, as shown in Table 5-3.

Food and water ingestion rates specific to the species were used whenever possible; otherwise, the *Wildlife Exposure Factors Handbook* (EPA, 1993b) was used. The food intake that is required for a bird in order to meet its metabolic needs is represented by an allometric regression equation. This equation describes the amount of food required to support the metabolic rate of an animal as a function of its body weight.

Water intake rates depend on the rate at which animals lose water to the environment from evaporation and excretion. Loss rates depend on body size, ambient temperature, and physiological adaptations for conserving water. The allometric regression equation for the water intake rate was

Table 5-3
Intake Equation and Parameters for Avian Assessment Endpoint Species

Intake (mg/kg/day) =

$$\frac{[SF \times B \times ((IR_f \times IF_{fish} \times C_{fish}) + (IR_f \times IF_{bo} \times C_{bo}) + (IR_f \times IF_{insects} \times C_{insects}) + (IR_f \times IF_{soil} \times C_{soil}) + (IR_w \times C_{water}))]}{BW}$$

Parameter	Assessment Endpoint Species Factors			Definition
	Killdeer	Mallard	Merganser	
SF (unitless)	100%[a]	58.3%[b]	58.3%[b]	Fraction ingested from contaminated source.
B (unitless)	100%	100%	100%	Bioavailability to be 100% since gut absorption values in wildlife are generally not available.
IR_f (kg dry wt/day)	0.013	0.061	0.083	Food ingestion rate based upon body weight ($=0.0582BW^{0.0651}$), (EPA, 1993b and Nagy 1987).
IF_{fish} (unitless)	0%	0%	98%[c]	Fraction of diet made up of fish. The merganser is the primary consumer of fish in this system.
IF_{bo} (unitless)	42.7%	96.6%	0%	Fraction of diet made up of benthic organisms. Killdeer and mallards consume benthics.
$IF_{insects}$ (unitless)	50%	0%	0%	Fraction of diet made up of insects. The killdeer's diet is partially made up of insects.
IF_{soil} (unitless)	7.3%	3.3%	2%	Species specific fraction of soil/sediment/sludge obtained through incidental ingestion (Beyer, et al., 1994).
IR_w (L/day)	0.01	0.0622	0.084	Water ingestion rate based upon body weight ($=0.059BW^{0.67}$), (EPA, 1993b and Nagy, 1987).
C_{fish} (mg/kg)[d]	-	-	-	Contaminant concentration in fish. See Appendix G for the actual concentrations.
C_{bo} (mg/kg)[d]	-	-	-	Contaminant concentration in benthic organisms. See Appendix G for the actual concentrations.
$C_{insects}$ (mg/kg)[d]	-	-	-	Contaminant concentration in insects. See Appendix G for the actual concentrations.
$C_{soil/sediment}$ (mg/kg)[d]	-	-	-	Contaminant concentrations in soil, sediment, or sludge depending on available samples.
C_{water} (mg/L)[d]	-	-	-	Contaminant concentrations in surface water (where available).
BW (kg)	0.101	1.082	1.709	Body weight (Dunning, 1993).

[a] Killdeer are conservatively assumed to get 100% of their food and water at the sewage lagoons and lakes.

[b] Mallard and mergansers are migratory waterfowl. The source fraction is based upon a conservative assumption of a seven month residence time.

[c] Mergansers are fish eating ducks. Fish are considered to be their primary food source.

[d] Contaminant concentrations are impoundment specific.

also taken from the *Wildlife Exposure Factors Handbook* (EPA, 1993b).

The species-specific factors used in the uptake model for each of the avian assessment endpoint species are listed in Table 5-3.

5.5 Toxicity Assessment

Unlike a human health risk assessment in which reference doses and slope factors are available for most chemicals of concern, established toxicity values are not readily available for most of the COPECs on a species-specific basis. Available literature was reviewed to identify the toxic effects of the COPECs to fish and wildlife. In cases where cumulative reviews were already completed, the data in these reports were used to a large degree. Not all of the COPECs have been researched to the same extent. The sections below outline the criteria used in determining the measurement endpoints for this ERA and the uncertainties associated with them.

5.5.1 Selection of Measurement Endpoints

To determine whether the assessment endpoint species are likely to be significantly affected by COPECs in the sewage lagoons and lakes remaining open after closure, measurement endpoints that are ecologically relevant must be defined. For the purposes of this ERA, the measurement endpoints were LOAEL toxicological studies showing the occurrence of adverse effects that would reduce assessment endpoint species survivorship and productivity (e.g., LOAELs with effects such as decreased eggshell thickness or reduced survivability).

The search focused on chronic toxicity studies of mortality or reproductive effects via food ingestion. When LOAEL studies were not available the median lethal dose (LD_{50}), the median lethal concentration (LC_{50}), or the no observed adverse effect level (NOAEL) was selected. Measurement endpoints were selected from searches of the TOXNET, TOXLINE, and Hazardous Substances Data Base (HSDB), the Registry of Toxic Effects of Chemical Substances (RTECS) databases, and available literature. An ecological toxicity profile for each COPEC is presented in Appendix H.

5.5.2 Uncertainty Factors

Because the precise measurement endpoint for each assessment endpoint species was not always available, it is necessary to adjust the endpoint by applying uncertainty factors (UFs) to ensure that the measurement endpoint is adequately conservative. UFs are intentional biases used to ensure that uncertainties in the measurement endpoints do not result in underestimation of potential impacts. The selected measurement endpoints are divided by these factors to produce a more conservative endpoint. Comparison of the physiology and life history patterns are made in addition to direct taxonomic comparison between the measurement endpoint species and the assessment endpoint species to address uncertainty. As discussed below, when the available data are obtained from an acute rather than a chronic study, a factor of 10 is applied to the uncertainty. If LOAELs are not available for a contaminant, the next preferred form of toxicity data was an LD_{50}, an LC_{50}, or a NOAEL. LD_{50} and LC_{50} data were also modified by an uncertainty factor of 10 and NOAEL data were modified by a factor of 0.1. Additional uncertainty factors were derived after considering approaches from both *Performing Ecological Risk Assessments* (Calabrese and Baldwin, 1993), and the *Final Integrated Endangerment Assessment/Risk Characterization Version 4.2* (Ebasco, 1994), and after conversations with Jeff Yurk of EPA Region VI. They include:

- Application of a measurement endpoint from a genera within the same family as the assessment endpoint species (5);

- Application of a measurement endpoint from a family within the same order as the assessment endpoint species (10); and
- Application of a measurement endpoint from an order within the same class as the assessment endpoint species (15).

Measurement endpoints were not extrapolated across taxonomic classes. For this ERA, the UF never exceeded 150.

5.5.3 Ecological Quotients for the Assessment Endpoint Species

Intakes calculated for both the body burden data and the modeled concentrations were compared with chemical-specific measurement endpoints through the quotient method. These intakes for the assessment endpoint species at each location were compared with each of the measurement endpoints modified by uncertainty factors as described below:

Fish:
Ecological Quotient =
Tissue Concentration/Measurement Endpoint

Measurement Endpoint =
(Toxicity Data/Uncertainty Factor) x
(Bioconcentration Factor)

Bird:
Ecological Quotient =
Daily Intake/Measurement Endpoint

Measurement Endpoint =
Toxicity Data/Uncertainty Factor

The ratio of these values is the EQ as discussed in Section 5.1. An EQ less than or equal to 1.0 indicates that the critical effect is unlikely to occur. An EQ greater than 1.0 indicates that a critical effect is possible. Because of the conservative methodology used in the ERA, an EQ that exceeds 1.0 does not necessarily indicate that a critical effect will occur. EQs are not risk numbers, but rather indicators of possible impacts to assessment endpoint species. EQs were used to assess potential critical effects for both the body burden tissue samples and the modeled uptakes. Those COPECs with an EQ greater than 1.0 are then defined as possible chemicals of ecological concern (COEC) and only these constituents are evaluated further for risks to the ecosystem. Table 5-4 presents the COECs and their possible critical effects for the assessment endpoint species.

Ecological quotients were not summed for any of the assessment endpoint species. Unlike human health risk assessments where hazard quotients are summed for chemicals that affect the same target organ, measurement endpoints for this ERA were selected on the basis of population effects. These effects can be caused by a number of different mechanisms (e.g., eggshell thinness, decreased litter size, reproductive effects, etc.). Because the mechanisms vary, additive effects from different chemicals cannot be assessed; therefore, EQs were not added to represent multichemical effects. Because the field of ERA is relatively new compared to human health risk assessment, studies that assess multichemical effects are rare.

Ecological quotients are screening numbers meant to give an estimation of possible impacts within an order of magnitude. If the sum of all EQs for a species at an impoundment exceeds 1.0, it indicates that the individual constituents should be examined to determine which specific chemicals are posing potential risk. In this ERA, specific chemicals were evaluated for each species at each impoundment.

Because the same measurement endpoints and UFs were used for both the body burden data and the modeled data, the EQs for both methods combine to give the best indication of possible

Table 5-4
Critical Effects for COECs at Holloman AFB

Chemical	Assessment Endpoint Species	Critical Effects
2,4'-DDD	Mosquito Fish	Not specified[a]
4,4'-DDT	Mosquito Fish	Not specified[a]
4,4'-DDE	Black-necked stilt, Mallard	Reproductive effects
	Mosquito Fish	Not specified[a]
4,4'-DDD	Mosquito Fish	Not specified[a]

[a] The endpoint is from the Ambient Water Quality Criteria (AWQC) which are designed to be protective of all aquatic life. No adverse effects are likely from exposure to COPECs at AWQC levels. AWQC may be conservative for mosquito fish as they are typically more tolerant than other aquatic species that were considered in setting the criteria.

adverse effects. In cases where the EQ is greater than 1.0 for both assessment methodologies for a given constituent, consideration must be given to the possibility of adverse effects to the trophic levels at risk as well as the movement of that constituent up the food chain.

Tables G-36 through G-43 in Appendix G present all of the calculated doses, UFs, and EQs for the lower trophic level biological data and the modeled data. All EQs greater than 1.0 are presented by species and assessment methodology in Section 6. These results may indicate the COPECs that are the most likely to produce adverse effects on individual animals within the system. Owing to the uncertainties and intentional biases, the magnitudes of the EQs are not necessarily indicative of the magnitudes of the adverse effects within the population.

Section 6
RESULTS AND CONCLUSIONS OF THE ECOLOGICAL RISK ASSESSMENT

In the 1993 ecological risk assessment (ERA), risk to the aquatic ecosystem was calculated based upon surface water and sediment samples. Since that time, additional data have been collected to supplement the existing surface water and sediment/sludge samples. Table 5-1 describes the types of additional data collected and the impoundment from which the sample was collected. Because so much additional information was collected including food source data and body burden tissue data, this assessment was much more extensive than the previous ERA. As a result, this ERA is intended to replace the conclusions of the 1993 ERA in their entirety.

The following subsections outline the results and conclusions of the ERA. Ecological quotients (EQs) were calculated by two different methodologies. The first method modeled concentrations in the assessment endpoint species by estimating uptake from their respective food sources. These modeled uptakes were then compared to measurement endpoints. Section 5.5.1 provides an explanation of measurement endpoint determination. The second method compared tissue concentrations from the upper trophic level assessment endpoint species to the same measurement endpoints used in the EQ calculations based on the food source uptake model.

Results and conclusions for both methods are presented below for each of the assessment endpoint species. Ponds A through F are not evaluated in this ERA since they are undergoing closure and will no longer provide a habitat for the aquatic species. The assessment endpoint for this evaluation is a decrease in the survivability and productivity of species within selected aquatic food chains; therefore, results and conclusions are based upon the overall impact on the food chains. The food chains being evaluated are presented at the beginning of each subsection and in Figure 5-2. Due to the potential for waterfowl to move from one impoundment to another, their modeled results and body burden results are combined and evaluated over the entire aquatic system. Mosquito fish results were calculated for Pond G, the ditch, and Lake Holloman independently due to the assumption that fish are less mobile and more likely to spend their entire life in a single impoundment. Because mergansers are dependent upon mosquito fish as their primary food source, and mosquito fish are evaluated by impoundment, mergansers are also evaluated on an impoundment-specific basis. This is a conservative assumption because it evaluates the worst-case scenario of a merganser getting all of its food from a single impoundment and would highlight if any one of the impoundments was contaminated.

6.1 Summary of Results

DDT and its derivatives, DDE and DDD, are the only constituents found in the sewage lagoons and lakes that have the potential to cause adverse effects to the ecology. Table 6-1 summarizes the species and locations where EQs exceeded 1.0. These results are further examined in the subsections that follow. In general, the results of the assessment showed that the aquatic food chains examined are unlikely to be threatened by the constituent concentrations found within Pond G, the ditch, and Lakes Holloman and Stinky.

6.2 Waterfowl

Killdeer, mallard, and mergansers were used as assessment endpoint species to represent waterfowl at the sewage lagoons and lakes. Their respective food chains are described below.

Table 6-1
Summary of Ecological Quotients

Species	Pond G	Ditch	Lake Holloman	Lake Stinky
Killdeer (Model)				
All Constituents	<1	<1	--[a]	--[a]
Mallard (Model)				
All Constituents	<1	<1	<1	<1
Merganser (Model)				
All Constituents	<1	<1	<1	--[b]
Black-Necked Stilt (Body Burden)				
4,4'-DDE	7.46			
All Other Constituents	<1			
Mallard (Body Burden)				
4,4'-DDE	1.13			
All Other Constituents	<1			
Mosquito Fish (Body Burden)				
2,4'-DDD	<1	3.8	<1	--[b]
4,4'-DDD	2.7	210	<1	--[b]
4,4'-DDE	1.2	63	<1	--[b]
4,4'-DDT	<1	11	<1	--[b]
All Other Constituents	<1	<1	<1	--[b]

[a] Killdeer were not evaluated at Lakes Holloman and Stinky because food source samples could not be collected.

[b] Because Lake Stinky dries up every year, fish are not expected to be regular residents there and were not evaluated. Subsequently, mergansers were not evaluated there because of the lack of a food source for them there.

Benthic organisms and insect samples were used to model intakes for the mallard and killdeer. Mosquito fish samples were used to model intake for the merganser. In addition, body burden samples from a mallard and from black-necked stilts were collected and evaluated.

Food Chains Represented:
Sediment/Water → Benthos → Mallard
Sediment/Water → Insects/Benthos → Killdeer
Sediment/Water → Benthos →Mosquito Fish → Merganser

Body Burden Evaluation:
Mallard and Black-necked Stilt

All of the modeled EQs for the mallard, killdeer, and merganser were less than 1.0 for each impoundment in which they were evaluated. These results indicate that the food and water sources present at the sewage lagoons and lakes do not pose a risk to the avian species that inhabit the area. The results from the body burden evaluation showed EQs greater than 1.0 for 4,4-DDE in the mallard (1.13) and black-necked stilt (7.46) which could indicate that adverse effects may be possible.

Although mergansers do not commonly utilize the ditch as a habitat, mergansers were evaluated at the ditch in order to fully assess food chain impacts. Currently, mosquito fish in the ditch are not readily accessible to mergansers due to vegetative cover. None of the EQs calculated on the basis of mergansers eating the mosquito fish found in Pond G, the ditch, and Lake Holloman exceeded 1.0. Based on these results, the aquatic food chain does not appear to be threatened by constituents found in the sewage lagoons and lakes.

DDE is a metabolite of DDT, which was once used as a pesticide at the sewage lagoons for mosquito control. DDT has not been used at the sewage lagoons since the 1970s. However, DDT and its metabolites, DDE and DDD, bind to sediment and water, are highly lipophilic, and have a long half-life. These factors combine to result in high levels of bioaccumulation, especially in aquatic systems and in the species that use the aquatic system as a food source. Because DDT is no longer used at the sewage lagoons, the concentrations in the media (i.e., sludge) are decreasing. This decrease was observed in a review of data collected between 1992 and 1994 where an order of magnitude difference was noted (*Site Characterization Report*, Radian 1995). As a result, the EQs are also expected to continue to decrease to safe levels as the remaining metabolites are further broken down.

Because the results modeled from the media did not show risk, it is also possible that the DDE present in the tissue was from another source. Before its ban in 1972, DDT was used extensively worldwide. The widespread use of DDT, combined with its persistence in the environment, has resulted in DDT and its metabolites becoming virtually ubiquitous with continual transformation and redistribution within the environment (*Toxicological Profile for DDT, DDE, and DDD*, ATSDR 1992).

Killdeer intakes were not modeled at Lake Holloman or Lake Stinky because invertebrate samples were not abundant at the time of sampling.

The assessment endpoint that was chosen for this evaluation is the decrease in survivorship and productivity of species within selected aquatic food chains in the sewage lagoons and lakes. Although the EQ for DDE in mallards and stilts exceeds 1.0 in the body burden tissue, it is unlikely that the assessment endpoint species are threatened. A decrease in the population size of these species has not been observed. Concentrations of constituents in the media and food sources are not considered to be high enough to pose a risk to the avian species at the sewage lagoons and lakes (see Tables G-36 through G-41). A decrease in the survivorship and productivity of the aquatic food

chains for the avian species at the sewage lagoons and lakes is not anticipated.

6.3 Mosquito Fish

Mosquito fish were chosen as the assessment endpoint species to represent aquatic organisms at the sewage lagoons and lakes. Mosquito fish are the only fish present and are not native. The food chains associated with the mosquito fish are presented below. Mosquito fish tissue samples were used to calculate EQs for the fish and were used in the model as a food source for the merganser. Merganser results are discussed in Section 6.2.

Food Chains Represented:
Sediment/Water → Benthos → Mosquito Fish
Sediment/Water → Benthos → Mosquito Fish → Merganser

Body Burden Evaluation:
Mosquito Fish

Mosquito fish were evaluated for Pond G, the ditch, and Lake Holloman individually based upon samples collected from each of those impoundments. Fish samples were not collected from Lake Stinky. Mosquito fish are not native, but were introduced to the sewage lagoons to aid in mosquito control. Mosquito fish were not introduced to Lake Holloman or Lake Stinky directly, though refugee fish are known to have migrated from the sewage lagoon discharge to the ditch and Lake Holloman. For this ERA, concentrations in mosquito fish tissue are associated only with the impoundment in which they were collected. Mosquito fish samples were also used to model EQs in mergansers since mergansers consume fish as a primary food source. In many cases, measurement endpoints from studies involving species other than mosquito fish were used. Because mosquito fish are an unusually tolerant and hardy species, EQs calculated for the mosquito fish from toxicity data based on a different species may be overly conservative. The impoundment-specific results are summarized in Table 6-1 and discussed below.

Mosquito fish EQs calculated for DDD and DDE in Pond G were slightly above 1.0 indicating that adverse effects from only these constituents may be possible. Mosquito fish EQs for DDD, DDE, and DDT in the ditch also exceeded 1.0, but to a greater extent as shown in Table 6-1. EQs of this magnitude indicate that adverse effects are possible or even probable; however, no fish kills have been observed at this site or at any other impoundment. DDD and DDE are both metabolites of DDT which was once used for mosquito control at the sewage lagoons. The properties and food chain mobility of DDT and its metabolites are discussed in detail in Section 6.2 as well as in the toxicity profiles for these chemicals found in Appendix H.

None of the EQs for mosquito fish found in Lake Holloman exceeded 1.0; therefore, adverse effects to the mosquito fish are not expected. Lake Stinky is a playa lake that does not contain water during most of the year. Although a few refugee mosquito fish have been found there, they are not expected to be regular residents. No mosquito fish samples were collected from Lake Stinky during the field investigation; therefore, no risks were evaluated..

6.4 Constituents Not Evaluated

Quantitative evaluation of COPECs was based upon toxicity studies found in searches of the TOXNET, TOXLINE, the Hazardous Substances Data Base, the Registry of Toxic Effects of Chemical Substances, and available literature. For some constituents, however, no applicable studies were found that could be used as a measurement endpoint. If a measurement endpoint could not be found for a species within the same taxonomic class as the assessment endpoint species, an EQ was not calculated. Although an EQ could not be calculated, a qualitative evaluation is provided.

Antimony was detected in the biological media and in the soil at the ditch. Antimony is naturally occurring in the earth's crust but is also released in manufacturing and processing industries such as metal smelting, refining, and coal-fired power plants. Releases are generally due to volatilization during combustion and can travel far from the original source once airborne. It does not appear to bioconcentrate appreciably in fish and aquatic organisms. Antimony could also come from cleaning and stripping auto or aircraft parts, although its distribution in the sewage lagoons and lakes is not consistent with these activities. If the wastewater stream was the source of antimony contamination, it seems likely that the concentrations would be decreasing as the water passed from the upper impoundments to the lower lakes. However, this was not the case as concentrations of antimony increase in the lower impoundments, suggesting that antimony is present under natural conditions.

Barium concentrations throughout the sewage lagoons and lakes, as well as the entire Base, are variable. However, concentrations of barium in the impoundments also increase in the lower impoundments, contrary to what would be expected if the concentrations were due to the wastewater stream. In fact, the highest concentrations of barium in the soil/sludge were found in Lake Holloman. All of these factors combine to suggest that the levels of barium found within this system are likely caused by natural sources rather than by a release. Barium is a naturally occurring component of minerals that is widespread throughout the earth's crust. Barium could also be present from cleaning and stripping auto or aircraft parts, although distribution in the sewage lagoons and lakes is not consistent with this process. Weathering of rocks and minerals is the primary means of barium release to the environment. It is likely that the concentrations of barium in the system are due to the bioconcentration of naturally occurring barium in the environment.

Hexachlorobenzene (HCB) was detected in biological media, but has never been detected in surface water or soil/sludge. The concentrations of HCB detected in the biological samples were very low and were below the detection limit for the surface water and soil/sludge analyses. Hexachlorobenzene is a fungicide that binds tightly to soil and sediment, but is not a constituent in any fungicides that can be purchased through the USAF. There are also no known historical sources of HCB at Holloman AFB.

Mirex was detected in fish and benthic organisms at Pond G at concentrations less than 1 part per billion (ppb). Mirex is an insecticide that was used throughout the U.S. in the 1960s for the control of fire ants, although fire ants have never been found at Holloman AFB. There are no known historical uses of mirex at Holloman AFB. Mirex is extremely persistent in sediment and soil for an extended length of time (*Toxicological Profile for Mirex and Chlordecone*, ATSDR 1993). Its use was banned in 1978. Mirex has a very long half-life.

Various polychlorinated dioxins/furans were detected at low levels in some of the biological samples. Most of these concentrations were below the method detection limit and are therefore somewhat suspect. No current or historical sources of these constituents are known at Holloman AFB.

Although quantitative conclusions cannot be drawn about these chemicals, it is unlikely that they represent risk to the system. Lack of toxicity values may underestimate risk; however, it is not possible to assess ecological risk if toxicity values are unavailable. Although some uncertainty is added to the investigation, the overall conclusions are not expected to be impacted.

6.5 Summary of Conclusions

For this ERA, conclusions are drawn from interpretation of the modeled results in conjunction

with the body burden data. The assessment endpoint has been determined to be the decrease in the survivorship and productivity of species within selected aquatic food chains in the sewage lagoons and lakes.

The results of the assessment indicated that DDD, DDE, and DDT are the only constituents with the potential to cause adverse effects to the assessment endpoint species. For avian species, this potential is very low. No EQs greater than 1.0 were calculated from the food source model. EQs for young of year avian species were less than 8 for DDE in the mallard and stilt body burden tissue. These are considered to be due to bioconcentration of the breakdown of residual DDT deposited in the sewage lagoons prior to the 1970s. A decrease in the survivorship and productivity of avian species of the aquatic food chains at the sewage lagoons and lakes is not anticipated.

Although EQs for mosquito fish were above 1.0 for DDD, DDE, and/or DDT in Pond G and the ditch, the potential for adverse effects to the assessment endpoint is still low. The assessment endpoint addresses the integrity of the trophic structure of the pond system. Because mergansers primarily consume fish, the assessment endpoint would be threatened if mergansers were at risk from eating the mosquito fish, or if the number of fish was not adequate to support the merganser population. This is not the case, however. None of the EQs for mergansers exceeded 1.0 for any constituent in any impoundment, and mergansers are not threatened by a lack of mosquito fish for food source purposes. The concentrations of constituents in mosquito fish do not appear to pose a threat to the survivorship or productivity of the merganser; thus, the trophic integrity is not threatened.

The presence of DDT and its metabolites in the aquatic system at the sewage lagoons and lakes is of concern. However, because the source was eliminated in the 1970s, site data indicate that the levels of these contaminants in media are decreasing to a level that poses no threat to the aquatic ecosystem. This is shown by the significant decrease in concentration of DDE over time in the impoundments (*Site Characterization Report*, Radian 1995c). Present concentrations in the media are self limiting and constituent levels are continuing to decrease. Thus, even though EQs were calculated that exceeded 1.0, the concentrations of these constituents appear to have already decreased to a level that does not threaten the survivorship or productivity of aquatic food chains in the sewage lagoons and lakes.

6.6 Uncertainty Assessment

Uncertainty occurs in almost every step of the ERA process. Most of the uncertainties described in the human health risk assessment apply to the ecological risk assessment as well. Additional uncertainty is added when measurement endpoints, or toxicity data, are for species other than the assessment endpoint species of concern. Uncertainty is often addressed by making intentionally biased, conservative assumptions throughout the entire process in order to ensure that risks are not underestimated. Individual assumptions are therefore conservative, but because of the compounded bias, the calculated EQs are even more conservative as a result of all of the assumptions throughout the process.

Uncertainty is also added as a result of the use of body burden data. The body burden samples allowed for a better starting point for modeling tissue concentrations in the assessment endpoint species. However, the sample sizes were often small and in one case, the concentrations used in the calculations were based on a single specimen. In order to address this uncertainty, modeling of contaminant intake for comparison to known toxic doses (measurement endpoints) was included to aid in interpreting the data. Table 6-2 describes specific uncertainties associated with this investigation.

Table 6-2
Uncertainties in the Ecological Risk Assessment

Parameter	Assumption	Uncertainty
Selection of Assessment End-point Species	Potential effects on the selected indicator species are representative of other animals at the sewage lagoons and lakes.	Exposures and chemical sensitivities vary among species.
Chemical Concentrations	Chemical concentrations in soil and groundwater are equal to the 95% UCL.	By definition, the average chemical concentration is most likely less than the 95% UCL.
	Biological samples for the duck and stilts collected in one location are representative of Pond G, the ditch, Lake Holloman, and Lake Stinky.	It is impossible to quantify the ingested fractions from each impoundment for these samples.
	Concentrations in the samples are consistent throughout the media represented.	Body burden samples were used in conjunction with modeled results to aid in this evaluation.
	The contaminant concentration in the duck and stilt tissue is representative of the total amount of contaminant consumed over the animals' lifetimes. Daily intakes for comparison to measurement endpoints can be calculated from this tissue concentration.	Although these animals were sacrificed at an early age, daily intakes derived from tissue concentrations may not be adequately represented due to metabolic effects. The animals may have a higher daily intake than what is shown in the tissue due to metabolism. This may not be the most conservative assumption. Stilts were two weeks old and the duck was nine months old.
Exposure Route Selection	The sewage lagoons and lakes provide 100% of water intake for assessment endpoint species.	The assumption that the sewage lagoons and lakes provide 100% of an indicator species' water intake is conservative.
	Ingestion of food, soil, and water directly from the contaminated areas is the most significant exposure pathway for the assessment endpoint species.	Indirect exposures to off-site receptors could occur, but are generally less than direct exposures to on-site receptors.
Food Chain Transport	Fish BCFs from the literature search are applicable to this system.	Bioconcentration depends on species and environment. Actual BCFs may be higher or lower.
Ingestion Rates	Because of the desert environment, other food and water sources are scarce. Thus, it is assumed that indicator species ingest food and soil only from the contaminated areas.	Home ranges and feeding habits for the assessment endpoint species were not studied at this site and may vary.
	An animal's average food ingestion rate is representative of all individuals' ingestion rates.	Actual ingestion rates can vary among individual animals.
	Food ingestion rates based on experimentally derived correlations with body weight are representative of actual ingestion rates.	The correlation statistics for the allometric equations indicate that for a given body weight, food consumption can vary.

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