03-95-19

ADMIN RECORD

TREATABILITY STUDY REPORT AND PROCESS FORMULATION REPORT

FOR

PONDCRETE

TEXT
APPENDIX A & B
VOLUME 1 OF 2

DRAFT
REVISION 0

HALLIBURTON NUS CORPORATION

APRIL 10, 1995

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April 12, 1995 C-49-04-5-065

Halliburton NUS Project No. 3A23

Mr. Tom Beckman
EG&G Rocky Flats
Rocky Flats Plant
P.O. Box 464
Golden, Colorado 80402-0464

Reference: MTS 225471AS
Task Order 353010ST3, Sludge and Pondcrete Treatability Studies

Subject: Transmittal of Preliminary Draft Pondcrete Treatability Study Report

Dear Mr. Beckman:

Enclosed please find ten (10) copies of the preliminary draft Treatability Study Report for pondcrete. This report is a contract deliverable of Task Order 353010ST3, under master task subcontract 225471AS. This report documents the treatability testing performed to develop a treated product that meets the waste acceptance criteria (WAC) outlined in the subject task order for pondcrete metals and pondcrete triwalls.

This report has been prepared using all available data as of April 7, 1995. The need to perform a second phase of WAC compliance testing forced a 1-month revision of the schedule for submittal of this report to allow inclusion of the results of this phase of testing (approved by EG&G Rocky Flats via Correspondence Number 95-RF-03079). Because of the short time frame between the conclusion of this phase of mixing and submittal of this report, it was not possible to include all analytical data. Data for some metals and radionuclides whose analytical tests require longer time frames were not available for this submittal, but will be included in Revision 1. However, it is estimated that more than 80 percent of expected data are included in this report. This amount of data was deemed to be sufficient to support meaningful conclusions about recipe development. Therefore, delaying the submittal schedule while waiting for the remaining data would not have affected the conclusions of this report.

The following activities will be performed concurrent with EG&G review of this report:

- Inclusion of all remaining data in tables and graphs (Appendix G).
- Re-evaluation of all interpretations and conclusions with regard to all remaining data.
- Preparation of an Executive Summary.

This information will be incorporated with EG&G review comments into Revision 1 of this report.

If you have any further comments regarding this deliverable, please call me at (412) 921-8746.

Very truly yours,

Richard M. Ninesteel, P.E.
Project Manager

Enclosures

RMN/blb

cc: L. Collins, EG&G Rocky Flats (w/o enclosure)
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03-95-19

DRAFT
TREATABILITY STUDY REPORT
AND
PROCESS FORMULATION REPORT

FOR

PONDCRETE

REVISION 0

PREPARED FOR
EG&G ROCKY FLATS
GOLDEN, COLORADO

PREPARED BY:
HALLIBURTON NUS CORPORATION
PITTSBURGH, PENNSYLVANIA

APRIL 10, 1995

SUBMITTED BY:

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APPROVED BY:

DONALD BRENNEMAN
EXECUTIVE SPONSER

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1.0 PROJECT DESCRIPTION

1.1 AUTHORIZATION

This report has been prepared by Halliburton NUS Corporation (HNUS) as part of the EG&G Subcontract MTS 225471AS, Task Order 353010ST3. The purpose of this report is to summarize the treatability study work conducted at the NUS Laboratory in Pittsburgh, Pennsylvania. This report provides supporting documentation for all treatment-related Waste Acceptance Criteria (WAC) required for ultimate waste disposal into the OU4 closure.

This report encompasses the Treatability Study Report and Process Formulation Report for Pondcrete. Included as appendices are the Equipment Recommendation Report and Computer Modeling Report.

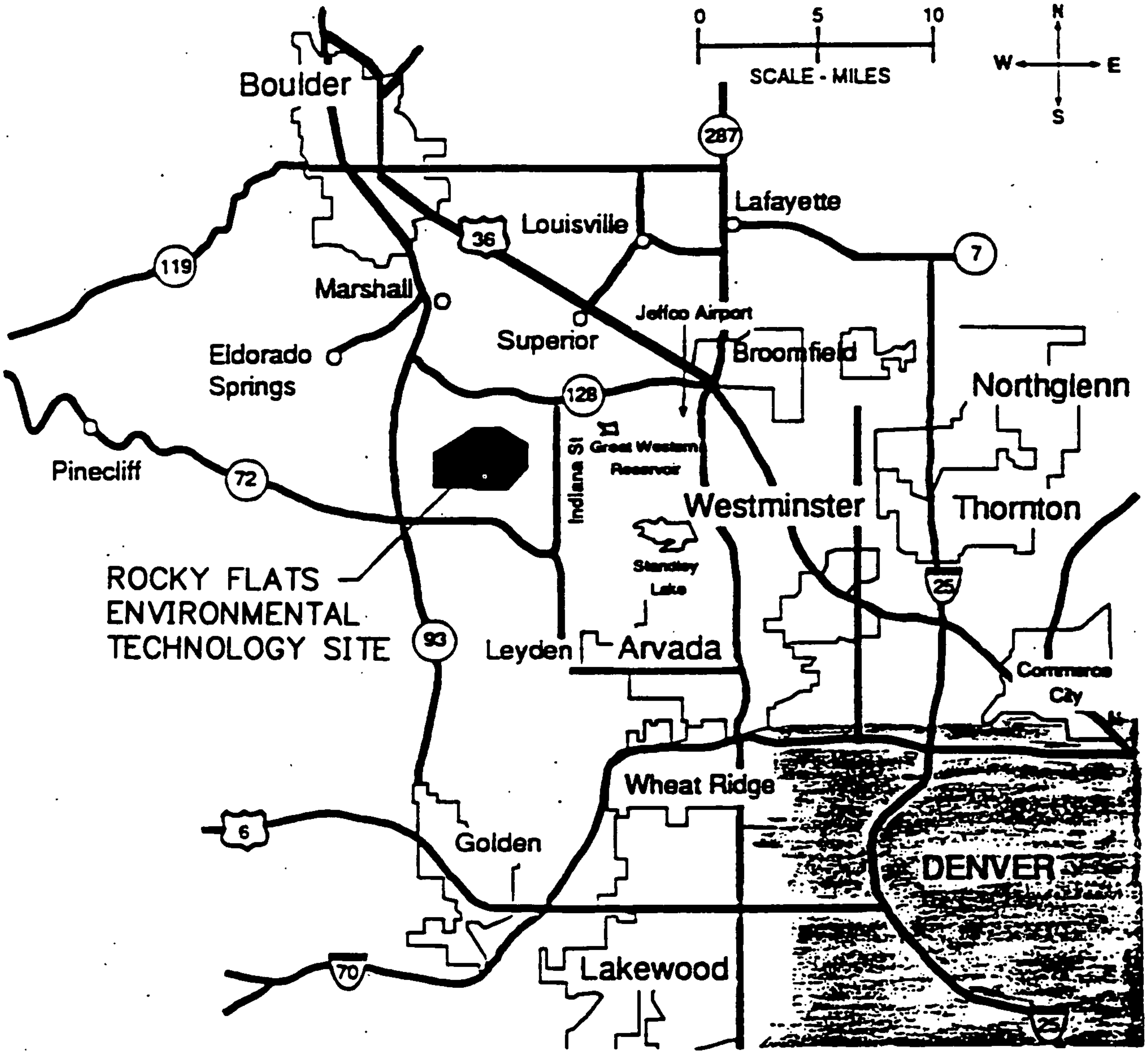
1.2 SITE DESCRIPTION

The Rocky Flats Environmental Technology Site (RFETS) is located in northern Jefferson County, Colorado. The site is currently managed by EG&G Rocky Flats, Inc. for the United States Department Of Energy (DOE). The plant consists of 6,550 acres of Federal land, bounded by Colorado Highways 93 and 128 on the west and north, respectively; Indiana Street on the east; and Colorado Highway 72 on the south (Figure 1-1). The plant structures are centrally located within the site inside a security fenced area of about 384 acres as shown in Figure 1-2.

1.2.1 Rocky Flats Plant Background

The RFETS is a government-owned, contractor-operated facility whose former mission was producing component parts for nuclear weapons. Key production activities involved the fabrication of parts from plutonium, uranium, and nonradioactive metals, principally beryllium, stainless steel, and aluminum. Components made at the RFETS were shipped elsewhere for final assembly. The site began operations in 1952 in 20 buildings and grew continuously to more than 100 buildings. In 1989 production operations were halted at the RFETS.

The plant's historical production mission was officially discontinued in 1992 with the end of the Cold War and the administration's decision not to resume weapons component production activities at the RFETS.



AREA MAP OF RFETS AND
SURROUNDING COMMUNITY
GOLDEN, COLORADO

FIGURE 1-1

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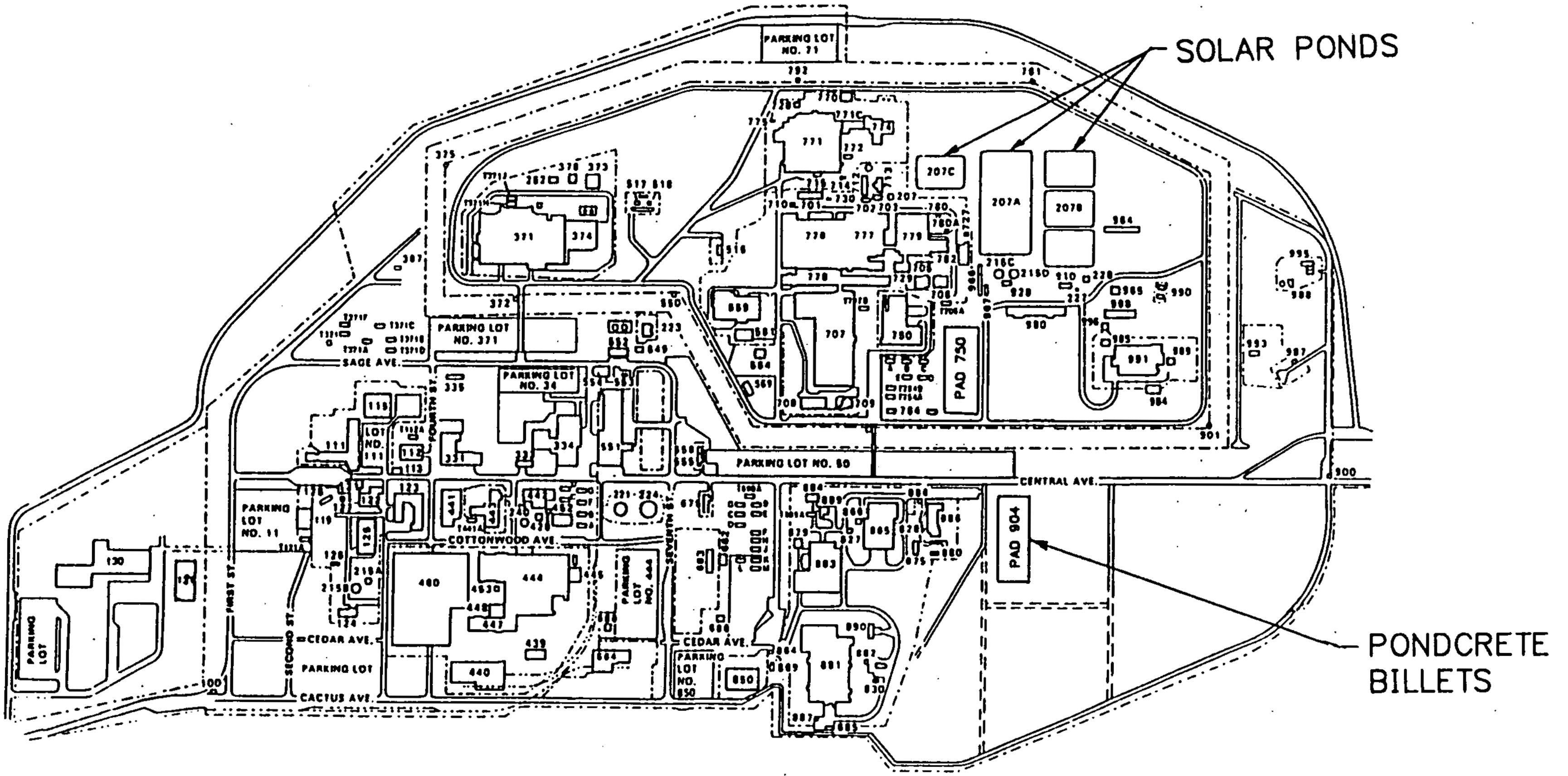

FIGURE 1-2

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE
GOLDEN, COLORADO

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EG&G formed a Transition Management organization to help the RFETS undertake a new mission focusing on environmental restoration, waste management, decontamination and decommissioning (D&D) of facilities, and economic development. The activities at the RFETS are currently continuing in these areas.

1.2.2 Operable Unit 4 Description

Operable Unit 4 (OU4), the Solar Ponds, is an element of the DOE Environmental Restoration Program at the RFETS. OU4 includes the five solar evaporation ponds designated 207A, 207B (north, center, and south), 207C, and the contents of the Building 788 Clarifier. Pondcrete will also be included in the OU4 closure.

During construction of the Rocky Flats Plant, a clay-lined solar evaporation pond was installed. The pond was designed for the impoundment of aqueous waste products discharged from the Process Waste Treatment Plant. The waste contained high levels of chemical contaminants, such as fluoride, nitrates, and various metallic ions. As a result of the changing plant operations and environmental requirements, additional evaporation ponds were constructed. On occasion these ponds were used for the disposal of untreated waste products, such as metallic lithium, acids, sewage sludge, plating residues, and several other wastes associated with operations at the RFETS.[1]

The sludges from Solar Evaporation Ponds 207A, 207B (series), and 207C have been removed and placed into approximately 70 tanks located on the 750 Pad. The removal of the Building 788 Clarifier sludge is currently scheduled for the Spring of 1995. Each tank has a nominal 10,000-gallon capacity and is constructed of High-Density Polyethylene (HDPE).

As part of the closure plans for OU4, pondcrete is to be treated to satisfy specific Waste Acceptance Criteria (WAC) requirements and then placed in the OU4 closure area and covered with an engineered cap.

1.3 WASTE DESCRIPTION

The pondcrete waste is classified as low-level mixed waste. United Sates Environmental Protection Agency (EPA) Hazardous Waste Numbers associated with the pondcrete are F001, F002, F003, F005, F006, F007, F009, and D006.

[1] Rocky Flats Solar Pond Program Lessons Learned, J. Wienand, S. Howard.

Waste characterization studies were conducted in 1991 and 1992 to determine the physical and chemical composition of pondcrete (Deliverable 224B, Pondcrete Waste Characterization Report, Halliburton NUS Environmental Corporation, September 1992, Rev. 0).

Pondcrete resulted from the previous remediation (June 1985) of the 207A pond. The remediation process consisted of pumping the water on top of the pond sediments/sludges to Building 374 for treatment. The sludge was then slurried and pumped to the pondcrete facility at Building 788 from which it was transferred to the Building 788 Clarifier for thickening. The thickened sludge was then pumped to a pug mill for blending with Type I portland cement. The resultant material, pondcrete, was placed in cardboard boxes which are referred to as triwalls. The mixture (pondcrete) was then allowed to cure and was labeled and transported to two outdoor asphalt pads for storage until shipment to Nevada Test Site (NTS) for disposal. The hardened pondcrete was routinely disposed of at NTS during the cleanout of Pond 207A until the Fall of 1986 when pondcrete was identified as low-level mixed waste.

In late May 1988, operations personnel observed that several of the pondcrete triwalls had deformed. Subsequently, the deteriorated triwalls were placed into metal containers for storage. Two to three triwalls were placed into each metal container.

Inventory pondcrete consists of approximately 8,200 triwalls of pondcrete (includes 2,500 pondcrete triwalls that have been placed into metals containers), 50 half-crates of previously reprocessed pondcrete, and several 55-gallon drums of inventory pondcrete.

Field measurements taken during the sampling of the pondcrete triwalls indicated that the majority were wet to damp with penetrometer readings from 0 to 2.5 tons/ft^2. Analytical results from the pondcrete triwalls characterization indicate the moisture content ranged from 46.5 to 69.7 percent with an average of 62.8 percent. Results for volatile organics ranged from 550 μg/kg to 8,600 μg/kg, with acetone detected at the highest concentrations. The TOC averaged approximately 4,100 mg/kg, which indicates significant organic content in the waste. In the TCLP extract, cadmium and chromium were detected at average concentrations of 20,600 μg/L and 5,290 μg/L, respectively. Baseline characterization data of the pondcrete triwalls used for this treatability study can be found in Section 3.1.1.

Field measurements taken during the sampling of the pondcrete metals indicated that the majority ranged from very wet to moist with penetrometer readings from 0 to >4.5 tons/ft^2. Analytical results from the pondcrete metals characterization indicate the moisture content ranged from 45.8 percent to 74.4 percent with an average of 63.2 percent. Results for volatile organics ranged from 310 μg/kg to 7,900 μg/kg, with acetone detected at the highest concentrations. Methanol was detected at 15.4 mg/kg. The TOC averaged approximately 2,600 mg/kg, which indicates significant organic content in the waste. In the TCLP extract, cadmium and chromium were detected at average concentrations of 10,800 μg/L and 1,520 μg/L, respectively. Historical characterization data (Weston) indicated the pondcrete metals contained higher concentrations of radionuclides, specifically americium and plutonium, than the triwalls. Baseline characterization data of the pondcrete metals used for this treatability study can be found in Section 3.1.1.

Comparing the 1991 characterization data, the pondcrete triwalls and pondcrete metals both exceeded the current LDR criteria for cadmium and chromium. Based on the current LDR criteria, the criteria for methanol could potentially be exceeded for the pondcrete metals, although results are not conclusive. No other analytes exceeded their respective LDR criteria for pondcrete triwalls or metals.

The 1991 characterization was completed to evaluate the waste according to LDR standards and support the processing and offsite disposal of the treated product. Currently, the treated waste is to be placed within the OU4 closure area. This treatment and subsequent placement will take place under the Corrective Action Management Units (CAMUs) and Treatment Units (TUs) regulations, as promulgated by U.S. EPA (40 CFR Parts 264 and 265) and the state of Colorado (6 CCR 1007-3). These regulations allow remediation wastes to be consolidated or processed without triggering LDRs or Minimum Technology Requirements (MTRs) which were promulgated to control hazardous waste production from ongoing manufacturing activities.

The current plan to dispose of the pondcrete within the OU4 closure area must prove to be protective of human health and the environment, and meet the WAC requirements and Performance Standards. Protection of human health (i.e., WAC requirements) must be demonstrated by computer modeling. The computer model predicts which contaminants have a potential to migrate from the waste area and potentially affect human health. These contaminants have been evaluated in the treatability study.

1.4 REMEDIAL TECHNOLOGY DESCRIPTION

The goal of the treatability study is to develop a treatment process that meets the Waste Acceptance Criteria (WAC) and Performance Standards (PS) for onsite closure (see Section 1.4.1), as well as the system engineering requirements defined by the preferred treatment system (see Section 1.4.2).

1.4.1 <u>Waste Acceptance Criteria</u>

The objective of the treatability study is to produce a minimally treated waste that will pass the following WAC and Performance Standards (PS):

- The treatment shall be the minimum needed to meet all WAC and PS.

- The treated waste shall not, prior to placement, contain free liquids as determined by the Paint Filter Liquids Test (SW 9095).

- The treated waste can be delivered as a monolith or in particulate form. If a monolith:

  - Shall fit within a rectilinear envelop 12" x 24" x 48"
  - Shall not exceed 3,000 psi compressive strength
  - Shear and tensile strengths shall not exceed those of 3,000 psi concrete
  - Shall not be delivered in molds, containers, or packaging that cannot be returned

  If in a particulate form:

  - Shall pass a 3-inch screen
  - Shall not agglomerate into particles > 3" during storage. If agglomeration does occur, the material shall meet all the criteria specified for a monolith, listed above.

- When treated waste is mixed with site soils, no agglomeration > 3" shall occur.

- Treated waste shall be resistant to dispersion by wind.

- During storage, treated waste shall not produce dust or dispersable fines, and will not degrade upon wetting.

- Treatment additives shall not cause the proposed remedy to fail to be protective of human health and the environment.

- Pathogens shall be removed or rendered innocuous.

- Treated waste shall not produce gas at a rate or volume greater than that produced by natural site soil.

- Total treated waste volume shall be less than 20,000 cy.

- Leachate shall not contain constituents at concentrations that, when modeled, are not protective of human health and the environment.

1.4.2 Process Description

As part of the conceptual design for the treatment of inventory pondcrete, Halliburton NUS prepared a Value Engineering Study that evaluated three potential pondcrete treatment alternatives and a variety of size reduction equipment to identify the treatment system that will satisfy the closure area WAC in the most efficient, reliable, and cost-effective manner, given the operating constraints present at the RFETS. The treatment alternatives evaluated were auger screw shedders, ring-and-pick shedders, and ball mills, all of which produce a friable product. The evaluation considered the following criteria: effectiveness, implementability, operability, and cost.

The auger screw shedder, followed by two ring-and-pick shedders, is the treatment system recommended as the preferred alternative because it has the least potential impact on the overall project schedule, is the easiest to operate and maintain, offers the greatest operating reliability, and has the lowest total cost.

The pondcrete treatment system is shown on Figure 1-3. The additives proposed for the treatment process are lime, which is not only a proven biocide, but is also effective in controlling moisture content; cement, for its pozzolanic properties; and a bulking agent, such as fly ash, to ensure a friable product. This system consist of the following unit operations:

- Transfer of the Pondcrete from the interim storage to size reduction and treatment.
- Storage and feeding of treatment additives.
- Pondcrete size reduction and mixing/blending treatment with additives.
- Treated waste storage and testing.
- Treated waste transfer to OU4 closure area.

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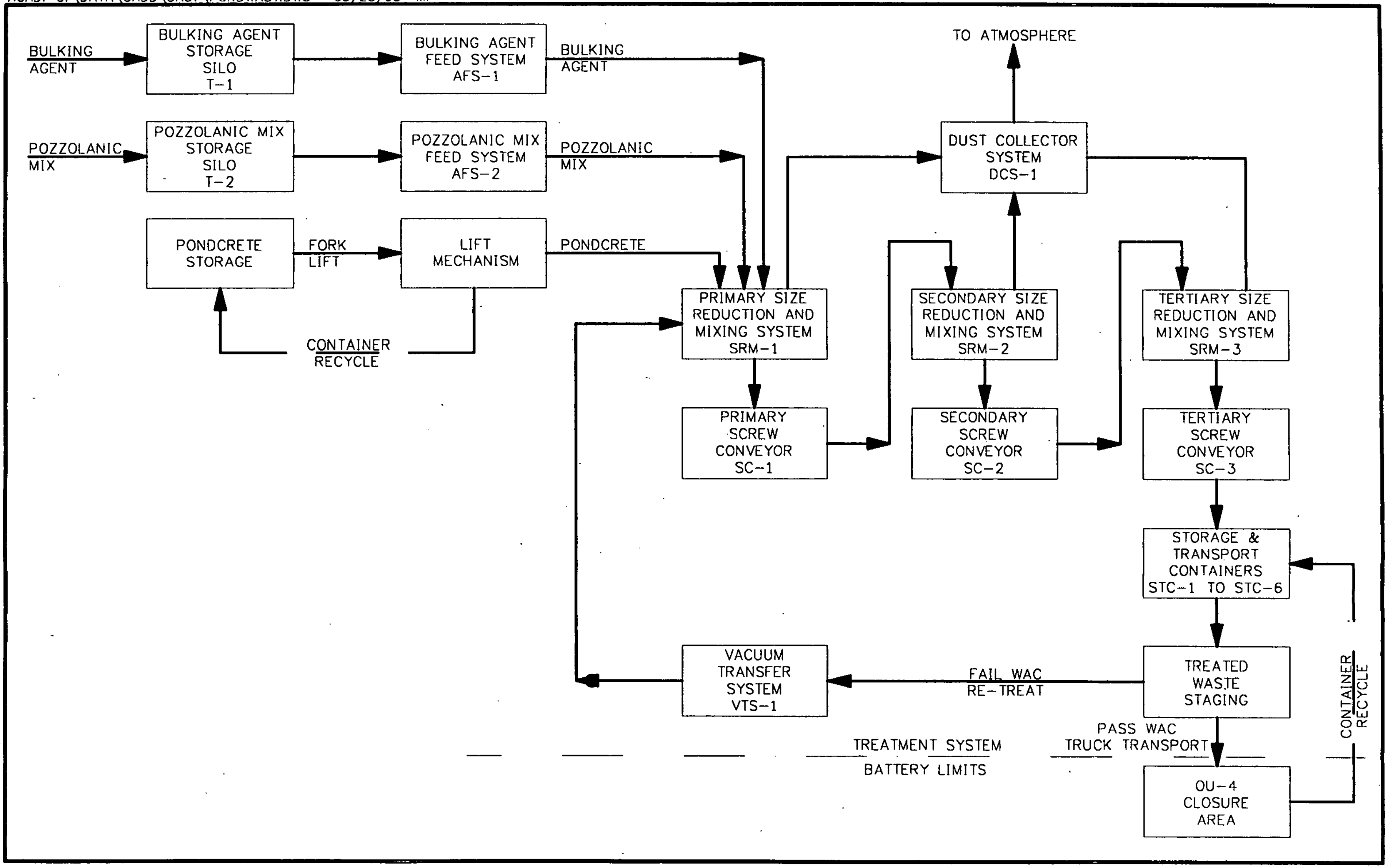

FIGURE 1-3
CONCEPTUAL BLOCK FLOW DIAGRAM
PONDCRETE SIZE REDUCTION AND TREATMENT SYSTEM
EG&G ROCKY FLATS, GOLDEN, COLORADO

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2.0 TREATABILITY STUDY APPROACH

This section describes the requirements and procedures for conducting the treatability study used to develop the chemical stabilization and solidification (CSS) formulations for pondcrete.

The purpose of this treatability study was to develop CSS formulations to stabilize the subject wastes while still providing a final product with the consistency of a friable soil. Candidate formulations were selected to produce a final waste form that achieves all waste acceptance criteria.

2.1 GOALS AND OBJECTIVES

The goal of the treatability study was to develop a CSS formula that is successful in producing a final waste product that can be certified for disposal as per the requirements as stated in Section 1.4.1 and has a final consistency of a friable soil. During the treatability study, it was necessary to determine the appropriate additives and optimum ratios of the waste to admixture(s) in order to achieve acceptable physical characteristics and chemical leachability criteria.

2.2 TREATABILITY STUDY OVERVIEW

The general concept used for developing process formulations for the waste form followed a progression from performing initial analysis and testing of the raw waste to screening various additives (pre-WAC) through a more comprehensive evaluation of variable and additive formulations (WAC-Phase I). Then, the selected candidate formulations that passed all of the previous evaluation criteria were subjected to final compliance testing (WAC-Phase II). The chronology of CSS formulation development is summarized in Table 2-1 and the logic is provided in Figure 2-1. An overview of the major phases of the treatability study is as follows:

- **Initial Preparation and Characterization**. The pondcrete material was mixed and a uniform aliquot was submitted for baseline analysis and TCLP leach + COC analysis. This information provided a basis against which to evaluate the CSS mixes.

- **Lime Addition Study**. One of the waste acceptance criteria for disposal of pond sludge on site under an engineered barrier is the treated waste cannot generate gas at a rate greater than the

TABLE 2-1

PONDCRETE TREATABILITY STUDY SUMMARY
ROCKY FLATS, COLORADO

Phase	Waste Material	Date Performed	Testing	Objective	Results
Baseline Testing	Pondcrete Triwalls Pondcrete Metals	12/29/94 12/29/94	"As Received" and TCLP • Rad. analysis • Metals (Be, Cd) • Bulk Density • Percent Moisture • pH	The "as received" material was analyzed to determine the makeup of the material. TCLP was performed on the "as received" material to determine which analytes present a problem and provide a baseline to compare against.	Results of TCLP indicated all analytes were under the WAC Scenario 1 criteria except for: • 207A/B, U-238 • 207C, Pu-239/240, U-238, cadmium • Clarifier, Pu-239/240, U-238, cadmium • Pondcrete triwalls, Pu-239/240, cadmium • Pondcrete metals, Pu-239/240, cadmium
Lime Addition Study	Pondcrete Triwalls	01/05/95	pH and plate count	Generated pH vs. lime addition curves. Performed bacteria evaluation at varying pH levels.	Able to create textbook lime curves showing a correlation between lime addition and pH in order to select an appropriate lime addition. Plate counts showed bacteria is not a concern in any of the wastes tested.
Pre-WAC Mixes	Pondcrete Triwalls Pondcrete Metals	02/07/95 02/13/95	Physical observations, temperature change, volumetric increases	Pre-WAC testing was performed to evaluate various types of additives and the quantities required to provide a friable soil consistency.	Based on this testing, three formulae were selected: • $Ca(OH)_2$ and fly ash • $Ca(OH)_2$, fly ash, and silica flour • $Ca(OH)_2$, fly ash, and cement
Phase I WAC Mixes	Pondcrete Triwalls Pondcrete Metals	02/08/95-02/13/95 02/20/95-02/21/95	Physical observations, volumetric increases, TCLP analysis, UCS analysis	To establish a range of pozzolan addition which will pass both the physical requirements and WAC criteria.	Established correlation between TCLP acceptance and pH, narrowed formulae test to one: • $Ca(OH)_2$, fly ash and cement.
Phase II WAC Mixes	Pondcrete Triwalls	03/21/95	Physical observation and TCLP analysis.	To establish a process range for selected mix.	Established a process range.

rate associated with native soil. Gas can be generated by the biological decomposition of organic material. Previous characterization data have shown that the pond sludges from which the pondcrete was produced contain a significant amount of organic material, measured as total organic carbon (TOC), which is available for biological decomposition by microorganisms. The average TOC concentration was 5,175 mg/kg in the clarifier sludge, which was the feed material for pondcrete. This TOC confirms the potential of the pondcrete to violate the WAC.

Considerable data are available supporting the use of lime to raise the pH to stabilize biological sludges. Most of the data are from studies conducted on the stabilization of municipal sewage sludges and septage in support of land disposal of these materials. This information is readily available from guidance documents and process design manuals published by the U.S. Environmental Protection Agency (USEPA), as follows:

- In the USEPA's Process Design Manual for Upgrading Existing Wastewater Treatment Plants (USEPA, 1974), the authors cite several studies that "have reported that the addition of lime to raw or digested sludges to pH ranges of 10.2 to 12.5 has effectively reduced the number of pathogenic organisms present. Current USEPA-sponsored work indicates that the pH should be increased to 12.0 for more effective disinfection."

- The USEPA's Process Design Manual, Wastewater Treatment Facilities for Sewered Small Communities (USEPA, 1977) states that "if the pH is raised to between 12.2 to 12.4 and then kept above 11 for 14 days, the sludge will be stabilized."

- More recent guidance contained in the USEPA's Guide to Septage Treatment and Disposal (USEPA, 1994) indicates that increasing the pH to 12 for 30 minutes meets the federal requirements for lime stabilization of septage.

Based on the references cited, it appears that achieving and maintaining a pH of 12 is sufficient to stabilize municipal sewage sludge or septage.

The goals of the lime addition study were to determine the dosage of lime needed to stabilize the pondcrete sludge, and to determine whether hydrated lime or quicklime was more advantageous. Small dosages of lime (both hydrated lime and quicklime) were incrementally added to a known quantity of the pondcrete materials. Samples were collected for pH analysis and bacterial standard plate count. pH was measured during testing to ensure that pH values were obtained over the pH range from that of the raw waste to the treated pondcrete. This data was then plotted to graphically show the dosages of lime needed to achieve the target pH.

A lime study was performed to establish a lime addition versus pH relationship in order to evaluate the proper lime dosage. Bacteriological activity was also tested with lime addition.

- Process Formulation Development (Treatability Study Mixes). Treatability study mixes were performed in the friable mix development (pre-WAC) phase and the WAC compliance testing (Phases I and II).

- Friable Mix Development. This phase of testing was used to evaluate various additives for their ability to create a friable soil material. These tests were also able to establish the amount of the acceptable additives required in order to achieve the desired consistency. Selected additive combinations were further tested in the WAC compliance testing phase.

- WAC Compliance Testing. Mixes performed in the WAC compliance testing phases evaluated specific CSS formulas and conducted analysis of the cured material to determine WAC compliance. Two phases were performed as discussed below.

    - **Phase I.** Mixes performed in Phase I evaluated the additive selected in the pre-WAC testing for compliance with the WAC criteria. These mixes compared the selected formulas against each other and attempt to establish process range. In an attempt to develop a process range, the mixes were performed which varied the percent solids of the waste and the water-to-pozzolan ratio. Figure 2-2 provides a schematic of the mixes performed in an attempt to establish a process range.

    - **Phase II.** Mixes performed on the Phase II evaluated the formula selected in Phase I. These mixes adjusted the percent solids of the waste feed, the water-to-pozzolan ratio, and the amount of lime added, in an attempt to establish a process operating range. A schematic of the mixes performed is provided in Figure 2-3.

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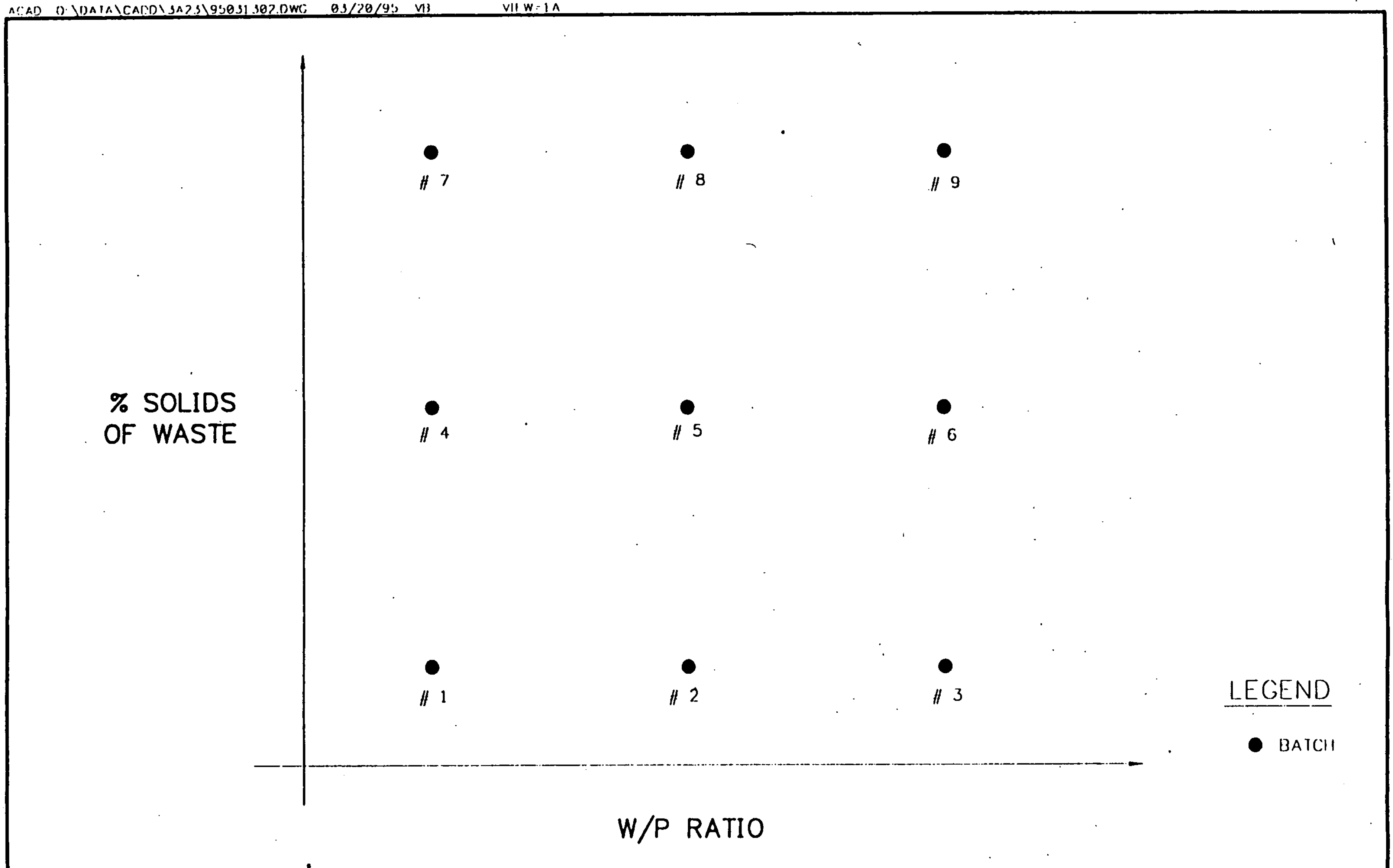

WASTE LOADING AND POZZOLAN ADDITION VARIATIONS FOR WAC PHASE I TESTING ROCKY FLATS, GOLDEN, COLORADO

FIGURE 2-2

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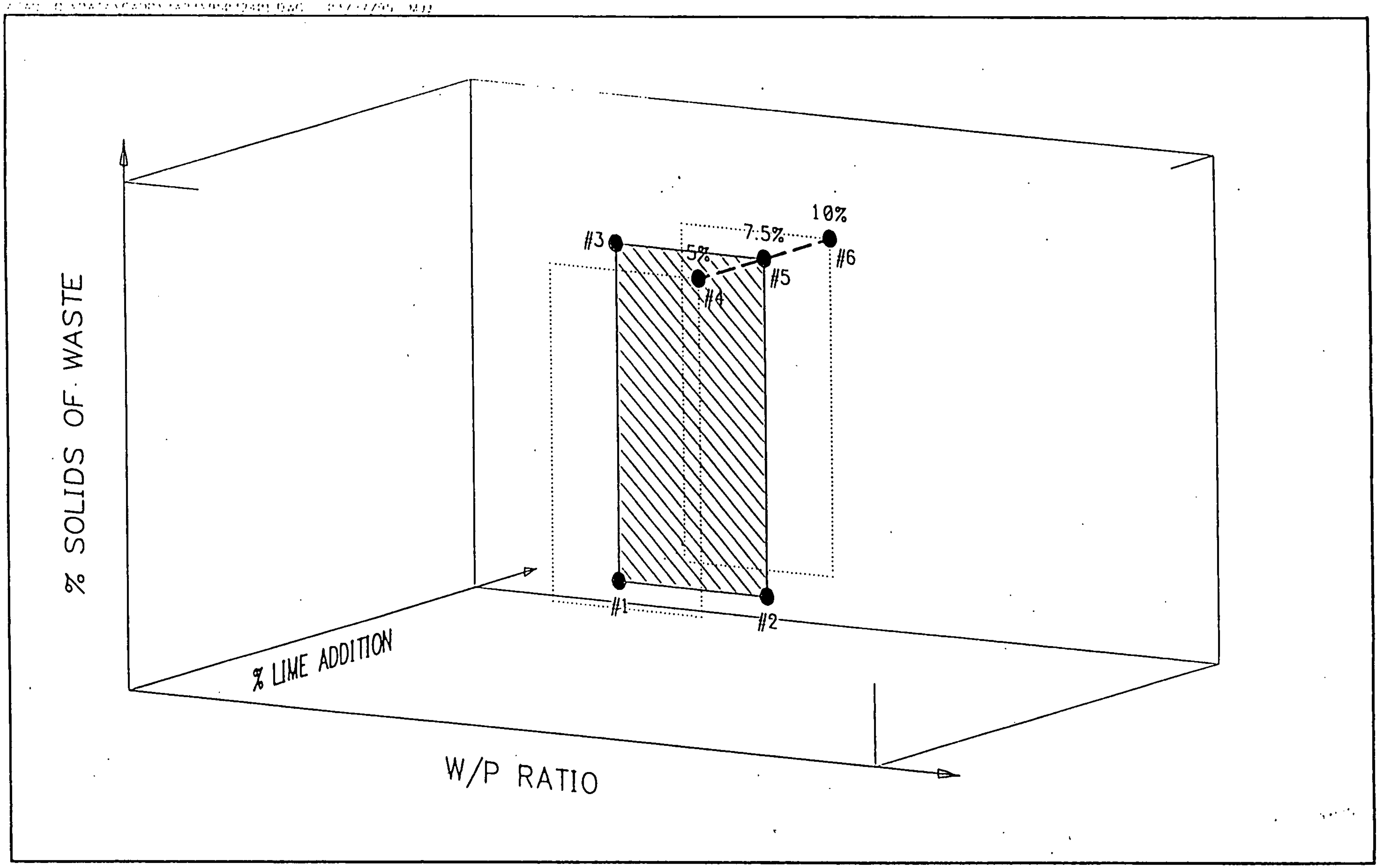

WASTE LOADING AND ADDITION VARIATIONS
FOR WAC PHASE II TESTING
ROCKY FLATS, GOLDEN, COLORADO

FIGURE 2-3

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The analytical program for the WAC Compliance Phase testing is provided in Table 2-2. The rationale for each analysis is provided below.

- Unconfined compressive strength (UCS) provides an estimate of the final product's agglomerated strength and allows comparisons with other formulations.

- The Paint Filter Test is required to verify that there are no free liquids present.

- TCLP analysis is required to ensure that the final waste form meets the WAC requirements for the listed analytes.

- pH of the TCLP leachate has been determined to have a direct correlation with analyte levels.

2.3 EQUIPMENT AND MATERIALS

2.3.1 Mixed-Waste Treatability Study Laboratory

The testing conducted for the CSS treatability study was performed at the Halliburton NUS Laboratory in Pittsburgh, Pennsylvania. The work was performed in a treatability room that was specifically designed to accommodate low-level mixed waste materials. The room has double air locks for entrance and exit along with a negative air ventilation system which exhausts air through HEPA filters. All personnel entering this secured area are required to wear personal protective equipment (Tyvek coverall, booties, and nitrile gloves). Personnel must also wear dosimetry badges and rings. Additionally, all personnel must also submit annual bioassays for radionuclide analysis.

2.3.2 Laboratory Equipment

A list of the major equipment used for the solidification portions of the treatability study is provided in Table 2-3. This table provides the manufacturer, model number and the pertinent equipment specification for the equipment.

TABLE 2-2

SUMMARY OF TESTING PERFORMED ON MIXES
PONDCRETE MATERIAL
ROCKY FLATS, COLORADO

Analysis	Method		Pre-WAC	WAC	
	Sludges and Solids	Liquids and Extracts		Phase I	Phase II
Unconfined Compressive Strength (UCS)	ASTM D4219-83 Liquid NA	NA	No	Yes	No
Paint Filter Liquids Test	SW 9095 Liquid NA	NA	No	Yes	Yes
Physical Observations	NA	NA	Yes	Yes	Yes
pH	SW 9045	EPA 150.1	No	Yes	Yes
Bulk Density	(1)	(1)	No	Yes	No
TCLP Leach	SW 1311	---	No	Yes	Yes
Cadmium	SW 3050/6010	SW 3010/6010	No	Yes	Yes
Beryllium	SW 3050/7091	SW 3020/7091	No	Yes	Yes
Sodium	SW3050/6010	SW3010/6010	No	No	Yes
Arsenic	SW3050/6010	SW3020/7060	No	No	Yes
Chromium	SW3050/6010	SW3010/6010	No	No	Yes
Lead	SW3050/7421	SW3020/7421	No	No	Yes
Nickel	SW3050/6010	SW3010/6010	No	No	Yes
Nitrite/Nitrate	NA	EPA 353.2	No	No	Yes
Americium-241	(2)	(2)	No	Yes	Yes
Plutonium-239/240	(2)	(2)	No	Yes	Yes
Uranium-233/234	(2)	(2)	No	Yes	Yes
Uranium-235	(2)	(2)	No	Yes	Yes
Uranium-238	(2)	(2)	No	Yes	Yes

TABLE 2-2 (Continued)
SUMMARY OF TESTING PERFORMED ON MIXES
PONDCRETE MATERIAL
ROCKY FLATS, COLORADO

Analysis	Methods		Pre-WAC	WAC	
	Sludges and Solids	Liquids and Extracts		Phase I	Phase II
Cesium-134	EPA 901.1	EPA 901.1	No	Yes	Yes
Cesium-137	EPA 901.1	EPA 901.1	No	Yes	Yes
Radium-226	EPA 903.1	EPA 903.1	No	Yes	Yes

(1) Agronomy No. 9 - "Methods of Soil Analysis, Part I," American Society of Agronomy, 1965.

(2) Alpha spectrometry preparation method: "Precipitation of Actinides as Fluorides or Hydroxides for High Resolution Alpha Spectrometry," Claude W. Sill, Nuclear and Chemical Waste Management, Vol. 7, pp. 201-215.
Alpha spectrometry counting reference: Digital Multiplexer Router II and instruction manual, Tennelac/Nucleus, Inc.

ASTM "Annual Book of ASTM Standards," American Society for Testing and Materials.

EPA "Methods for Chemical Analyses of Water and Wastes," Environmental Protection Agency, 1979, Revised March 1983.

SM "Standard Methods for the Examination of Water and Wastewater," American Public Health Association. 17th Edition. EPA's list of approved methods (40 CFR 136) currently references the 17th edition.

SW "Tests Methods for Evaluating Solid Waste-Physical/Chemical Methods," Environmental Protection Agency, SW846, 3rd Edition, Revised July 1992.

TABLE 2-3

EQUIPMENT SUMMARY
ROCKY FLATS, COLORADO

Equipment	Manufacturer	Model No.	Pertinent Specifications
Mixer	Hobart	N-50	Motor Rating: 1/6 HP, 1725 RPM, Single Phase, 115V., 60 Hz, 2.85 Amps
Unconfined Compressive Strength	Geotest Instrument Corporation	S2013	Max. Load Ring = 2000 lb.
Balance	Denver Instrument Company	XD-12K	Range: 0.1 - 5,000.0 grams
Drying Oven	Fisher Scientific Isotemp® Oven	655F	Accuracy ±2°F
Stirrer (T-Line Laboratory Stirrer)	Talboys Engineering Company	134-1	NA
Temperature Gauge	Fisher Scientific Digital Thermometer	NA	-40.0 through 300°F -40.0 through 150.0°C
pH Meter	Fisher Scientific Digital pH Meter	Field Model	± 1 (non-analytical use only)

2.3.3 CSS Material Specifications

The materials used for the CSS formulas include: lime, fly ash, silica flour, and cement. The Material Safety Data Sheets and product information for these additives are provided in Appendix D. In addition, Stergo® was added to the pondcrete mixes to simulate onsite conditions.

The lime used was a high calcium hydrated lime manufactured by Mississippi Lime Company, St. Genevieve, Missouri. The typical specifications for a high-calcium hydrated lime are as follows:

- Specific Gravity: 2.3 to 2.4
- Bulk Density: 25 to 35 lb./cu. ft.
- Specific Heat at 100°F: 0.29 BTU/lb.
- Contains less than 5% magnesium oxide
- Contains less than 1% unhydrated oxides

The cement used for the CSS formula development is classified as Type I/II cement manufactured by Southwestern Portland Cement, Mountain Division, Lyons, Colorado. Type I/II is a general purpose cement with moderate exposure resistance to sulfate attack.

The fly ash that was used for the CSS formulas was Type C, which meets the ASTM C618 specification. Two different sources of Type C fly ash were used, both supplied by the Western Ash Company. One was from the Comanche power plant, and the other was from the Pawnee power plant. The Pawnee fly ash was used for the majority of the testing. The two fly ashes are similar in chemical make-up and physical characteristics.

2.3.4 Solubility Considerations

Waste acceptance criteria (WAC) for various metals and radionuclides at the site are based upon the proposed IM/IRA closure plan which includes a cap with no lateral groundwater controls and an estimated infiltration rate of 0.0068 inches per year. They are applied by evaluating the leachability (as measured by the Toxicity Characteristic Leaching Procedure (TCLP)) of the various chemically stabilized/solidified waste sludges evaluated in this treatability study. No free liquids, leachability, and consistency of the final product (a friable soil-like substance) were the most important criteria in developing successful CSS formulations.

During this study, the preferred CSS formulations generally included additions of lime, fly ash, and cement to the waste. These additives supplied alkalinity in the form of hydroxides and some carbonate to the waste mixtures in such amounts as to raise the pH far enough above 12 that the addition of acid in the TCLP procedure still results in the pH of the waste mixtures being in excess of 11 when the leachability tests are performed. Leachability or contaminant mobility in this high pH matrix is tied to the solubility of various radionuclide and metal hydroxide species. In water chemistry, there typically exists a pH range where the speciation of certain metal hydroxides is such that the greatest portion will form an insoluble precipitate. These optimum pH ranges vary by compound (see Figure 2-4) for many of the radionuclide and metal hydroxides present at OU4. In water, the optimum pH ranges are typically 8 - 12. At lower pH, there is not sufficient hydroxide concentration to create significant amounts of the insoluble compound, while above the high end of the optimum pH range, the formulation of soluble complexes tend to redissolve the insoluble precipitates.

Although a problem in wastewater treatment, exceeding the high end of the optimum pH range is not a concern in the solidification/stabilization process. Because of their large size compared to free metal ions present at lower pH, most soluble complexes which may tend to form are more susceptible to being bound in the matrix of the solidified/stabilized material. The ability to stabilize the waste is the same whether the material is solidified into a monolith or into a friable soil-like material such as in the case at OU4. In addition, the ability of the cement to take up excess moisture in the final product also aids in reducing the mobility of the various radionuclides and heavy metals of concern.

2.4 PONDCRETE TREATABILITY STUDY TESTING

Pondcrete is described or defined by the type of containers in which it is stored. There are two types of pondcrete which were evaluated in this treatability study: pondcrete triwalls (PCTW) and pondcrete metals (PCM).

Testing performed on the pondcrete was different for each material. Pondcrete triwalls testing included a baseline analysis of the "as received" material and TCLP leachate, a lime addition versus pH evaluation which included a bacteriological study, pre-WAC mixes, and WAC Phase I and Phase II mixes. The pondcrete metals testing included a baseline analysis of the "as received" material and TCLP leachate, pre-WAC mixes, and WAC Phase I mixes.

2.4.1 Initial Preparation and Characterization

Both PCTW and PCM material delivered to the NUS Laboratory contained the consistency of a pudding or light brownish mud. The PCM material had hard chunks about 2 to 3 inches in diameter in the bottom of the buckets. The PCTW appeared to contain no chunks.

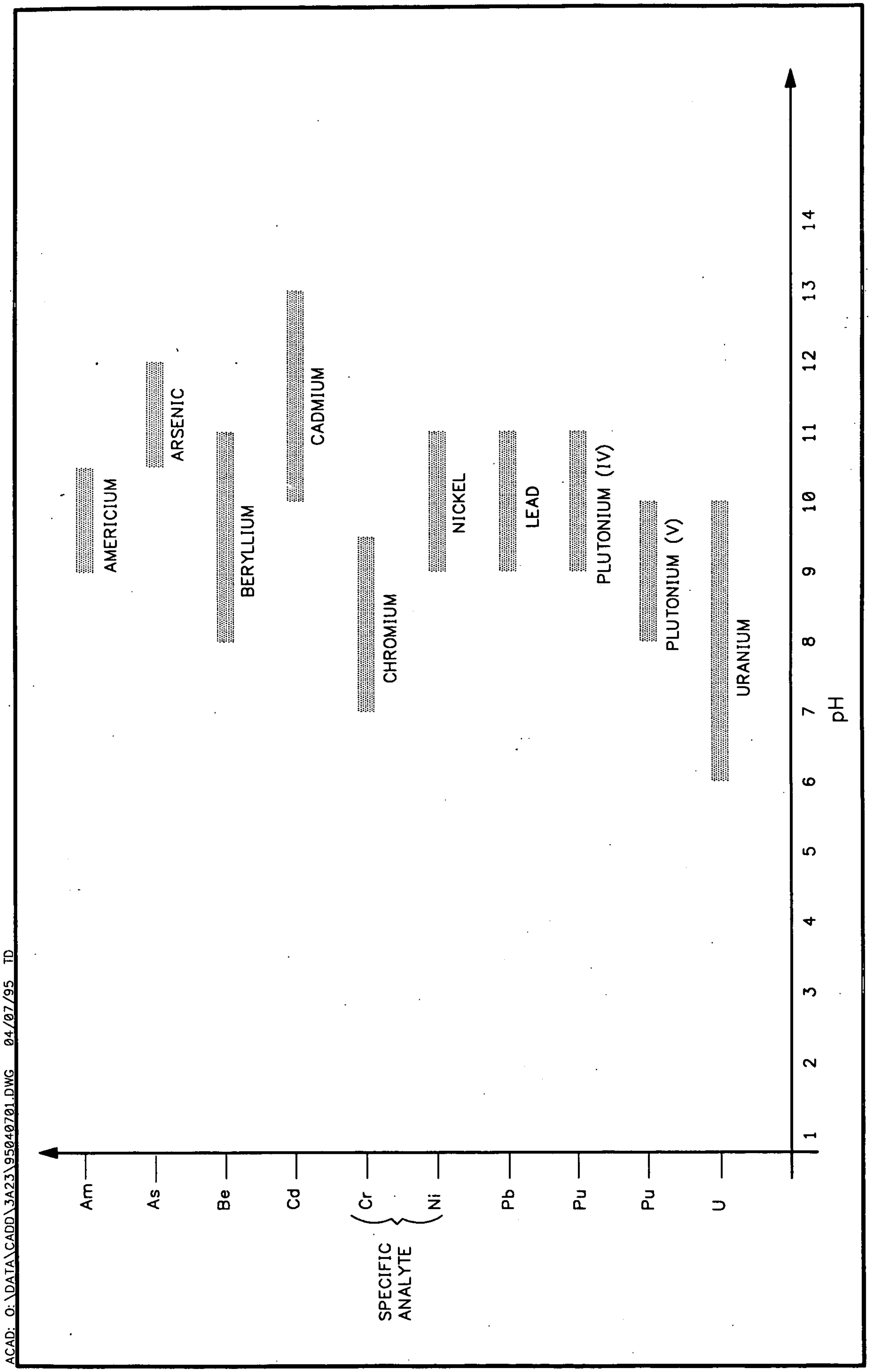


FIGURE 2-4

OPTIMUM pHs FOR PRECIPITATION OF VARIOUS METAL HYDROXIDES ROCKY FLATS, COLORADO

Halliburton NUS CORPORATION

The PCTW and PCM material were submitted for "as received" baseline analysis and TCLP leachate analysis.

2.4.2 Lime Addition Study

A lime additive study was performed only on PCTW due to limited quantity of PCM. Hydrated lime [$Ca(OH)_2$] was added at 1.7%, 17%, and 33% by weight of waste material and quick lime [CaO] was added at 1.7%, 8.3%, and 17% by weight of waste material to determine the effect various dosages of lime had on the pH of the material. These samples were also submitted for bacteriological analysis (plate count).

2.4.3 Process Formulation Development

2.4.3.1 Friable Mix Development

The pre-WAC mixes were used to determine the approximate amount of pozzolans which need to be added to the waste to form a final product with the consistency of a friable soil. The additives selected to be evaluated were confined to those which were found successful in the 207A/B, 207C, and clarifier mixes. Those additive combinations included:

- Lime and Fly Ash. The lime was added at 5% by weight of the pondcrete material for all pre-WAC mixes. The pre-WAC mix using lime and fly ash added the fly ash in increments of 50 grams until a friable soil consistency was achieved.

- Lime, Fly Ash and Silica Flour. The pre-WAC mix which evaluated lime, fly ash, and silica flour added the fly ash and silica flour at a ratio of 85% to 15%, respectively, in increments of 50 grams until a friable soil was achieved.

- Lime, Fly Ash, and Cement. The third and final pre-WAC mix added fly ash and cement at a ratio of 2:1 in increments of 50 grams until the desired consistency was achieved. Physical observations were taken after each addition and recorded in the logbook.

2.4.3.2 WAC Compliance Testing

This information was then used in the WAC Phases I and II to develop a testing range for the WAC mixes.

Phase I. This phase of the treatability study performed mixes to develop a process range for the pondcrete material. The PCTW was evaluated using the three combinations of additives selected based on the previous testing. The additive combinations included:

- Lime and Fly Ash.
- Lime, Fly Ash, and Silica Flour.
- Lime, Fly Ash and Cement.

The amount of lime added was 5% by weight of the PCTW material for all Phase I mixes. The ratio of the pozzolans added was 2:1 (fly ash to cement) and 5.6711 (fly ash to silica flour). To establish a process range, the waste loading was tested at 25% solids, 34.8% solids, and 41.3% solids. This gives a range which is slightly diluted, "as received," and slightly dried. One group of mixes was performed diluting the PCTW to 15% solids, but this was determined to be extreme. Therefore, the samples were not submitted for analysis. The water-to-pozzolan (W/P) ratio was also adjusted to provide a range. The ratios tested were 0.28, 0.34, and 0.40 for the lime, fly ash, cement mixes at the 15%, 25%, and 34.8% solids and 0.20, 0.25, and 0.30 ratios for the 41.3% solids. The lime and fly ash mixes and the lime, fly ash, and silica flour mixes were tested at a W/P ratios of 0.2, 0.25, and 0.30. A summary of the mixes performed for the PCTW are provided in Table 2-4.

The PCM material was tested using the same three additive combinations. The waste loading was only tested "as received" and slightly dried, which corresponds to 38.8% and 48.6% solids, respectively. The mixes performed using lime and fly ash were tested at a W/P range of 0.25, 0.30, and 0.35 for the "as received" material, and 0.25, 0.35, and 1.0 for the dried material. The mixes performed using lime, fly ash, and silica flour, and lime, fly ash, and cement were performed at a W/P range of 0.35, 0.65, and 1.0. Due to damage to the mixer caused by the PCM material, mixes 1C and 6C were not able to be performed. A summary of the mixes performed for the PCM is provided in Table 2-5.

Phase II. This phase of the treatability study was performed to establish the process range of the formula selected. The formula selected is lime, fly ash, and cement. The range tested was 25% and 40% solids, 0.2 and 0.3 W/P ratio and a lime range tested at 5.0%, 7.5%, and 10.0% lime by weight of the PCTW material. Due to insufficient material, PCM was not tested in this phase. A summary of the PCTW mixes is provided in Table 2-6.

TABLE 2-4

ROCKY FLATS TREATABILITY STUDY
SUMMARY OF PONDCRETE TRIWALL PHASE I WAC MIXES
ROCKY FLATS, COLORADO

Batch Number	Date Mixed	Waste % Solids	Water/ Pozzolan Ratio	Lime (% by weight of waste)	Flyash/Cement/ Silica Flour Ratio
1A	02/08/95	15	0.28	5.0	2 / 1 / 0
2A	02/08/95	15	0.34	5.0	2 / 1 / 0
3A	02/08/95	15	0.40	5.0	2 / 1 / 0
4A	02/08/95	25	0.28	5.0	2 / 1 / 0
5A	02/08/95	25	0.34	5.0	2 / 1 / 0
6A	02/08/95	25	0.40	5.0	2 / 1 / 0
7A	02/08/95	34.8	0.28	5.0	2 / 1 / 0
8A	02/08/95	34.8	0.34	5.0	2 / 1 / 0
9A	02/09/95	34.8	0.40	5.0	2 / 1 / 0
10A	02/10/95	41.3	0.20	5.0	2 / 1 / 0
11A	02/10/95	41.3	0.25	5.0	2 / 1 / 0
12A	02/10/95	41.3	0.30	5.0	2 / 1 / 0
13A	02/10/95	34.8	0.20	5.0	2 / 1 / 0
1B	02/09/95	25	0.20	5.0	5.67 / 0 / 1
2B	02/09/95	25	0.25	5.0	5.67 / 0 / 1
3B	02/09/95	25	0.30	5.0	5.67 / 0 / 1
4B	02/09/95	34.8	0.20	5.0	5.67 / 0 / 1
5B	02/09/95	34.8	0.25	5.0	5.67 / 0 / 1
6B	02/09/95	34.8	0.30	5.0	5.67 / 0 / 1
7B	02/10/95	41.3	0.20	5.0	5.67 / 0 / 1
8B	02/10/95	41.3	0.25	5.0	5.67 / 0 / 1
9B	02/10/95	41.3	0.30	5.0	5.67 / 0 / 1
1C	02/09/95	25	0.20	5.0	1 / 0 / 0
2C	02/09/95	25	0.25	5.0	1 / 0 / 0
3C	02/10/95	25	0.30	5.0	1 / 0 / 0
4C	02/10/95	34.8	0.20	5.0	1 / 0 / 0
5C	02/10/95	34.8	0.25	5.0	1 / 0 / 0
6C	02/13/95	34.8	0.30	5.0	1 / 0 / 0
7C	02/13/95	41.3	0.20	5.0	1 / 0 / 0
8C	02/13/95	41.3	0.25	5.0	1 / 0 / 0
9C	02/13/95	41.3	0.30	5.0	1 / 0 / 0

Note: Mixes 7A -- 9C each have 1.14 g of Stergo® additive.

TABLE 2-5

ROCKY FLATS TREATABILITY STUDY
SUMMARY OF PONDCRETE METAL PHASE I WAC MIXES
ROCKY FLATS, COLORADO

Batch Number	Date Mixed	Waste % Solids	Water/ Pozzolan Ratio	Lime (% by weight of waste)	Flyash/Cement/ Silica Flour Ratio
1A	02/20/95	38.8	0.25	5.0	1 / 0 / 0
2A	02/20/95	38.8	0.30	5.0	1 / 0 / 0
3A	02/20/95	38.8	0.35	5.0	1 / 0 / 0
4A	02/20/95	48.6	0.25	5.0	1 / 0 / 0
5A	02/20/95	48.6	1.00	5.0	1 / 0 / 0
6A	02/20/95	48.6	0.35	5.0	1 / 0 / 0
1B	02/20/95	38.8	0.35	5.0	5.67 / 0 / 1
2B	02/20/95	38.8	0.65	5.0	5.67 / 0 / 1
3B	02/20/95	38.8	1.00	5.0	5.67 / 0 / 1
4B	02/20/95	48.6	0.35	5.0	5.67 / 0 / 1
5B	02/20/95	48.6	0.65	5.0	5.67 / 0 / 1
6B	02/20/95	48.6	1.00	5.0	5.67 / 0 / 1
2C	02/21/95	38.8	0.65	5.0	2 / 1 / 0
3C	02/21/95	38.8	1.00	5.0	2 / 1 / 0
4C	02/21/95	48.6	0.35	5.0	2 / 1 / 0
5C	02/21/95	48.6	0.65	5.0	2 / 1 / 0

TABLE 2-6

ROCKY FLATS TREATABILITY STUDY
SUMMARY OF PCTW PHASE II WAC MIXES
ROCKY FLATS, COLORADO

Batch Number	Date Mixed	Waste % Solids	Water/ Pozzolan Ratio	Lime (% by weight of waste)	Flyash/Cement Ratio
1	03/21/95	25	0.20	7.5	2 / 1
2	03/21/95	25	0.30	7.5	2 / 1
3	03/21/95	40	0.20	7.5	2 / 1
4	03/21/95	40	0.30	5.0	2 / 1
5	03/21/95	40	0.30	7.5	2 / 1
6	03/21/95	40	0.30	10.0	2 / 1

3.0 RESULTS AND DISCUSSION

These sections describe the results of the testing performed on pondcrete triwalls and pondcrete metals. Section 3.1 discusses pondcrete triwalls and Section 3.2 discusses pondcrete metals.

3.1 PONDCRETE TRIWALL RESULTS

Testing performed on pondcrete triwalls included initial characterization, a lime addition study, a friable mix development (pre-WAC), and a waste acceptance criteria (WAC) evaluation, Phase I and Phase II.

3.1.1 Initial Characterization Data

The "as received" material was submitted for baseline analysis and TCLP leachate analysis. The results of the TCLP leachate analysis are used for comparison against the TCLP leachate of the CSS mixes to determine the effectiveness of the treatment process. A summary of the results are provided in Table 3-1.

Sample analysis was conducted for selected contaminants determined to be of potential concern when the treated waste is eventually placed in the OU4 closure. The data reveal similar levels of contaminants in comparison to the Pondcrete Metals.

A sample of the Pondcrete Triwalls was tested using TCLP to determine the leachability of the as received material. The results indicate that plutonium 239/240 and cadmium leached at concentrations above the design WAC and the WAC associated with a one inch per year infiltration rate.

3.1.2 Lime Addition Study

The lime addition study for pondcrete triwalls was conducted using as received materials, at approximately 34.8 percent solids. As described in Section 2.6.2, small dosages of both hydrated lime [$Ca(OH)_2$] and quicklime (CaO) were added incrementally to the pondcrete, and samples were collected for measurement of pH and bacterial plate count. As explained in Section 2.6.2, the goal of the study was to determine the dosage required to achieve a pH of 12, which is sufficient to stabilize the sludge from the perspective of reducing the bacterial population present and thus inhibit any future biological degradation of organics in the waste (refer to discussion in Section 2.3.2).

TABLE 3-1

ROCKY FLATS TREATABILITY STUDY
ANALYTICAL RESULTS SUMMARY
PONDCRETE TRIWALL TCLP LEACH
ROCKY FLATS, COLORADO

	Sample ID:	WAC for Scenario 1		Pondcrete Triwall "As Received"	Pondcrete Triwall TCLP
	Sample No.:	0.0068 in/yr Infiltration	1 in/yr Infiltration	P0297078	P0297079
	Date:			12/29/94	12/28/94
	W/P:			NA	NA
	% Solids:			34.8%	NA
Analyte	Units(1)				
Am-241	pCi/L	17,100	74.5	Incomplete	Incomplete
Cs-134	pCi/L	3,510,000	12,800	< 1 pCi/g	< 4
Cs-137	pCi/L	111,000	737	< 2 pCi/g	5.4 ± 1.8
Pu-238	pCi/L	NA	NA	Incomplete	< 62 ± 16
Pu-239/240	pCi/L	1,070	4.43	Incomplete	2,600 ± 300
Ra-226	pCi/L	117,000	415	Incomplete	1.3 ± 0.4
U-233/234	pCi/L	35,200	254	Incomplete	54 ± 6
U-235	pCi/L	1,410	10.2	Incomplete	2.3 ± 1.0
U-238	pCi/L	24,500	177	Incomplete	61 ± 7
Arsenic	ug/L	13,600	142	NA	NA
Beryllium	mg/L	1.43	0.0142	130 mg/kg	0.39
Cadmium	mg/L	5.19	0.0518	926 mg/kg	12
Chromium	ug/L	142,000	881	NA	NA
Nitrate	mg/L	15,900	166	NA	NA
Sodium	mg/L	1,750	14.9	NA	NA
TCLP Extraction Fluid	--	NA	NA	NA	2
pH	Units	NA	NA	13.0	6.4 (Leachate)
Paint Filter Liquids Test	mL	NA	NA	NA	NA
Bulk Density	g/cc	NA	NA	1.45	NA

NA Not available.
(1) Units unless otherwise specified.

[shading] Shading indicates that the concentration in the TCLP extract exceeded the Waste Acceptance Criteria (WAC) for disposal in the OU4 closure, assuming 1 in/yr infiltration through the cap and no groundwater controls (Scenario 1). See Appendix B for details on the development of the WAC.

A summary of the bacterial plate count data is presented in Table 3-2. Plots of lime dosage versus pH are presented in Figure 3-1. The initial pH of the pondcrete was already 12.6, and was most likely the result of previous addition of cement, which is alkaline and will subsequently raise the pH. As can be seen by the data plotted on Figure 3-1, the addition of minimal dosages of both hydrated lime and quicklime resulted in a slight rise of pH from the initial pH of 12.6 to 12.8-13.0. The breakpoints occurred at dosages of less than 2 percent for both limes. It is recommended that the process operate to the right of the breakpoint on the curve so that any variations in the dosage will have minor affects on the pH. The lime dosages that achieve the stated goals are approximately two percent for both hydrated lime and for quicklime.

The plate count data are less useful for evaluating the effectiveness of increased pH in reducing the bacterial count due to the low plate count of aerobic and facultative bacteria observed in the untreated sample.

3.1.3 Process Formulation Development Data

This section describes the results of the friable mix development (pre-WAC) and the waste acceptance criteria testing for WAC Phase I and Phase II.

3.1.3.1 Friable Mix Development Results

Testing was performed using the additives selected from the previous pre-WAC testing performed on 207A/B and 207C contents (HNUS 1995, Pond Sludge Process Formulation and Treatability Study Report). The pondcrete triwall pre-WAC phase was used to determine the approximate quantity of additives required to achieve a friable mix. The results of these mixes are summarized in Table 3-3.

The results indicated that a friable product could be achieved using a variety of additives. However, a relatively low water/pozzolan (W/P) ratio (approximately 0.2) was required. This indicates that extra pozzolan is needed to react with the free water in the short mixing time. The three mixes tested achieved a friable product.

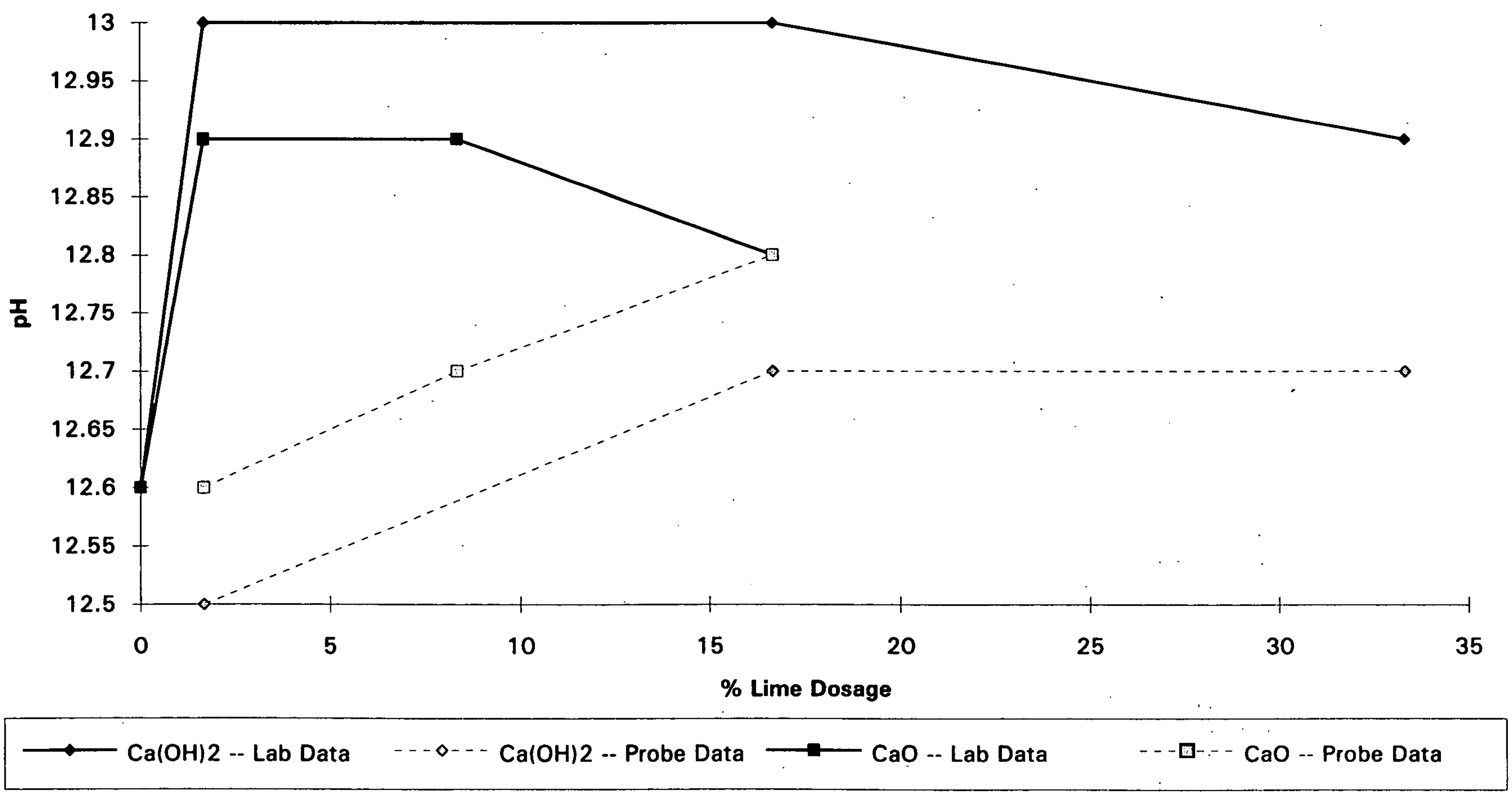
TABLE 3-2

ROCKY FLATS TREATABILITY STUDY
SUMMARY OF BACTERIOLOGY RESULTS FOR THE LIME ADDITION STUDY
PONDCRETE TRIWALLS
ROCKY FLATS, COLORADO

Sample Number	Lime Addition (g)	% Lime Addition by Weight (%)	Type of Lime	Amount of Material (g)	Plate Count
25	0	0	NA	300	<1000
26	5	1.7	$Ca(OH)_2$	300	<1000
27	50	17	$Ca(OH)_2$	300	<1000
28	100	33	$Ca(OH)_2$	300	<1000
29	5	1.7	CaO	300	<1000
30	25	8.3	CaO	300	<1000
31	50	17	CaO	300	<1000

NA Not applicable, no lime added.

Figure 3-1
Rocky Flats Pondcrete Treatability Study
Lime Addition Study for PCTW



- Probe Data -- pH check performed in Treatability Lab using field pH instrument
- Lab Data -- pH value received from Inorganic Lab following full QA/QC procedures

LIMEPCTW.XLC

TABLE 3-3

ROCKY FLATS TREATABILITY STUDY
SUMMARY OF PRE-WAC MIXES
PONDCRETE TRIWALLS
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		Temperature Increase	Observations
					Not Compacted	Compacted		
1	PCTW $Ca(OH)_2$ Fly ash	250 g 12.5 g 800 g	1 0.05 3.2	0.20	4.7 X	N/A	63.7°F → 64.5°F	Pellets, small, round and hard. Able to break with finger pressure.
2	PCTW $Ca(OH)_2$ Fly ash Silica Flour	250 g 12.5 g 681 g 120 g	1 0.05 2.72 0.48	0.20	4.7 X	N/A	62.4°F → 64.0°F	Pellets, round, hard. Poured out of mixing bowl. Able to break pellets with finger pressure.
3	PCTW $Ca(OH)_2$ Fly ash Cement	250 g 12.5 g 480 g 240 g	1 0.05 1.92 0.90	0.22	4.5 X	N/A	62.5°F → 63.8°F	Round hard pellets. Note: chunks or smooth balls formed back at a W/P ratio of 0.29.

All mixes performed in a Hobart mixer.
PCTW "as received" is at 34.8% solids.

* Lime mixed into sludge and allowed to react before the addition of other additive(s).

N/A = Not available. Pellets formed so didn't try vibration compaction (tamping on table top).

3.1.3.2 WAC Compliance Testing Results

Phase I. Based on the results at the pre-WAC, the three formulations were bracketed adjusting the waste loading and W/P. A summary of the mixes performed using lime, fly ash, and cement is provided in Table 3-4. A summary of the mixes performed using lime, fly ash, and silica flour is provided in Table 3-5. A summary of the mixes performed using lime and fly ash is provided in Table 3-6. Several of the mixes included STERGO, an adsorbent material, which is currently being added to the pondcrete as part of the repackaging effort.

The samples were submitted for analysis and the results of the mixes prepared using lime, fly ash, and cement are presented in Table 3-7. The mixes prepared using lime, fly ash, and silica flour are presented in Table 3-8. The mixes prepared using lime and fly ash are presented in Table 3-9. The results of the analyses were plotted against pH and are provided in Appendix G.

The data shown on Tables 3-7 through 3-9 indicate that some of the analytes are leachable under certain conditions. None of the leachate concentrations exceeded the concentrations for the design WAC. However, several of the analyte leachate concentrations exceeded the one inch per year WAC concentrations. In some cases the uranium isotopes, cadmium, and nitrate/nitrite leached at concentrations which exceeded the one inch per year WAC concentrations.

The graphs of pH versus TCLP leachate concentration, in Appendix G, are useful for determining the relationship between pH and leachate concentration. The isotopic uranium data shows that as the pH drops below 7.0, the concentration in the leachate increases. Cadmium concentrations in the leachate increase as the pH of the leachate decreases to below 8.0. Nitrate/nitrite leached at concentrations exceeding the WAC concentration, although this phenomenon is not related to pH.

Phase II. For the Phase II WAC confirmatory tests, the lime, cement, and fly ash additive combination was selected as the preferred formulation. The lime, cement, and fly ash mixture consistently resulted in higher pH compared to the lime and fly ash mixture which is more favorable for reducing leachate concentrations. Based on the Phase I results the silica flour and fly ash formulation offered no advantage compared to the lime, cement, and fly ash formulation. In addition, the lime, cement, and fly ash formulation has been demonstrated to be successful in previous treatability studies with the 207A/B material which has chemical properties similar to pondcrete (Halliburton NUS, Deliverable 235A1 and 236A1, 1992).

TABLE 3-4

ROCKY FLATS TREATABILITY STUDY
SUMMARY OF WAC PHASE I MIXES, PCTW SLUDGE (ADDITIVES: LIME, FLY ASH AND CEMENT)
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		48-Hour Cure Compacted Material UCS	Observations
					Not Compacted	Compacted		
1A	PCTW sludge @ 15% Solids $Ca(OH)_2$ Cement Fly ash	400 g 20 g 405 g 810 g	1 0.05 1.01 2.02	0.28	N/A *	2.6 X	> 637 psi	After 30 seconds of mixing made a clay or moist bread dough consistency which turned into a final product of cake icing. Did not submit for analysis because determined PCTW at 15% solids is out of waste loading range. WET MIX.
2A	PCTW sludge @ 15% Solids $Ca(OH)_2$ Cement Fly ash	400 g 20 g 333 g 667 g	1.0 0.05 0.83 1.67	0.34	N/A *	2.3 X	> 637 psi	Immediately formed a clay ball which turned to cake icing after 30 seconds. Final product a moist cake icing. Did not submit for analysis because determined PCTW at 15% solids is out of processing range. WET MIX.
3A	PCTW sludge @ 15% Solids $Ca(OH)_2$ Cement Fly ash	400 g 20 g 283 g 567 g	1.0 0.05 0.71 1.42	0.40	N/A *	2.1 X	> 637 psi	This produced a very wet clay mix. Did not submit for analysis because determined PCTW at 15% solids is out of processing range. WET MIX.
4A	PCTW sludge @ 25% Solids $Ca(OH)_2$ Cement Fly ash	400 g 20 g 357 g 714 g	1.0 0.05 0.89 1.79	0.28	N/A **	2.6 X	> 637 psi	Produced a final product with the consistency of cake icing. WET MIX.
5A	PCTW sludge @ 25% Solids $Ca(OH)_2$ Cement Fly ash	400 g 20 g 294 g 588 g	1.0 0.05 0.74 1.47	0.34	N/A **	2.1 X	> 637 psi	Produced a final product which was a wet monolithic mix, the consistency of a wet clay. WET MIX.
6A	PCTW sludge @ 25% Solids $Ca(OH)_2$ Cement Fly ash	400 g 20 g 250 g 500 g	1.0 0.05 0.62 1.25	0.40	N/A **	2.0 X	> 637 psi	Produced a final product which was a monolithic clay. WET MIX.

TABLE 3-4 (Continued)
ROCKY FLATS TREATABILITY STUDY
SUMMARY OF WAC PHASE I MIXES, PCTW SLUDGE (ADDITIVES: LIME, FLY ASH AND CEMENT)
ROCKY FLATS, COLORADO

Mix No.	Additives	Additive Weight Ratios	W/P	Bulk Volumetric Increase: Not Compacted	Bulk Volumetric Increase: Compacted	48-Hour Cure Compacted Material UCS	Observations
7A	PCTW sludge @ 34.8% Solids 400 g $Ca(OH)_2$ 20 g Cement 311 g Fly ash 621 g STERGO® 1.14 g	1 0.05 0.78 1.55 0.003	0.28	4.6 X	3.5 X	0 psi	Produced a final product with the consistency of clay, monolithic. WET MIX.
8A	PCTW sludge @ 34.8% Solids -400 g $Ca(OH)_2$ -20 g Cement 256 g Fly ash 512 g STERGO® 1.14 g	1.0 0.05 0.64 1.28 0.003	0.34	4.3 X	3.2 X	395 psi	Produced a final product of a clay. Monolith. WET MIX.
9A	PCTW sludge @ 34.8% Solids 400 g $Ca(OH)_2$ 20 g Cement 218 g Fly ash 435 g STERGO® 1.14 g	1.0 0.05 0.55 1.09 0.003	0.40	N/A *	2.0 X	> 637 psi	After one minute produced large clay clumps with heavy packing on sides of bowl. Final product a stiff clay or bread dough. GOOD MIX, SLIGHTLY WET.
10A	PCTW sludge @ 41.3% Solids 400 g $Ca(OH)_2$ 20 g Cement 391 g Fly ash 782 g STERGO® 1.14 g	1.0 0.05 0.98 1.96 0.003	0.20	7.2 X	5.0 X	89.8 psi	Produced a final product of a moist powder, some packing on sides of bowl. DRY MIX.
11A	PCTW sludge @ 41.3% Solids 400 g $Ca(OH)_2$ 20 g Cement 313 g Fly ash 626 g STERGO® 1.14 g	1.0 0.05 0.78 1.56 0.003	0.25	6.3 X	3.8 X	62.4 psi	Produced a final product of a moist powder, some packing occurred. DRY MIX.

TABLE 3-4 (Continued)
ROCKY FLATS TREATABILITY STUDY
SUMMARY OF WAC PHASE I MIXES, PCTW SLUDGE (ADDITIVES: LIME, FLY ASH AND CEMENT)
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		48-Hour Cure Compacted Material UCS	Observations
					Not Compacted	Compacted		
12A	PCTW sludge @ 41.3% Solids $Ca(OH)_2$ Cement Fly ash STERGO®	400 g 20 g 261 g 522 g 1.14 g	1.0 0.05 0.65 1.30 0.003	0.30	5.3 X	3.2 X	86.3 psi	Final product a moist powder. Mix had some packing of material on side of bowl. DRY MIX.
13A	PCTW sludge @ 41.3% Solids $Ca(OH)_2$ Cement Fly ash STERGO®	400 g 20 g 435 g 870 g 1.14 g	1.0 0.05 1.09 2.18 0.003	0.20	7.4 X	4.9 X	73.6 psi	Final product a moist powder. Some packing on sides of bowl occurred. DRY MIX.

N/A * Too much moisture to allow for uncompacted cake.
N/A ** Clay-like material - could only do packed volume.

TABLE 3-5

ROCKY FLATS TREATABILITY STUDY
SUMMARY OF WAC PHASE I MIXES
PCTW SLUDGE (ADDITIVES: LIME, FLY ASH, AND SILICA FLOUR)
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		48-Hour Cure Compacted Material UCS	Observations
					Not Compacted	Compacted		
1B	PCTW sludge @ 25% Solids $Ca(OH)_2$ Fly ash Silica Flour STERGO®	400 g 20 g 1275 g 225 g 1.14 g	1.0 0.05 3.18 0.56 0.003	0.20	6.2 X	3.8 X	51 psi	This mix produced a moist powder. The product formed a hard pack on the sides of the bowl. Final product a moist powder. DRY MIX.
2B	PCTW sludge @ 25% Solids $Ca(OH)_2$ Fly ash Silica Flour STERGO®	400 g 20 g 1020 g 180 g 1.14 g	1.0 0.05 2.55 0.45 0.003	0.25	5.2 X	2.7 X	201 psi	After 1 minute of mixing the product went from a moist powder to large clay clump. After 2 minutes, went to a medium-curd-size friable soil (worm dirt). Final product a clumpy dry clay mix. GOOD MIX.
3B	PCTW sludge @ 25% Solids $Ca(OH)_2$ Fly ash Silica Flour STERGO®	400 g 20 g 850 g 150 g 1.14 g	1.0 0.05 2.12 0.38 0.003	0.30	N/A	2.3 X	>637 psi	After 30 seconds a heavy pack on sides of bowl with clay clumps in center. After 1 minute mixing formed bread dough. Final product is a stiff clay. GOOD MIX, SLIGHTLY WET.
4B	PCTW sludge @ 34.8% Solids $Ca(OH)_2$ Fly ash Silica Flour STERGO®	400 g 20 g 1109 g 196 g 1.14 g	1.0 0.05 2.77 0.49 0.003	0.20	6.6 X	3.3 X	39 psi	Final product a moist powder. DRY MIX.
5B	PCTW sludge @ 34.8% Solids $Ca(OH)_2$ Fly ash Silica Flour STERGO®	400 g 20 g 887 g 157 g 1.14 g	1.0 0.05 2.22 0.39 0.003	0.25	5.6 X	3.8 X	0 psi	This mix formed a heavy pack of material on sides of bowl. The final product was a moist powder. DRY MIX.

TABLE 3-5 (Continued)
ROCKY FLATS TREATABILITY STUDY
SUMMARY OF WAC PHASE I MIXES
PCTW SLUDGE (ADDITIVES: LIME, FLY ASH, AND SILICA FLOUR)
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		48-Hour Cure Compacted Material UCS	Observations
					Not Compacted	Compacted		
6B	PCTW sludge @ 34.8% Solids $Ca(OH)_2$ Fly ash Silica Flour STERGO®	400 g 20 g 740 g 130 g 1.14 g	1.0 0.05 1.85 0.33 0.003	0.30	4.3 X	3.0 X	90 psi	Final product a moist powder. DRY MIX.
7B	PCTW sludge @ 41.3% Solids $Ca(OH)_2$ Fly ash Silica Flour STERGO®	400 g 20 g 998 g 176 g 1.14 g	1.0 0.05 2.50 0.44 0.003	0.20	7.7 X	4.3 X	0 psi	Final product formed a moist powder. DRY MIX.
8B	PCTW sludge @ 41.3% Solids $Ca(OH)_2$ Fly ash Silica Flour STERGO®	400 g 20 g 798 g 141 g 1.14 g	1.0 0.05 2.00 0.35 0.003	0.25	6.1 X	3.4 X	126 psi	Final product formed a moist powder. DRY MIX.
9B	PCTW sludge @ 41.3% Solids $Ca(OH)_2$ Fly ash Silica Flour STERGO®	400 g 20 g 665 g 117 g 1.14 g	1.0 0.05 1.66 0.29 0.003	0.30	5.3 X	3.5 X	0 psi	Final product formed a moist powder. DRY MIX.

N/A No loose form since additions resulted in a stiff clay.

03-95-19/P

TABLE 3-6

ROCKY FLATS TREATABILITY STUDY
SUMMARY OF WAC PHASE I MIXES
PCTW SLUDGE (ADDITIVES: LIME AND FLY ASH)
ROCKY FLATS, COLORADO

Mix No.	Additives	Additive Weight Ratios	W/P	Bulk Volumetric Increase		48 Hour Cure Compacted Material UCS	Observations
				Not Compacted	Compacted		
1C	PCTW Sludge @ 25% Solids 400 g $Ca(OH)_2$ 20 g Fly ash 1500 g STERGO® 1.14 g	1.0 0.05 3.75 0.003	0.20	5.9 X	4.0 X	69 psi	Final product produced was a moist powder. DRY MIX.
2C	PCTW Sludge @ 25% Solids 400 g $Ca(OH)_2$ 20 g Fly ash 1200 g STERGO® 1.14 g	1.0 0.05 3.00 0.003	0.25	4.7 X	2.3 X	513 psi	After 30 seconds of mixing produced clay clumps and packing on side of bowl. After 1.5 minutes, became a cookie dough. Final product consistency of bread dough, but dry like a friable soil. GOOD MIX.
3C	PCTW Sludge @ 25% Solids 400 g $Ca(OH)_2$ 20 g Fly ash 1000 g STERGO® 1.14 g	1.0 0.05 2.50 0.003	0.30	N/A	2.4 X	>637 psi	After 30 seconds produced a clumps soil or worm dirt approximately 1 inch in diameter. After 1 minute, consistency of bread dough which turned to cookie dough. Final product a stiff pasty clay. After 4-hour cure, became hard. GOOD MIX, SLIGHTLY WET.
4C	PCTW Sludge @ 34.8% Solids 400 g $Ca(OH)_2$ 20 g Fly ash 1305 g STERGO® 1.14 g	1.0 0.05 3.26 0.003	0.20	7.1 X	3.9 X	36.3 psi	Produced a moist powder. DRY MIX.
5C	PCTW Sludge @ 34.8% Solids 400 g $Ca(OH)_2$ 20 g Fly ash 1044 g STERGO® 1.14 g	1.0 0.05 2.61 0.003	0.25	5.3 X	3.2 X	166.2 psi	Produced a moist powder. DRY MIX.
6C	PCTW Sludge @ 34.8% Solids 400 g $Ca(OH)_2$ 20 g Fly ash 870 g STERGO® 1.14 g	1.0 0.05 2.18 0.003	0.30	4.6 X	2.8 X	155 psi	After 1.5 minutes mixing, a hard pack on sides of bowl formed. Moist powder was final product. DRY MIX.

TABLE 3-6 (Continued)
ROCKY FLATS TREATABILITY STUDY
SUMMARY OF WAC PHASE I MIXES
PCTW SLUDGE (ADDITIVES: LIME AND FLY ASH)
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		48-Hour Cure Compacted Material UCS	Observations
					Not Compacted	Compacted		
7C1	PCTW Sludge @ 43.3% Solids $Ca(OH)_2$ Fly ash STERGO®	400 g 20 g 1134 g 1.14 g	1.0 0.05 2.84 0.003	0.20	7.1 X	4.4 X	0 psi	Final product a moist powder. DRY MIX.
7C2	PCTW Sludge @ 43.3% Solids $Ca(OH)_2$ Fly ash STERGO®	300 g 20 g 134 g 1.14 g	1.0 0.07 0.45 0.004	1.12	3.6 X	1.8 X	111 psi	Immediately formed large clay clumps which turned to cake icing, then to a friable soil or worm dirt for a final product. GOOD MIX.
8C	PCTW Sludge @ 43.3% Solids $Ca(OH)_2$ Fly ash STERGO®	400 g 20 g 907 g 1.14 g	1.0 0.05 2.27 0.003	0.25	6.1 X	3.4 X	0 psi	Final product a moist powder. DRY MIX.
9C	PCTW Sludge @ 43.3% Solids $Ca(OH)_2$ Fly ash STERGO®	400 g 20 g 756 g 1.14 g	1.0 0.05 1.89 0.003	0.30	5.2 X	3.2 X	77.4 psi	Final product a moist powder. DRY MIX.

N/A No loose form since additions resulted in a stiff clay.

TABLE 3-7

WAC PHASE I ANALYTICAL RESULTS
PCTW MIXES (ADDITIVES: LIME, FLY ASH, AND CEMENT)
ROCKY FLATS, COLORADO

	Sample ID:	WAC for Scenario 1		4A-PCTW	5A-PCTW	6A-PCTW	7A-PCTW	8A-PCTW	9A-PCTW	10A-PCTW	11A-PCTW	12A-PCTW	13A-PCTW
	Sample No.:	0.068 in/yr Infiltration	1 in/yr Infiltration	P0300818 P0300817	P0300819	P0300821 P0300820	P0300823 P0300822	P0300824	P0301004 P0301003	P0301069 P0301068	P031070	P031072 P031071	P0301074 P0301073
	Date:			02/08/95	02/08/95	02/08/95	02/08/95	02/08/95	02/09/95	02/10/95	02/10/95	02/10/95	02/10/95
	W/P:			0.28	0.34	0.40	0.28	0.34	0.40	0.20	0.25	0.30	0.20
	% Solids:			25%	25%	25%	34.8%	34.8%	34.8%	41.3%	41.3%	41.3%	34.8%
Analyte	Units												
Am-241	pCi/L	17,100	74.5		NS			NS			NS		
Cs-134	pCi/L	3,510,000	12,800	< 6		< 4	< 5		< 4	< 5		< 5	< 5
Cs-137	pCi/L	111,000	737	5.5 ± 2.2	NS	< 5	6.0 ± 2.3	NS	< 5	≤ 5	NS	4.0 ± 1.9	< 6
Pu-239/240	pCi/L	1,070	4.43		NS			NS			NS		
Ra-226	pCi/L	117,000	415		NS			NS			NS		
U-233/234	pCi/L	35,200	254	55 ± 6	NS	65 ± 7	0.68 ± 0.29	NS	0.6 ± 0.3	0.32 ± 0.21	NS	<0.3	
U-235	pCi/L	1,410	10.2	2.2 ± 0.5	NS	3.1 ± 0.6	<0.2	NS	0.12 ± 0.12	<0.1	NS	<0.3	
U-238	pCi/L	24,500	177	60 ± 6	NS	72 ± 8	0.49 ± 0.25	NS	0.54 ± 0.25	0.54 ± 0.24	NS	0.17 ± 0.14	
Arsenic	mg/L	13.6	0.142	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
Beryllium	mg/L	1.43	0.0142	<0.0006	NS	<0.0006	<0.0007	NS	<0.0006	<0.0006	NS	<0.0006	<0.0007
Cadmium	mg/L	5.19	0.0518	0.24	NS	0.21	0.05	NS	<0.005	<0.005	NS	<0.005	0.006
Chromium	mg/L	142	0.881	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
Nitrate/Nitrite	mg/L	15,900	166	76	NS	91	130	NS	140	94	NS	180	75
Sodium	mg/L	1,750	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
TCLP Extraction Fluid	N/A		NA	2	NS	2	2	NS	2	2	NS	2	2
Final Leachate pH	Units		NA	7.2	NS	7.2	8.6	NS	8.2	9.2	NS	9.6	9.5
Paint Filter Liquids Test	mL		NA										
Bulk Density	g/cc		NA										

Note: Mixes 1A-PCTW, 2A-PCTW, and 3A-PCTW not submitted for analysis.

NA Not Applicable
NS Not Submitted
NT Not Tested

TABLE 3-8

WAC PHASE I ANALYTICAL RESULTS
PCTW MIXES (ADDITIVES: LIME, FLY ASH, AND SILICA FLOUR)
ROCKY FLATS, COLORADO

	Sample ID:	WAC for Scenario 1		1B-PCTW	2B-PCTW	3B-PCTW	4B-PCTW	5B-PCTW	6B-PCTW	7B-PCTW	8B-PCTW	9B-PCTW	6Dup.-PCTW(1)
	Sample No.:	0.0068 in/yr Infiltration	1 in/yr Infiltration	P0301006 P0301005	P0301007	P0301009 P0301008	P0301011 P0301010	P0301012	P0301014 P0301013	P0301076 P0301075	P0301077	P0301079 P0301078	P0301418
	Date:			02/09/95	02/09/95	02/09/95	02/09/95	02/09/95	02/09/95	02/10/95	02/10/95	02/10/95	02/17/95
	W/P:			0.20	0.25	0.30	0.20	0.25	0.30	0.20	0.25	0.30	0.20
	% Solids:			25%	25%	25%	34.8%	34.8%	34.8%	41.3%	41.3%	41.3%	34.8%
Analyte	Units												
Am-241	pCi/L	17,100	74.5		NS			NS			NS		
Cs-134	pCi/L	3,510,000	12,800	< 4		< 4	< 4		< 6	< 5		< 7	< 6
Cs-137	pCi/L	111,000	737	< 5	NS	< 5	< 4	NS	5.6 ± 2.1	< 5	NS	< 7	< 7
Pu-239/-240	pCi/L	1,070	4.43		NS			NS			NS		
Ra-226	pCi/L	117,000	415		NS			NS			NS		
U-233/-234	pCi/L	35,200	254	5.3 ± 0.8	NS	5.3 ± 0.8	2.8 ● 0.5	NS	11 ± 2	53 ± 8	NS	190 ± 20	
U-235	pCi/L	1,410	10.2	0.38 ± 0.21	NS	0.4 ± 0.2	<0.3	NS	0.61 ± 0.29	3.5 ± 2.0	NS	7.2 ± 1.1	
U-238	pCi/L	24,500	177	4.2 ± 0.7	NS	4.2 ± 0.7	3.8 ± 0.7	NS	14 ± 2	65 ± 9	NS	210 ± 30	
Arsenic	mg/L	13.6	0.142										
Beryllium	mg/L	1.43	0.0142	<0.0006	NS	<0.0006	<0.0006	NS	<0.0006	<0.002	NS	<0.002	0.013
Cadmium	mg/L	5.19	0.0518	<0.005	NS	0.015	0.046	NS	0.042	2.0	NS	4.2	5.6
Chromium	mg/L	142	0.881										
Nitrate/Nitrite	mg/L	15,900	166	120	NS	91	130	NS	110	120	NS	160	73
Sodium	mg/L	1,750											
TCLP Extraction Fluid	N/A		NA	2	NS	2	2	NS	2	2	NS	2	2
Final Leachate pH	Units		NA	9.4	NS	8.8	7.9	NS	6.8	7.1	NS	6.4	6.4
Paint Filter Liquids Test	mL		NA										
Bulk Density	g/cc		NA										

(1) QA/QC field duplicate mix of 020995-4B-PCTW
NA Not Applicable
NS Not Submitted
NT Not Tested

TABLE 3-9

WAC PHASE I ANALYTICAL RESULTS
PCTW MIXES (ADDITIVES: LIME AND FLY ASH)
ROCKY FLATS, COLORADO

	Sample ID:	WAC for Scenario 1		1C-PCTW	2C-PCTW	3C-PCTW	4C-PCTW	5C-PCTW	6C-PCTW	7C-1-PCTW	7C-2-PCTW	8C-PCTW	9C-PCTW	7Dup-PCTW(1)
	Sample No.:	0.0068 in/yr Infiltration	1 in/yr Infiltration	P0301015 P0301016	P0301017	P0301080 P0301081	P0301082 P0301083	P0301084	P0301147 P0301148	P0301149 P0301150	P0301151 P0301152	P0301153	P0301154 P0301155	P0301419
	Date:			02/09/95	02/09/95	02/10/95	02/10/95	02/10/95	02/13/95	02/13/95	02/13/95	02/13/95	02/13/95	02/17/95
	W/P:			0.20	0.25	0.30	0.20	0.25	0.30	0.20	1.48	0.25	0.30	0.20
	% Solids:			25%	25%	25%	34.8%	34.8%	34.8%	43.3%	43.3%	43.3%	43.3%	34.8%
Analyte	Units													
Am-241	pCi/L	17,100	74.5		NS			NS				NS		
Cs-134	pCi/L	3,510,000												
Cs-137	pCi/L	111,000	737	4.4 ± 2.1	NS	< 4	< 6	NS	< 7	< 7	4.8 ± 2.2	NS	< 7	< 7
Pu-239/-240	pCi/L	1,070	4.43		NS			NS				NS		
Ra-226	pCi/L	117,000	415		NS			NS				NS		
U-233/-234	pCi/L	35,200	254	0.36 ± 0.21	NS	24 ± 3	790 ± 80	NS	98 ± 10	5.5 ± 0.8	2100 ± 220	NS	80 ± 8	44 ± 5
U-235	pCi/L	1,410	10.2	<0.1	NS	1.2 ± 0.4	38 ± 8	NS	4.5 ± 0.7	0.4 ± 0.24	95 ± 14	NS	4.7 ± 0.8	1.2 ± 0.5
U-238	pCi/L	24,500	177	0.25 ± 0.16	NS	29 ± 3	890 ± 80	NS	110 ± 20	5.7 ± 0.9	2500 ± 250	NS	94 ± 10	46 ± 5
Arsenic	mg/L	136												
Beryllium	mg/L	143	0.0142	<0.0005	NS	0.0008	1.1	NS	0.0035	< 0.0007	1.6	NS	0.0021	0.0019
Cadmium	mg/L	519	0.0518	<0.005	NS	1.2	8.0	NS	4.3	0.71	24	NS	3.2	3.1
Chromium	mg/L	142												
Nitrate/Nitrite	mg/L	15,900	166	47	NA	55	83	NS	150	150	370	NS	200	81
Sodium	mg/L	1,750												
TCLP Extraction Fluid	NA		NA	2	NS	2	2	NS	2	2	2	NS	2	2
Final Leachate pH	Units		NA	9.6	NS	7.3	5.3	NS	6.7	7.0	5.6	NS	6.7	6.3
Paint Filter Liquids Test	mL		NA											
Bulk Density	g/cc		NA											

(1) QA/QC field duplicate mix of 021995-4C-PCTW

NA - Not Applicable; NS - Not Submitted; NT - Not Tested

Phase II provided a range of mixes to develop an operating range for the CSS formulation. A summary of the mixes performed is provided in Table 3-10. A summary of the analytical results are provided in Table 3-11. Graphs plotting the analytical results are provided in Appendix G.
The analytical results provided in Table 3-11 for the pondcrete triwalls are compared to the WACs. Two

WACs are shown on Table 3-11, one WAC is associated with the design infiltration rate of 0.0068 inches per year and the other WAC is associated with a one inch per year infiltration rate. The latter WAC represents the leachate concentrations that would have to be achieved if a significant failure of the OU4 closure system occurred, resulting in an increased infiltration rate (see Appendix B).

All analytes leached at concentrations less than the design WAC concentrations. All analytes also leached at concentrations less than the one inch per year WAC concentrations with the exception of sodium. Sodium leached in all of the mixes at concentrations in excess of the WAC and ranged from 280 mg/l to 530 mg/l.

The figures provided in Appendix G indicate that the increase in the lime dosage from 5 percent to 7.5 percent resulted in an increase in the leachate pH. The leachate pH for the Phase II mixes ranged from 10.8 to 11.7 S.U. as shown on Figure G-2A. Minimal relationship between pH and concentrations of chemicals can be distinguished from the figures shown in Appendix G. This observation is because of the high pH ranges which resulted in low leachate concentrations (near detection limits) for the analytes. Sodium leachate concentrations are not dependent on pH.

Phase II provided a range of mixes to develop an operating range for the CSS formulation. A summary of the mixes performed is provided in Table 3-10. A summary of the analytical results are provided in Table 3-11. Graphs plotting the analytical results are provided in Appendix G.

3.2 PONDCRETE METAL RESULTS

Testing performed on pondcrete metals included an initial characterization, a friable mix development (pre-WAC), and a waste criteria acceptance (WAC Phase I).

3.2.1 Initial Characterization Data

The "as received" pondcrete metals were submitted for baseline analysis and leachate (TCLP) analysis. A summary of the results are provided in Table 3-12.

TABLE 3-10

SUMMARY OF WAC PHASE II MIXES
PCTW (ADDITIVES: LIME, FLY ASH, AND CEMENT)
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Observations
1	PCTW Sludge @ 25% Solids	400 g	1.0		N/A
	$Ca(OH)_2$	30 g	0.075		
	Fly ash, Type C	999 g	2.50	0.20	
	Cement, Type I/II	499 g	1.25		
	STERGO®	1.14 g	0.003		
2	PCTW Sludge @ 25% Solids	400 g	1.0		N/A
	$Ca(OH)_2$	30 g	0.075		
	Fly ash, Type C	666 g	1.67	0.30	
	Cement, Type I/II	333 g	0.83		
	STERGO®	1.14 g	0.003		
3	PCTW Sludge @ 40% Solids	300 g	1.0		N/A
	$Ca(OH)_2$	22.5 g	0.075		
	Fly ash, Type C	600 g	2.0	0.20	
	Cement, Type I/II	300 g	1.0		
	STERGO®	0.86 g	0.003		
4	PCTW Sludge @ 40% Solids	300 g	1.0		N/A
	$Ca(OH)_2$	15 g	0.05		
	Fly ash, Type C	400 g	1.33	0.30	
	Cement, Type I/II	200 g	0.67		
	STERGO®	0.86 g	0.003		
5	PCTW Sludge @ 40% Solids	300 g	1.0		N/A
	$Ca(OH)_2$	22.5 g	0.075		
	Fly ash, Type C	400 g	1.33	0.30	
	Cement, Type I/II	200 g	0.67		
	STERGO®	0.86 g	0.003		
6	PCTW Sludge @ 40% Solids	300 g	1.0		N/A
	$Ca(OH)_2$	30 g	0.10		
	Fly ash, Type C	400 g	1.33	0.30	
	Cement, Type I/II	200 g	0.67		
	STERGO®	0.86 g	0.003		

TABLE 3-11

ROCKY FLATS TREATABILITY STUDY
WAC PHASE II ANALYTICAL RESULTS
PCTW (ADDITIVES: LIME, FLY ASH, AND CEMENT)
ROCKY FLATS, COLORADO

Sample ID:		WAC for Scenario 1		#1-PCTW	#2-PCTW	#3-PCTW	#4-PCTW	#5-PCTW	#6-PCTW
Sample No.:		0.0068 in/yr Infiltration	1 in/yr Infiltration	P0304313 P0304314	P0304315 P0304316	P0304317 P0304318	P0304319 P0304320	P0304321 P0304322	P0304323 P0304234
Date:				03/21/95	03/21/95	03/21/95	03/21/95	03/21/95	03/21/95
W/P:				0.20	0.30	0.20	0.30	0.30	0.30
% Solids:				25	25	40	40	40	40
Analyte	Units								
Am-241	pCi/L	17,100	74.5	< 0.57	< 0.26	< 0.25	< 0.28	< 0.11	< 0.31
Cs-134	pCi/L	3,510,000	12,800	< 6	< 5	< 6	< 5	< 4	< 7
Cs-137	pCi/L	111,000	737	< 6	< 6	< 6	< 6	< 4	< 6
Pu-238	pCi/L		NA	< 0.025	< 0.11	< 0.16	< 0.071	< 0.027	<0.095
Pu-239/240	pCi/L	1,070	4.43	< 0.025	< 0.028	< 0.12	0.039 ± 0.38	< 0.072	< 0.028
Ra-226	pCi/L	117,000	415						
U-233/234	pCi/L	35,200	254	< 0.028	< 0.027	0.082 ± 0.057	< 0.028	< 0.071	< 0.026
U-235	pCi/L	1,410	10.2	< 0.028	< 0.027	<0.028	< 0.077	< 0.026	<0.026
U-238	pCi/L	24,500	177	0.042 ± 0.041	< 0.092	< 0.076	0.062 ± 0.05	< 0.071	< 0.026
Arsenic	mg/L	13.6	0.0142	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Beryllium	mg/L	1.43	0.0142						
Cadmium	mg/L	5.19	0.0518	< 0.005	< 0.005	< 0.005	< 0.005	< 0.01	< 0.005
Chromium	mg/L	142.0	0.881	0.12	0.13	0.34	0.36	0.15	0.09
Nitrate/Nitrite	mg/L	15,900	166	45	59	110	150	150	150
Sodium	mg/L	1,750	14.9	280	300	400	500	470	630
Lead	mg/L	NA	NA	< 0.05	< 0.005	< 0.05	< 0.05	< 0.05	< 0.05
Nickel	mg/L	NA	NA	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
TCLP Extraction Fluid	N/A	NA	NA	2	2	2	2	2	2
Final Leachate pH	Units	NA	NA	11.5	10.8	11.6	11.4	11.6	11.7
Paint Filter Liquids Test	mL	0	0	0	0	0	0	0	0
Bulk Density	g/cc	NA	NA						

TABLE 3-12

ROCKY FLATS TREATABILITY STUDY
ANALYTICAL RESULTS SUMMARY
PONDCRETE METALS TCLP LEACH
ROCKY FLATS, COLORADO

	Sample ID:	WAC for Scenario 1		Pondcrete Metals "As Received"	Pondcrete Metals TCLP
	Sample No.:	0.0068 in/yr Infiltration	1 in/yr Infiltration	P0297080	P0297081
	Date:			12/29/94	12/28/94
	W/P:			NA	NA
	% Solids:			38.8%	NA
Analyte	Units[1]				
Am-241	pCi/L	17,100	74.5	Incomplete	Incomplete
Cs-134	pCi/L	3,510,000	12,800	< 1 pCi/g	< 3
Cs-137	pCi/L	111,000	737	< 1 pCi/g	6.2 ± 1.5
Pu-238	pCi/L	NA	NA	Incomplete	41 ± 9
Pu-239/240	pCi/L	1,070	4.43	Incomplete	1,800 ± 200
Ra-226	pCi/L	117,000	415	Incomplete	1.2 ± 0.4
U-233/234	pCi/L	35,200	254	Incomplete	49 ± 6
U-235	pCi/L	1,410	10.2	Incomplete	1.0 ± 0.8
U-238	pCi/L	24,500	177	Incomplete	47 ± 6
Arsenic	mg/L	13.6	142	NA	NA
Beryllium	mg/L	1.43	0.0142	170 mg/kg	0.22
Cadmium	mg/L	5.19	0.0518	1,320 mg/kg	13
Chromium	mg/L	142	881	NA	NA
Nitrate	mg/L	15,900	166	NA	NA
Sodium	mg/L	1,750	14.9	NA	NA
TCLP Extraction Fluid	--	NA	NA	NA	2
pH	Units	NA	NA	13.0	6.4 (Leachate)
Paint Filter Liquids Test	mL	NA	NA	NA	NA
Bulk Density	g/cc	NA	NA	1.47	NA

NA Not available
(1) Units unless otherwise noted.
[shaded] Shading indicates that the concentration in the TCLP extract exceeded the Waste Acceptance Criteria (WAC) for disposal in the OU4 closure, assuming 1 in/yr infiltration through the cap and no groundwater controls (Scenario 1). See Appendix B for details on the development of the WAC.

Sample analysis was conducted for selected contaminants determined to be of potential concern when the treated waste is eventually placed in the OU4 closure. The data reveal similar levels of contaminants in comparison to the pondcrete triwalls.

A sample of the pondcrete metals was tested using TCLP to determine the leachability of the as received material. The results indicate that plutonium 239/240 and cadmium leached at concentrations above the WAC associated with the design infiltration rate and the one inch per year infiltration rate.

3.2.2 Lime Addition Study

A lime addition study was not performed for this material because of limited material availability. It is assumed that the results from the triwall study (Section 3.1.2) will be applicable to the pondcrete metals.

3.2.3 Process Formulation Development Data

This section describes the results of the friable mix development (pre-WAC) and the Phase I waste acceptance criteria testing.

3.2.3.1 Friable Mix Development Results

Testing was performed using the additives selected from the previous pre-WAC testing performed on 207A/B and 207C contents, lime/fly ash, lime/fly ash/cement, and lime/fly ash/silica flour (HNUS, 1995, Pond Sludge Process Formulation and Treatability Study Report). This pre-WAC phase was used to determine the approximate quantity of additives required to achieve a friable mix.

The results of these mixes are summarized in Table 3-13.

The results indicated that a friable product could be achieved using a variety of additives. However, relatively low water/pozzolan (W/P) ratios (approximately 0.24 to 0.30) were required. This indicates that extra pozzolan is needed to react with the free water in the short mixing time. The three mixes tested achieved a friable product.

3.2.3.2 WAC Compliance Testing Results

Phase I. Based on the results of the three pre-WAC mixes, this phase of testing was used to bracket an operating range for the formulations by varying the W/P ratio and waste loadings. A summary of the mixes

TABLE 3-13

ROCKY FLATS TREATABILITY STUDY
SUMMARY OF PRE-WAC MIXES - PONDCRETE METALS
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		Temperature Increase	Observations
					Not Compacted	Compacted		
1	PCM STERGO® $Ca(OH)_2$ Fly ash	400 g 1.14 g 20 g 775 g	1 0.003 0.05 1.94	0.31	3.8 X	NA	NA	Dry, hard pellets.
2	PCM STERGO® $Ca(OH)_2$ Fly ash Cement	400 g 1.14 g 20 g 600 g 300 g	1 0.003 0.05 1.5 0.75	0.26	3.9 X	NA	NA	Dry, hard pellets.
3	PCM STERGO® $Ca(OH)_2$ Fly ash Silica Flour	400 g 1.14 g 20 g 862.6 g 152 g	1 0.003 0.05 2.1 0.38	0.24	4.3 X	NA	NA	Pellets, smooth, round.

All mixes performed in a Hobart mixer.
PCM "as received" at 38.2% solids.

* Lime mixed into sludge and allowed to react before the addition of other additive(s).

performed using lime and fly ash is provided in Table 3-14. A summary of the mixes performed using lime, fly ash, and silica flour is provided in Table 3-15. A summary of the mixes performed using lime, fly ash, and cement is provided in Table 3-16. Graphs plotting the analytical results are provided in Appendix G.

The data shown on Tables 3-17 through 3-19 indicate that some of the analytes are leachable under certain conditions. None of the leachate concentrations from the selected formulation (lime/cement/fly ash) exceeded the concentrations for the design WAC. In some of the lime and fly ash mixes, uranium isotopes, cadmium, and nitrate/nitrite leached at concentrations which exceeded the one inch per year WAC concentrations. For the lime/fly ash formulation, cadmium also exceeded the design infiltration WAC. This was clearly related to the lower TCLP extract pH associated with two of the lime/fly ash mixes.

The graphs of pH versus TCLP leachate concentration, in Appendix G, are useful for determining the relationship between pH and leachate concentration. The isotopic uranium data shows that as the pH drops below 7.0, the concentration in the leachate increases. Cadmium concentrations in the leachate increase as the pH of the leachate decreases to below 9.0. Nitrate/nitrite leached at concentrations exceeding the WAC concentration, although this phenomenon is not related to pH.

No Phase II WAC mixes were conducted for the pondcrete metals. At the time when the Phase I data became available, the decision had been made to select a process formulation based on lime/cement/fly ash for the treatment of all wastes. This decision was based on data available for pond sludges form 207 A/B and 207C. Since the lime/cement/fly ash data for the Phase I testing of pondcrete metals showed consistently high TCLP extract pHs (which in turn controls the leachate concentrations of most metals and radionuclides of concern) it was not considered necessary to repeat the testing in a second phase.

TABLE 3-14

ROCKY FLATS TREATABILITY STUDY
SUMMARY OF WAC PHASE I MIXES
PCM SLUDGE (ADDITIVES: LIME AND FLY ASH)
ROCKY FLATS, COLORADO

Mix No.	Additives	Additive Weight Ratios	W/P	Bulk Volumetric Increase		48-Hour Cure Compacted Material UCS	Observations
				Not Compacted	Compacted		
1A	PCM "As Received" 400 g $Ca(OH)_2$ 20 g Fly ash, Type C 979 g	1 0.05 2.45	0.25	5.9 X	3.7 X	113 psi	After 30 seconds of mixing, produced pea-size chunks which broke down to the consistency of brown sugar. Final product a moist powder. DRY MIX.
2A	PCM "As Received" 400 g $Ca(OH)_2$ 20 g Fly ash, Type C 816 g	1 0.05 2.04	0.30	4.5 X	3.4 X	138 psi	After 30 seconds of mixing, produced small chunks of moist material which broke down to a moist powder. Final product a moist powder. DRY MIX.
3A	PCM "As Received" 400 g $Ca(OH)_2$ 20 g Fly ash, Type C 699 g	1 0.05 1.75	0.35	4.0 X	3.0 X	73 psi	Immediately formed pea-size clumps with heavy packing on sides of bowl. Final product after scraping sides of bowl was a moist powder. DRY MIX.
4A	PCM "As Received" 400 g $Ca(OH)_2$ 20 g Fly ash, Type C 822 g	1 0.05 2.05	0.25	4.8 X	3.3 X	0 psi	This mix produced a moist powder with heavy packing on sides of bow. Final product a moist powder. DRY MIX.
5A	PCM "As Received" 500 g $Ca(OH)_2$ 25 g Fly ash, Type C 257 g	1 0.05 1.94	1.0	N/A	1.7 X	343 psi	Immediately formed large clay clumps approximately 2 inches in diameter which broke down to medium-size friable soil chunks (worm dirt). After 1.5 minutes, turned to a cake icing. Final product was a smooth cake icing consistency. GOOD MIX.
6A	PCM "As Received" 400 g $Ca(OH)_2$ 20 g Fly ash, Type C 587 g	1 0.05 5.00	0.35	2.8 X	2.1 X	0 psi	This mix was a moist powder mix and produced a final product of a moist powder. DRY MIX.

N/A Not available, material too wet, already in compacted state.

TABLE 3-15

ROCKY FLATS TREATABILITY STUDY
SUMMARY OF WAC PHASE I MIXES
PCM SLUDGE (ADDITIVES: LIME, FLY ASH, AND SILICA FLOUR)
ROCKY FLATS, COLORADO

Mix No.	Additives		Additive Weight Ratios	W/P	Bulk Volumetric Increase		48-Hour Cure Compacted Material UCS	Observations
					Not Compacted	Compacted		
1B	PCM "As Received" $Ca(OH)_2$ Fly ash, Type C Silica Flour	400 g 20 g 595 g 105 g	1 0.05 1.49 0.26	0.35	4.3 X	2.7 X	175 psi	This mix produced a final product with the consistency of moist powder. DRY MIX.
2B	PCM "As Received" $Ca(OH)_2$ Fly ash, Type C Silica Flour	400 g 20 g 320 g 56 g	1 0.05 0.80 0.14	0.65	N/A	1.7 X	>637 psi	After 30 seconds of mixing, produced a friable soil (worm dirt) consistency which turned into a bread dough or clay, then to cake icing after 1 minute and 30 seconds. Final product consistency of molding clay. GOOD MIX, slightly wet.
3B	PCM "As Received" $Ca(OH)_2$ Fly ash, Type C Silica Flour	400 g 20 g 208 g 37 g	1 0.05 0.35 0.06	1.0	N/A	1.4 X	328 psi	Immediately turned to consistency of cookie dough then to a dryish icing. Final product consistency of molding clay. WET MIX.
4B	PCM "As Received" $Ca(OH)_2$ Fly ash, Type C Silica Flour	400 g 20 g 500 g 88 g	1 0.05 1.25 0.22	0.35	4.3 X	2.7 X	0 psi	Produced a final product of moist powder. DRY MIX.
5B	PCM "As Received" $Ca(OH)_2$ Fly ash, Type C Silica Flour	500 g 25 g 269 g 47 g	1 0.05 0.67 0.12	0.65	4.1 X	2.6 X	65 psi	Moist powder mix with some sticking to side of bowl. Final product a moist powder. DRY MIX.
6B	PCM "As Received" $Ca(OH)_2$ Fly ash, Type C Silica Flour	400 g 20 g 218 g 39 g	1 0.05 0.44 0.08	1.0	N/A	1.4 X	0 psi	Immediately formed large clay clumps approximately 2 inches in diameter. After 30 seconds, made medium curd worm dirt which turned to cookie dough then to sticky bread dough. Final product is a dry, sticky, molding clay. GOOD MIX.

N/A Not available, material too wet, already in compacted state.

TABLE 3-16

ROCKY FLATS TREATABILITY STUDY
SUMMARY OF WAC PHASE I MIXES
PCM SLUDGE (ADDITIVES: LIME, FLY ASH, AND CEMENT)
ROCKY FLATS, COLORADO

Mix No.	Additives	Additive Weight Ratios	W/P	Bulk Volumetric Increase		48-Hour Cure Compacted Material UCS	Observations
				Not Compacted	Compacted		
1C	Equipment failure. No test.	—	0.35	—	—	—	Large clumps of concrete or rocks in the PCM material caused the Hobart's shear pin to break and lose a large quantity of the material.
2C	PCM "As Received" 400 g $Ca(OH)_2$ 20 g Cement, Type I/II 126 g Fly ash, Type C 251 g	1 0.05 0.31 0.63	0.65	N/A	1.4 X	> 637 psi	After 15 seconds of mixing produced a friable soil (worm dirt) which turned to bread dough, then a cake icing after 1 minute 30 seconds. Final product was the consistency of molding clay. GOOD MIX.
3C	PCM "As Received" 600 g $Ca(OH)_2$ 30 g Cement, Type I/II 122 g Fly ash, Type C 245 g	1 0.05 0.20 0.41	1.0	N/A	1.4 X	> 637 psi	After 15 seconds formed clay chunks 1 to 2 inches in diameter. Turned to cake icing after 30 seconds. Final product a moist stiff molding clay. GOOD MIX, SLIGHTLY WET.
4C	PCM "Dried Out" 400 g $Ca(OH)_2$ 20 g Cement, Type I/II 196 g Fly ash, Type C 392 g	1 0.05 0.49 0.98	0.35	4.3 X	3.2 X	27 psi	After 30 seconds produced soft pellets which became hard. These hard pellets broke down to form a final product of powder. DRY MIX.
5C	PCM "Dried Out" 374 g $Ca(OH)_2$ 19 g Cement, Type I/II 98 g Fly ash, Type C 197 g	1 0.05 0.26 0.53	0.65	3.0 X	1.7 X	357 psi	Immediately formed large chunks which broke down to small pea-size balls, which turned to a friable soil (worm dirt) after 1.5 minutes. Turned to large clumpy soil, then a final product of clumps stiff clay. GOOD MIX.
6C	Equipment failure. No test.	—	1.0	—	—	—	Attempting to mix, broke shear pin on two remaining Hobart mixers.

N/A Not available, material too wet, already in compacted state.

TABLE 3-17

ROCKY FLATS TREATABILITY STUDY
WAC PHASE I ANALYTICAL RESULTS
PCM MIXES (ADDITIVES: LIME AND FLY ASH)
ROCKY FLATS, COLORADO

	Sample ID:	WAC for Scenario 1		1A-PCM	2A-PCM	3A-PCM	4A-PCM	5A-PCM	6A-PCM
	Sample No.:	0.0068 in/yr Infiltration	1 in/yr Infiltration	P0301505 P0301506	P0301507	P0301508 P0301509	P0301510	P0301511 P0301512	P0301513 P0301514
	Date:			02/20/95	02/20/95	02/20/95	02/20/95	02/20/95	02/20/95
	W/P:			0.25	0.30	0.35	0.25	1.0	0.35
	% Solids:			38.8%	38.8%	38.8%	48.6%	48.6%	48.6%
Analyte	Units								
Am-241	pCi/L	17,100	74.5		NS		NS		
Cs-134	pCi/L	3,510,000	12,800						
Cs-137	pCi/L	111,000	737		NS		NS		
Pu-239/240	pCi/L	1,070	4.43		NS		NS		
Ra-226	pCi/L	117,000	415		NS		NS		
U-233/234	pCi/L	35,200	254	280 ± 30	NS		NS		
U-235	pCi/L	1,410	10.2	12 ± 2	NS		NS		
U-238	pCi/L	24,500	177	320 ± 40	NS		NS		
Arsenic	mg/L	13.6	0.142						
Beryllium	mg/L	1.43	0.0142	0.019	NS	0.014	NS	<0.0007	<0.0007
Cadmium	mg/L	5.19	0.0518	6.6	NS	6.8	NS	0.014	<0.005
Chromium	mg/L	142	0.881						
Nitrate/Nitrite	mg/L	15,900	166	100	NS	94	NS	210	130
Sodium	mg/L	1,750	14.9						
TCLP Extraction Fluid	NA	NA	NA	2	NS	2	NS	2	2
Final Leachate pH	Units	NA	NA	6.5	NS	6.5	NS	9.2	9.9
Paint Filter Liquids Test	mL	NA	NA						
Bulk Density	g/cc	NA	NA						

NA Not Applicable
NS Not Submitted

TABLE 3-18

ROCKY FLATS TREATABILITY STUDY
WAC PHASE I ANALYTICAL RESULTS
PCM MIXES (ADDITIVES: LIME, FLY ASH, AND SILICA FLOUR)
ROCKY FLATS, COLORADO

	Sample ID:	WAC for Scenario 1		1B-PCM	2B-PCM	3B-PCM	4B-PCM	5B-PCM	6B-PCM
	Sample No.:	0.0068 in/yr Infiltration	1 in/yr Infiltration	P0301515 P0301516	P0301517	P0301518 P0301519	P0301520 P0301521	P0301522	P0301523 P0302028
	Date:			02/20/95	02/20/95	02/20/95	02/20/95	02/20/95	02/20/95
	W/P:			0.35	0.65	1.0	0.35	0.65	1.0
	% Solids:			38.8%	38.8%	38.8%	48.6%	48.6%	48.6%
Analyte	Units								
Am-241	pCi/L	17,100	74.5		NS			NS	
Cs-134	pCi/L	3,510,000	12,800						
Cs-137	pCi/L	111,000	737		NS			NS	
Pu-239/240	pCi/L	1,070	4.43		NS			NS	
Ra-226	pCi/L	117,000	415		NS			NS	
U-233/234	pCi/L	35,200	254		NS			NS	
U-235	pCi/L	1,410	10.2		NS			NS	
U-238	pCi/L	24,500	177		NS			NS	
Arsenic	mg/L	13.6	0.142						
Beryllium	mg/L	1.43	0.0142	<0.0006	NS			NS	
Cadmium	mg/L	5.19	0.0518	<0.005	NS	<0.005	<0.005	NS	<0.005
Chromium	mg/L	142	0.881						
Nitrate/Nitrite	mg/L	15,900	166	180	NS	190	120	NS	190
Sodium	mg/L	1,750	14.9						
TCLP Extraction Fluid	NA	NA	NA	2	NS	2	2	NS	2
Final Leachate pH	Units	NA	NA	9.6	NS	10.1	9.9	NS	9.9
Paint Filter Liquids Test	mL	NA	NA						
Bulk Density	g/cc	NA	NA						

NA Not Applicable
NS Not Submitted

TABLE 3-19

ROCKY FLATS TREATABILITY STUDY
WAC PHASE I ANALYTICAL RESULTS
PCM MIXES (ADDITIVES: LIME, FLY ASH AND CEMENT)
ROCKY FLATS, COLORADO

Sample ID:		WAC for Scenario 1		1C-PCM	2C-PCM	3C-PCM	4C-PCM	5C-PCM	6C-PCM
Sample No.:		0.0068 in/yr Infiltration	1 in/yr Infiltration	---	P0302030 P0302031	P0302032 P0302033	P0302034 P0302035	P0302036 P0302037	---
Date:				02/21/95	02/21/95	02/21/95	02/21/95	02/21/95	02/21/95
W/P:				0.35	0.65	1.0	0.35	0.65	1.0
% Solids:				38.8%	38.8%	38.8%	48.6%	48.6%	48.6%
Analyte	Units								
Am-241	pCi/L	17,100	74.5	NS	<0.093	<0.17	<0.098	<0.14	NS
Cs-134	pCi/L	3,510,000	12,800						
Cs-137	pCi/L	111,000	737	NS					NS
Pu-238	pCi/L	NA	NA	NS	<.027	<0.013	<0.047	.05 ± .044	
Pu-239/240	pCi/L	1,070	4.43	NS	<0.074	<0.005	<0.055	<0.074	NS
Ra-226	pCi/L	117,000	415	NS	0.4 ± 0.1	0.7 ± 0.1	1.6 ± 0.2	.3 ± 0.1	NS
U-233/234	pCi/L	35,200	254	NS	<0.6		0.22 ± 0.17	<0.3	NS
U-235	pCi/L	1,410	10.2	NS	<0.5		<0.08	<0.07	NS
U-238	pCi/L	24,500	177	NS	<0.7		0.19 ± 0.14	<0.2	NS
Arsenic	mg/L	13.6	0.142						
Beryllium	mg/L	1.43	0.0142	NS	<0.0005		<0.0005	<0.0007	NS
Cadmium	mg/L	5.19	0.0518	NS	<0.005	<0.005	<0.005	<0.005	NS
Chromium	mg/L	142	0.881						
Nitrate/Nitrite	mg/L	15,900	166	NS	100	150	110	140	NS
Sodium	mg/L	1,750	14.9						
TCLP Extraction Fluid	N/A	NA	NA	NS	2	2	2	2	NS
Final Leachate pH	Units	NA	NA	NS	10.9	11.1	11.5	10.9	NS
Paint Filter Liquids Test	mL	NA	NA	NS	0	0	0	0	NS
Bulk Density	g/cc	NA	NA	NS	1.17	1.09	1.07	1.16	NS

NA Not Applicable
NS Not Submitted

4.0 PROCESS FORMULATION/OPERATING ENVELOPE

This section provides a discussion of the treatability study results and the development of an operating envelope for key process parameters. The development of a large operating envelope for key parameters will facilitate the operation of the treatment system under variable waste feed conditions.

The treatability study evaluated various formulations to determine which resulted in a product that produced a friable product that met all Waste Acceptance Criteria. Once it was determined that a specified formulation resulted in an acceptable end product, testing was conducted to develop an operating envelope which could be used during remediation. The operating envelope was developed to be conservative enough to ensure that all samples passed the required criteria.

Based on the treatability testing, several parameters appear to be the most significant regarding process control. These include the pozzolanic mixture composition, the ratio of water to pozzolans in the process stream, and the solids/moisture content of the waste.

4.1 PONDCRETE TRIWALLS

4.1.1 <u>CSS Formulation</u>

A treatment system consisting of the addition of hydrated lime, Type C fly ash, and Type I/II Portland cement is recommended for treating Pondcrete triwalls. The hydrated lime is necessary to raise the pH to greater than 12 to stabilize the sludge and inhibit gas generation via biological decomposition of the organics in the waste, and to reduce the leachability of most metals and radionuclides. The cement and fly ash are required to eliminate the free water in the waste, a WAC requirement for disposal in the OU4 closure, and to aid in the production of a friable product.

4.1.1.1 Fly Ash/Cement Ratio

The selected formulation for lime/fly ash/cement is the same system investigated for pond sludges in 1992 for the production of monoliths for offsite disposal. (Halliburton NUS, 1992). The current treatability study for the production of a friable product, as well as the previous treatability study, both selected ratios of fly ash/cement of 2/1 as the desired operating ratio. The 1992 study looked at a wide range of fly ash/cement ratios (0/1 to 3.34/1) and concluded that the process performance was not sensitive to variations in the fly ash/cement ratio.

Small variations from the target fly ash/cement ratio of 2/1 are likewise not expected to cause any problems in meeting the WAC.

Because the testing in the final phase was centered upon developing a range for the water to pozzolan ratio and the solids loading, it was not considered necessary to develop a range for the cement to fly ash ratio. Therefore, all of the testing done in the final phase of the treatability study was conducted at a fly ash to cement ratio of 2 to 1.

4.1.1.2 Hydrated Lime Addition

A requirement of the treatment process is the addition of lime to inhibit biological activity. Lime is also used in the CSS formula to provide sufficient amounts of alkalinity to lower the solubility of most of the metals of concern. The solubility of many metals will remain low when the pH of the solution is alkaline, which results in successfully passing the WAC for protection of human health and the environment via the groundwater pathway. Although there are some metals which are amphoteric (solubility increases under acidic or alkaline conditions) such as arsenic, cadmium, chromium, and lead, no significant problems have been observed by maintaining sufficient amounts of alkalinity to maintain an alkaline pH in the TCLP extract.

In the final phase of testing lime was added in a fixed percent (7.5 percent) by weight of raw waste. The addition of lime at this percentage resulted in a final leachate extract pH range of 10.8 to 11.5.

Because of the importance of the addition of the lime for adjusting the pH of treated waste, which in turn controls the leachability of metals and radionuclides, a range of lime dosages was investigated. In the Phase II WAC confirmatory testing, the worst-case mix (assumed to be the mix with the highest water content in the raw waste and the highest water/pozzolan ratio) was tested at 5 percent and 10 percent lime dosages in addition to the target dosage of 7.5 percent. The data indicate that this variation of lime dosage around the target concentration of 7.5 percent has no appreciable affect on WAC compliance. Therefore, the treatment system should be able to tolerate this amount of variation from the target lime dosage.

4.1.2 Operating Range of Key Parameters

The waste loading of the raw waste, measured as the solids content of the pondcrete and the water/pozzolan ratio of the treated waste (how much treatment additive added as a percentage of the sludge water content) are the key parameters that control the operation of the treatment system. Figure 4-1 shows graphically the range of key operating parameters tested during the Phase II WAC compliance study.

4.1.2.1 Waste Loading (Percent Solids of Pondcrete)

Phase I WAC testing was conducted at 25 percent, 34.8 (as received) percent, and 43.3 percent solids. The 34.8 percent solids content represents an assumed average solids concentration. The upper range is a worst-case scenario to increase the loading of metals and rationuclides for leachability testing. It must be noted that lower solids content pondcrete could also be treated by adding enough treatment additives to achieve the desired water/pozzolan ratios)see next section).

4.1.3 Water to Pozzolan Ratio

The criteria determined to be the most critical for successful production of a friable product that meets all WAC is the water to pozzolan ratio. Once the percent solids of the pondcrete entering the screw auger shredder is determined, the weight of the water can be calculated. The quantity of pozzolans to be added is determined by dividing the weight of the water by the desired water to pozzolan ratio. For the purpose of testing during the treatability study, pozzolan was defined as cement plus fly ash.

The full-scale treatment system will operate within a water/pozzolan (w/p) ratio range that is capable of achieving a friable product. This range is determined during the pre-WAC testing phase and is estimated to be 0.22 to 0.27. For the purpose of defining a w/p range for WAC compliance, the friable product range was expanded to bracket the probable operating range. The low end of the range (0.20) is probably too dry for full-scale operation, while the high end (0.30) is probably too wet. However, if these extreme conditions meet the WAC, then any operating points in-between will also meet the WAC.

The Phase II WAC compliance testing for pondcrete triwalls showed that the WAC requirements could be met at w/p ratios between 0.20 and 0.30, notably no free liquids and leachate concentrations within an acceptable range. The percent solids tested during Phase II WAC compliance testing were 25 percent and 40 percent.

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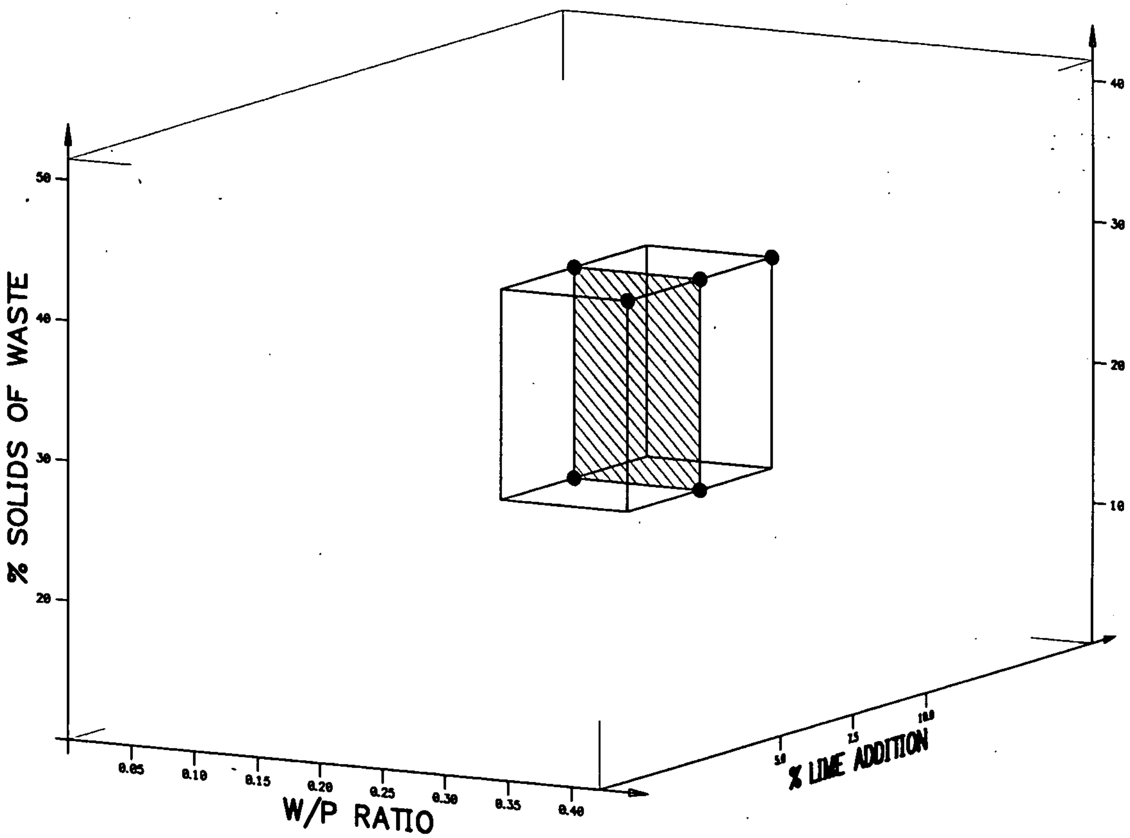

% SOLIDS	W/P	% LIME
25	0.20	7.5
25	0.30	7.5
40	0.20	7.5
40	0.30	5.0
40	0.30	7.5
40	0.30	10.0

PONDCRETE TRIWALLS WASTE LOADING AND ADDITIVES ADDITION VARIATION PROCESS RANGE FOR WAC PHASE II TESTING ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

FIGURE 4–1

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4.2 PONDCRETE METALS

4.2.1 CSS Formulation

A treatment system consisting of the addition of hydrated lime, Type C fly ash, and Type I/II Portland cement is recommended for treating pondcrete metals. The hydrated lime is necessary to raise the pH to greater than 12 to stabilize the sludge and inhibit gas generation via biological decomposition of the organics in the waste, and to reduce the leachability of most metals and radionuclides. The cement and fly ash are required to eliminate the free water in the waste, a WAC requirement for disposal in the OU4 closure, and to aid in the production of a friable product. Only pre-WAC and Phase I WAC phases were required to complete the pondcrete metals testing.

4.2.1.1 Fly Ash/Cement Ratio

The selected formulation for lime/fly/cement ash is the same system investigated for pond sludge in 1992 for the production of monoliths for offsite disposal. (Halliburton NUS, 1992). The current treatability study for the production of a friable product, as well as the previous treatability study, both selected ratios of fly ash/cement of 2/1 as the desired operating ratio. The 1992 study looked at a wide range of fly ash/cement ratios (0/1 to 3.34/1) and concluded that the process performance was not sensitive to variations in the fly ash/cement ratio.

Small variations from the target fly ash/cement ratio of 2/1 are likewise not expected to cause any problems in meeting the WAC.

Because the testing in the final phase was centered upon developing a range for the water to pozzolan ratio and the solids loading, it was not considered necessary to develop a range for the cement to fly ash ratio. Therefore, all of the testing done in the final phase of the treatability study was conducted at a flyash to cement ratio of 2 to 1.

4.2.1.2 Hydrated Lime Addition

A requirement of the treatment process is the addition of lime to inhibit biological activity. Lime is also used in the CSS formula to provide sufficient amounts of alkalinity to lower the solubility of most of the metals of concern. The solubility of many metals will remain low when the pH of the solution is alkaline, which results in successfully passing the WAC for protection of human health and the environment via the groundwater pathway. Although there are some metals which are amphoteric (solubility increases under acidic or alkaline conditions) such as arsenic, cadmium, chromium, and lead, no significant problems have been observed by maintaining sufficient amounts of alkalinity to maintain an alkaline pH in the TCLP extract.

In the phase I WAC testing, lime was added in a fixed percent (5.0 percent) by weight of raw waste. The addition of lime at this percentage resulted in a pH range of 10.7 to 11.5 in the TCLP leachate.

Because the data from the pondcrete triwalls is considered applicable, no additional testing was conducted with lime for the pondcrete metals. The pondcrete triwalls data indicate that slight variations of the lime dosage around the target concentration had no appreciable affect on WAC compliance. A lime dosage of 7.5 percent is recommended for the metals based on testing on the triwalls.

4.2.2 Operating Range of Key Parameters

The waste loading of the raw waste, measured as the solids content of the sludge, and the water/pozzolan ratio of the treated waste (how much treatment additive added as a percentage of the sludge water content) are the key parameters that control the operation of the treatment system. Figure 4-2 shows graphically the range of key operating parameters tested during the Phase I WAC compliance study.

4.2.2.1 Waste Loading (Percent Solids of Sludge)

Phase I WAC testing was conducted at 38.8 and 48.6 percent solids. The 38.8 percent solids content represents an assumed average solids concentration. The upper range is a worst-case scenario to increase the loading of metals and radionuclides for leachability testing. It must be noted that lower solids content sludges could also be treated by adding enough treatment additives to achieve the desired water/pozzolan ratios (see next section).

4.2.3 Water to Pozzolan Ratio

The criteria determined to be the most critical for successful production of a friable product that meets all WAC is the water to pozzolan ratio. Once the percent solids of the pondcrete metals entering the screw auger shredder is determined, the weight of the water can be calculated. The quantity of pozzolans to be added is determined by dividing the weight of the water by the desired water to pozzolan ratio. For the purpose of testing during the treatability study, pozzolan was defined as cement plus fly ash.

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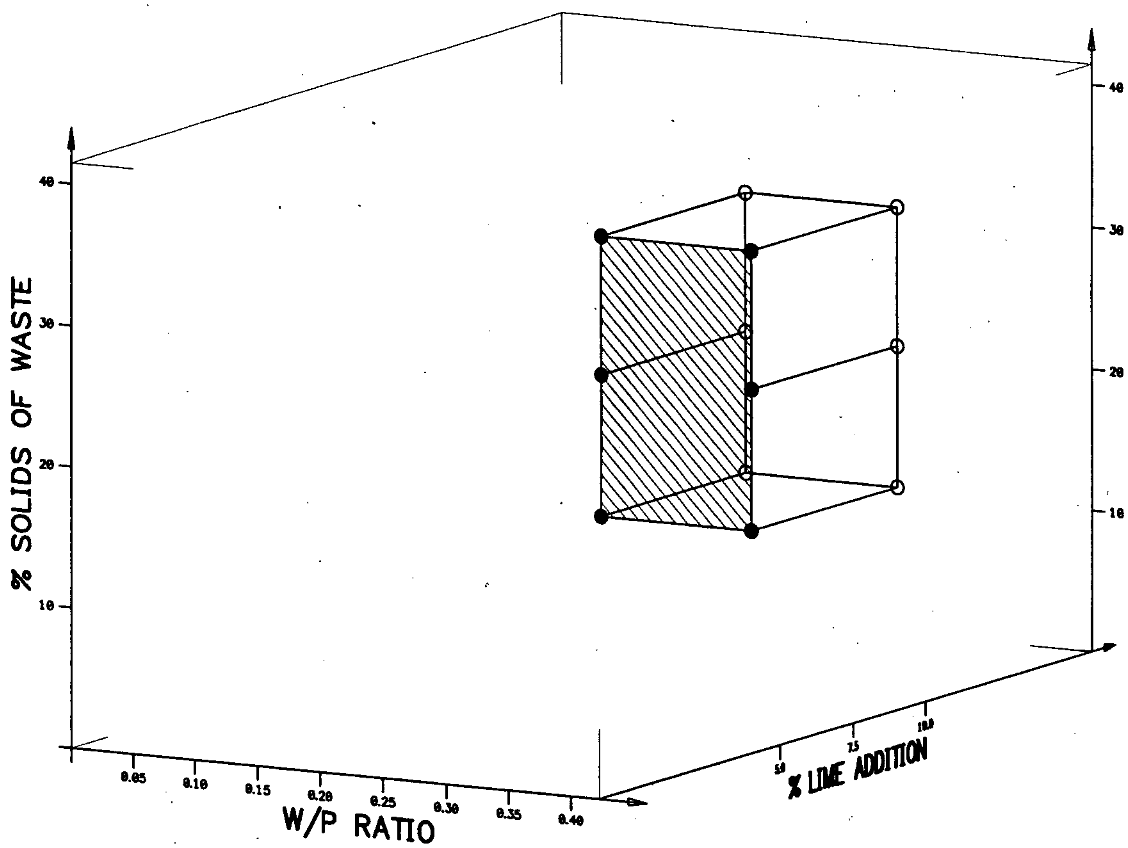

% SOLIDS	W/P	% LIME
15	0.28	5.0
15	0.40	5.0
25	0.28	5.0
25	0.40	5.0
34.8	0.28	5.0
34.8	0.40	5.0

PONDCRETE METALS WASTE LOADING AND ADDITIVES ADDITION VARIATION PROCESS RANGE FOR WAC PHASE I TESTING ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

FIGURE 4-2

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The full-scale treatment system will operate within a water/pozzolan (w/p) ratio range that is capable of achieving a friable product. This range is determined during the pre-WAC testing phase and is estimated to be 0.45 to 0.55. For the purpose of defining a w/p range for WAC compliance, the friable product range was expanded to bracket the probable operating range. The low end of the range, (0.35) is probably too dry for full-scale operation, while the high end (1.0) is probably too wet. However, if these extreme conditions meet the WAC, then any operating points in-between will also meet the WAC.

The Phase I WAC compliance testing showed that the WAC requirements could be met at w/p ratios between 0.35 and 1.0, notably no free liquids and leachate concentrations within an acceptable range. The percent solids tested during Phase I WAC compliance testing were 38.8 percent and 48.6 percent.

5.0 CONCLUSIONS

The objective of the treatability study was to develop a treatment system for the inventory pondcrete such that the treated wastes meet the waste acceptance criteria for disposal in the OU4 closure. The following sections summarize the conclusions of the treatability study for each of the waste materials investigated.

5.1 PONDCRETE TRIWALLS

Following are the conclusions of the treatability study conducted on the pondcrete in triwalls.

5.1.1 Formulation

The CSS formulation selected for the pondcrete triwalls includes hydrated lime, Type C flyash, and Type I/II Portland cement. The lime is added at 7.5% by weight of the untreated waste. The flyash and cement are combined in a 2:1 flyash-to-cement ratio, and are added at a rate determined by the desired water-to-pozzolan ratio.

5.1.2 Water/Pozzolan Ratio

Compliance with waste acceptance criteria was achieved at water/pozzolan ratios from 0.2 to 0.3. The optimum range for achieving a friable product is a subset of this range, at water/pozzolan ratios from 0.22 to 0.27.

5.1.3 Waste Loading

The treatability study testing was conducted on waste with total solids concentrations that ranged from 25% to 40%. The treatability study results indicate that the proposed stabilization formula will produce a final product that meets the waste acceptance criteria if the waste loading is within the above range. It should be noted that waste with lower solids concentrations can be effectively treated by adding additional pozzolans.

5.1.4 Waste Acceptance Criteria Compliance

Based on the results of the treatability study, it is concluded that the treatment process will meet all applicable waste acceptance criteria (with the exception of the total volume of treated waste) if the system is operated within the stated formulation, water/pozzolan ratio and waste loading ranges. Specific WAC requirements met include the following:

- The treatment is the minimum needed to meet all WAC.

- The treated waste will not contain free liquids as measured by the Paint Filter Liquids Test (SW 9095).

- The treated waste will be in particulate form, not a monolith. The particle size will be less than 3 inches and will not tend to agglomerate when the system is operated on the drier end of the water/pozzolan range.

- The treated waste will not agglomerate into particles greater than 3 inches when mixed with site soils.

- The treated waste will be resistant to dispersion by wind. The conceptual design of the treatment system uses a screen to capture any fine particles and recycle them back into the treatment process, which will allow the system to operate at the dry end of the water/pozzolan range.

- The treated waste will have a pH of 12 or greater, which is sufficient to inhibit the biological degradation of any organics. The lack of biological activity will reduce the potential for gas generation.

- The volume of the treated waste, when added to the volumes of the other treated wastes, will slightly exceed 20,000 cy.

- The leachate will not contain any of the constituents of concern at concentrations that are not protective of human health and the environment. This is based on comparison of TCLP leach data with values predicted by a contaminant transport model using the design infiltration rate for the OU4 closure.

5.2 PONDCRETE METALS

Following are the conclusions of the treatability study conducted on the pondcrete triwalls in metal containers.

5.2.1 Formulation

The CSS formulation selected for the pondcrete triwalls includes hydrated lime, Type C flyash, and Type I/II Portland cement. The lime is added at 7.5% by weight of the untreated waste. The flyash and cement are combined in a 2:1 flyash-to-cement ratio, and are added at a rate determined by the desired water-to-pozzolan ratio.

5.2.2 Water/Pozzolan Ratio

Compliance with waste acceptance criteria was achieved at water/pozzolan ratios from 0.35 to 1.0. The optimum range for achieving a friable product is a subset of this range, at water/pozzolan ratios from 0.45 to 0.55.

5.2.3 Waste Loading

The treatability study testing was conducted on waste with total solids concentrations that ranged from 38.8% (as received) to 48.6%. The treatability study results indicate that the proposed stabilization formula will produce a final product that meets the waste acceptance criteria if the waste loading is within the above range. It should be noted that waste with lower solids concentrations can be effectively treated by adding additional pozzolans.

5.2.4 Waste Acceptance Criteria Compliance

Based on the results of the treatability study, it is concluded that the treatment process will meet all applicable waste acceptance criteria (with the exception of the total volume of treated waste) if the system is operated within the stated formulation, water/pozzolan ratio and waste loading ranges. Specific WAC requirements met include the following:

- The treatment is the minimum needed to meet all WAC.

- The treated waste will not contain free liquids as measured by the Paint Filter Liquids Test (SW 9095).

- The treated waste will be in particulate form, not a monolith. The particle size will be less than 3 inches and will not tend to agglomerate when the system is operated on the drier end of the water/pozzolan range.

- The treated waste will not agglomerate into particles greater than 3 inches when mixed with site soils.

- The treated waste will be resistant to dispersion by wind. The conceptual design of the treatment system uses a screen to capture any fine particles and recycle them back into the treatment process, which will allow the system to operate at the dry end of the water/pozzolan range.

- The treated waste will have a pH of 12 or greater, which is sufficient to inhibit the biological degradation of any organics. The lack of biological activity will reduce the potential for gas generation.

- The volume of the treated waste, when added to the volumes of the other treated wastes, will slightly exceed 20,000 cy.

- The leachate will not contain any of the constituents of concern at concentrations that are not protective of human health and the environment. This is based on comparison of TCLP leach data with values predicted by a contaminant transport model using the design infiltration rate for the OU4 closure.

5.3 SUMMARY

The CSS formulation developed for pondcrete meets all of the goals of the treatability study. Following is a summary of the major conclusions of this treatability study:

- The treatment system is able to meet all waste acceptance criteria for the wastes studied.

- The formulation developed for pondcrete relies on the addition of a blend of flyash and cement to eliminate the free water. Lime is also added to stabilize the treated waste to reduce the potential for biological decomposition of any organics. By slightly adjusting the lime dosage, the formulation is also able to achieve maximum reduction of leachability of most metals and radionuclides of concern.

- The treatment system produces a friable product, which is a more desirable final product than a monolith. The friable product can be transported directly to the OU4 closure area for disposal, while a monolith would require additional processing before disposal.

- The rapid curing of the treated waste, and thus the rapid compliance with the WAC, minimizes the staging area requirements for the treatment system.

- A single formulation was developed for both types of pondcrete (also the same formulation for treatment of pond sludge). This enhances the operability of the system.

APPENDIX A

EQUIPMENT RECOMMENDATIONS REPORT

PONDCRETE EQUIPMENT RECOMMENDATION REPORT

Throughout the coarse of the treatability study physical and chemical properties of the pondcrete and of the final, friable soil type, product have been measured and observations noted. These data, combined with the applicable data/results from past treatability and characterization studies, were used to evaluate the compatibility of the recommended equipment, pondcrete waste, and additives. Also, physical properties of the friable product were evaluated during the selection of the materials handling equipment. All equipment selected for the process train is capable of handling a wide range of physical properties. Upon review of the equipment selected and the properties of the wastes and products, no vendor-specific equipment will be required. All equipment is of the "off-the-shelf" type. However, the CDR will provide a vendor specific listing of equipment in order to finalize the design and equipment lay down arrangement drawings. Following is a brief description of the major unit operations and equipment.

Transfer of the Pondcrete From the Interim Storage to Size Reduction and Treatment

The transfer of the Pondcrete from the interim storage to the processing train will be accomplished using standard fork-lift trucks. The fork-lift trucks will deposit the metal containers or triwalls onto a lifting mechanism located at the foot of the primary size reduction unit. This equipment is standard off-the-shelf items. However, the equipment must meet the design specifications as described in the Pondcrete white paper and CDR.

Storage and Feeding of Treatment Additives

The treatment additives storage and feed unit process operation consists of bulk storage silos, rotary valve feeders, weigh-belt conveyors, and screw conveyors. This equipment is routinely used to store and feed dry bulk reagents, such as pozzolans and lime. These common additives (cement, fly ash, and lime) have no characteristics that preclude the use of commonly available, "off-the-shelf" type of equipment for this unit operation.

Pondcrete Size Reduction and Mixing/Blending Treatment With Additives

The pondcrete size reduction unit process operation will be completed using primary, secondary, and tertiary equipment to achieve 6", 1", and 0.5" size reductions, respectively. The primary size reduction equipment consist of a screw-auger type shredder. The secondary and tertiary units are both of the ring-and-pick shredder type. The physical and chemical properties of the pondcrete and the packing material do not exclude the usage of "off-the-shelf" type of equipment for any of the size reducing steps. However, specific design criteria are specified within the pondcrete white paper and forthcoming CDR.

Treated Waste Storage and Testing

The equipment specified within the treated waste storage and testing unit process operation are roll-off type containers with removable covers. These containers are commonly used to transport soil like materials. The potential for dusting will be controlled with the use of covers. The final product, being a friable soil-like material, will have minimal dusting properties as specified in the WAC. These containers will also be used for the treated waste transfer to OU4 closure area. Upon consideration of the physical and chemical properties of the final product, no specialized containers will be needed.

APPENDIX B

PRELIMINARY SUMMARY

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE
OPERABLE UNIT 4 SOLAR PONDS DISPOSAL FACILITY
PRELIMINARY WASTE ACCEPTANCE CRITERIA DEVELOPMENT

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PRELIMINARY SUMMARY

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE
OPERABLE UNIT 4 SOLAR PONDS DISPOSAL FACILITY
PRELIMINARY WASTE ACCEPTANCE CRITERIA DEVELOPMENT

The liquid-phase Waste Acceptance Criteria (WAC) is the chemical-specific leachate concentration generated from the waste material in an engineered disposal facility which will ensure an acceptable groundwater concentration at the point of compliance (POC) within a required protective time frame. The waste material to be placed in the disposal facility is from the Solar Evaporation Ponds (SEP)s at the Rocky Flats Environmental Technology Site (RFETS). The leachate concentrations of treated or untreated waste materials which are proposed to be placed in the disposal facility will be determined using the Toxicity Characteristic Leaching Procedure (TCLP). The material-specific TCLP results will then be compared to the WAC value to determine if the material is acceptable to be placed in the disposal facility.

B.1.0 INTRODUCTION AND OBJECTIVES

This report presents preliminary WACs and a brief description of their development. The objective of the preliminary WAC development is to support the treatability study by providing a measure which can either be used to determine the acceptability of the untreated or treated waste material for placement in the disposal facility. For waste material which is unacceptable to be placed in the disposal facility untreated, the WACs will be used to determine the acceptability of the proposed mix designs to stabilize and treat the waste material. The WACs were developed for the same Constituents of Concern (COCs) that are to be tested for in the treatability study of Operable Unit 4 (OU4) waste materials (i.e., soil, sludge, debris, and pondcrete). The COCs are listed in Table B-1 along with the acceptable water concentrations at the POC. At the present time only the WACs for the inorganic and radionuclide COCs have been completed and are included in this report. The WACs for the organic COCs will be included in the final report.

The computer model of contaminant fate and transport from the SEPs was developed and calibrated using available site-specific data. Once the model had been calibrated, it was used to determine WACs for various disposal facility designs and for a range of infiltration rates through the engineered infiltration barrier (cap). The range of infiltration rates will allow for design changes and /or changes in the assumptions of the long-term performance of the cap without the need for redeveloping the WACs.

B.2.0 CONCEPTUAL MODEL

The conceptual model of the contaminant fate and transport represents a simplified but conservative interpretation of the complex natural aquifer system and the movement of contaminants within it. The following paragraphs describe the groundwater flow beneath the SEPs and the simplified representation of it used in the preliminary WAC development.

The SEPs currently consist of five ponds (207-A, 207-B [North, Central, and South], and 207-C). In the vicinity of pond 207-C three ponds once existed but have since been removed and replaced by pond 207-C. The SEPs received process wastes (liquid and sludge) and sanitary effluents which then evaporated from the ponds. The first ponds in this area were built in the mid-1950s. The ponds leaked and were repaired several times over their service life. It has been shown that the leakage from the ponds has adversely impacted groundwater migrating beneath the SEPs (DOE 1993a). The groundwater in the vicinity of the RFETS has been grouped into a upper and lower hydrostratigraphic units (UHSU and LHSU respectively). The UHSU or "upper" aquifer is unconfined and consists of surficial material (alluvium), weathered bedrock, and sandstone in hydraulic connection with the surficial deposits. The LHSU is a confined aquifer, however, the present understanding of the hydrogeologic relationships indicate that there are no known bedrock pathways through which groundwater contamination can directly leave the RFETS and migrate into a confined aquifer system off site (EG&G 1994). The water table of the UHSU in the vicinity of the ponds is very close to the bottom elevation of SEPs. The material under the ponds consist of a relatively thin layer of alluvium on top of weathered bedrock which in turn is on top of unweathered bedrock. Groundwater flow through the alluvium and the weathered bedrock under the ponds is generally to the north and east toward North Walnut Creek.

Conceptually the liquids in the ponds leaked out of breaks in the pond liners into the unsaturated zone beneath the ponds. Some of the contaminants were adsorbed to the unsaturated soils as the contaminated liquids percolated to the saturated zone. When the leaks in the ponds were patched the vertical flow of liquid through the contaminated soil was cut off so the contaminants had a tendency to remain in the unsaturated soil. In the saturated zone some of the contaminant adsorbed to the soils and some traveled with the groundwater.

The historical loading of contaminants to the groundwater from the SEPs is very complex. The various construction techniques and timing of the construction of the SEPs, the varying contents and usage of the ponds, the location and duration of leaks from the various ponds all contribute to a very heterogeneous contaminant loading pattern from the SEPs. This contaminant loading pattern has resulted contaminant plumes under and around the SEPs which show a high degree of variability.

Comparison of the contaminant concentrations in the saturated zone over time with water level measurements over time indicate that contaminant concentrations increase following rises in the water table elevation beneath the SEPs. Figures B-1, B-2, and B-3 show plots of tritium, nitrate, and uranium-238 concentrations, respectively, in well 2886 with time. These figures also present the water level in these wells over the same time period that the concentration measurements were made. As can be seen from the plots, following the period of high water around June 1987 the concentration for each of these constituents increased. The same effect is shown to a lesser degree following a period of high water in April 1992 for nitrate and tritium. This may have been caused by water entering soils which are generally unsaturated and washing previously adsorbed contaminants out of this zone. The smaller fluctuations in the groundwater table do not show the corresponding fluctuation in the concentrations because the portion of soil which is becoming saturated is regularly saturated so the release of the constituents from these soils is more constant.

B.3.0 MODELING TOOLS

The WACs were determined using a computer groundwater flow and contaminant transport model. This model is implemented on the spreadsheet software Excel 4.0 and Crystal Ball 3.0 and is called ECTran (which stands for Excel-Crystal Ball Transport [Chiou 1993, DOE 1993b]). Based on a conceptual understanding of the site, the ECTran model of the SEPs was first calibrated to simulate the existing contaminant plumes which enabled the estimation and further refinement of flow and chemical mobility parameters.

The following paragraph discusses how the conceptual groundwater flow and contaminant fate and transport at the SEPs discussed above was modeled with ECTran. The conceptual model of the groundwater flow under the SEPs includes two layers, an unsaturated zone and a saturated zone. Based on the average high water table elevation, a typical, conservative (thin) thickness of the unsaturated zone was estimated to be 3 feet and the saturated thickness above the bedrock was estimated to be 5 feet. The ECTran model uses these constant layer thicknesses. The underlying bedrock and the flow through it were not simulated for most of the scenarios in the modeling since the flow through the bedrock of the UHSU is much slower than the alluvium (DOE 1993a). For the scenarios in which flow through the alluvium is not controlled, contaminants which leak out of the disposal facility will reach the POC quicker in the alluvium (than in the bedrock) so the model predicted concentrations in the saturated alluvium were used to determine the WAC values. For the scenario in which the flow through the alluvium is cut off, the predicted concentration in the bedrock at the POC is used to develop the WACs. Additional constant water flow through the unsaturated zone was added in the model to simulate the washing effect on the unsaturated zone by the fluctuation of the groundwater elevation. The amount of this additional flow through the unsaturated zone was estimated during the model calibration.

B.4.0 CALIBRATION

The model calibration is used to ensure that the computer model set up in accordance to the conceptual understanding of the site is accurately or conservatively simulating the transport of contaminants. The calibration is completed by refining estimations of model input parameters (e.g., flow parameters and chemical mobilities). Once the model has been calibrated, it was used to determine the WACs. During the model calibration, the past loading of contaminants are simulated and the input parameters adjusted until the predicted groundwater contaminant concentrations match the groundwater sample results. The computer model of the SEPs is a simplified representation of the movement of contaminants through the groundwater. Due to the heterogeneous nature of the contaminant loading and the corresponding variation of the contaminant concentrations in the groundwater, the simplified, modeled representation of the contaminant transport only attempts to yield a typical prediction of the measured groundwater data and is not intended to match every data point.

The calibration allowed the estimation of parameters which could not or were not measured and were unavailable for use in the current modeling. The model calibration resulted in estimates of model parameters such as layer- and COC-specific soil/water partitioning coefficients (K_ds), infiltration rate, and lateral flow rates in both the unsaturated and saturated zones.

Calibration data was available from: previous modeling efforts for the SEPs, groundwater analytical data, lysimeter analytical results in the unsaturated zone beneath and around the SEPs, soil analytical results from samples taken from the lysimeter bore holes, and characterization of the pond contents for two periods (1984-88, and 1991).

Groundwater analytical data was available for 46 wells in the vicinity of the SEPs. Only the wells which were screened in the UHSU were considered in the calibration. The wells were grouped into three categories: upgradient, under source and downgradient wells. Wells which were cross gradient to the average high water level contours were not used in the calibration. The model was then calibrated to predict concentrations which were representative for each of these groups. Table B-2 lists the wells used in the calibration. The well data spans the time frame from 1987 to the present, however, most of the data is more recent.

B.4.1 Hydraulic Parameters

In order to simulate the past loading of contaminants, the amount of water leaking from the ponds to the groundwater is needed. This was estimated by calculating the groundwater flow rate upgradient and downgradient of the SEPs and performing a water balance to determine how much water entered the system. The water entering the system would represent the amount of water infiltrating into the pervious ground surface surrounding the ponds and the amount of water leaking from the bottom of the ponds. It was assumed that the water infiltrating vertically to the bedrock was negligible for this estimate of the infiltration rate since the groundwater velocity in the bedrock has been estimated to be much less than the alluvium which would indicate a lower hydraulic conductivity. Calculation of flow velocities and gradients were based on the average high water table elevations. The hydraulic conductivities were based on the values presented in previous modeling effort at the SEPs.

The model was first calibrated using tritium since the mobility of tritium is very close to that of water (DOE 1995) enabling a good estimate of its soil/water partitioning coefficient (K_d) (e.g., very close to zero). Since tritium's mobility is already known, it was used to estimate or refine the flow parameters in the model such as the infiltration rate, the flow used to simulate the fluctuating groundwater table in the unsaturated zone, and the flow parameters in the saturated zone. Some of the tritium concentrations in the groundwater were higher than the characterization of the contents of the ponds. The source of contamination must have been higher at some time prior to the characterization available from 1984-1988 and 1991 to cause these higher groundwater concentrations. Because the source loading must have been higher than the characterization concentrations of the ponds, the source concentration for tritium was then calibrated along with the flow parameters. The length of source loading was taken as 32 years for tritium (the time that pond 207-A was put into operation in 1956 until the sludges were cleaned out of this pond in 1988). For the model calibration ponds 207-A and the 207-B ponds were simulated using a single source area because of the close proximity of the ponds. The groundwater flow from pond 207-C appears to travel almost directly north rather than north and east for the other ponds so that 207-C was not included in the calibration source area (See Figure B-4). Figure B-4 is a plot of the mean seasonal high water elevations with the source area used in the ECTran model for calibration superimposed on it. Figure B-4 is reproduced from the OU4 IM/IRA Decision Document (DOE 1995). Figure B-5 presents the conceptual model used for calibration.

Tritium was calibrated to three points in the flow system below the SEPs, in the unsaturated zone under the source, the saturated zone under the source, and the saturated zone downgradient of the source area. Lysimeter 43193 upper cup results were used as the calibration target for the unsaturated zone. Tritium sample results from the under source wells (both alluvium and bedrock) were used for the saturated zone, and results from wells P209889 and P209589 were used for the downgradient targets. Both of these wells are screened in the bedrock but was still used in the calibration of tritium since no downgradient wells screened in the alluvium were available for calibration. Plots of the predicted and measured groundwater concentrations for tritium for each of these points are shown in Figures B-6 through B-8. As can be seen in Figures B-6 through B-8 the measured concentration data fluctuates. The model calibration is intended to predict typical concentrations and so the predicted concentrations do not fluctuate to the same degree as the measured data.

Figure B-7 includes the upgradient well concentrations in addition to the under source wells for reference. As can be seen from the plots the concentration of tritium decreases rapidly under the source as the source loading decreases. This indicated that the tritium is being "washed" out from underneath the source. The down gradient wells do not show this same effect as rapidly because the washing effect is delayed by the groundwater travel time to the downgradient wells. The predicted down gradient concentration matches the data from well P209889 much better then well P209589. Well P209589 tritium concentration is higher than well P209889. This may be the result of a quicker washing effect at well P209889 which indicates a higher flow of water around this well. Calibrating to this well should result in more conservative flow parameters to be used in the development of the WACs. The calibrated hydraulic flow parameters are shown in Table B-3.

B.4.2 COC Mobility Parameters

The calibration of the COCs used the hydraulic parameters defined from the calibration of tritium. The COCs were primarily calibrated to concentrations in the under-source wells since the POC for the WAC development is essentially under the source.

The initial values of the mobility parameters (K_ds) were estimated two ways and then refined by the model calibration. The first estimate of the K_d values was made by reviewing literature values and values used in previous modeling at the RFETS for each of the COCs. The second method calculated K_d values based on liquid concentrations of pore water in the vadose zone from the lysimeter data and soil concentration data from soil samples taken in the same location and depths as the lysimeter cups. It was assumed that the liquid and soil concentrations were at equilibrium. Based on this assumption, a K_d value was then estimated from this data by dividing the solid concentration by the liquid concentration after subtracting out the background concentrations. Any data pairs in which one or both of the solid and liquid concentrations were either nondetect or below background were not used in the calculation of K_d. Positive data for both solid and liquid samples were available to calculate K_d values for cadmium, uranium, and radium-226. The geometric mean of the chemical-specific K_d values calculated with the lysimeter data was used as the initial values in the calibration.

The K_d values were then refined by the model calibration. By definition, the K_d value represents the soil water partitioning coefficient which is a measure of a chemicals affinity to adsorb to soil from the liquid phase and is therefor a measure of the chemical's mobility through its interaction of adsorption and desorption to soil. When a chemical is calibrated to groundwater data in a model which only uses the K_d value to simulate chemical mobility, the K_d value no longer only accounts for the adsorption and desorption of the chemical to the soil but also other mechanisms which are effecting the mobility of the chemical such as colloidal transport. The calibrated K_d values can then be thought of as a lumped mobility parameter accounting for the various mobility mechanisms which are occurring between the source and the measurement point of the groundwater concentration. It would not be unexpected then that the K_d values determined through calibration could be lower than literature values determined through tests which only considered adsorption and desorption.

The concentration of the liquids in the SEPs was assumed to be the source loading concentration to the groundwater. The concentration of the contents of the SEPs were only available for two time periods; 1984-1988 and 1991. Prior to this, the concentration of the source loading to the groundwater in the model was assumed. In most cases of the calibrations, the source loading prior to 1984 was assumed to be the same as the source loading from 1984 to 1988. The source loadings used in the model were taken from the range of measured concentration data in the 207-A and the 207-B ponds. All of the calibrations of the COCs then used a two-step loading to the groundwater; the first step from years 1956 to 1987 (32 years) and the second step from 1988 on. The characterization of the SEPs in 1984 to 1988 was used for the first loading step and the characterization from 1991 was used for the second loading step.

Based on the amount of information available, and the relationship of the different data available to the calibration, the calibration of the COCs falls in several categories which results in different level of confidence in the calibration results. Most of the COC's source loading concentrations were available for the calibration and an ample number of groundwater sample results under the source were also available. The following are exceptions. No source loading data was available for radium-226. The source loading was calibrated using the K_d values calculated with the lysimeter data. This calibration was conducted primarily to see if it was possible for the model to predict concentrations in the groundwater similar to the measured concentrations using the calculated K_d value. The calibration of Arsenic is similar in that the source loading available matched the under source measured concentration. The source loading would have had to been higher than the under source concentration at sometime during the operation of the SEPs. The source concentration was then also assumed for arsenic. Only total cesium source data was available for the SEPs. It was assumed that the mobility of total cesium is similar to the cesium isotopes and could be used for cesium-134. In addition, only two sample results were available for total cesium under the source to be matched to the predicted concentration during the calibration. Due to the limited data for radium, cesium, and arsenic the calibrated mobility values for these COC should be viewed as more uncertain that the other COCs.

Table B-4 lists the COC-specific K_d values determined during the calibration, the literature values, and calculated K_d values from the lysimeter data. The mobility of all of the uranium isotopes were assumed to be the same so only U-238 was calibrated. For comparison purposes, Table B-5 lists K_d values used for radionuclides at other DOE facilities. Figures B-9 through B-19 present plots of the calibration results under the source for each of the COCs.

B.5.0 WASTE ACCEPTANCE CRITERIA

As was discussed previously, the WAC is the leachate concentration from the waste that will not exceed the acceptable water criteria at the point of compliance if it percolates out of the disposal facility. The WACs were calculated for three design scenarios and a range of infiltration rates through the cap for each scenario. The range of infiltration rates will allow for the changes in the design of the cap and/or changes in the assumptions of the long-term performance of the cap. Each of the three modeling scenarios are presented in the following paragraphs. Figures B-20 through B-22 provide drawings of the conceptual models of Scenarios 1, 2, and 3, respectively, for reference during the following discussion.

The current disposal cell design includes a drainage layer beneath the disposal cell to prevent the groundwater table from rising and coming in contact with the waste material. Conceptually if the groundwater table rises, water will enter the drainage layer which is designed to carry the flow laterally away before it can rise further and come in contact with the disposal cell contents. In the event that contaminants do leach out of the disposal cell (the focus of this study) the leachate will enter this drainage layer and travel laterally to the POC. In this case, if the leachate is not collected, the WACs would directly match the compliance criteria. The development of the WACs presented herein considers the time frame in which the maintenance of the disposal cell can no longer be assured (since the design life of the disposal cell is 1000-years it is unlikely that maintenance on the disposal facility will be continued for the entire design life). It is assumed then that the drainage layer beneath the disposal cell become plugged and does not function. The leachate leaving the disposal cell then migrates vertically down into the saturated zone beneath the disposal cell where it travels with the groundwater.

B.5.1 Scenario 1

Scenario 1 considers the placement of the engineered cover over the waste materials, but no groundwater cut off trenches to limit the flow of groundwater beneath the disposal cell. This Scenario is conceptually similar to the current hydrologic conditions except that the infiltration through the waste material is reduced due to the engineered cover. Figures B-5 and B-20 present drawings of the conceptual models of the scenarios used for calibration and Scenario 1 respectively. The range of infiltration rates that the WACs were developed for will allow for conservative assumptions concerning the long-term performance of the cap (i.e., what would the WAC be if the impermeable layer fails after a certain number of years). The WACs were determined for a range of infiltration rates between 0.0068 to 2.5 inches per year. The estimated initial infiltration through the cap under normal conditions is 0.0068 inches per year (DOE 1995).

The source area size used in the development of the WAC was based on the footprint size of the disposal facility. The POC for all of the scenarios is groundwater under the edge of the disposal facility. The ECTran model calculates an average concentration in the saturated zone beneath the source area. This average concentration was compared to the acceptable groundwater concentration in developing the WACs. The constant source leachate concentration in the model is iteratively adjusted until the modeled maximum groundwater concentration in 1000 years matches the water criteria. Figures B-23 through B-35 present the WACs for each of the COCs. These figures contain plots of the WAC values for each of the three design scenarios which were modeled for comparison purposes.

B.5.2 Scenario 2

Scenario 2 is similar to Scenario 1 except that shallow trenches are dug around the waste disposal facility to limit the fluctuation of the groundwater table and shallow barrier walls are constructed around the waste disposal facility. This was modeled by removing the additional flow in the unsaturated zone determined during the hydraulic calibration. Figure B-21 presents the conceptual model of Scenario 2. The other assumptions and ranges of input values are the same as Scenario 1. The same iteration process that was used in Scenario 1 is used to determine the acceptable source leachate concentration for Scenario 2. Figures B-23 through B-35 present plots of the WAC for each of the ten COCs.

B.5.3 Scenario 3

Scenario 3 is similar to Scenario 2 except that the trenches around the waste disposal cell are deepened to the bedrock surface and barrier walls are constructed around the waste disposal facility. This is intended to cut off the flow in the surficial materials from migrating under the waste disposal cell. Conceptually the only movement of water under the waste disposal facility cell is driven by the infiltration through the cap. Also the two overburden layers in the model are both assumed to be unsaturated in this scenario. However, it is assumed that the water infiltrating through these layers flows out radially from the waste disposal facility through the underlying bedrock layer. Looking at the cell in cross section half of the flow would flow in one direction and the other half in the other direction. The distance that the average plume concentration would need to transverse and discharge into the cutoff trench would be one quarter of the width of the disposal cell. This distance was then used to calculate the travel distance of the average plume concentration through the bedrock to the edge of the disposal facility (the POC). Figure B-22 presents the conceptual model of Scenario 3.

Figures B-23 through B-35 present the plots of the WAC for each of the ten COCs. The WAC for some of the COCs for Scenario 3 are not presented because the combination of the slow flow velocity in the bedrock and the relatively high K_d values result in the contaminant plume not reaching the POC within the 1000 year time frame. Theoretically this would result in pure product concentration for the WAC for this COC so they were not included on the figures.

B.5.4 Summary of WAC Results

The WACs developed in this study allow for many combinations of design scenarios and assumed representative infiltration rates through the disposal facility. In order to compare the WAC results to the TCLP leachate results of the treated and untreated waste materials, a specific scenario and infiltration rate must be chosen . Since the current disposal facility design matches WAC scenario 1 this scenario is recommended to be used for comparison. The infiltration rate of one inch per year was estimated as the current infiltration rate through the SEPs area (See Section 4.1). Using this infiltration rate for the WACs should produce a worst case scenario for infiltration through the disposal cell assuming that the cap fails sometime before the end of its design life. It would not be expected that the infiltration through the cap would be more than the current infiltration through the SEPs area. The actual infiltration through the cap will likely be much less (0.0068 inches per year predicted using the HELP model, DOE 1995), so this will produce conservative results. It is recommended to use a worst case scenario for comparison of the WACs to TCLP leachate results. This corresponds to scenario 1 and one inch of infiltration per year through the disposal cell. Table B-6 lists the WACs for scenario 1 and two infiltration rates through the disposal cell; 0.0068 and 1 inch per year.

B.6.0 INFORMATION TO BE PRESENTED IN THE FINAL REPORT

The following paragraph describes the additional information which will be contained in the final report for this task. This report focuses on the development of the WACs and the results obtained at this time. The final report will include a section on the review of previous computer modeling conducted at the SEPs and will include infiltration modeling results describing the long term performance of the cap. In addition, the results of the development of the WACs for the organic COC will be presented and discussed. A preliminary assessment of the available groundwater data indicates that very few positive detections of the organic COCs in the groundwater in the vicinity of the SEPs. In this case calibration could not be performed since it appears that the organic COCs are not presently migrating in the groundwater. The development of WACs for these COCs will be based on literature values of the mobility parameters. A sensitivity analysis will be conducted and described which incorporates both deterministic and probabilistic approaches to ascertain the uncertainty of the WACs relative to various model input parameters.

B.7.0 REFERENCES

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Thibault, D.H., M.I. Sheppard and P.A. Smith, 1990, "A Critical Compilation and Review of Default Soil Solid/Liquid Partition Coefficients, K_d for use in Environmental Assessments," AECL-10125, Whiteshell Nuclear Research Center.

Table B-1

Constituents of Concern and Acceptable Groundwater Criteria at the Point of Compliance (a)

Constituents of Concern	Acceptable Groundwater Criteria	Unit
Americium-241	2.11	pCi/L
Cesium-134	81.3 (b)	pCi/l
Cesium-137	119 (b)	pCi/L
Plutonium-239/240	0.207	pCi/L
Radium-226	0.63	pCi/L
Uranium-233/234	74.22	pCi/L
Uranium-235	2.98	pCi/L
Uranium-238	51.6	pCi/L
Arochlor-1254	1	ug/L
Arsenic	50	ug/L
Benzo(a)anthracene	1	ug/L
Benzo(b)fluoranthene	1	ug/L
Benzo(b)pyrene	1	ug/L
Benzo(g,h,i)perylene	1	ug/L
Benzo(k)fluoranthene	1	ug/L
Beryllium	5	ug/L
bis-(2-Ethylhexyl)phthalate	6.07	ug/L
Cadmium	18.2	ug/L
Chromium	182	ug/L
Chrysene	11.6	ug/L
Indeno(1,2,3-CD)pyrene	1	ug/L
Nitrate	58400	ug/L
Phenanthrene	1	ug/L
Sodium	5000	ug/L

(a) Acceptable groundwater criteria are from Parsons Letter SP307:021795.03 from P. Nixon to A. Ledford dated February 17, 1995 (See column labeled Comparison Criteria)

(b) Acceptable groundwater criteria for the cesium isotopes are equivalent to 4 mrem/yr assuming 2 liters of daily intake.

Table B-2

Groundwater Monitoring Wells Used in the Model Calibration

Upgradient Wells	Under-Source Wells	Downgradient Wells
P207489	P209089	P209589
P209389	P210289	P209889
2486	P208989	
	P209489	
	05193	
	3086	
	2886	
	2786	

Table B-3

Input Parameters Used in the ECTran Model

Parameter	Calibration	WAC Development
Source Area Size Length (ft) Width (ft)	 590 390	 650 865
Unsaturated Zone Thickness (ft)	3	3
Saturated Zone Thickness (ft)	5	5
Soil Density (g/cm^3)	1.7	1.7
Porosity	0.338	0.338
Hydraulic Conductivity (a) (ft/yr)	141	141
Infiltration (in/yr)	1	0.0068 to 2.5
Flow in the Unsaturated Zone(Used to Simulate the Fluctuation of the Groundwater Table[b]) (L/day)	1490	3640
Flow in the Saturated Zone (c) (L/day)	1370	3050
Groundwater Velocity (d) (ft/yr)	26.7	26.7

(a) Hydraulic Conductivity from previous modeling at the SEPs.

(b) Flow in the unsaturated zone was calibrated using tritium. The flow volume was adjusted for the WAC development to account for the change in source area size.

(c) Flow based on groundwater velocity, saturated zone thickness,and width of source area.

(d) Groundwater flow velocity based on hydraulic conductivity and the average gradient in the model area from the mean seasonal high groundwater elevations.

Table B-4

Calibrated Soil/Water Partitioning Coefficients (K_ds), Literature Values, and Calculated Values From Lysimeter Data

Constituent of Concern	Calibrated Kd Unsaturated Zone, L/kg	Calibrated Kd Saturated Zone, L/kg	Literature Value (a) L/kg	Literature Value (b) L/kg	Kd Calculated From Lysimeter Data, L/kg (c)	Number of Lysimeter Data Pairs Used to Calculate K_d
Americium-241	100	10	$8.2 - 3 \times 10^5$	700	NA(d)	NA
Arsenic	2	0.5	--(f)	200	NA	NA
Beryllium	5	1	250	650	NA	NA
Cadmium	5	1	2.7 - 625	6.5	597	2
Cesium-137	1	0.1	40-3968	1000	NA	NA
Chromium	35	1.5	1.7-1729	850	NA	NA
Nitrate	0.01	0.01	--(e)	--(e)	0.127	11
Plutonium-239/240	100	20	27-36000	4500	NA	NA
Radium-226	690	106	57-21000	450	690	1
Sodium	10	1.5	--(f)	100	NA	NA
Uranium-233/234	17	2	0.03-2200	450	19.8	8
Uranium-235	17	2	0.03-2200	450	NA	NA
Uranium-238	17	2	0.03-2200	450	14.5	7

a Thibault et al., 1990
b Baes et. al., 1984
c Value represents the geometric mean of the calculated Kd values from the pairs of water/soil concentrations
d Not Applicable; No pairs of data were available to calculate Kd values
e Values for Nitrate were not reported in these sources. A Kd value of 0 was used for Nitrate in previous modeling at the SEPs.
f Values were not reported in this source.

Table B-5

K_d Values Used for Radionuclide COCs
at Other DOE Facilities (a)

COC	Oak Ridge L/kg	Savannah River Site L/kg	Hanford Site L/kg	Idaho National Engineering Laboratory (unsat'd) L/kg	Idaho National Engineering Laboratory (sat'd) L/kg	Fernald Environmental Management Project (unsat'd) L/kg	Fernald Environmental Management Project (sat'd) L/kg	Rocky Flats Environmental Technology Site (Unsat'd) L/kg	Rocky Flats Environmental Technology Site (Sat'd) L/kg
Americium-241	40	150	100	NA	NA	100	10	100	10
Cesium-137	3000	100	1	20	20	1810	1370	1	0.1
Plutonium-239/240	40	100	100	2000	200	1700	100	100	20
Radium-226	3000	500	10	50	5	696	106	690	106
Uranium-233/234	40	50	0	1000	100	3.1	1.78	17	2
Uranium-235	40	50	0	1000	100	3.1	1.78	17	2
Uranium-238	40	50	0	1000	100	3.1	1.78	17	2

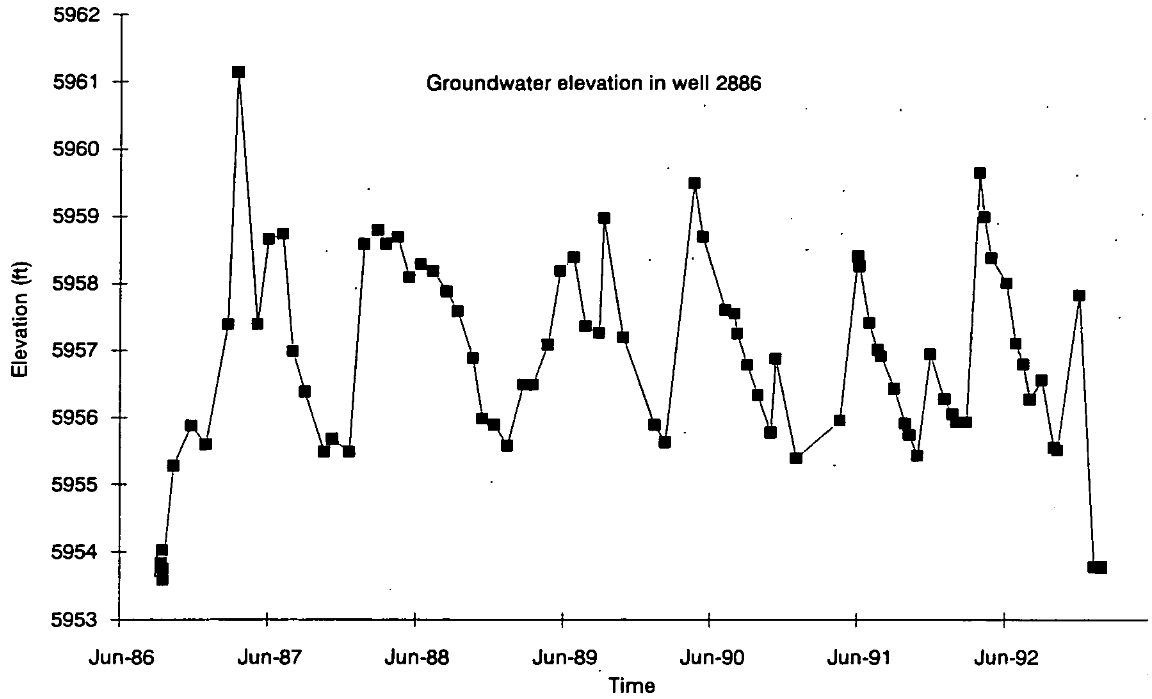
(a) All data except RFETS data from the draft table "Comparison of K_d Values" DOE Disposal Working Group, Performance Evaluations for Mixed Low-Level Waste.

Table B-6

WAC Results for Scenario 1
0.0068 and 1 Inch of Infiltration Per Year
Rocky Flats, Colorado

COC	Unit	Leachate Concentration that is Protective at 0.0068 in/yr Infiltration[1]	Leachate Concentration that is Protective at 1 in/yr Infiltration[1]
Am-241	pCi/L	17,100	74.5
Cs-134	pCi/L	3,510,000	12,800
Cs-137	pCi/L	111,000	737
Pu-239/240	pCi/L	1,070	4.43
Ra-226	pCi/L	117,000	415
U-233/234	pCi/L	35,200	254
U-235	pCi/L	1,410	10.2
U-238	pCi/L	24,500	177
Arsenic	ug/L	13,600	142
Beryllium	ug/L	1,430	14.2
Cadmium	ug/L	5,190	51.8
Chromium	ug/L	142,000	881
Nitrate	mg/L	15,900	166
Sodium	mg/L	1,750	14.9

(1) Estimated concentration of contaminant leaving bottom of closure that will be protective of human health and the environment at the point of compliance, assuming the stated infiltration rate and Scenario 1.



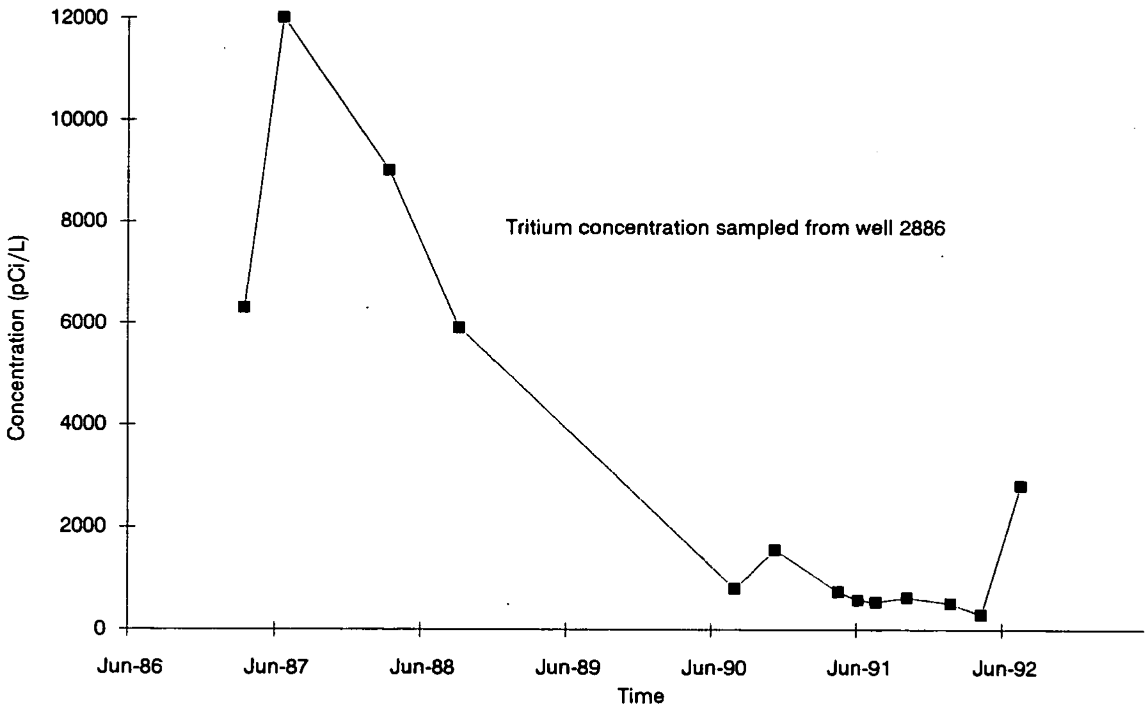
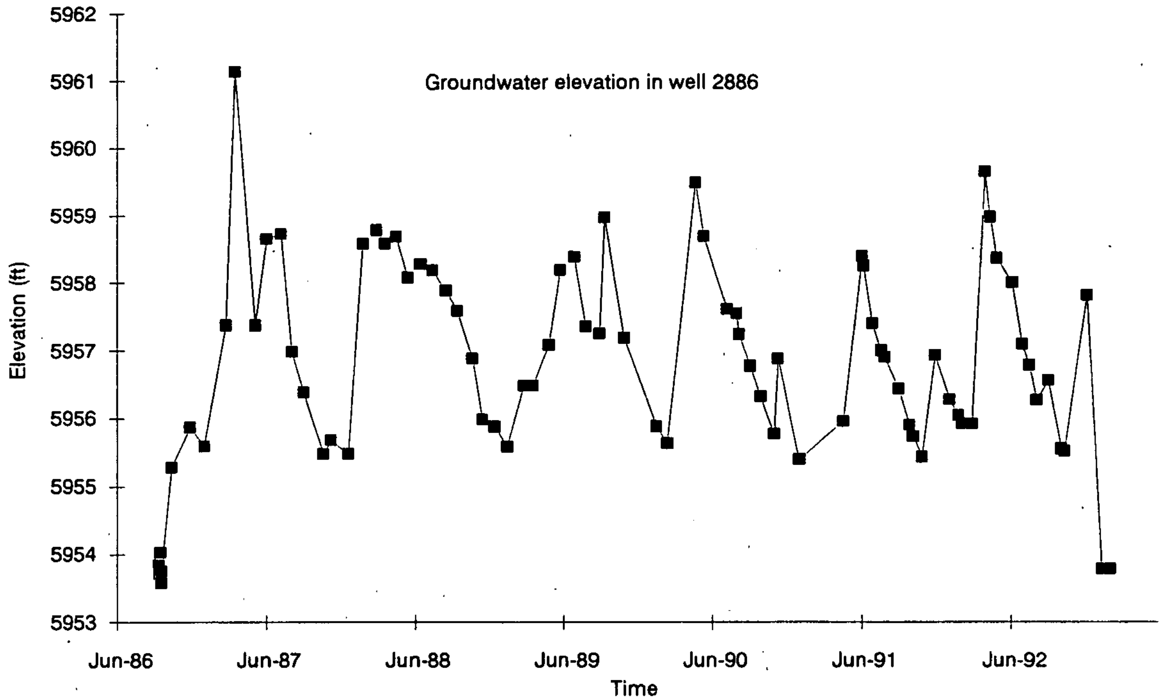


FIGURE B-1 TRITIUM CONCENTRATION VS. WATER ELEVATION IN WELL 2886



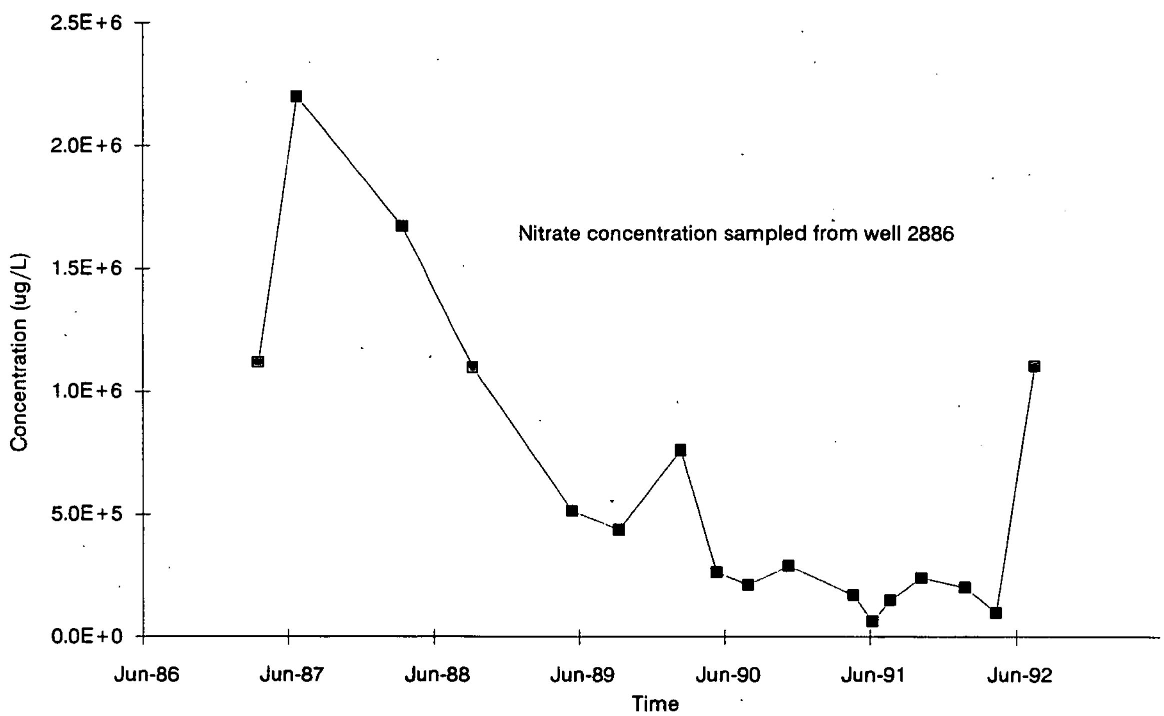
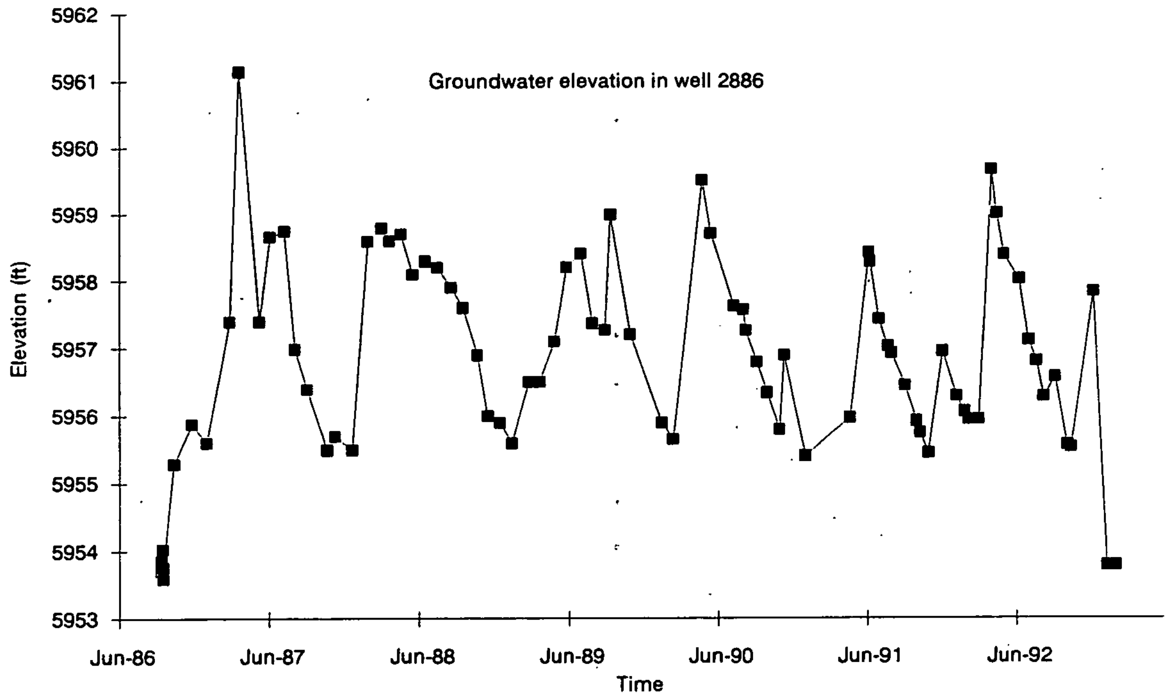


FIGURE B-2 NITRATE CONCENTRATION VS. WATER ELEVATION IN WELL 2886



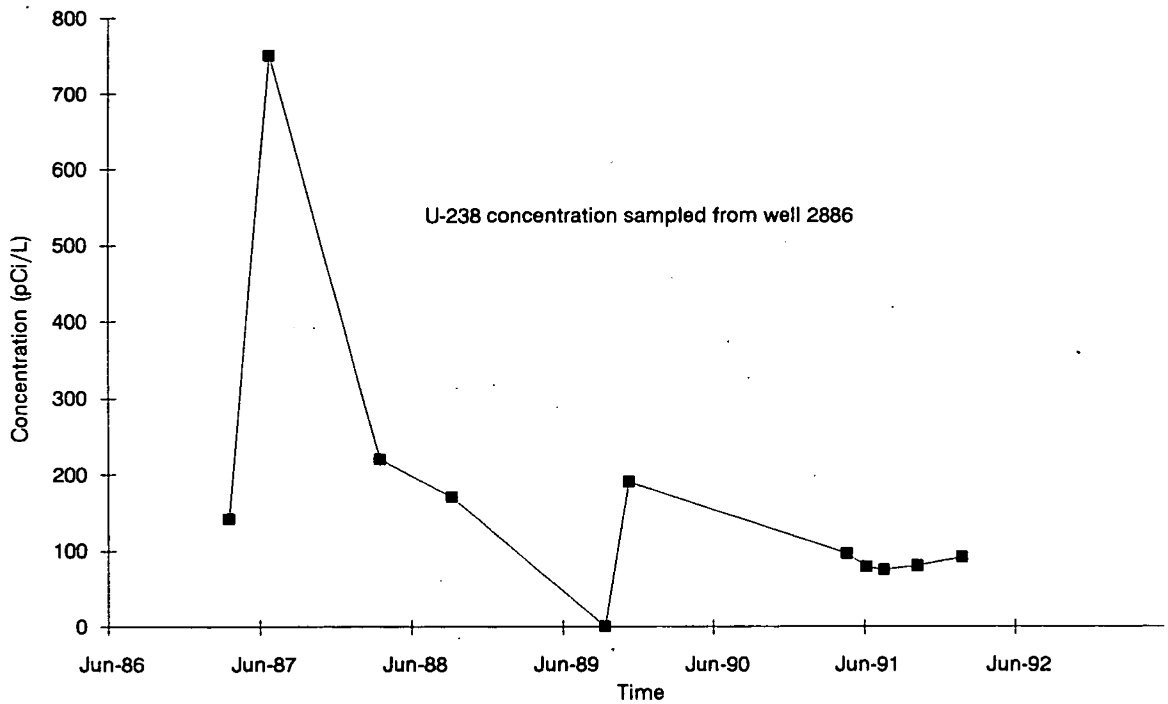


FIGURE B-3 URANIUM-238 CONCENTRATION VS. WATER ELEVATION IN WELL 2886

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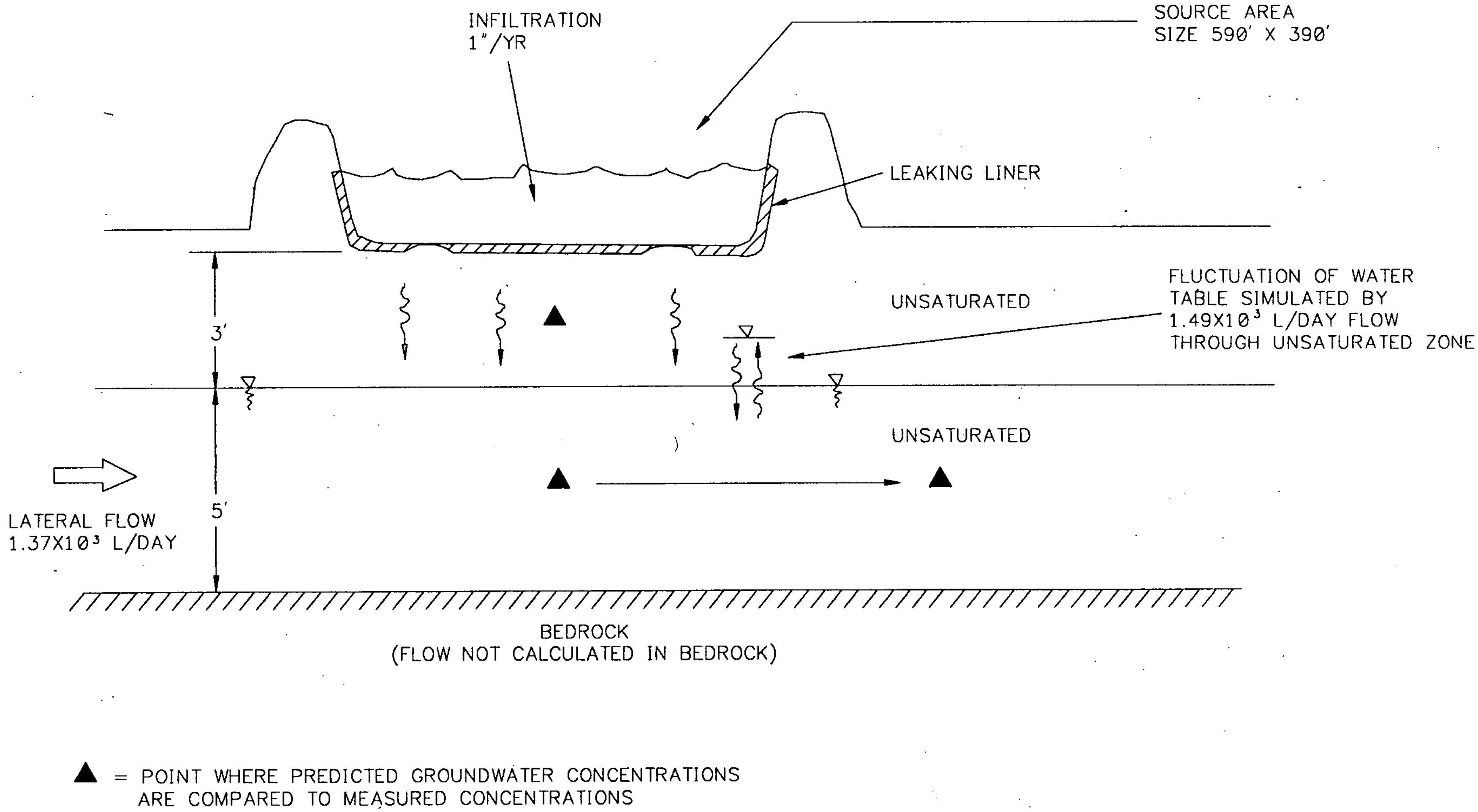


CALIBRATION CONCEPTUAL MODEL
ROCKY FLATS ENVIRONMENTAL
TECHNOLOGY SITE
GOLDEN, COLORADO

FIGURE B-5

Halliburton NUS CORPORATION

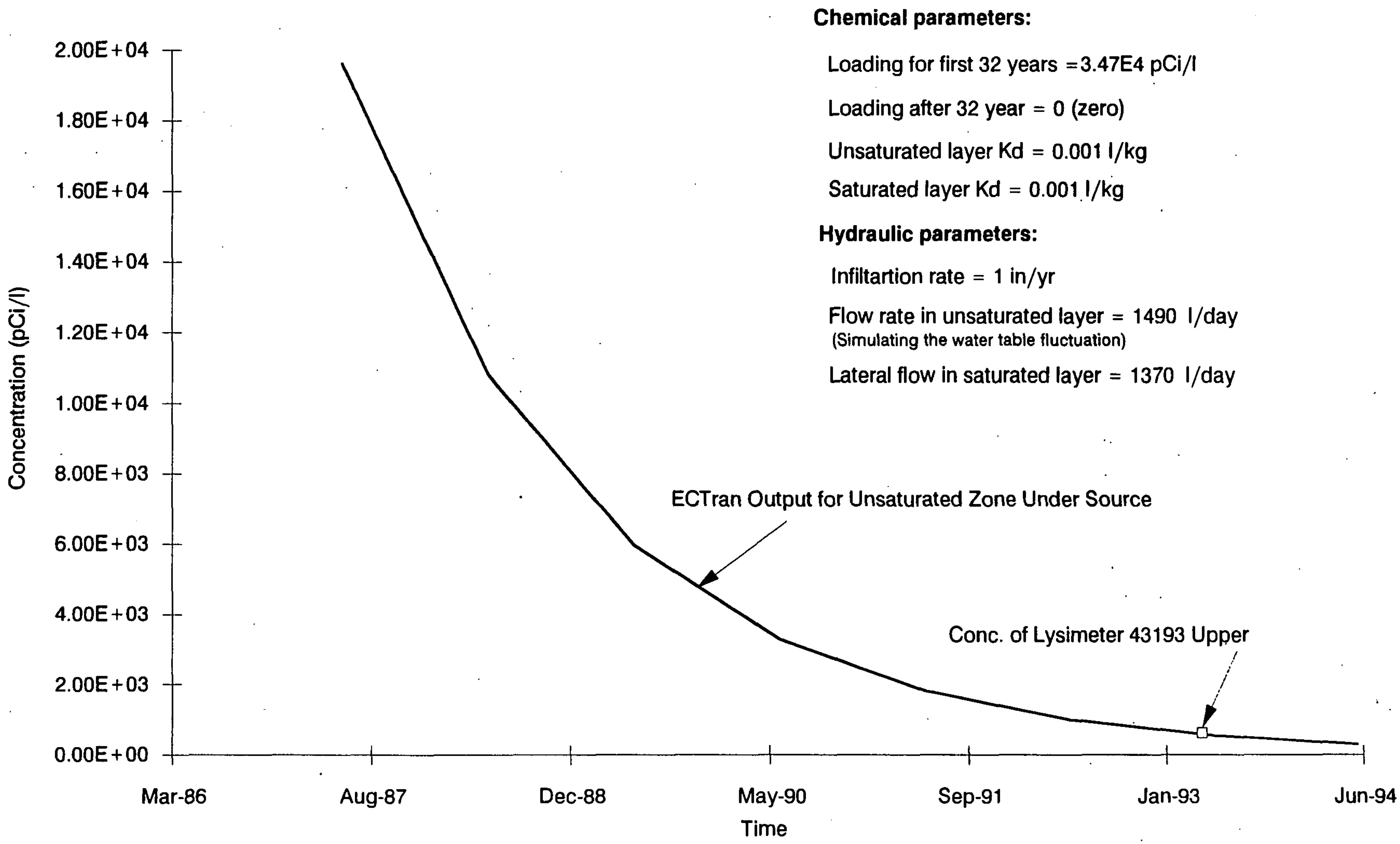


FIGURE B-6 TRITIUM CALIBRATION RESULTS IN THE UNSATURATED ZONE

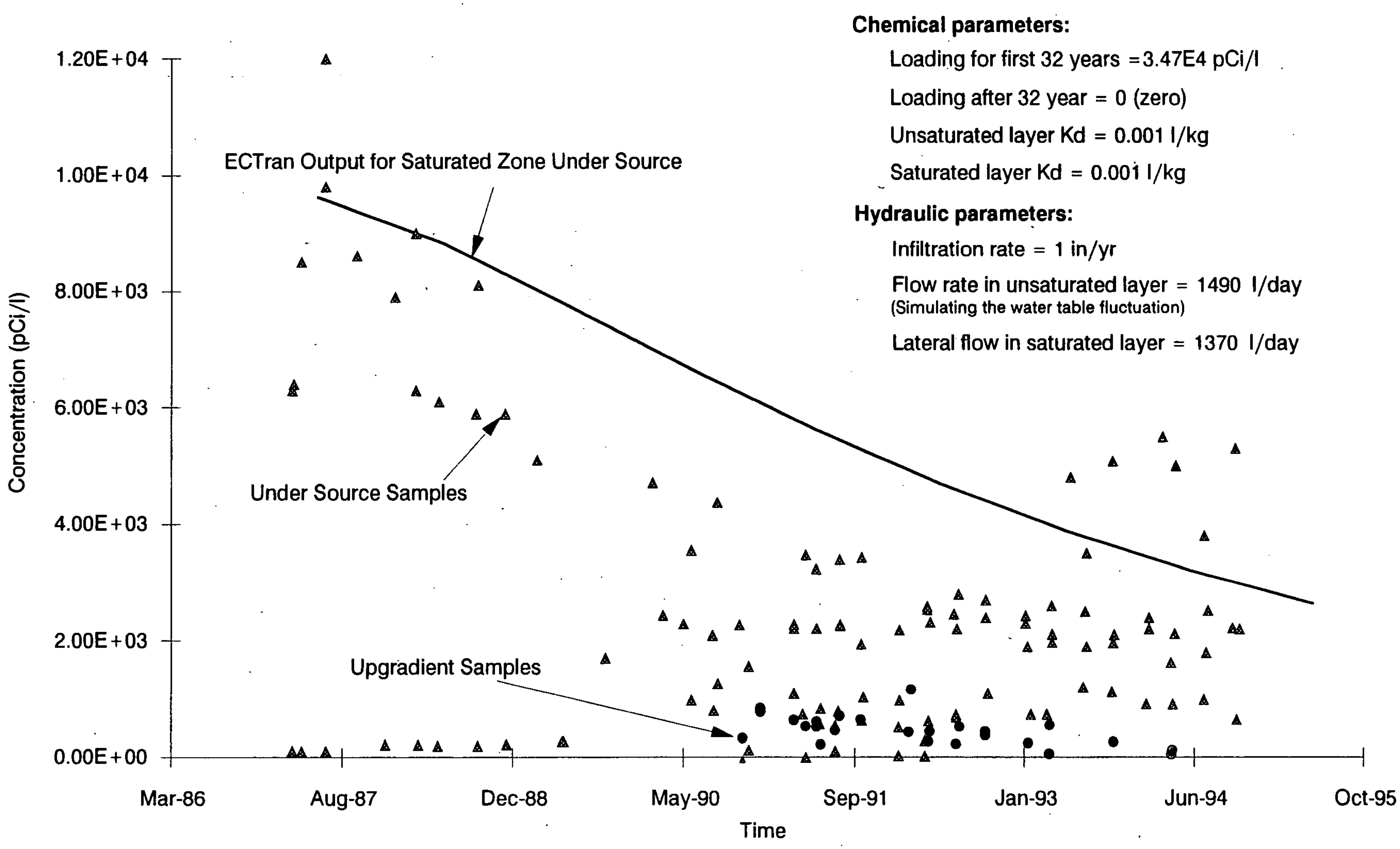


FIGURE B-7 TRITIUM CALIBRATION RESULTS IN THE SATURATED ZONE UNDER THE SOURCE

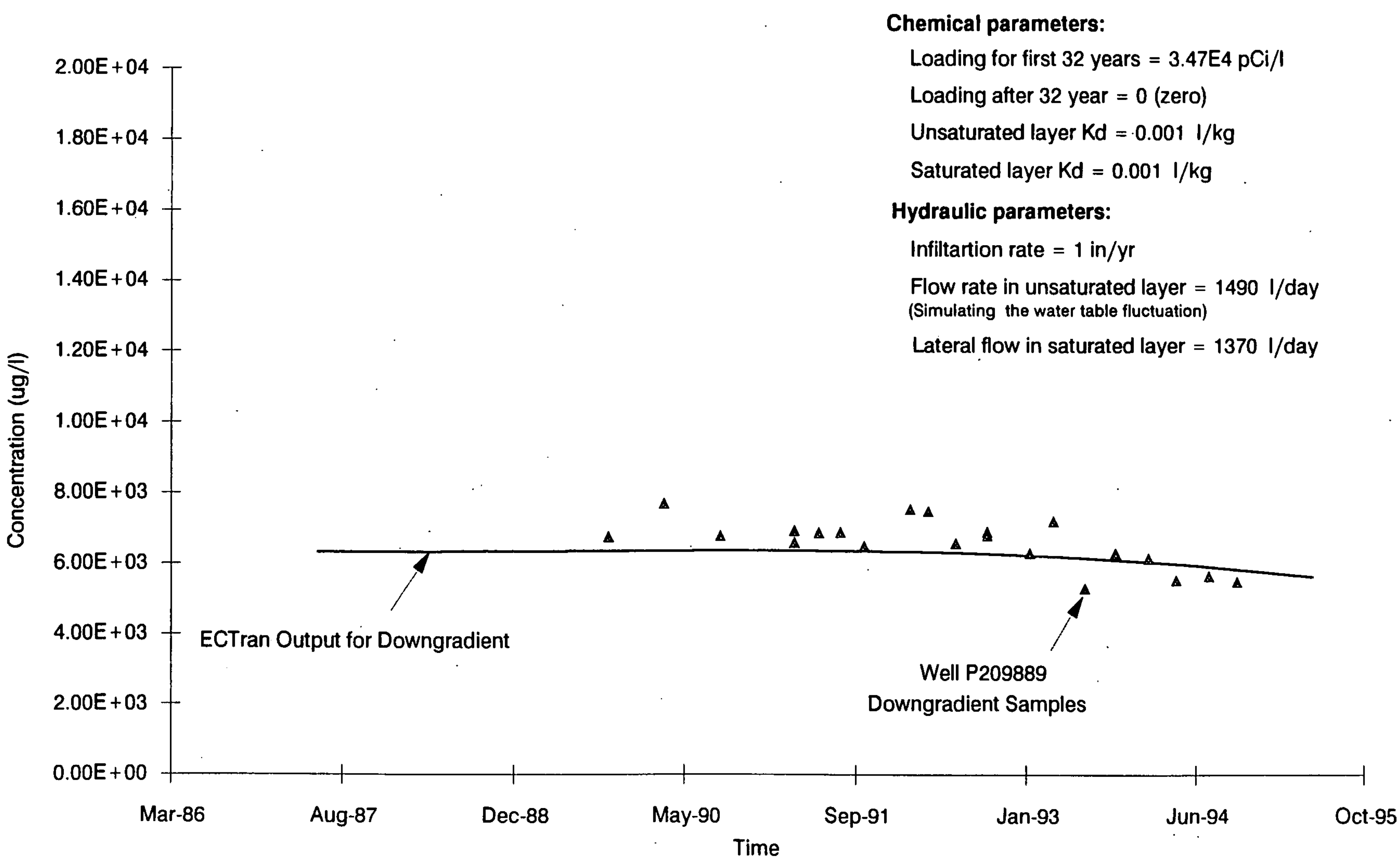


FIGURE B-8 TRITIUM CALIBRATION RESULTS IN THE SATURATED ZONE DOWN GRADIENT

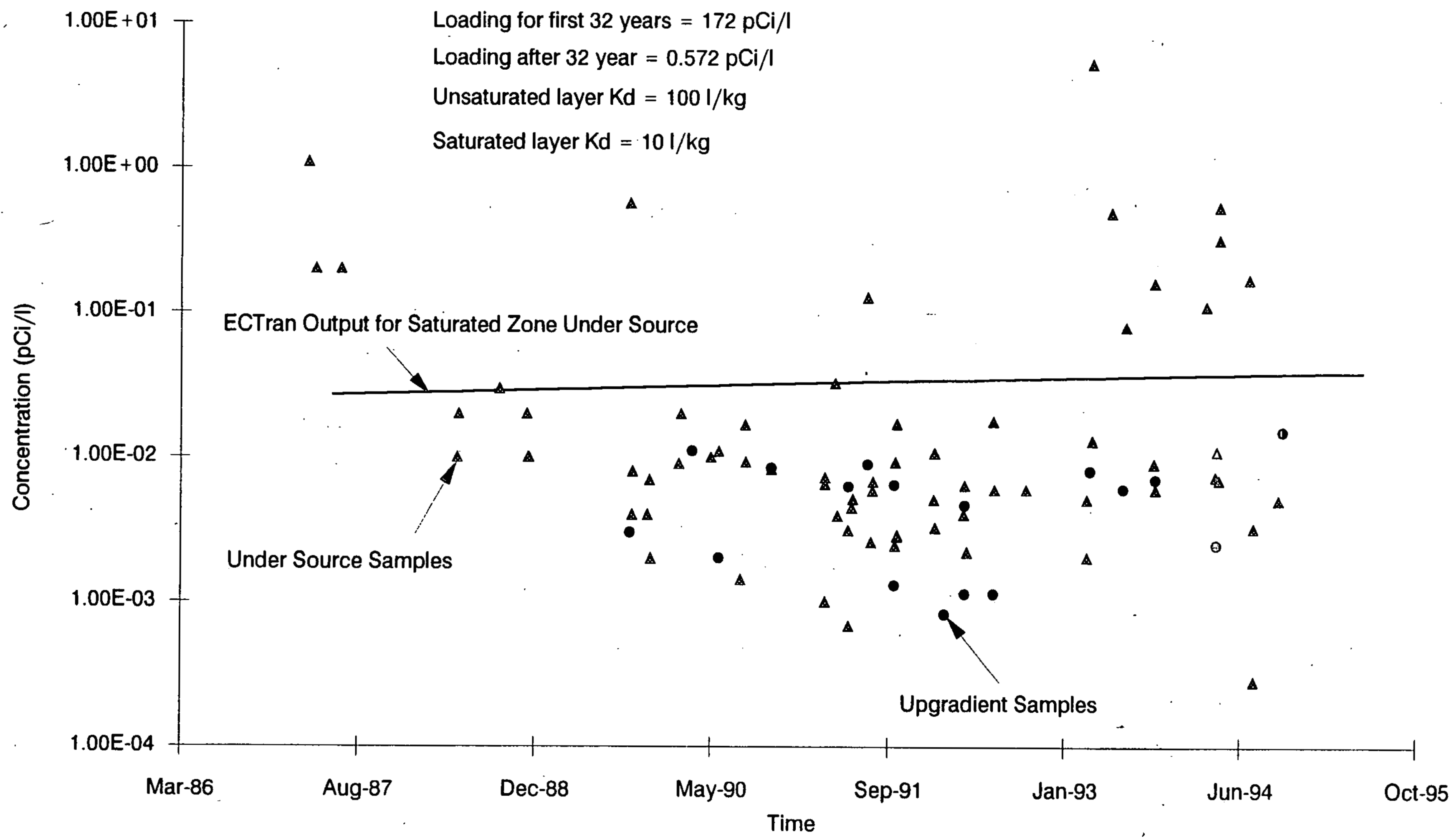


FIGURE B-9 AMERICIUM-241 CALIBRATION RESULTS

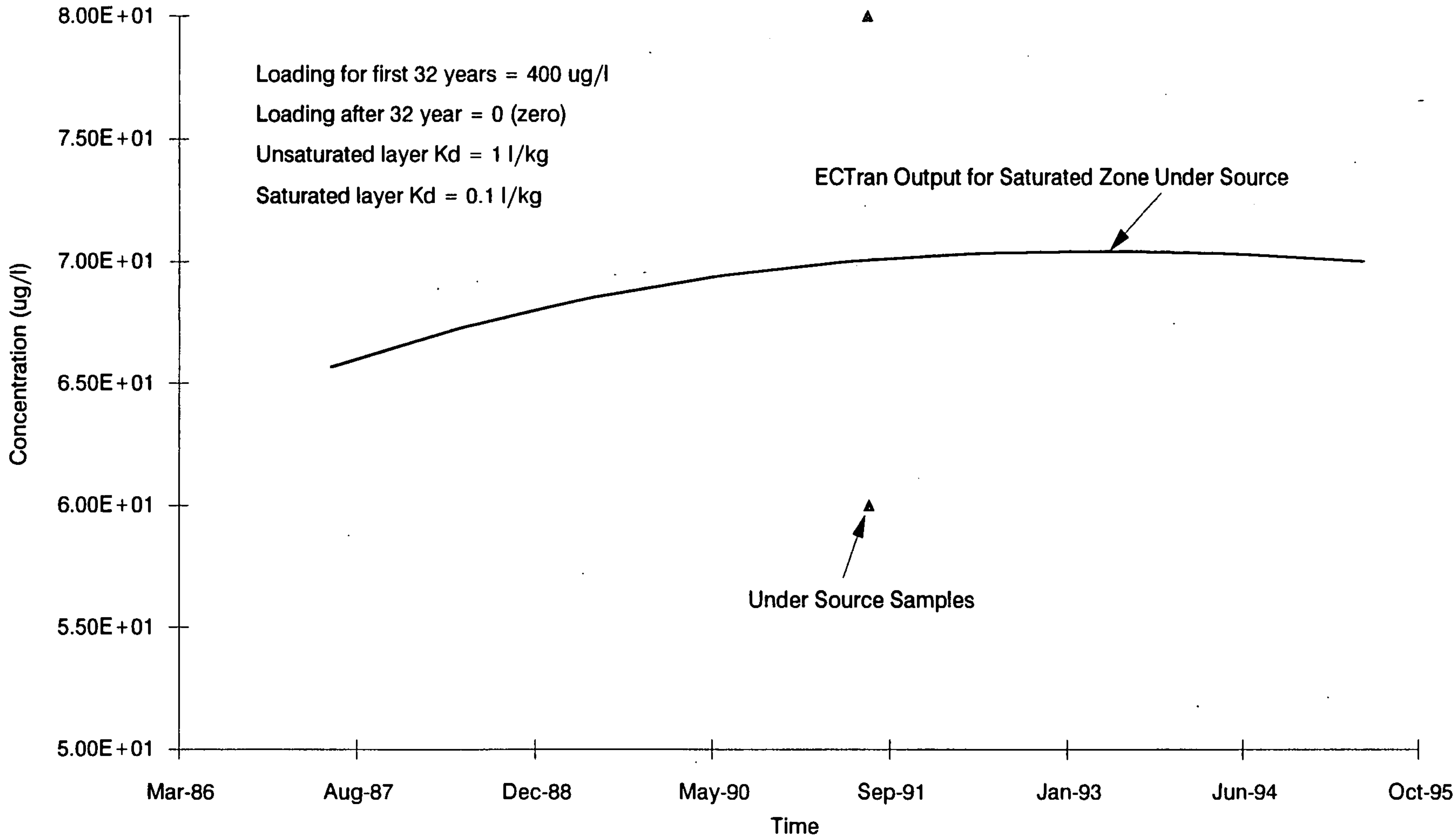


FIGURE B-10 CESIUM CALIBRATION RESULTS

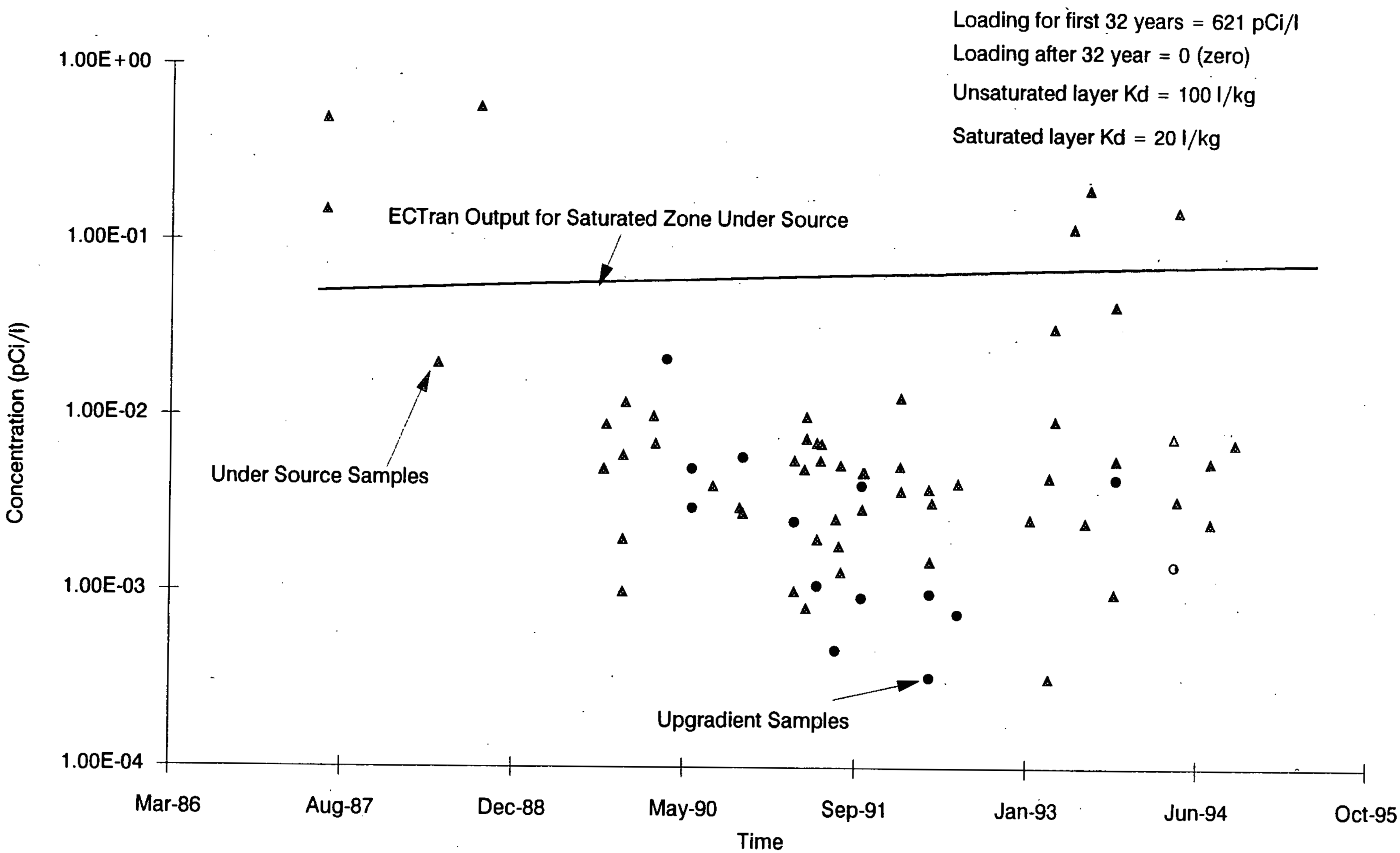


FIGURE B-11 PLUTONIUM-239/240 CALIBRATION RESULTS

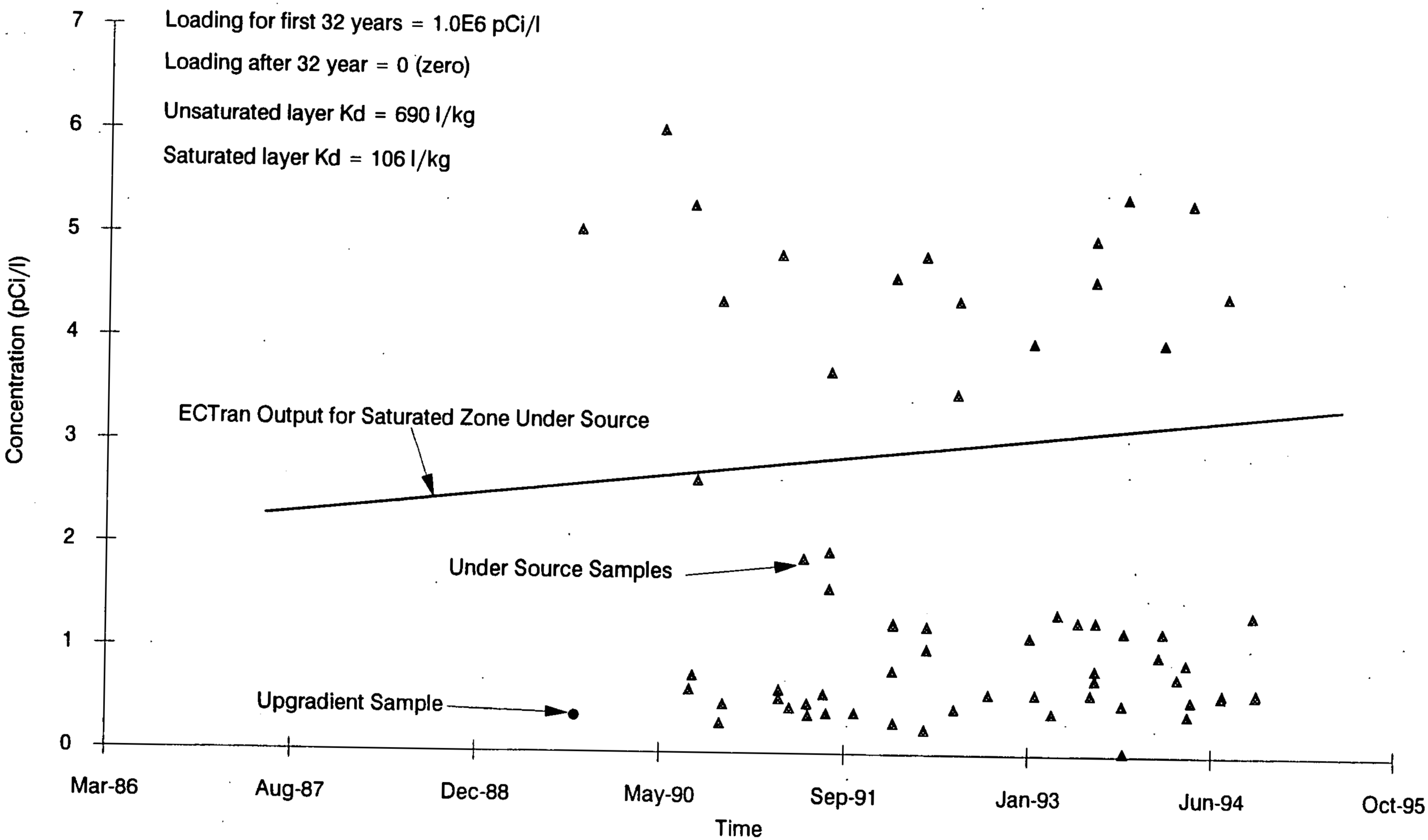


FIGURE B-12 RADIUM-226 CALIBRATION RESULTS

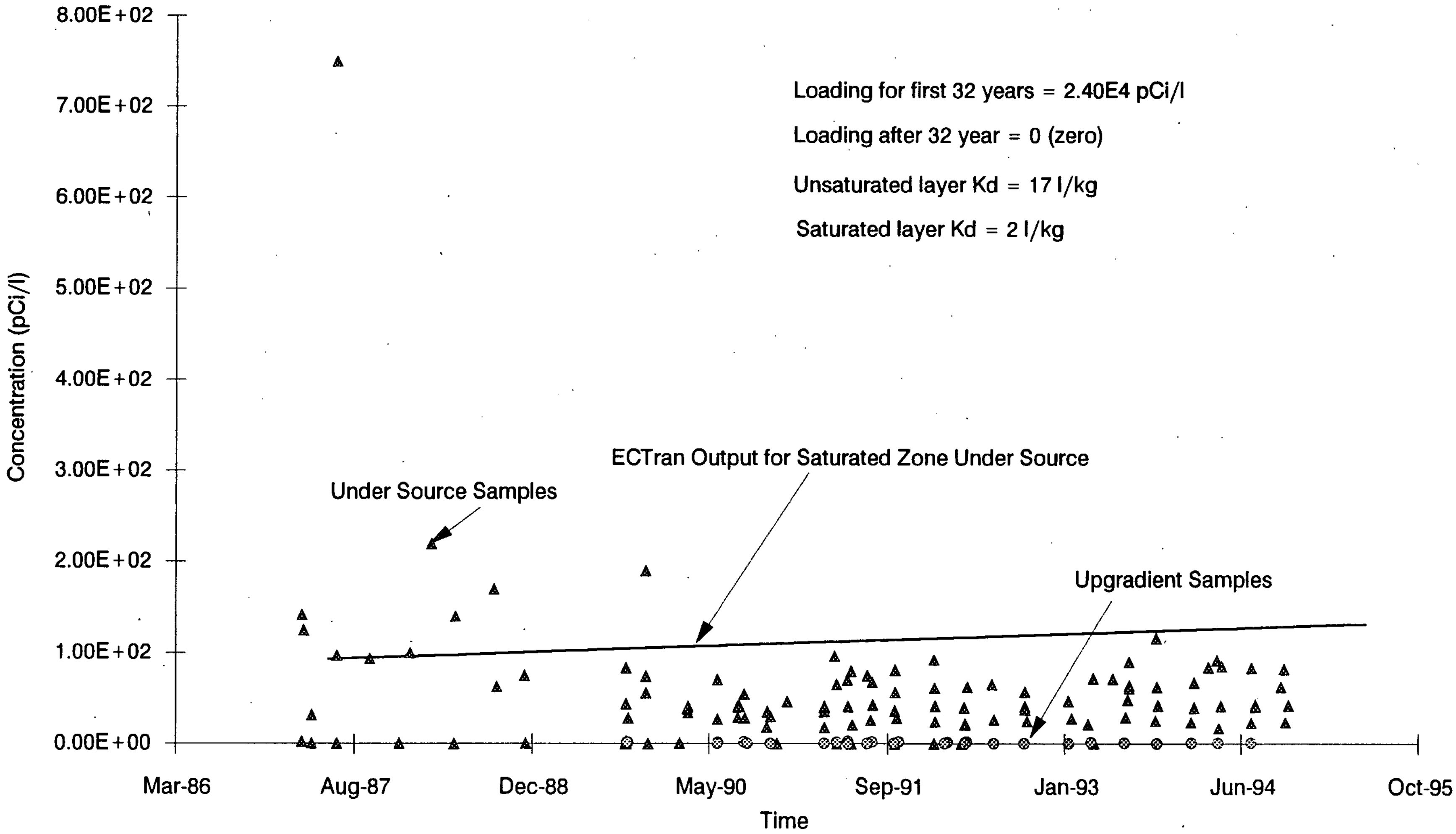


FIGURE B-13 URANIUM-238 CALIBRATION RESULTS

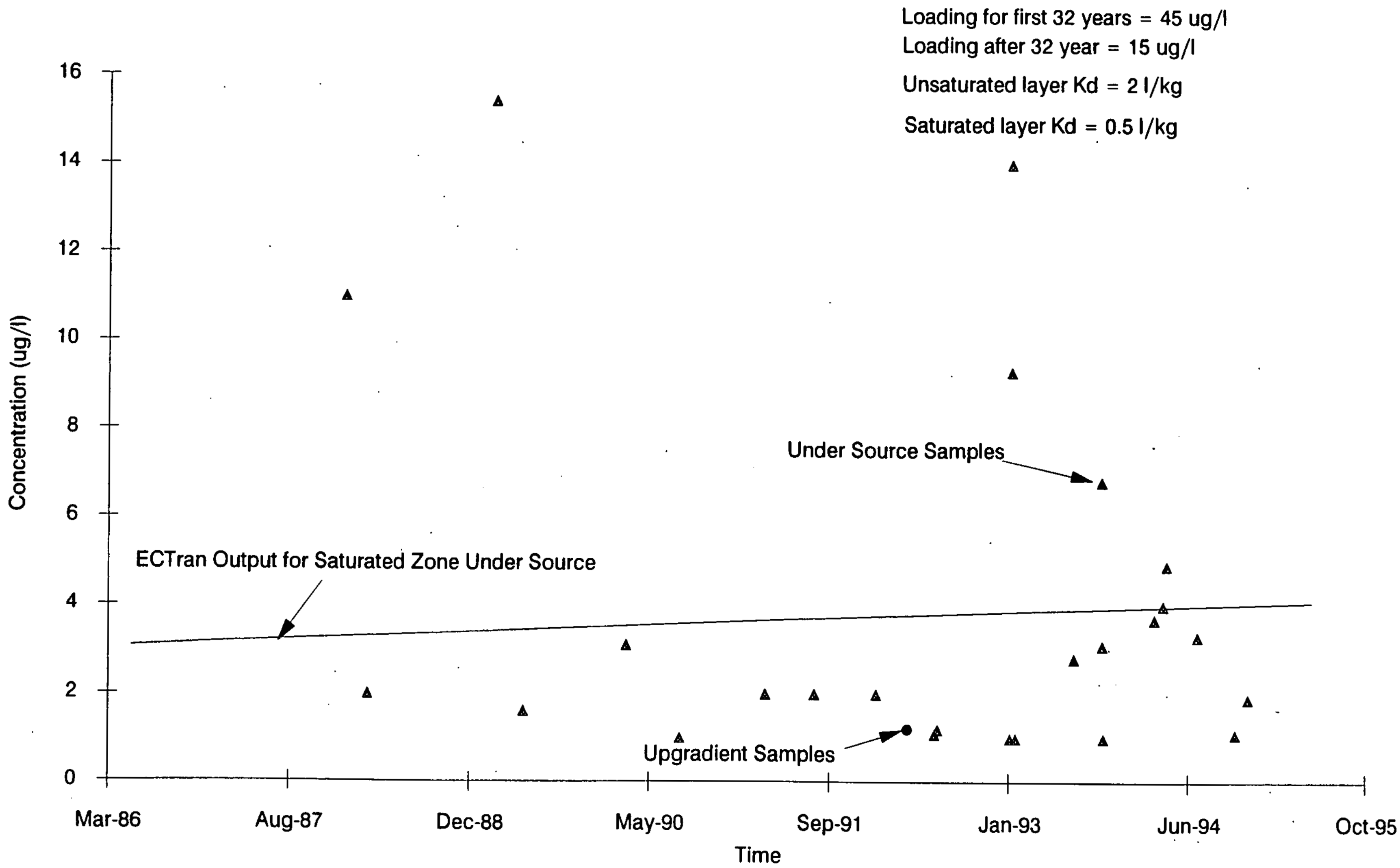


FIGURE B-14 ARSENIC CALIBRATION RESULTS

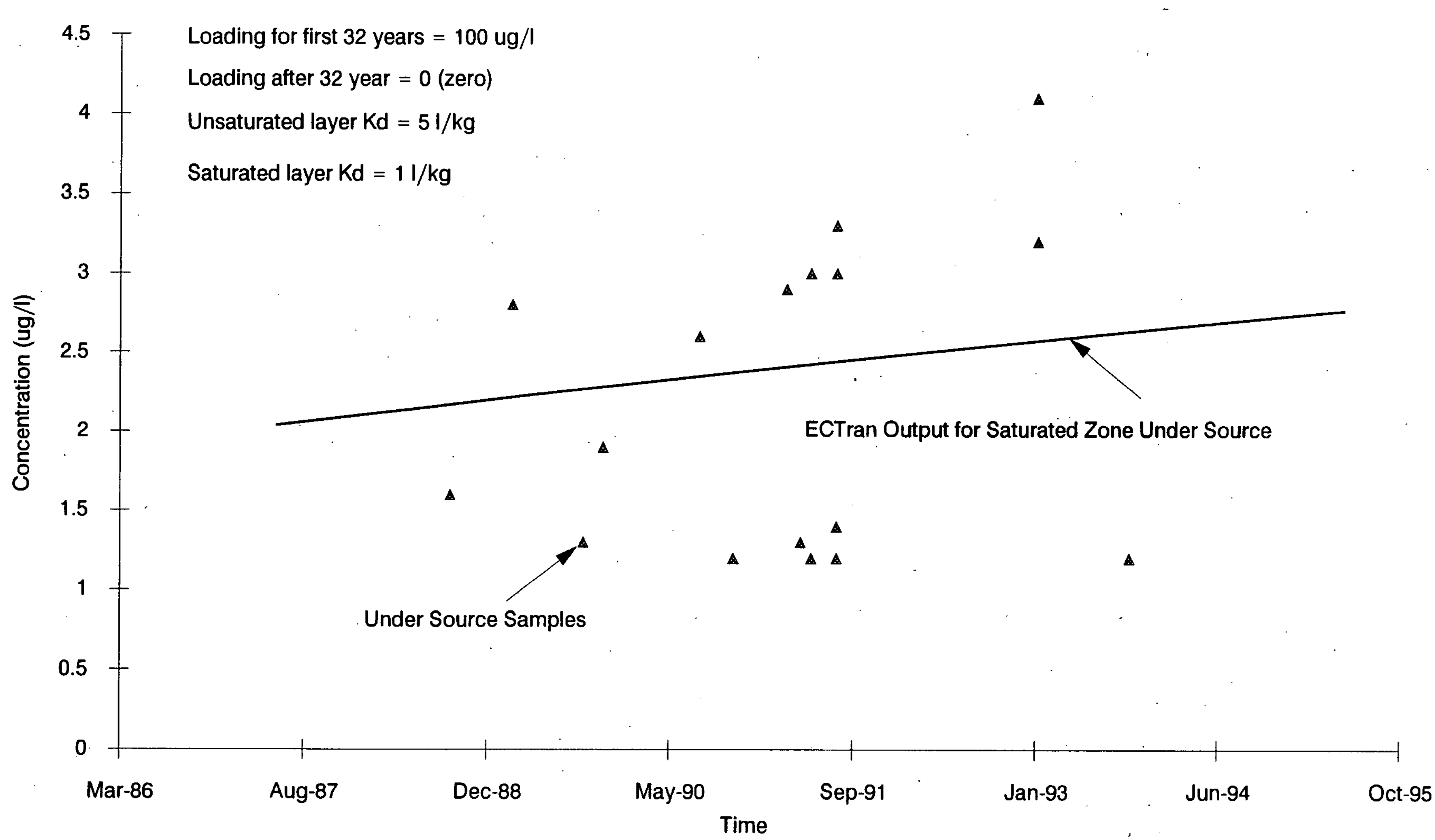


FIGURE B-15 BERYLLIUM CALIBRATION RESULTS

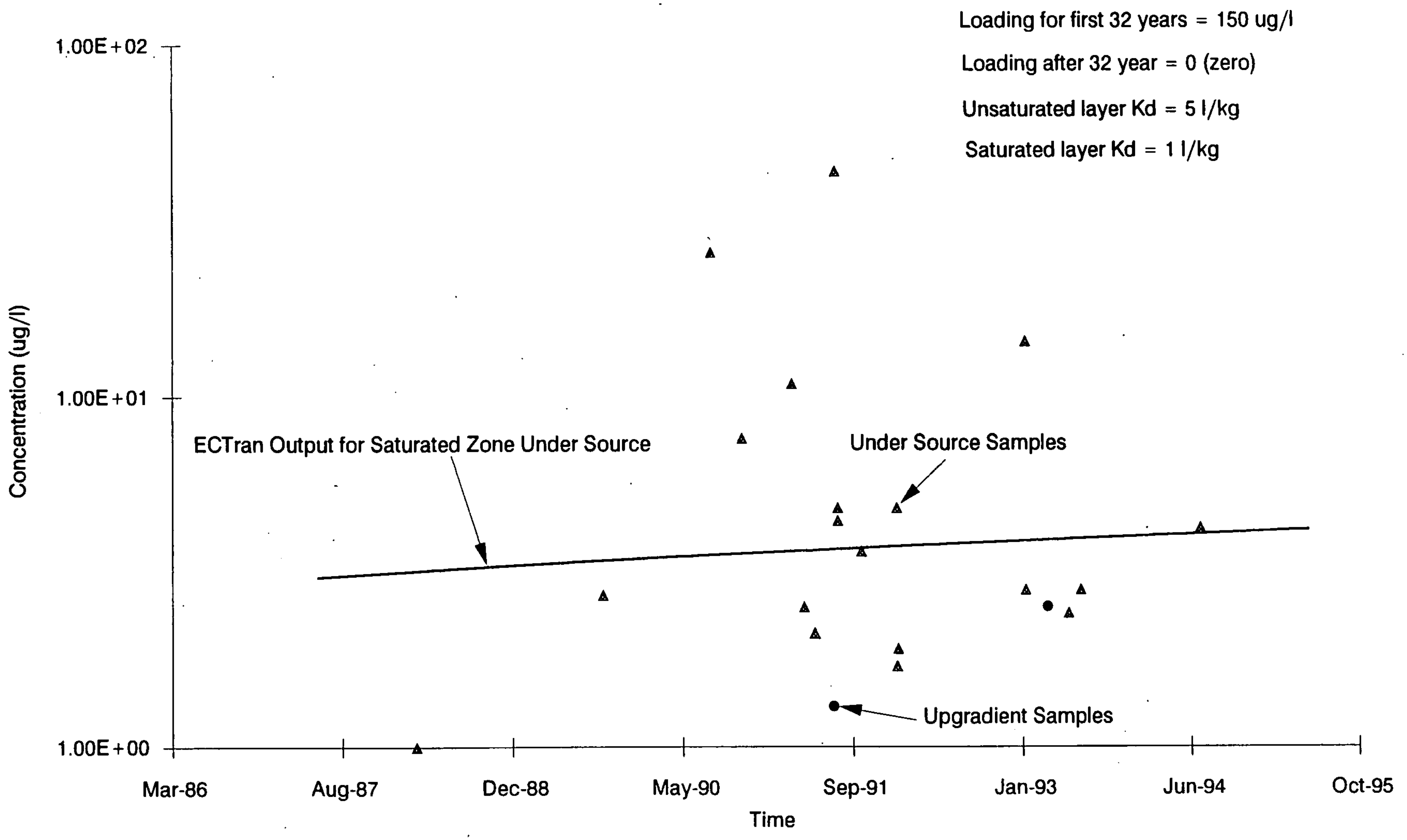


FIGURE B-16 CADMIUM CALIBRATION RESULTS

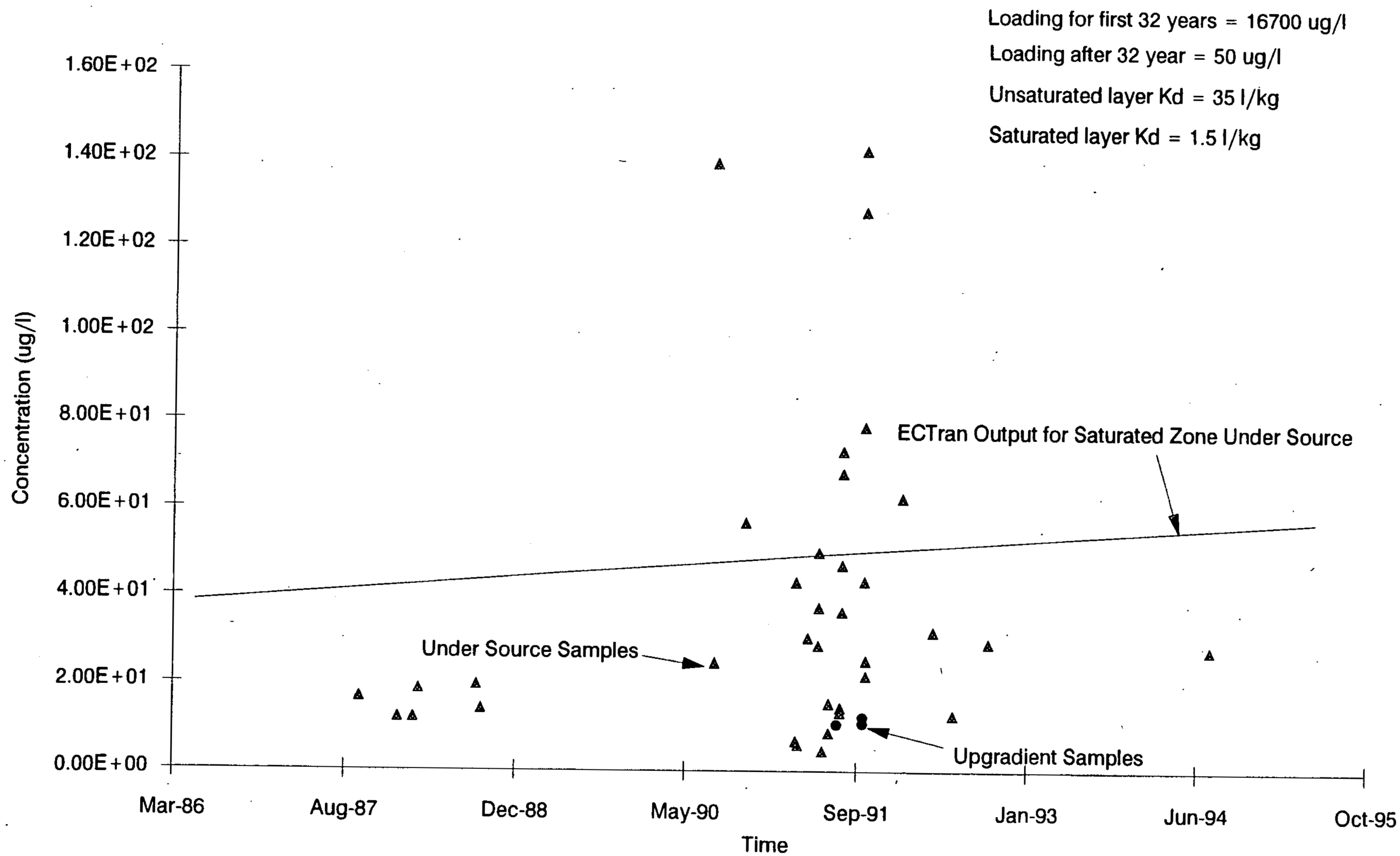


FIGURE B-17 CHROMIUM CALIBRATION RESULTS

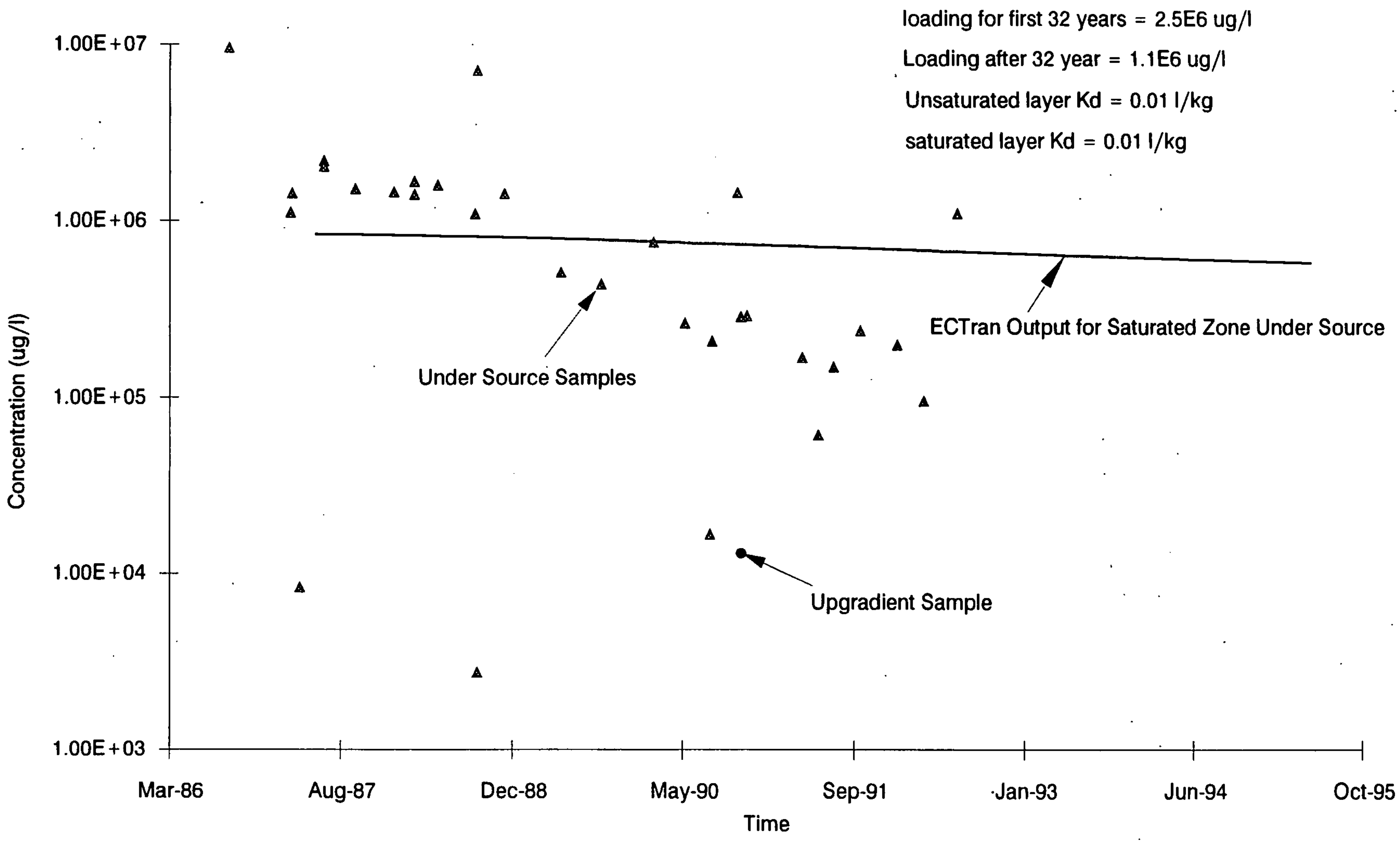


FIGURE B-18 NITRATE CALIBRATION RESULTS

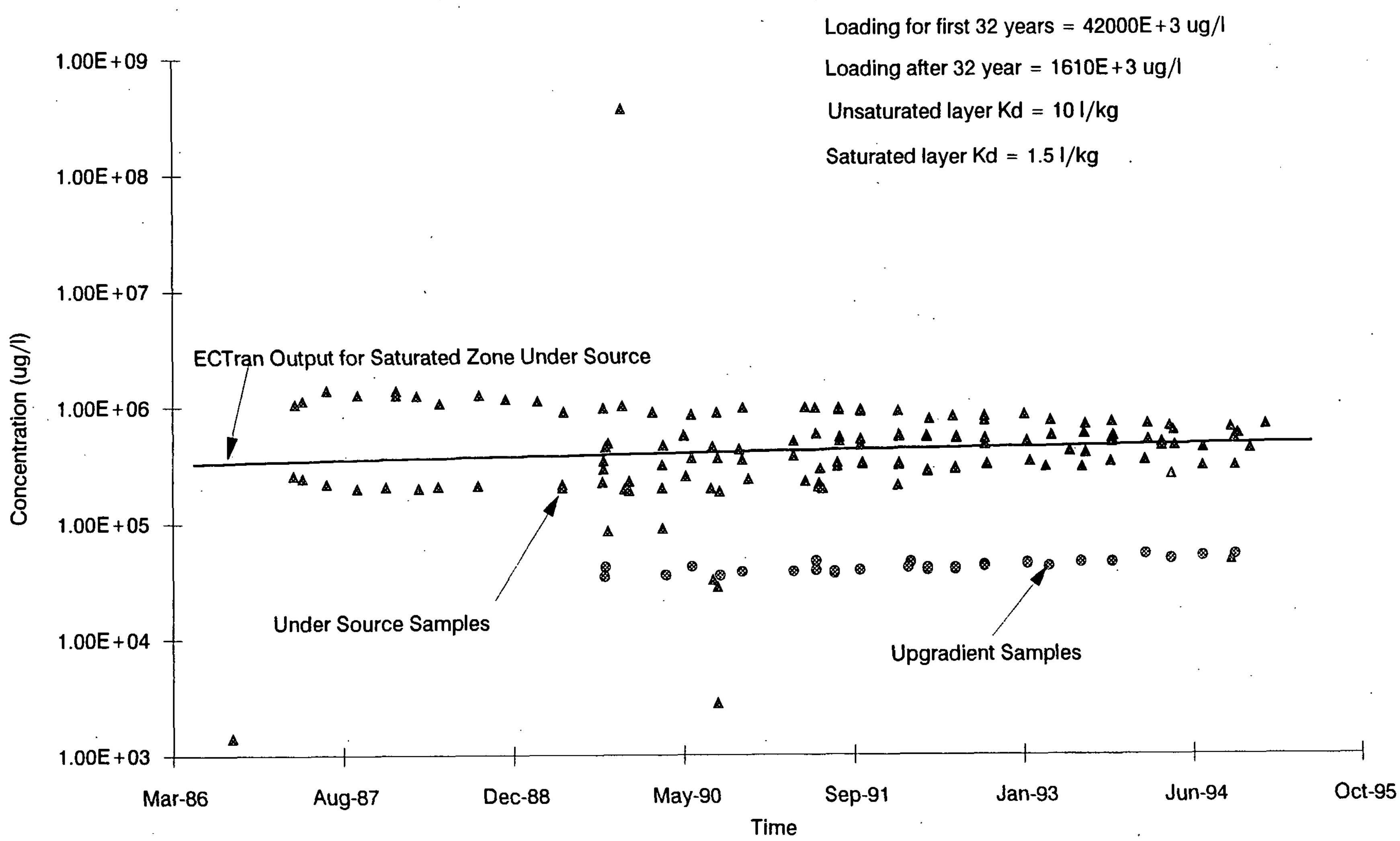
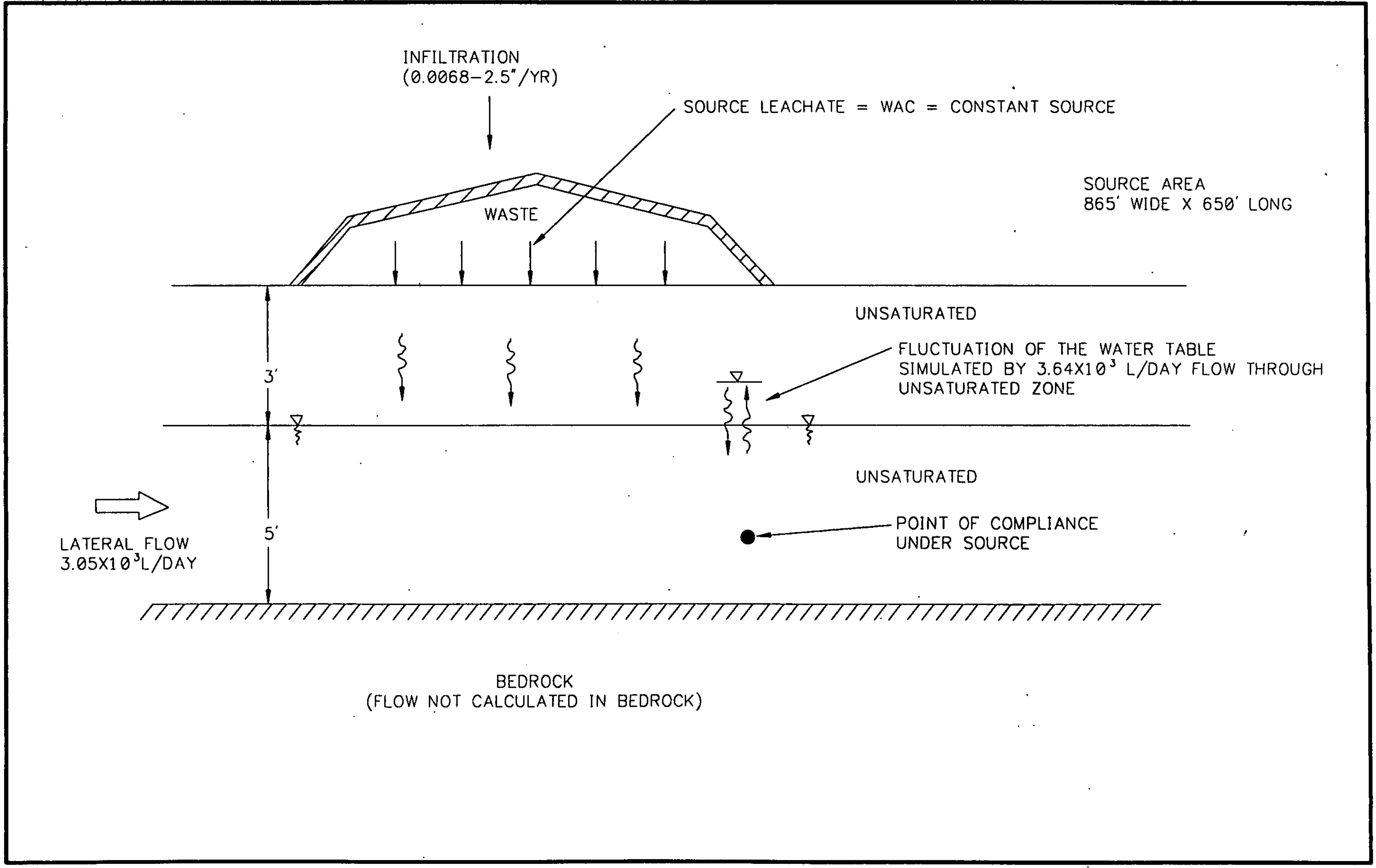


FIGURE B-19 SODIUM CALIBRATION RESULTS

ACAD: O:\DATA\CADD\3A75\95040302.DWG 04/03/95 VB VIEW=1B

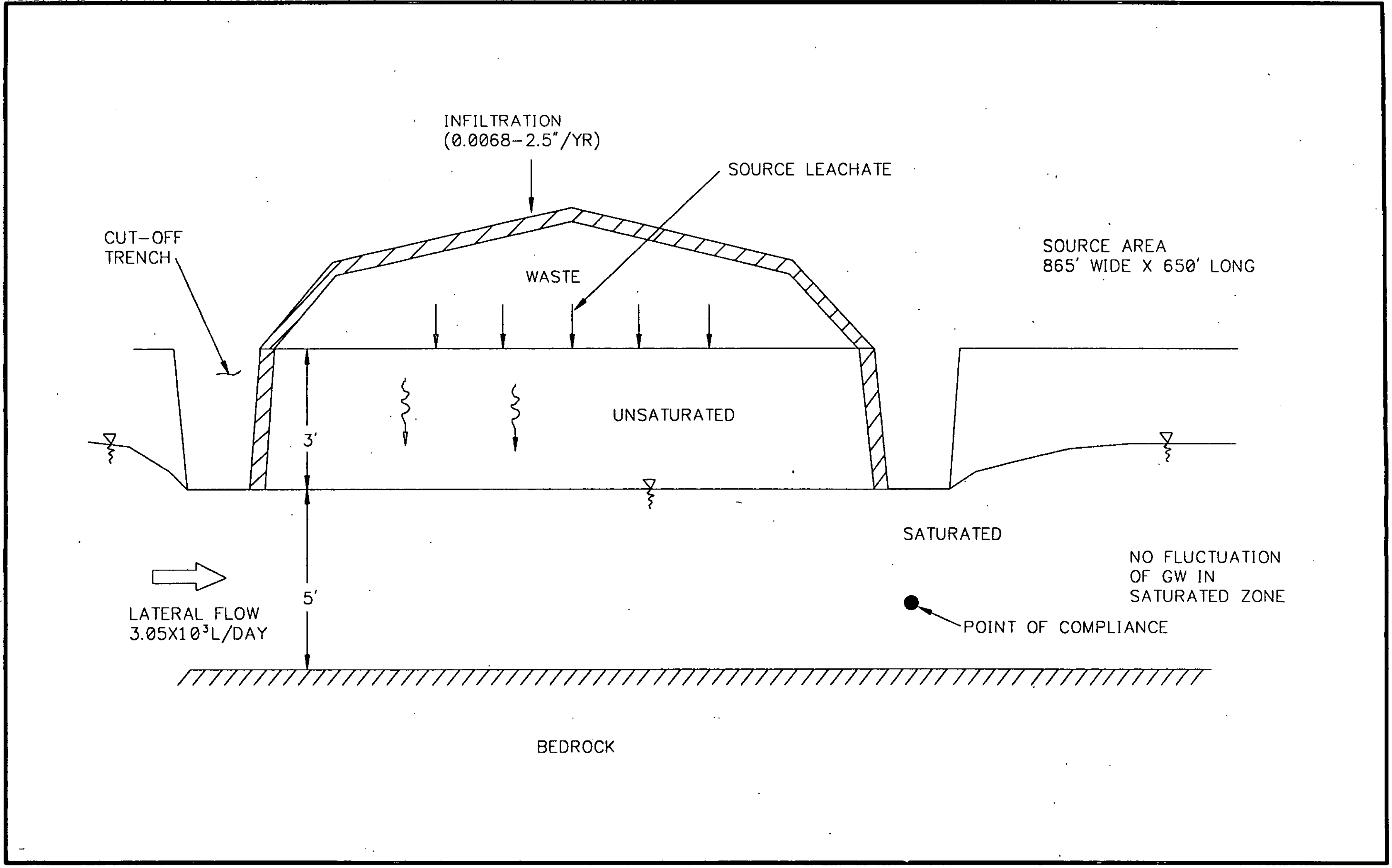


SCENARIO 1 – CONCEPTUAL MODEL
ROCKY FLATS ENVIRONMENTAL
TECHNOLOGY SITE
GOLDEN, COLORADO

FIGURE B-20

Halliburton NUS CORPORATION

ACAD: O:\DATA\CADD\3A75\95040302.DWG 04/03/95 VB VIEW=2A

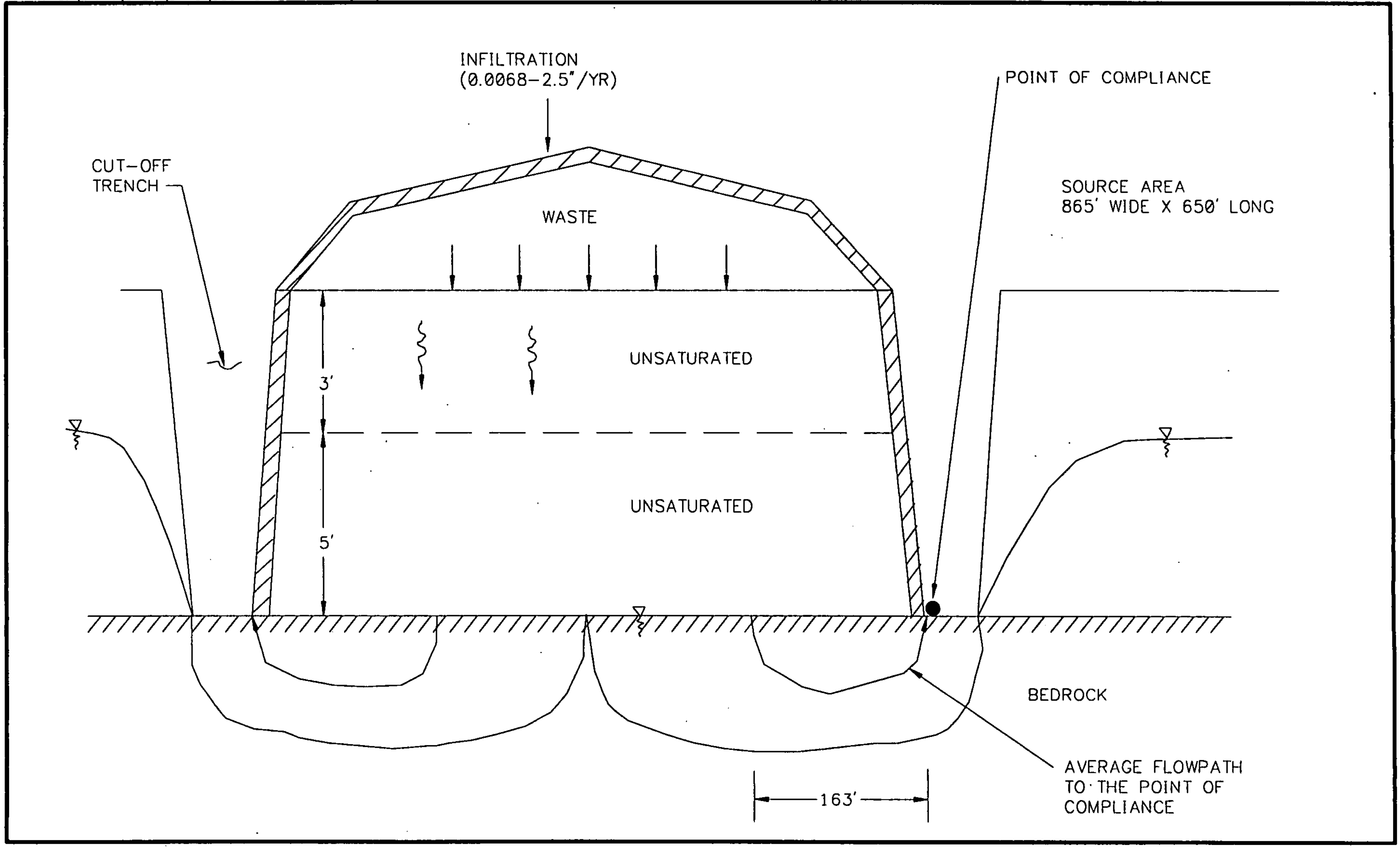


SCENARIO 2 – CONCEPTUAL MODEL
ROCKY FLATS ENVIRONMENTAL
TECHNOLOGY SITE
GOLDEN, COLORADO

FIGURE B-21

Halliburton NUS CORPORATION

ACAD: O:\DATA\CADD\3A75\95040302.DWG 04/03/95 VB VIEW=3B



SCENARIO 3 - CONCEPTUAL MODEL
ROCKY FLATS ENVIRONMENTAL
TECHNOLOGY SITE
GOLDEN, COLORADO

FIGURE B-22

Halliburton NUS CORPORATION

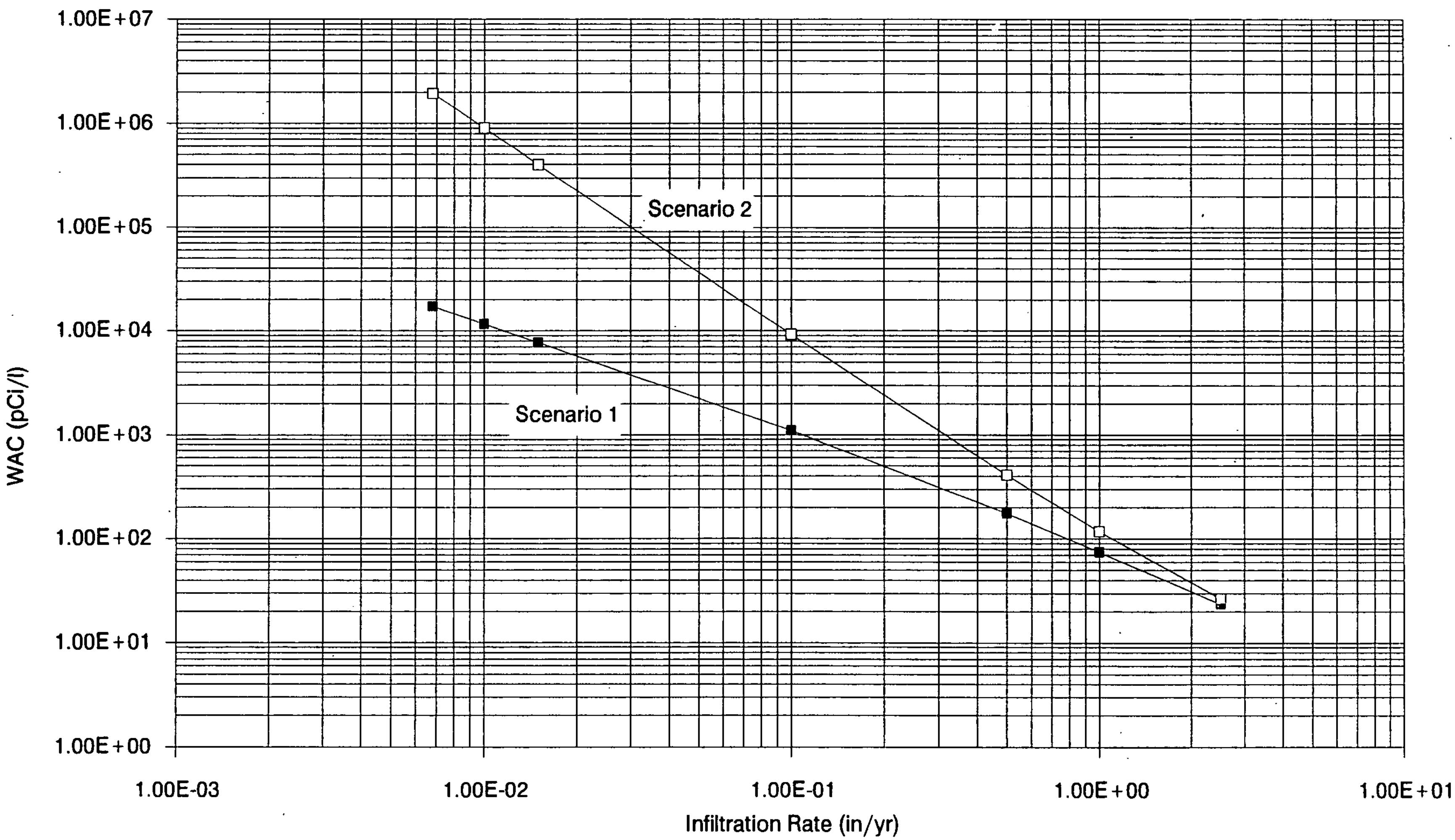


FIGURE B-23 AMERICIUM-241 WAC RESULTS

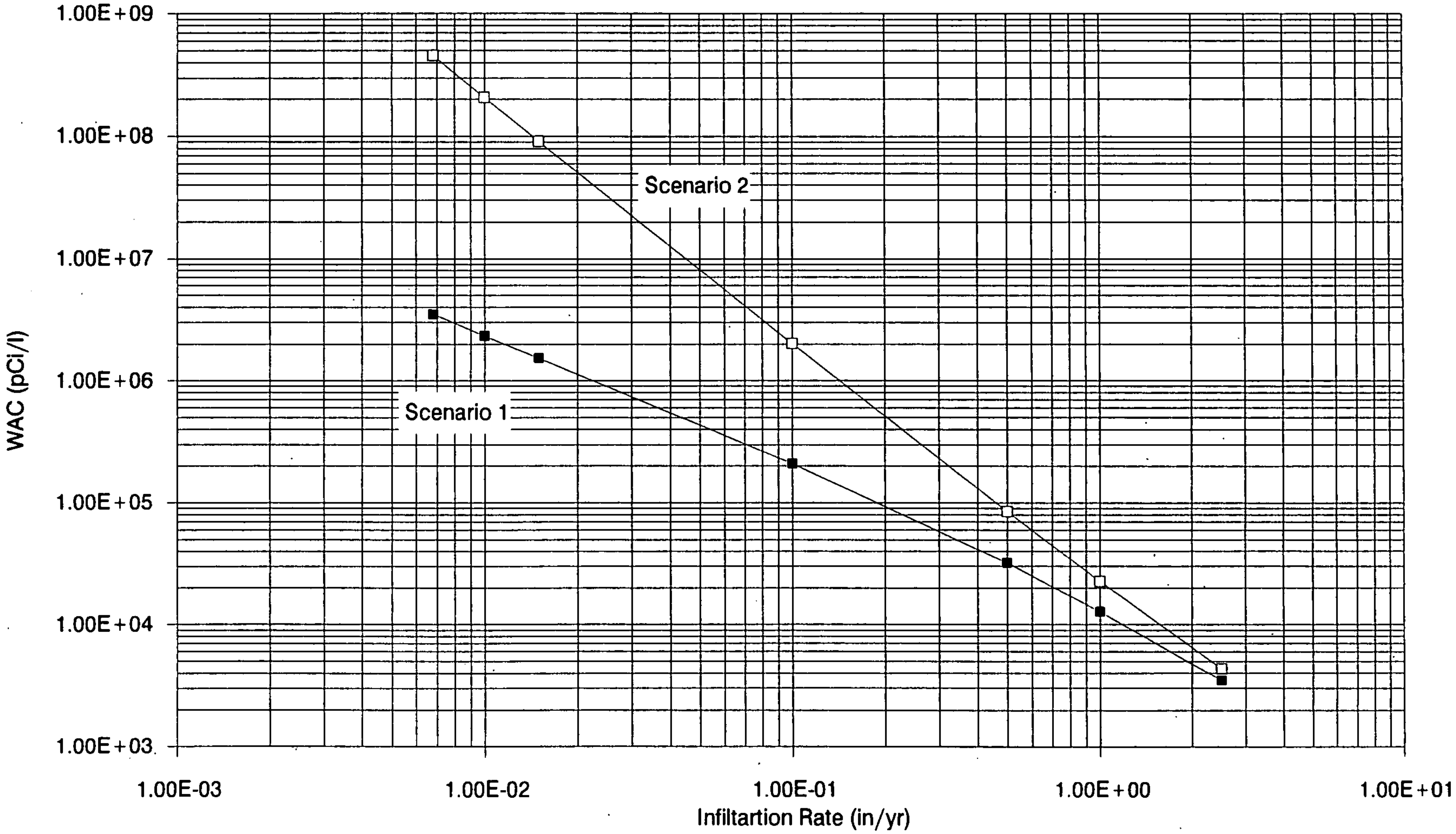


FIGURE B-24 CESIUM-134 WAC RESULTS

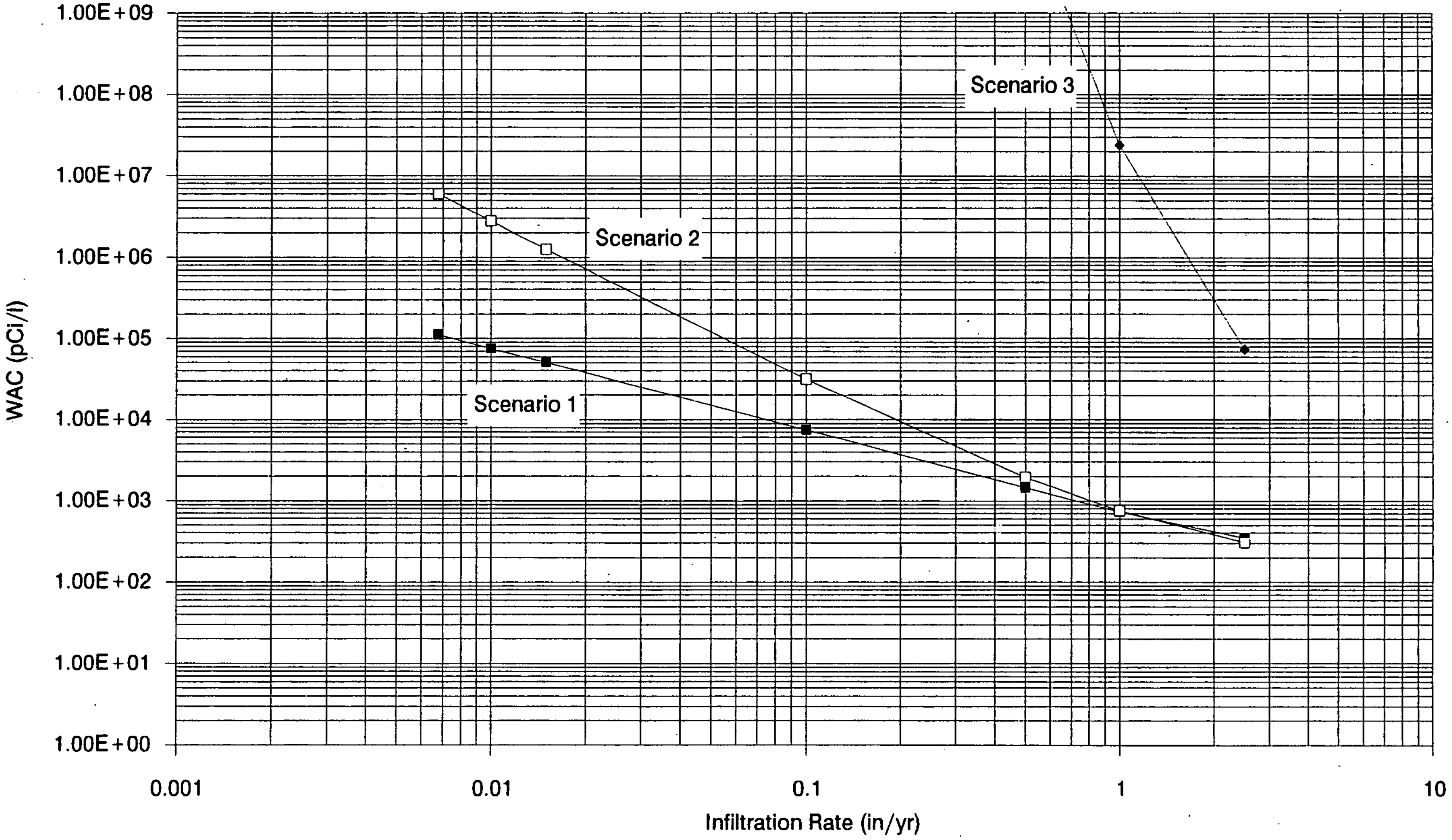


FIGURE B-25 CESIUM-137 WAC RESULTS

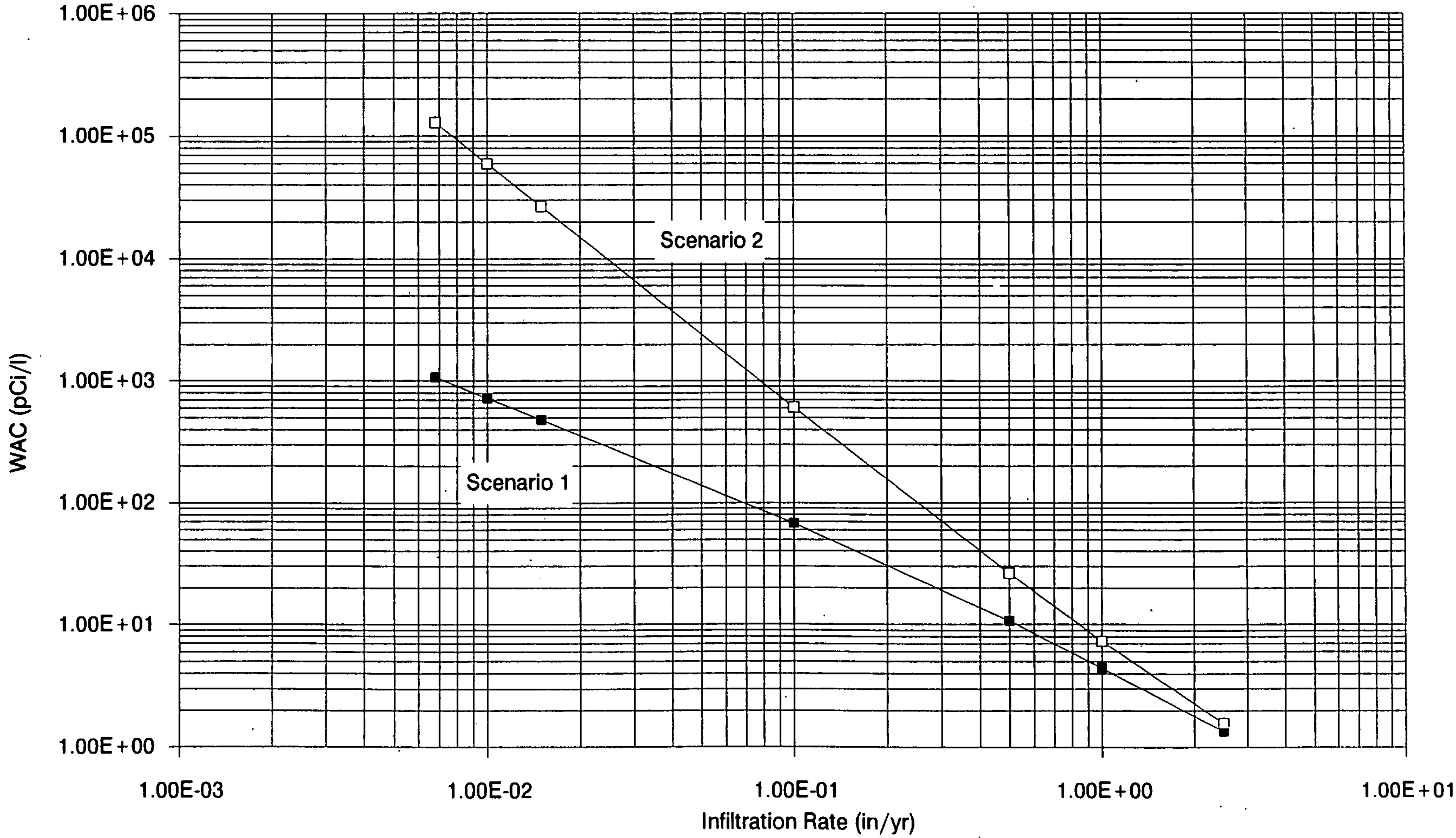


FIGURE B-26 PLUTONIUM-239/240 WAC RESULTS

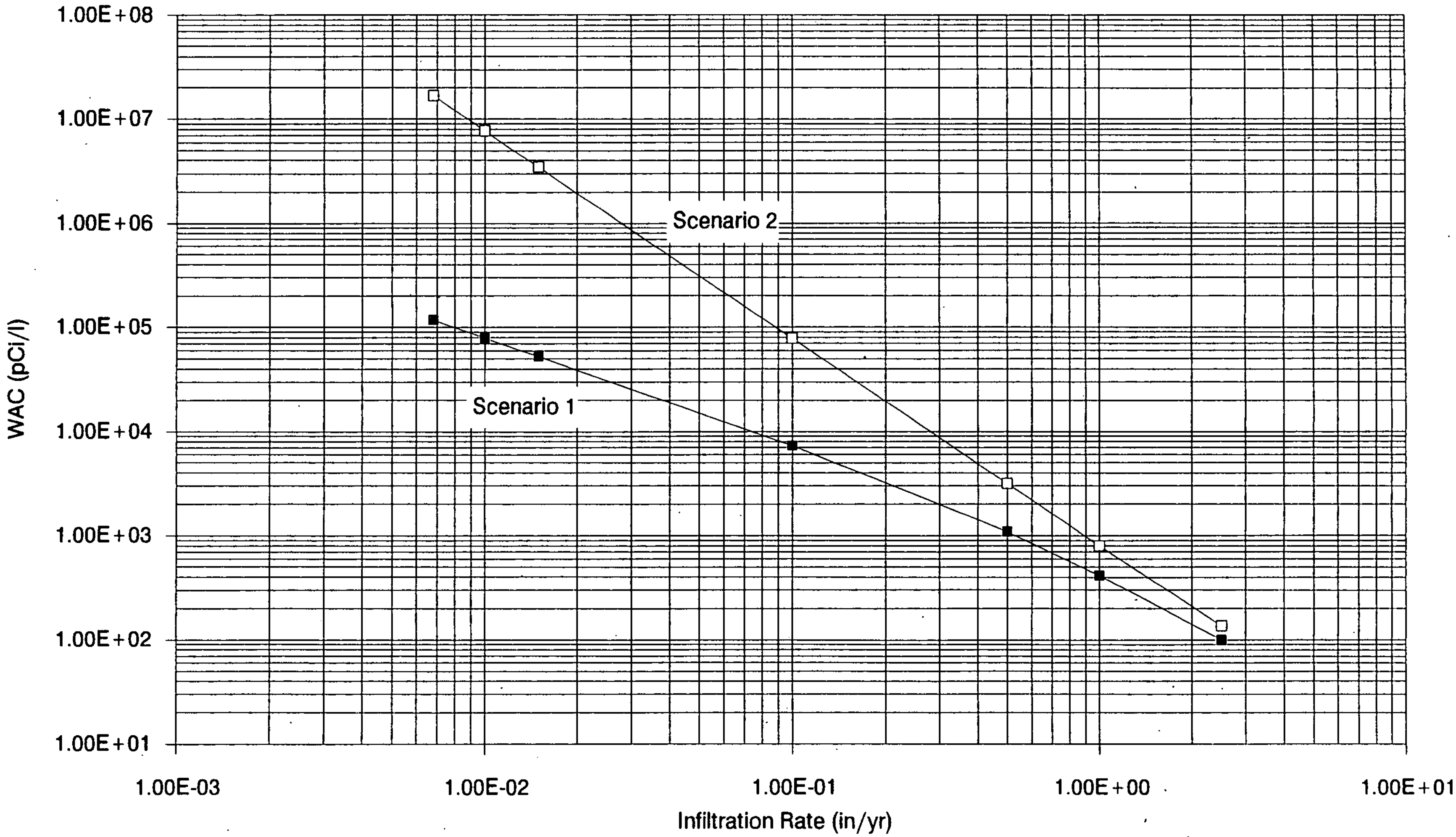


FIGURE B-27 RADIUM-226 WAC RESULTS

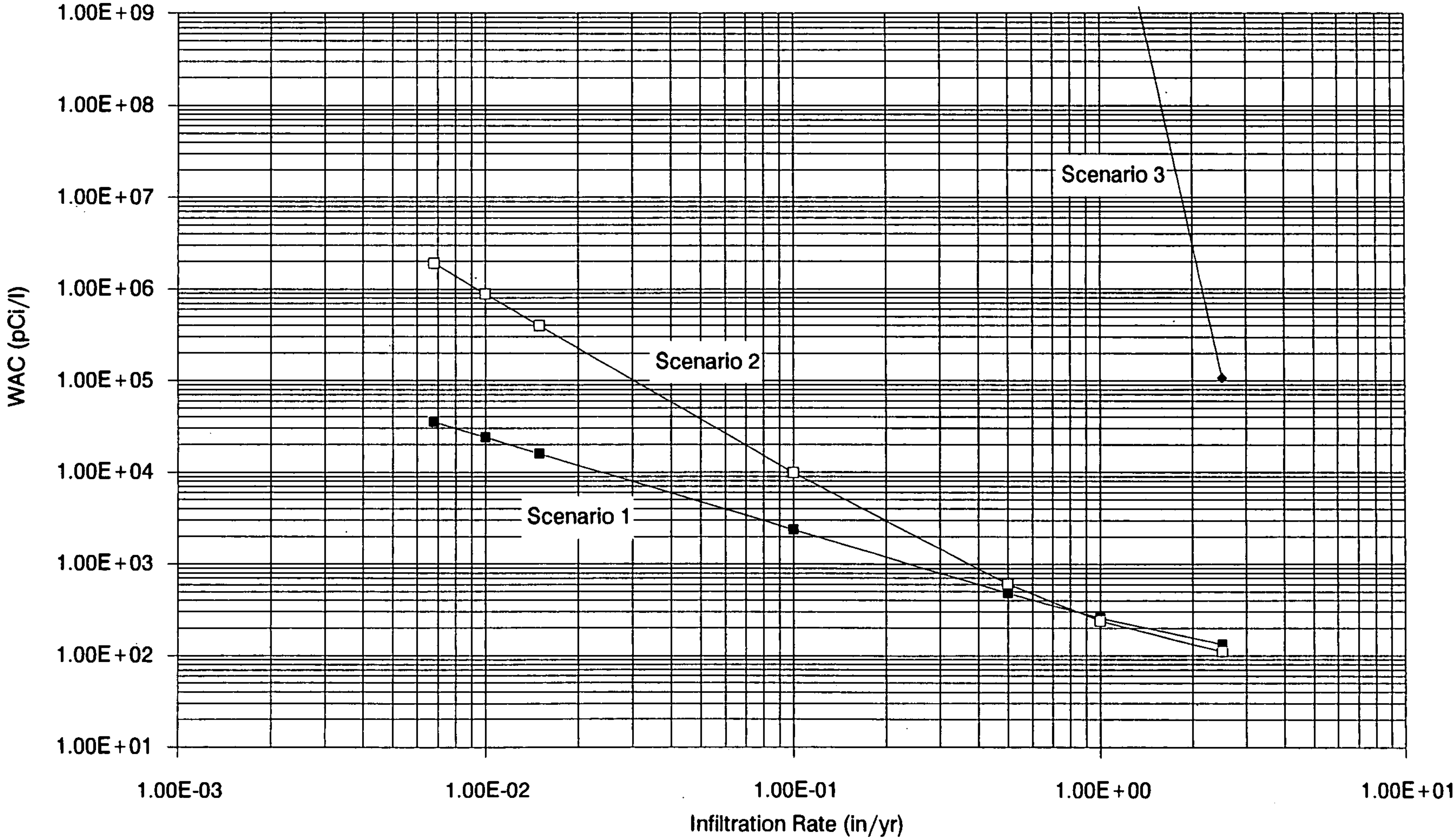


FIGURE B-28 URANIUM-233/234 WAC RESULTS

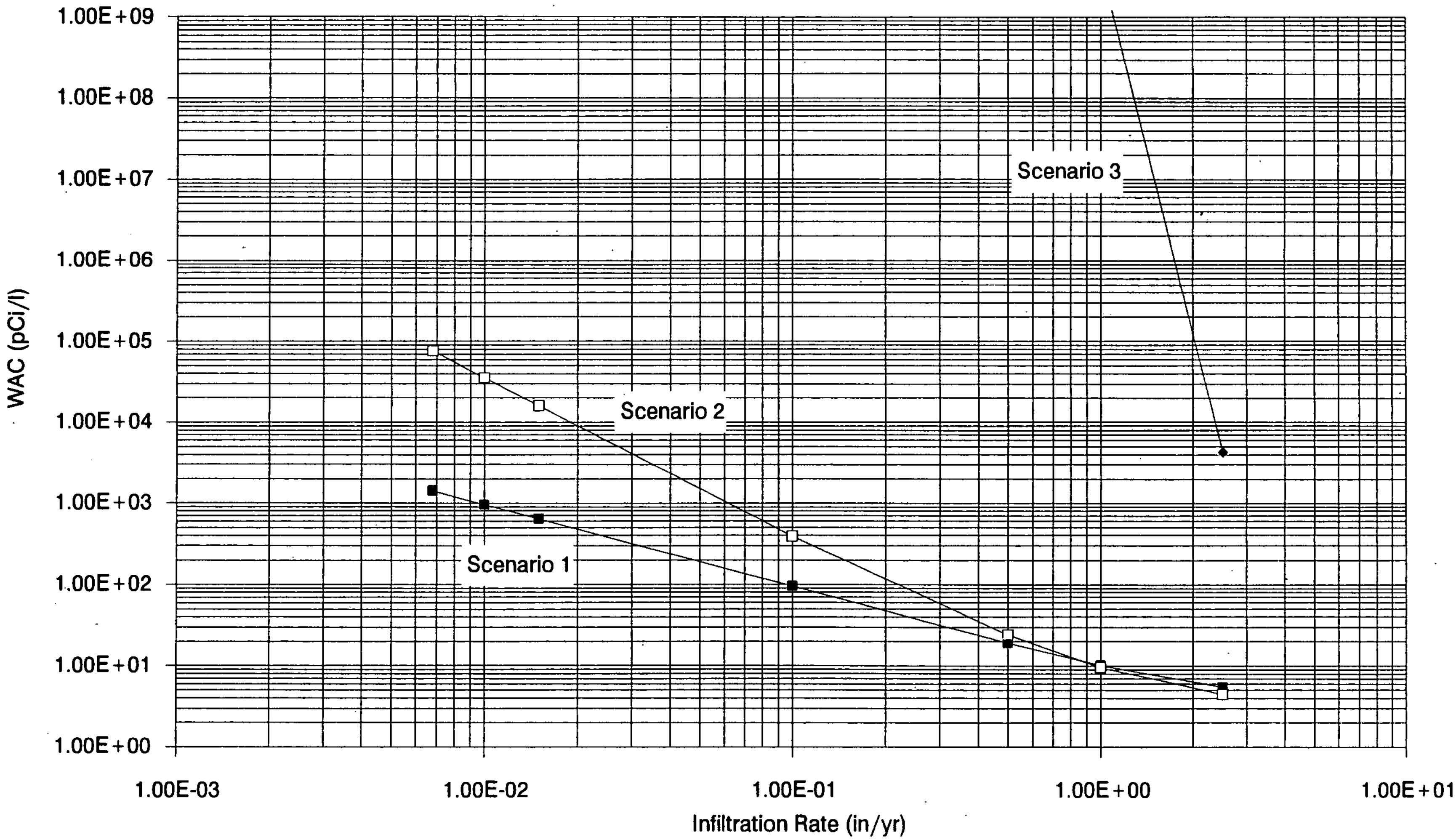


FIGURE B-29 URANIUM-235 WAC RESULTS

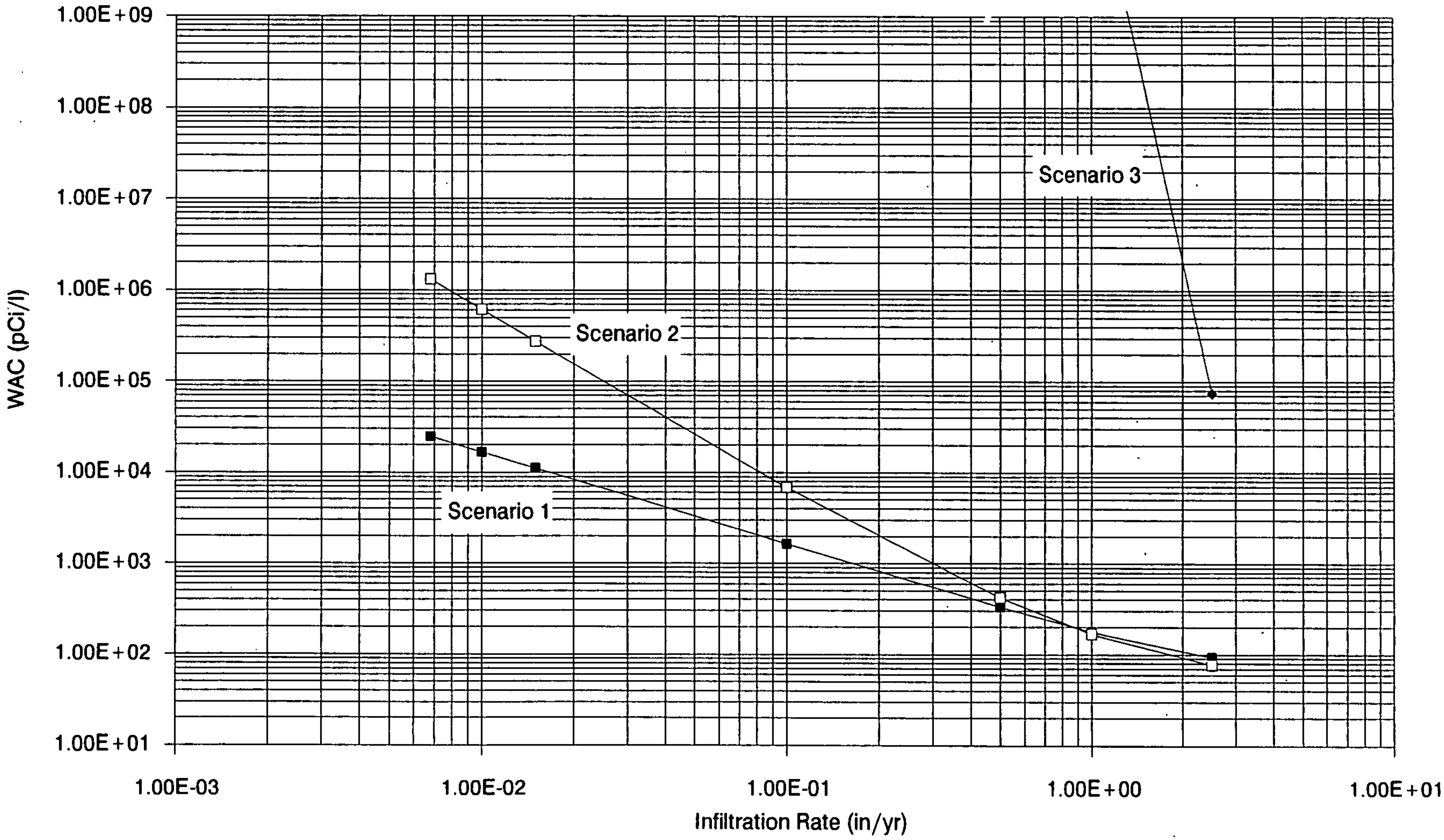


FIGURE B-30 URANIUM-238 WAC RESULTS

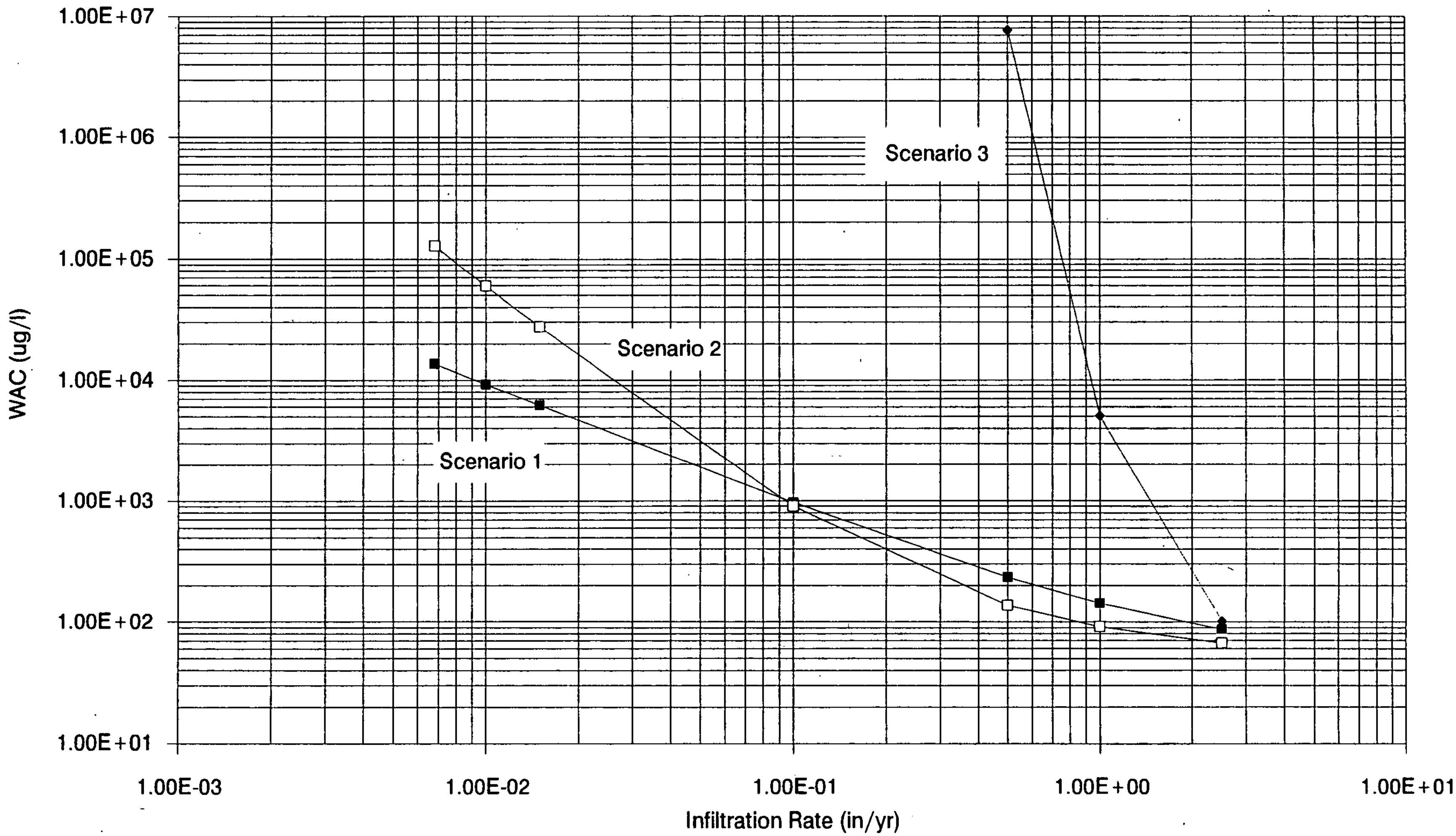


FIGURE B-31 ARSENIC WAC RESULTS

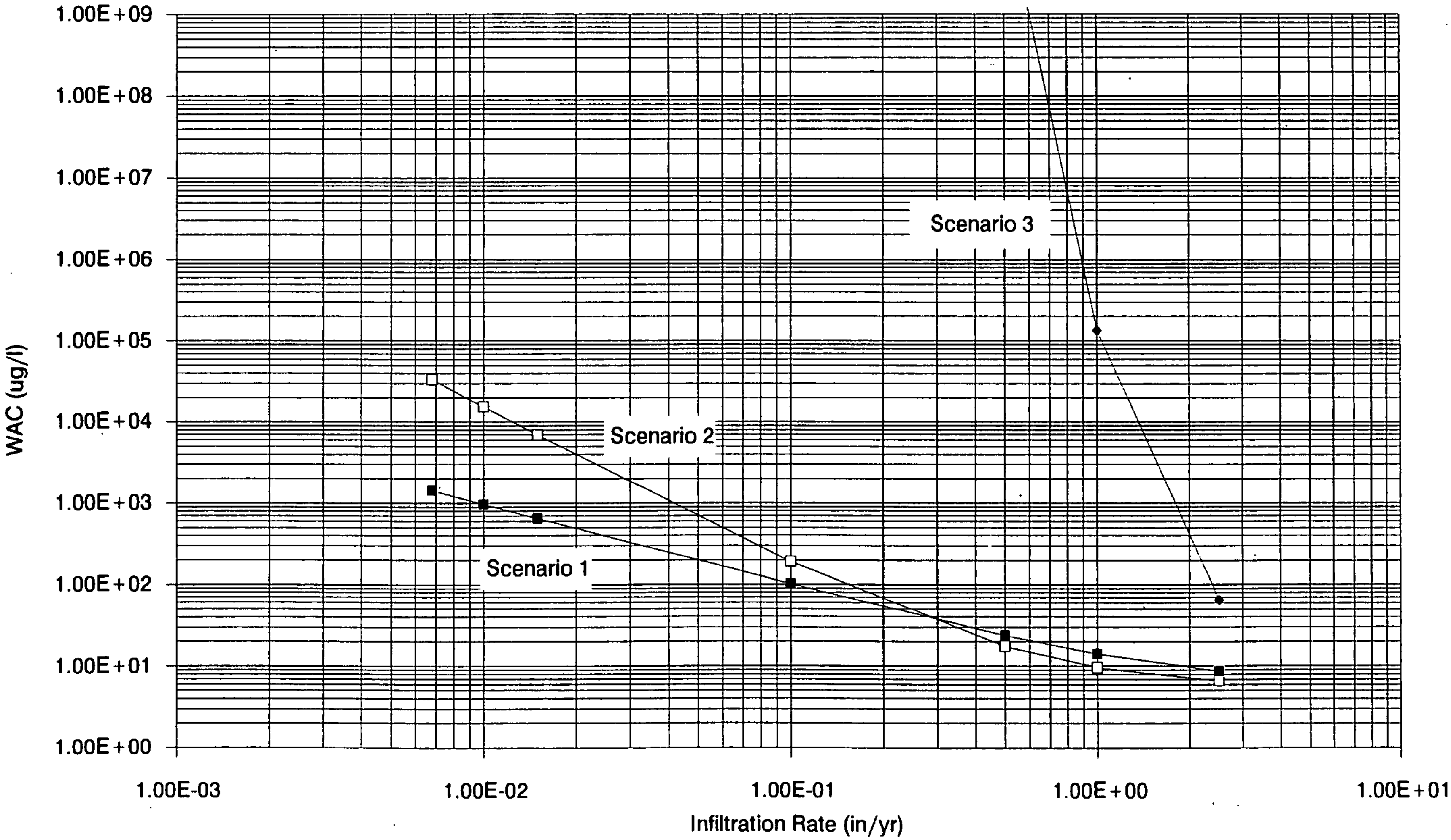


FIGURE B-32 BERYLLIUM WAC RESULTS

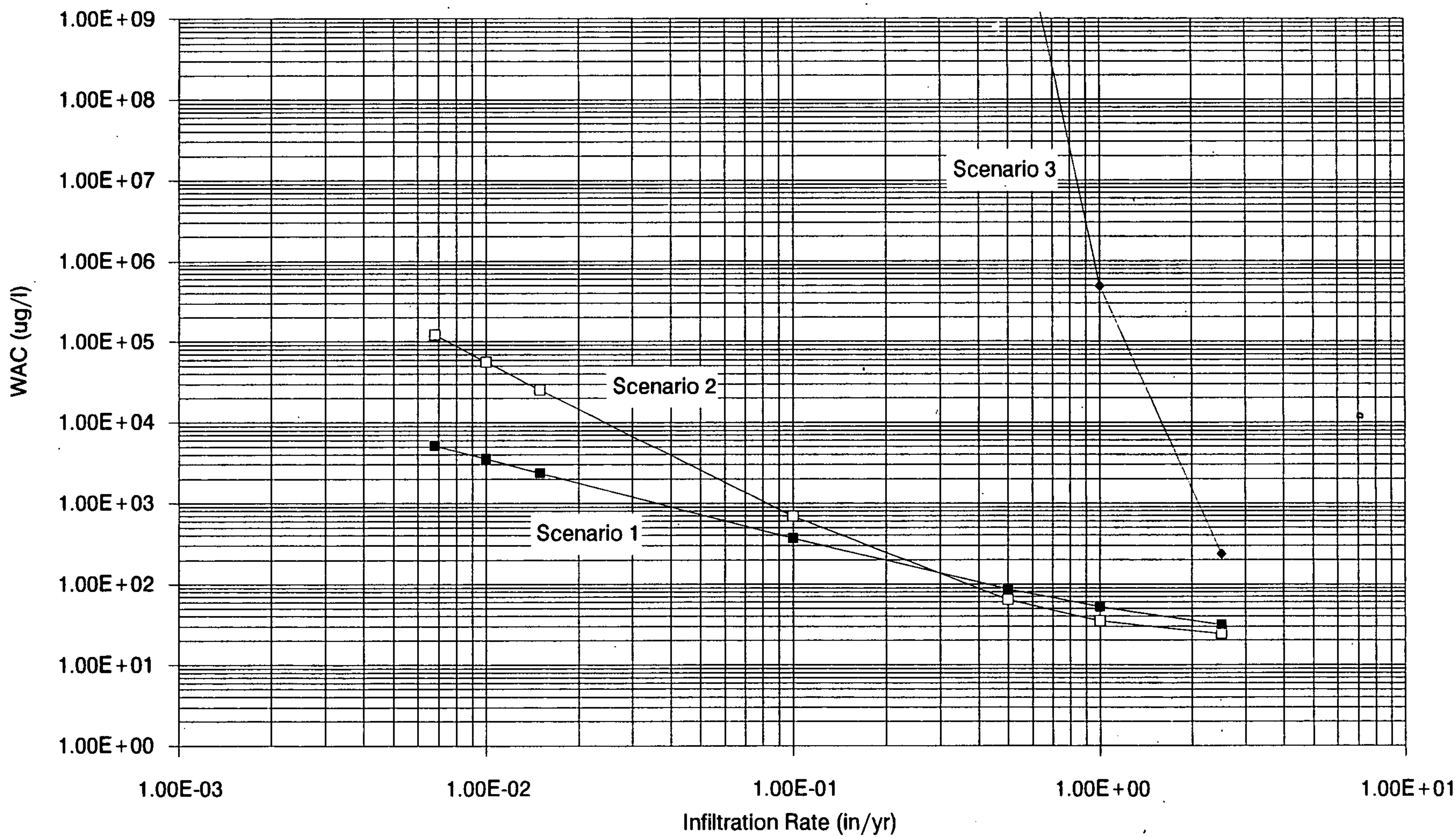


FIGURE B-33 CADMIUM WAC RESULTS

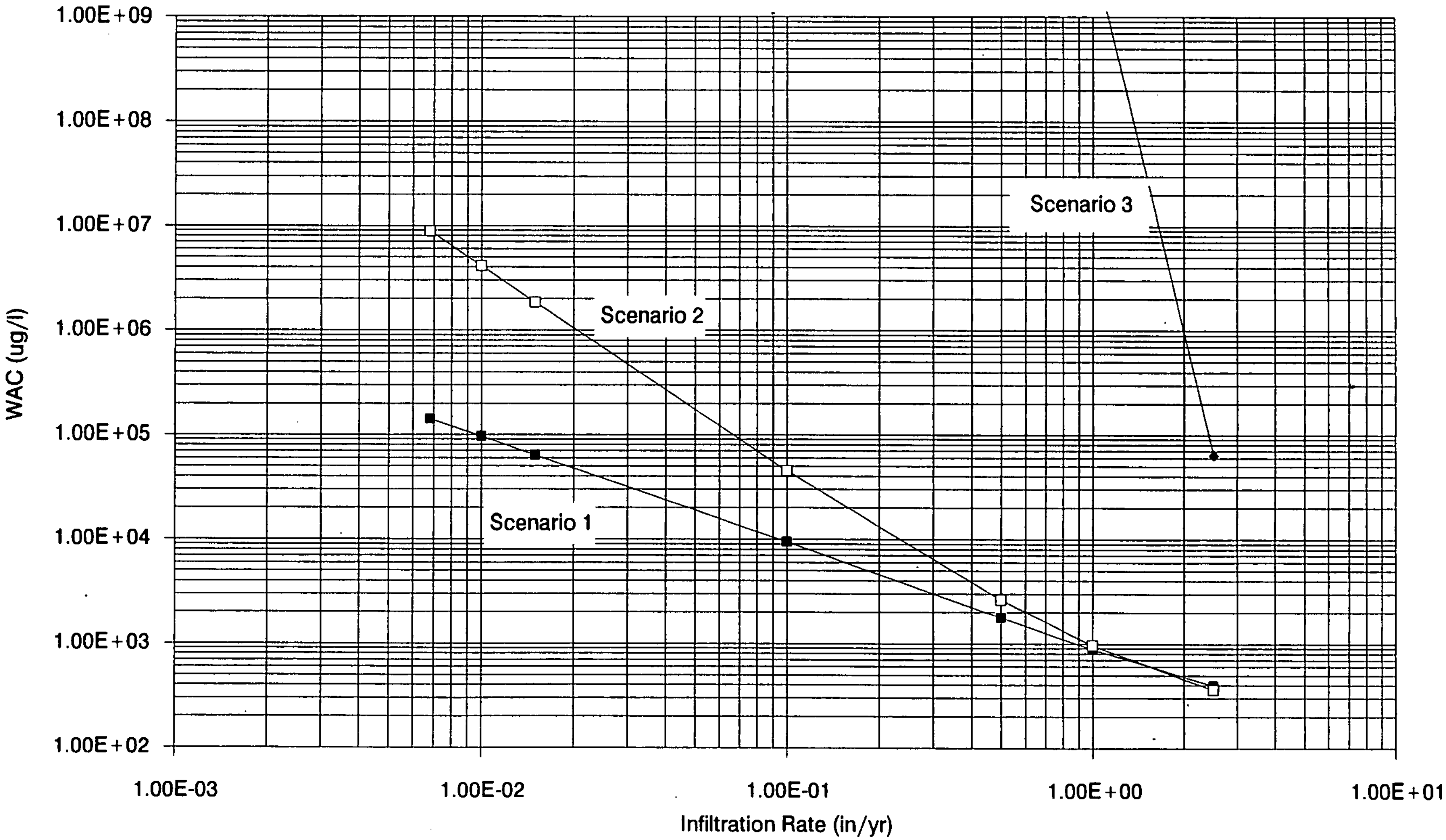


FIGURE B-34 CHROMIUM WAC RESULTS

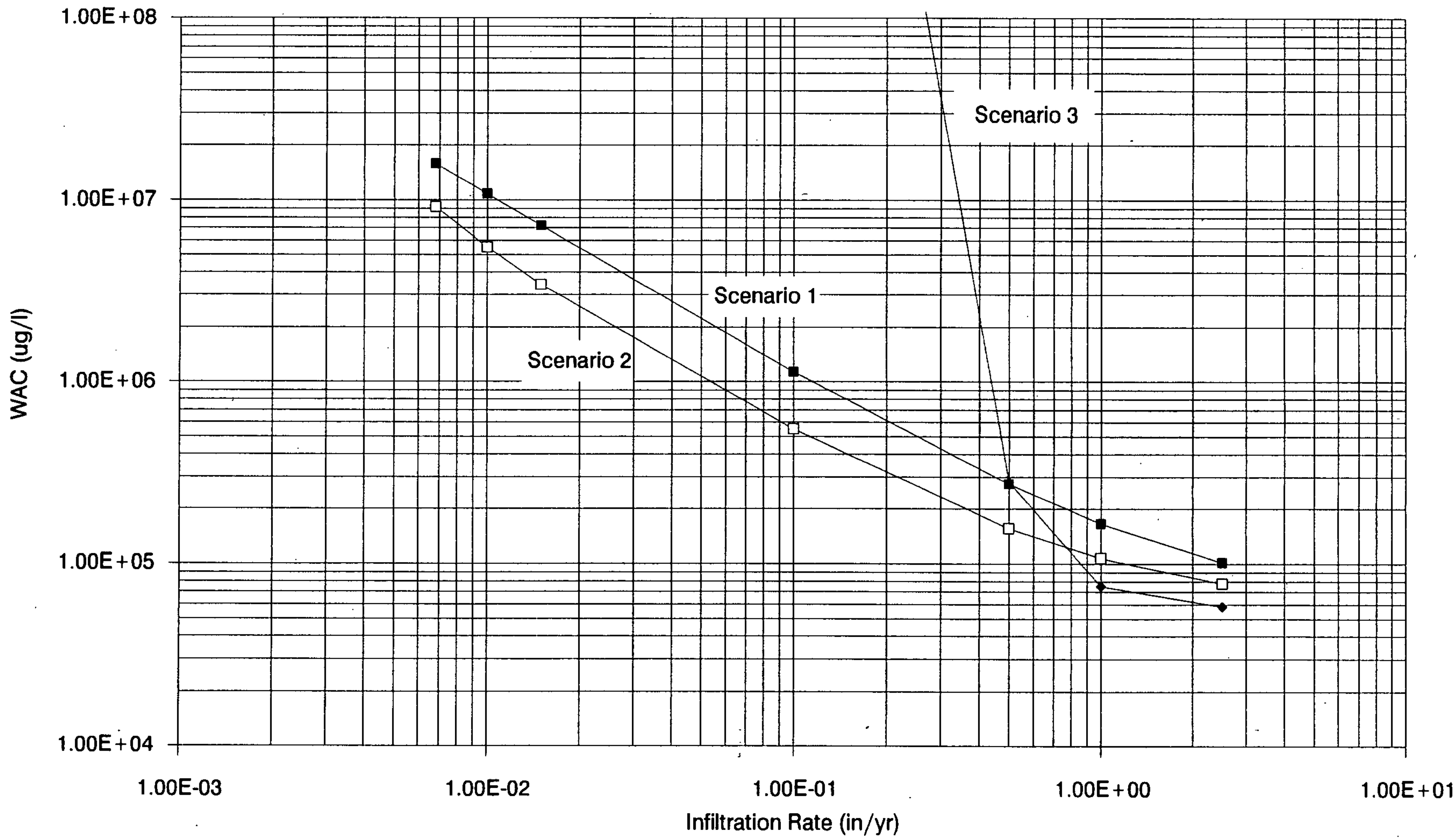


FIGURE B-35 NITRATE WAC RESULTS

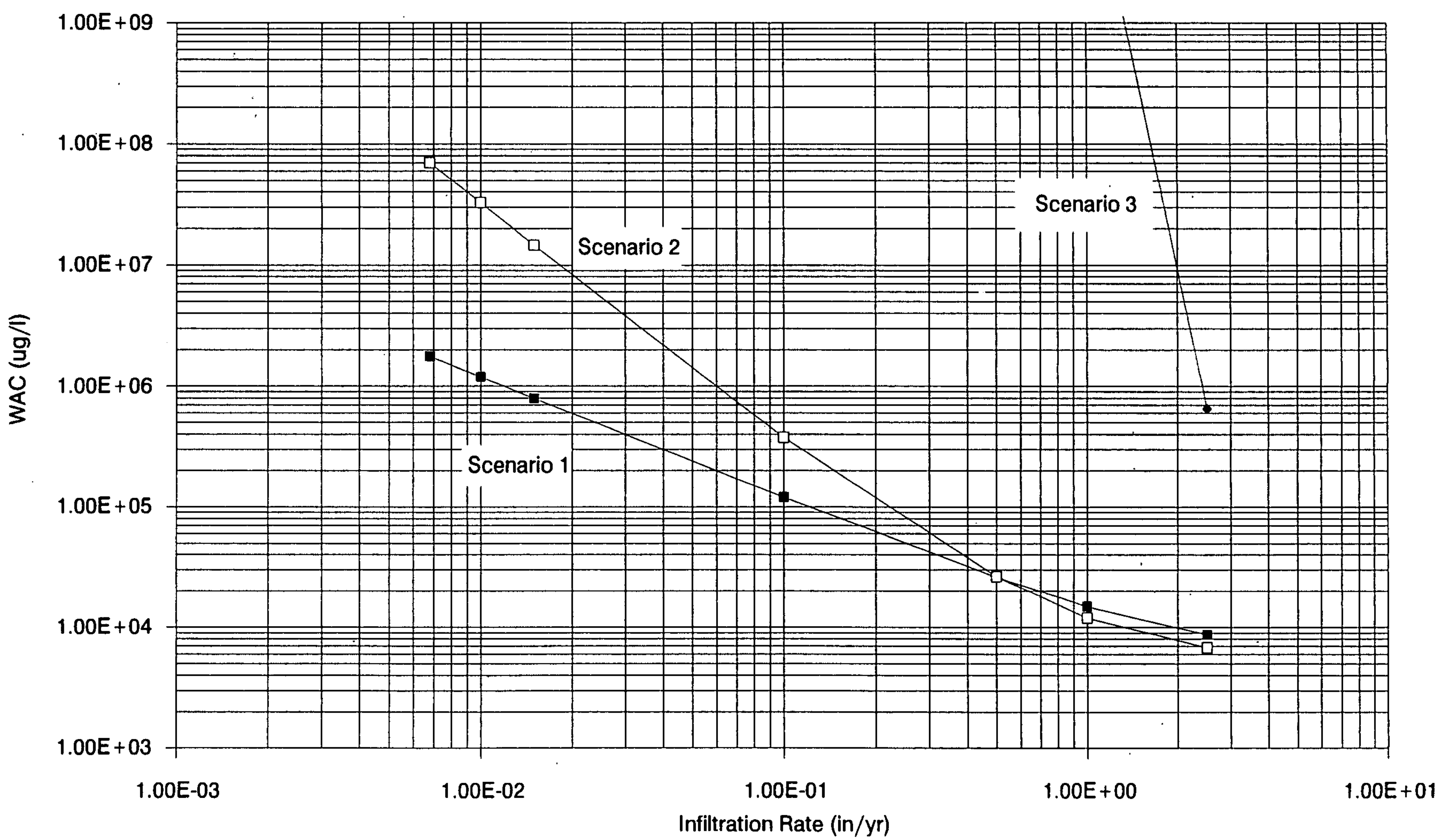


FIGURE B-36 SODIUM WAC RESULTS

NOTICE

All drawings located at the end of the document.

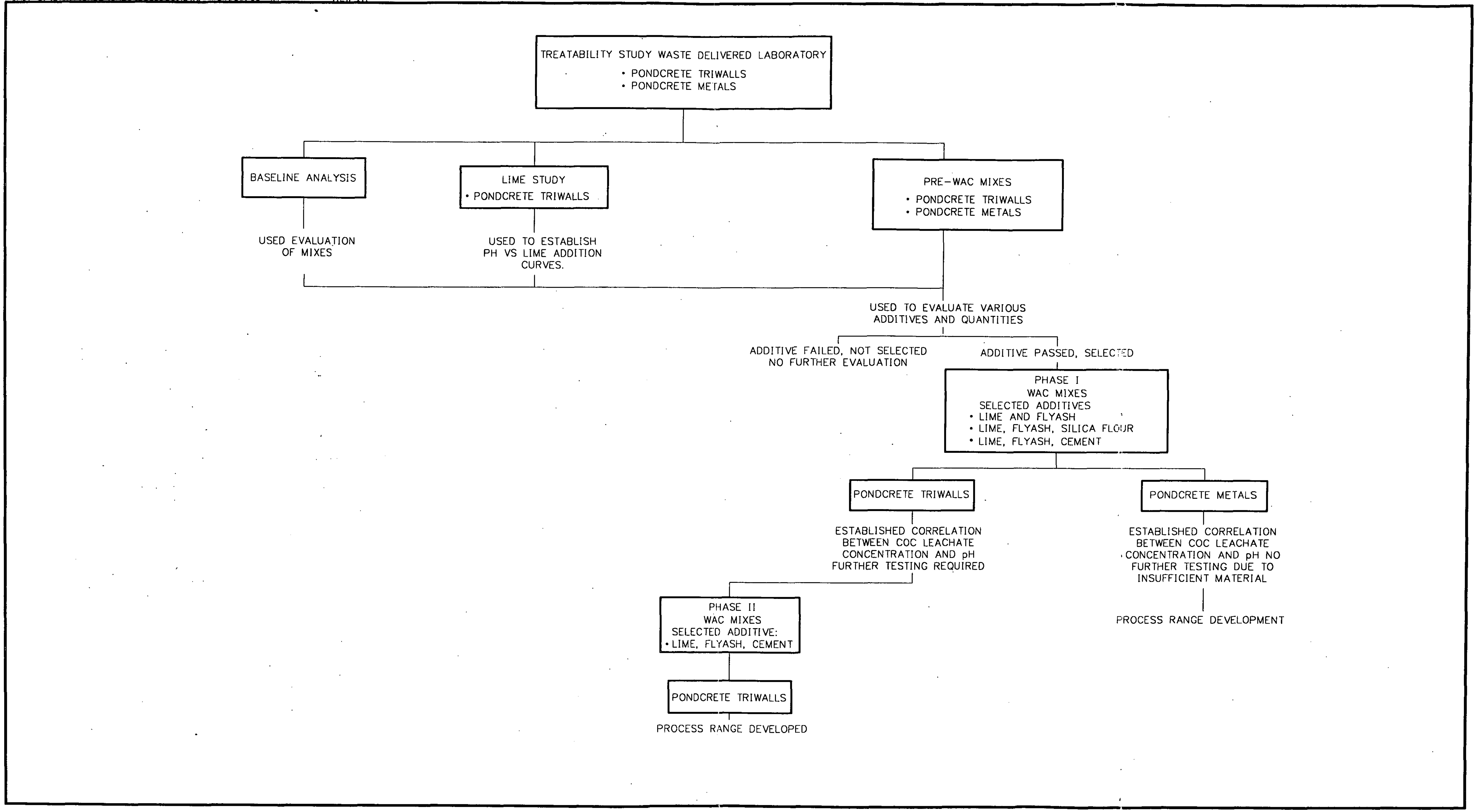
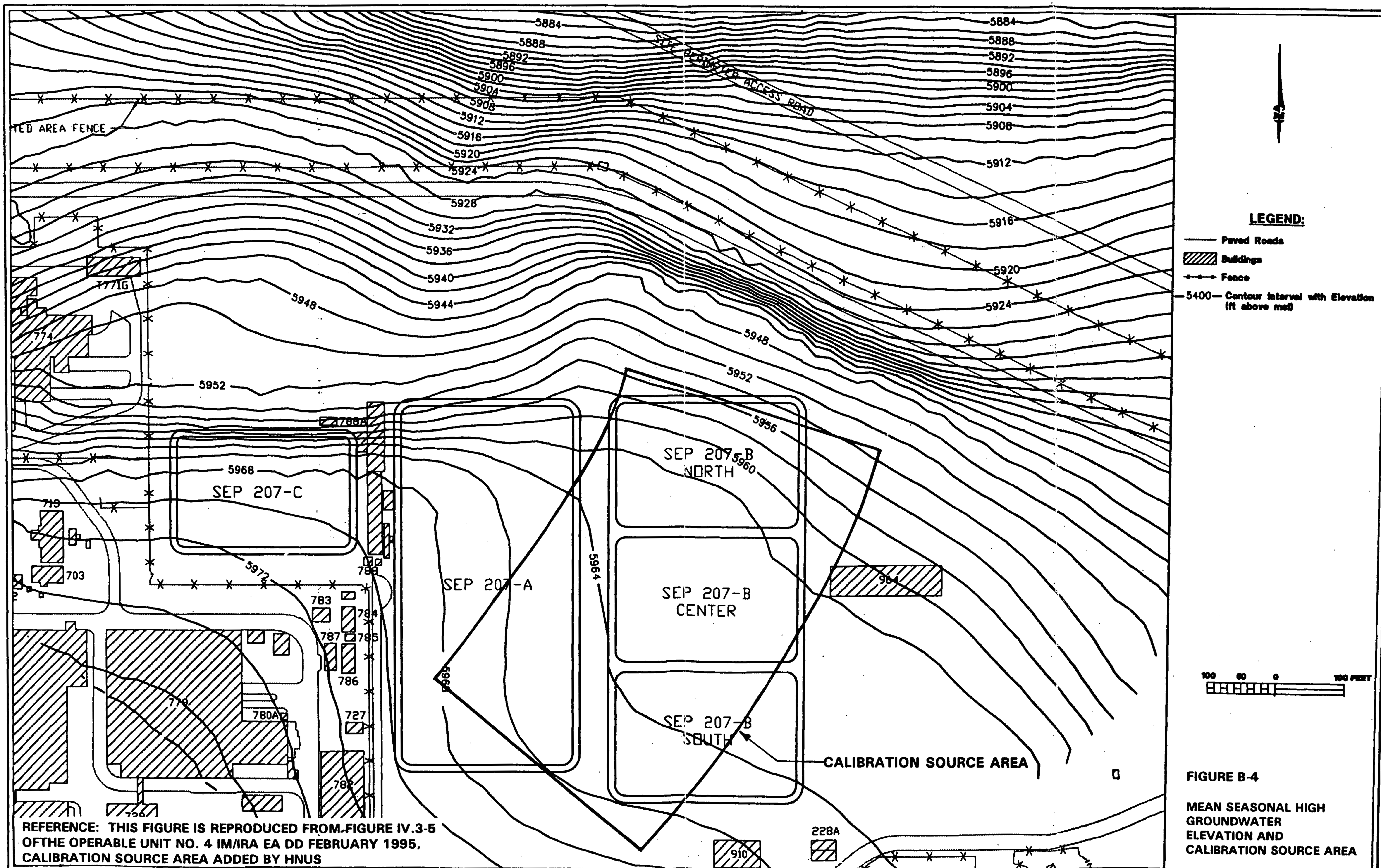


FIGURE 2-1

PONDCRETE TREATABILITY STUDY LOGIC DIAGRAM
ROCKY FLATS, GOLDEN, COLORADO



REFERENCE: THIS FIGURE IS REPRODUCED FROM FIGURE IV.3-5 OFTHE OPERABLE UNIT NO. 4 IM/IRA EA DD FEBRUARY 1995, CALIBRATION SOURCE AREA ADDED BY HNUS

FIGURE B-4

MEAN SEASONAL HIGH GROUNDWATER ELEVATION AND CALIBRATION SOURCE AREA