

Final Environmental Impact Statement

**REMEDIAL ACTIONS AT THE FORMER
VITRO CHEMICAL COMPANY SITE
SOUTH SALT LAKE, SALT LAKE COUNTY
UTAH**

VOLUME II - APPENDICES



July, 1984

U.S. DEPARTMENT OF ENERGY

Final Environmental Impact Statement

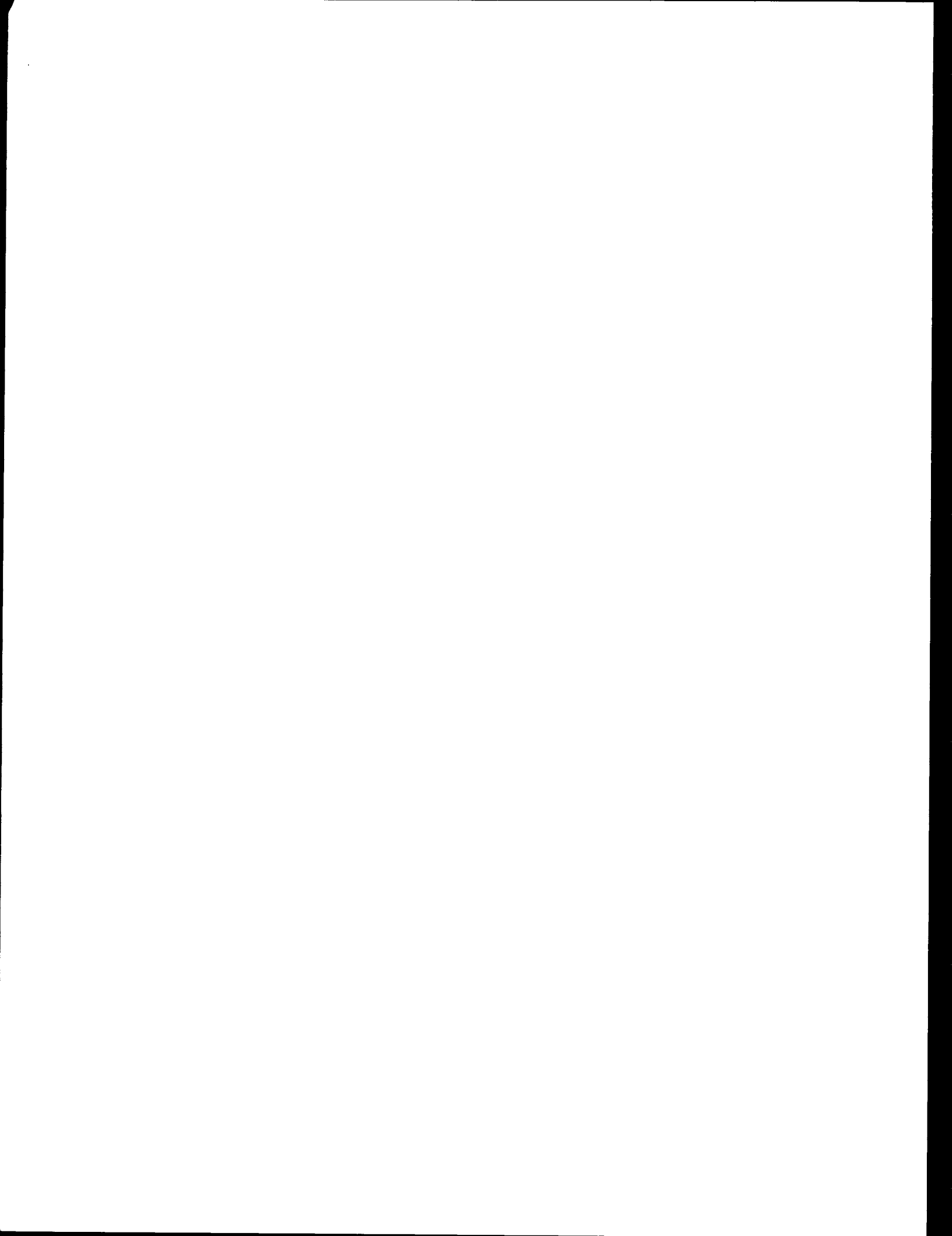
**REMEDIAL ACTIONS AT THE FORMER
VITRO CHEMICAL COMPANY SITE
SOUTH SALT LAKE, SALT LAKE COUNTY
UTAH**

VOLUME II - APPENDICES



July, 1984

U.S. DEPARTMENT OF ENERGY



Appendix A

Site Conceptual Design

Table of Contents

	<u>Page</u>
A.1 Introduction.....	A-1
A.1.1 Purpose.....	A-1
A.1.2 Design objectives.....	A-1
A.2 Stabilization on the Vitro site (Alternative 2).....	A-3
A.2.1 Major elements of the design.....	A-3
A.2.2 Description of final condition.....	A-5
A.3 Design features - Vitro site (Alternative 2).....	A-7
A.3.1 Introduction.....	A-7
A.3.2 Design considerations.....	A-9
A.3.2.1 Cover design.....	A-9
A.3.2.2 Long-term stability.....	A-12
A.4 Construction sequence - Vitro site (Alternative 2).....	A-15
A.4.1 Site preparation.....	A-15
A.4.1.1 Mobilization.....	A-15
A.4.1.2 Clearing.....	A-15
A.4.1.3 Storm drainage.....	A-15
A.4.1.4 Sedimentation basins.....	A-15
A.4.1.5 Waste-water treatment.....	A-16
A.4.2 Fugitive dust control.....	A-16
A.4.3 Demolition.....	A-16
A.4.4 Preloading (see note to Table A-1).....	A-17
A.4.5 Liner system construction.....	A-17
A.4.6 Embankment construction.....	A-17
A.4.7 Restoration.....	A-18
A.4.8 Existing utilities.....	A-18
A.4.9 Revegetation.....	A-18
A.4.10 Fencing.....	A-18
A.4.11 Temporary facilities.....	A-18
A.4.11.1 Security.....	A-18
A.4.11.2 Water supply.....	A-18
A.4.11.3 Waste water.....	A-19
A.4.11.4 Transportation.....	A-19
A.4.12 Borrow area.....	A-19
A.5 Relocation to South Clive (Alternative 3) - proposed action.....	A-21
A.5.1 Major elements of the design.....	A-21
A.5.1.1 Train transportation.....	A-21
A.5.1.2 Truck transportation.....	A-23
A.5.2 Description of final condition.....	A-24
A.6 Design features - South Clive (Alternative 3).....	A-27
A.6.1 Introduction.....	A-27
A.6.2 Design considerations.....	A-27
A.6.2.1 Cover.....	A-27
A.6.2.2 Long-term stability.....	A-31
A.7 Construction sequence - South Clive (Alternative 3).....	A-33
A.7.1 Vitro site work.....	A-33
A.7.1.1 Mobilization.....	A-33
A.7.1.2 Clearing.....	A-33
A.7.1.3 Erosion and sediment controls.....	A-33
A.7.1.4 Storm drainage and waste-water sedimentation basins.....	A-33
A.7.1.5 Dewatering.....	A-35

Table of Contents (continued)

	<u>Page</u>
A.7.1.6 Waste-water treatment.....	A-35
A.7.1.7 Fugitive dust control.....	A-35
A.7.1.8 Demolition.....	A-35
A.7.1.9 Railroad construction (train transport mode)....	A-35
A.7.1.10 Excavation and loading.....	A-36
A.7.1.11 Transportation.....	A-36
A.7.1.12 Restoration.....	A-37
A.7.1.13 Existing utilities.....	A-37
A.7.1.14 Temporary facilities.....	A-37
A.7.2 South Clive site work.....	A-38
A.7.2.1 Mobilization.....	A-38
A.7.2.2 Clearing.....	A-38
A.7.2.3 Erosion and sediment controls.....	A-38
A.7.2.4 Storm drainage and waste-water retention basins.....	A-38
A.7.2.5 Fugitive dust control.....	A-38
A.7.2.6 Roads.....	A-38
A.7.2.7 Rail car unloading (train transport mode).....	A-39
A.7.2.8 Embankment construction.....	A-39
A.7.2.9 Cover construction.....	A-39
A.7.2.10 Restoration.....	A-40
A.7.2.11 Fencing.....	A-40
A.7.2.12 Temporary facilities.....	A-40
A.8 Equipment, personnel, energy consumption, and fuel estimates, Alternatives 2 and 3.....	A-41
A.8.1 Vitro site - introduction.....	A-41
A.8.1.1 Site preparation.....	A-41
A.8.1.2 Tailings relocation.....	A-41
A.8.1.3 Liner system placement.....	A-42
A.8.1.4 Tailings consolidation.....	A-42
A.8.1.5 Cover installation.....	A-43
A.8.1.6 Site restoration.....	A-43
A.8.1.7 Summary of personnel, energy consumption, and fuel estimates.....	A-44
A.8.2 South Clive site - introduction.....	A-44
A.8.2.1 Site preparation - train option.....	A-44
A.8.2.2 Site preparation - truck option.....	A-47
A.8.2.3 Tailings relocation - train option.....	A-47
A.8.2.4 Tailings relocation - truck option.....	A-48
A.8.2.5 Embankment and cover construction - train option.....	A-48
A.8.2.6 Embankment and cover construction - truck option.....	A-49
A.8.2.7 Site restoration - train option.....	A-49
A.8.2.8 Site restoration - truck option.....	A-50
A.8.2.9 Summary of personnel, energy consumption, and fuel estimates.....	A-50
A.9 Capital cost estimates.....	A-55
A.9.1 Vitro site - Alternative 2.....	A-55
A.9.2 South Clive site - Alternative 3 (proposed action).....	A-59
References for Appendix A.....	A-69

List of Figures

	<u>Page</u>
A-1 Future water reclamation facility and proposed embankment area, South Salt Lake site.....	A-4
A-2 Plot plan showing the stabilized pile, South Salt Lake site.....	A-8
A-3 Typical liner and embankment section, South Salt Lake site.....	A-10
A-4 South Clive vicinity map.....	A-22
A-5 Plot plan for South Clive	A-25
A-6 Restoration of the Vitro site.....	A-26
A-7 Typical section of the embankment, South Clive site.....	A-30
A-8 Plot plan, Vitro site.....	A-34

List of Tables

	<u>Page</u>
A-1 Earthwork volume summary - stabilization on the Vitro site.....	A-7
A-2 Earthwork volume summary - train relocation to South Clive.....	A-28
A-3 Earthwork volume summary - truck relocation to South Clive.....	A-29
A-4 Personnel requirements and exposure type, stabilization in place.....	A-45
A-5 Energy consumption, stabilization in place.....	A-46
A-6 Water consumption, stabilization in place.....	A-46
A-7 Personnel requirements and exposure, train option, relocation to South Clive.....	A-51
A-8 Personnel requirements and exposure, truck option, relocation to South Clive.....	A-52
A-9 Energy consumption, train option.....	A-53
A-10 Energy consumption, truck option.....	A-53
A-11 Summary of water use, gallons.....	A-53
A-12 Site cost estimate summary (1983 - \$000) Alternative 2.....	A-55
A-13 Cost estimate - detailed, Alternative 2.....	A-56
A-14 Site cost estimate summary (1983 - \$000) Alternative 3, train transportation.....	A-59
A-15 Site cost estimate summary (1983 - \$000) Alternative 3, truck transportation.....	A-60
A-16 Cost estimate, detailed, Alternative 3, train transportation....	A-61
A-17 Cost estimate, detailed, Alternative 3, truck transportation....	A-65

A.1 INTRODUCTION

A.1.1 Purpose

This appendix provides the information needed to understand the conceptual designs for the remedial action alternatives addressed in this FEIS. This appendix is intended to provide sufficient detail for the reader to understand the remedial action alternatives and the anticipated environmental impacts. This appendix is not intended to provide the detailed engineering necessary to implement the alternatives. Additional details of the proposed remedial action (i.e., Alternative 3--relocation to South Clive) can be found in the Draft Remedial Action Plan (DOE, 1984). Details of stabilization on the Vitro site (i.e., Alternative 2) are available in the DOE UMTRA Project Office in Albuquerque, NM.

A.1.2 Design objectives

The purpose of the remedial action is to dispose of the uranium mill tailings and other contaminated material in a manner which complies with EPA standards (40 CFR 192). Consistent with these standards, and project objectives, the following major design objectives have been established for both action alternatives:

- Reduce the average radon flux from the disposal site to 20 picocuries per square meter per second.
- Design controls to be effective for up to 1000 years with minimum maintenance and a minimum design life of 200 years.
- Prevent inadvertent human intrusion through the use of passive techniques.
- Ensure that existing or anticipated beneficial uses of ground and surface waters are not adversely affected.
- Reduce contaminant levels on areas released for unrestricted use to levels which do not exceed 5 picocuries per gram (Ra-226) above background in the top 15 centimeters of soil and do not exceed 15 picocuries per gram above background in any 15-centimeter layer below that depth.
- Protect against releases of contaminants from the site during construction.
- Provide flood protection, runoff and sediment control, and treatment of waste water as required.
- Minimize areas disturbed during construction and minimize worker and public exposure to contaminated materials.

A.2 STABILIZATION ON THE VITRO SITE (ALTERNATIVE 2)

A.2.1 Major elements of the design

The principal feature of this design concept is the consolidation of the tailings and other contaminated materials into an embankment on the southcentral and southeast portions of the Vitro site (Figure A-1). This design would require the following major construction activities:

- Preparation of the site, including erection of a security fence, and construction of waste-water sedimentation basins to protect against inadvertent release of contaminants from the site during construction.
- Construction of drainage control measures to direct waste-water and storm-water runoff to sedimentation basins during construction activities.
- Removal, relocation, or abandonment of surface and subsurface utilities within the embankment area to prevent the need for human access on the site.
- Excavation and handling of tailings and other contaminated materials.
- Installation of measures to control erosion and sedimentation from disturbed areas during construction.
- Installation and operation of a waste-water treatment facility to protect against release of contamination to surface waters during construction.
- Construction of a liner system to isolate the tailings and other contaminated materials from the ground water.
- Construction of the embankment to isolate tailings and other contaminated material.
- Demolition and disposal of structural foundations and rubble on the site.
- Decontamination of existing surface waterways and placement of material in the embankment.
- Construction of the final cover system over the tailings to inhibit water infiltration and radon exhalation.

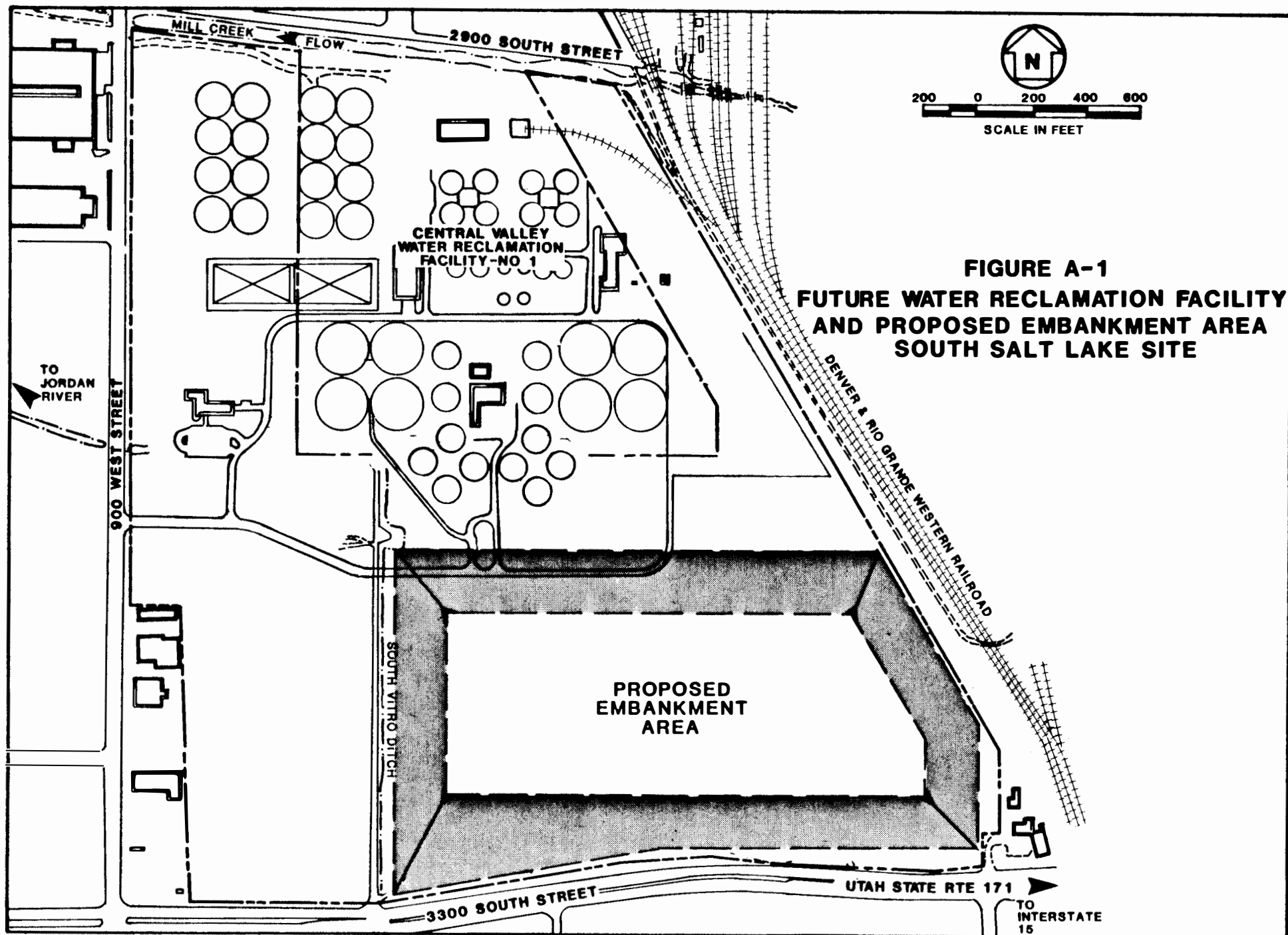


FIGURE A-1
FUTURE WATER RECLAMATION FACILITY
AND PROPOSED EMBANKMENT AREA
SOUTH SALT LAKE SITE

- Restoration of all excavated areas of the site to at or near natural contours with imported fill and final grading to provide suitable drainage control.
- Emplacement of erosion protection on the embankment.
- Revegetation of all disturbed areas to mitigate erosion.
- Installation of temporary and permanent fencing to discourage human intrusion.

A.2.2 Description of final condition

The completed site would be an embankment situated on the southcentral and southeast portions of the present site and would occupy approximately 53 acres. The completed site would be bounded on the west by the existing South Vitro Ditch, on the south by Utah Highway 171 (3300 South Street), on the east by the railroad right-of-way (R.O.W.), and on the north by the CVWRF property (Figure A-1). The embankment boundary would extend north from Utah Highway 171 and along the east side of the South Vitro Ditch for approximately 1250 feet and thence east to the railroad R.O.W.

The top of the embankment would cover about 25 acres. Side slopes of the embankment would have a slope of 1 vertical to 5 horizontal and the top would be slightly convex (2 percent), reaching a maximum elevation of approximately 50 feet above the surrounding terrain. The top and sides would be covered with pit run rock for erosion protection.

An unpaved access road, tied into the pit run rock, would loop the bottom of the embankment. A security fence with warning signs would enclose the embankment and roadway. Channels adjacent to the embankment would provide drainage and divert surface runoff around and away from the embankment.

The remaining areas of the present site would be restored with clean soil, contoured for surface drainage, and revegetated. Approximately 75 acres of the present site would be released and available for uses permitted by local zoning ordinances.

A.3 DESIGN FEATURES - VITRO SITE (ALTERNATIVE 2)

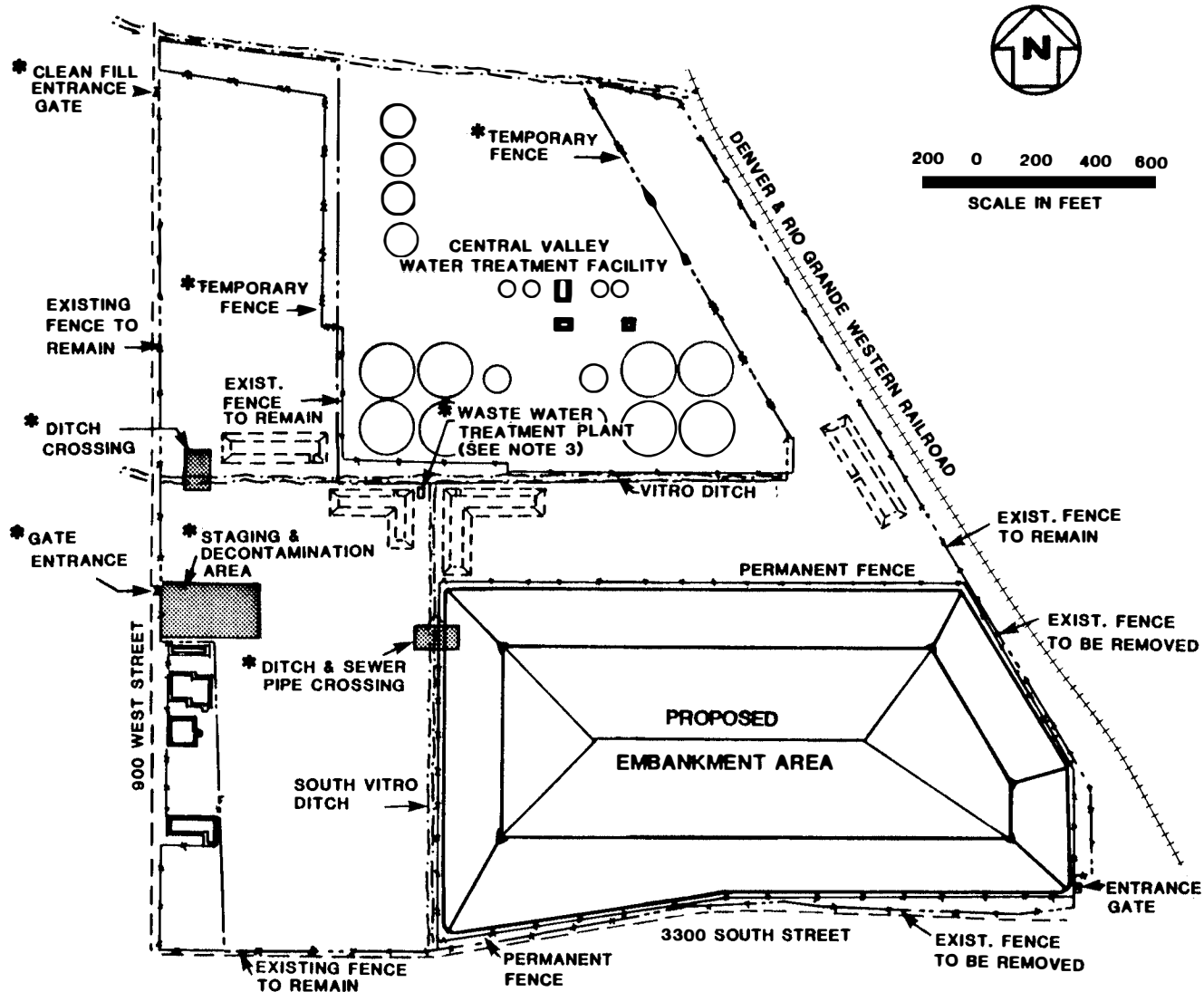
A.3.1 Introduction

Included in this section is a description of the major features of the design. Table A-1 summarizes earthwork volumes described in the following sections. Figure A-2 illustrates the site concept.

Table A-1. Earthwork volume summary--stabilization on the Vitro site

Item description	Estimated volume (cubic yards)
1. CONTAMINATED MATERIAL RELOCATION:	
Excavation outside embankment area	1,370,000
Relocation in embankment area	850,000
Windblown and vicinity properties (spread and compact)	150,000
Rubble	80,000
2. (PRELOAD SYSTEM):*	(3,000,000)
3. LINER SYSTEM:	
Subbase (random fill)	220,000
Base (granular soil)	300,000
Liner (fine grained soil)	190,000
4. EMBANKMENT COVER:	
Radon barrier (silty sand)	290,000
Erosion barrier (pit run rock)	155,000
5. RESTORATION (select fill)	710,000

*The designs included in this EIS are based upon available information and supporting engineering analyses. It is recognized that there are "margins of error" or "risks" associated with these analyses and that with additional field and laboratory analysis these "margins of error" or "risks" could be reduced. For example, the design for Alternative 2 does not include provisions for preloading (to reduce excessive differential settlement) based upon the analyses to date; however, the State of Utah has indicated that differential settlement may indeed be more of a concern than indicated by the

**NOTES**

1. FOR BOUNDARY SURVEY AND BASIS OF BEARINGS SEE "VITRO PLANT SITE SURVEY" DATED NOVEMBER 2, 1982. PREPARED BY WESTERN DESIGN CONSULTANTS FOR FORD, BACON & DAVIS UTAH INC.
2. AERIAL TOPOGRAPHY BY OLYMPUS AERIAL SURVEY INC., SALT LAKE CITY, UTAH DATED SEPTEMBER 18, 1982
3. WASTE WATER TREATMENT PLANT TO BE LOCATED AS REQUIRED DURING CONSTRUCTION SEQUENCE.

LEGEND

- ▲— SLOPE
- * INDICATES INTERIM CONSTRUCTION
- PERMANENT FENCE
- *--- TEMPORARY FENCE
- PROPERTY BOUNDARY
- *--- SEDIMENTATION POND
- *--- EMERGENCY SPILLWAY

FIGURE A-2
PLOT PLAN SHOWING THE STABILIZED PILE
SOUTH SALT LAKE SITE

engineering analyses included in this EIS. If preloading were to be required, based upon engineering analyses and cost estimates prepared by the state, an additional 3.0 million cy of fill would be needed for about 2.5 years to preload the site prior to tailings placement. This would increase the cost of Alternative 2 by \$10.8 million to \$42.0 million (letter from State of Utah Department of Transportation to the Department of Health, December 19, 1983.)

A.3.2 Design considerations

The remedial action was designed to ensure that the disposal site would withstand the forces of nature for a long period of time (1000 years), and provide radon control and required ground-water protection consistent with the EPA standards.

Several factors were investigated and are discussed below.

A.3.2.1 Cover Design

The cover would be constructed of two basic layers: a lower compacted earthen layer to act as a radon and water infiltration barrier and an upper rock layer for surface stability (Figure A-3). The cover would also:

- Act as a barrier against inadvertent human intrusion.
- Act as a barrier to discourage intrusion by burrowing animals.
- Act as a barrier to discourage root intrusion.

Radon control

Control of radon emissions from the stabilized embankment would be accomplished through a combination of techniques including the following:

- Sequencing of excavation and construction in order to place lesser contaminated "sands" over higher contaminated "slimes."
- Placing lesser contaminated foundation soils and windblown soils over the tailings.
- Placing a compacted soil cover over the tailings and other contaminated materials.

Data on the distribution of radium in the tailings, on the properties of the borrow material, and on the anticipated depth of excavation in areas to be restored were analyzed in order to develop an estimate of cover thickness.

Radon emissions before and after the remedial action were calculated using the RAECO model (Rogers et al., 1981). Four parameters for each layer of the cover and tailings are required to compute the exit flux from the pile using the RAECO model. The first input is the source term of the tailings; this is the available radon per unit volume of tailings that can be released into the atmosphere each second. The second input is the effective diffusion

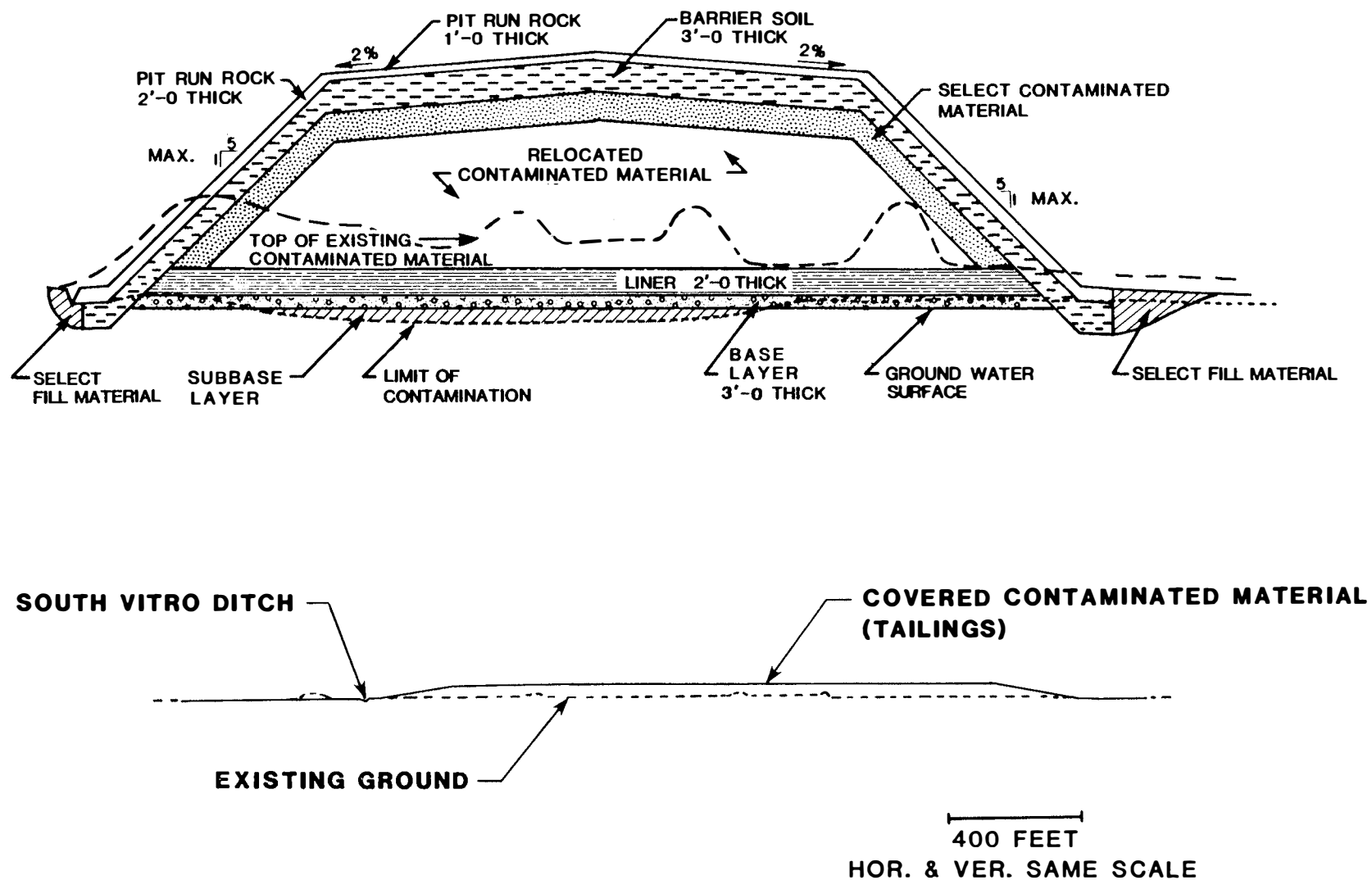


FIGURE A-3
TYPICAL LINER AND EMBANKMENT SECTION
SOUTH SALT LAKE SITE

coefficient of each layer which is based on the porosity and level of moisture saturation in the layer. The diffusion coefficient defines how well a layer confines the radon gas as it migrates through that layer. If confined long enough, the radon will decay to radon daughters, which are particles and will be trapped in the cover layer. The third input is the porosity of a layer. A low porosity soil will better attenuate the diffusion of the radon gas. The fourth input variable is the thickness of each layer which defines the path length the radon gas must take to be released to the atmosphere. A thicker layer confines the radon gas longer allowing time for it to decay to its daughters. These four inputs, adjusted for long-term cover thickness and moisture retention of the tailings and cover, allow the model to conservatively calculate the radon flux through the cover compared to the background radon concentration of the atmosphere which is 0.59 pCi for Salt Lake City.

Based upon these data and analyses, the radon barrier required to meet the EPA standard would be constructed of approximately 3 feet of locally available borrow. Radon emissions after remedial action, including the additional erosion barrier are calculated to be about 17 pCi/m² sec. These data and analyses are available in the DOE UMTRA Project Office, Albuquerque, New Mexico.

Ground-water protection

Ground-water contamination at the Vitro site currently is generated by two processes: by water infiltrating into and through the contaminated material, and by ground water flowing laterally through the base of the tailings. After remedial action, ground-water protection would be provided by the embankment cover, which would reduce infiltration through the tailings, and by the liner system, which would raise the embankment out of the ground water.

The cover, including the rock erosion barrier, was analyzed for infiltration using the modified HELP model (Walski et al., 1982). Daily and monthly climatologic data for Salt Lake City (1974-1978) were used as model inputs. Five years of simulation showed that the post-remedial action net average annual infiltration through the cover system would be 1.3 inches. This reduction to about 8 percent of the average annual rainfall in the Salt Lake City area will substantially reduce the volume of leachate entering the ground water. The modelling runs, inputs, and other supporting data are available in the DOE UMTRA Project Office, Albuquerque, New Mexico.

The liner system is designed to raise the embankment out of the ground water. The granular base layer will prevent capillary water from rising into the embankment. The liner will also filter the water that percolates through the tailings, reducing the downward migration of contaminants. The liner system, by preventing contact between the ground water and the contaminated material, will substantially reduce the volume and concentration of leachate.

Ground-water protection will also be provided by sealing the existing monitoring wells during remedial action. This is especially important for the wells completed in the confined aquifer. These wells represent a potential

avenue for loss of water from the confined system; or even for contamination of the confined aquifer if a local reversal of the vertical head gradient were to allow downward movement of water from the unconfined aquifer. Additionally, the location of a suspected artesian well at the head of Vitro ditch (see Section D.3.1.2) will be excavated during remedial action. If the remnants of a well are found, it will be plugged and sealed.

A.3.2.2 Long-term stability

Water erosion

To protect the embankment from the effects of water erosion, the embankment slopes would be limited to 1 vertical to 5 horizontal (20 percent). The top of the embankment would be convex with gentle (2 percent or less) slopes to promote drainage.

To ensure that the remedial action would withstand water erosion during the design life, the surfaces of the radon barrier cover would be graded and the corners rounded, and the entire radon barrier would be covered with a rock erosion barrier.

Over its design life, the embankment cover may be subjected to severe rainfall events. The most severe potential rainfall event is a Probable Maximum Precipitation (PMP), which would have a peak 5-minute intensity of 30 inches/hour on the embankment. To protect against the erosive effects of a PMP, the side slopes of the embankment would be covered with a 2-foot-thick layer of 6-inch mean diameter pit run rock; the top of the embankment, which has much gentler slopes, would be covered with a 1-foot thick layer of 2-inch mean diameter pit run rock.

Wind erosion

Due to the height of the embankment above the surrounding terrain, wind velocities at the site, and the long reach, the embankment is subject to erosion from wind. The rock layer used to protect against water erosion would protect the embankment against wind erosion.

Flood protection

The embankment is located in the wide, relatively flat alluvial valley of the Jordan River. The river, at its nearest point, is approximately 2500 feet from the embankment. Mill Creek, a tributary of the Jordan River, flows across the valley and joins the river northwest of the proposed embankment. Mill Creek, at its nearest point, is approximately 1500 feet from the embankment.

HEC-2 was used to model Probable Maximum Flood (PMF) flows for the Jordan River and Mill Creek using cross sections obtained from the Sacramento District Corps of Engineers and extended using USGS quadrangle maps. The results of this analysis indicated that the bottom of the embankment is above the 100-year flood level. During a 500-year flood, standing water would rise about 2 to 3 feet above the base of the embankment. Although the base of the

embankment would be inundated (6 to 10 feet) under PMF flood conditions, the embankment would not be subject to erosive water velocities (estimated at 4 to 5 fps).

Geomorphology (stream meander)

As discussed above, the embankment is located in the alluvial valley of the Jordan River and Mill Creek. The Jordan River, in particular, would normally be classified as a meandering river. The location of the embankment in relation to the water bodies, combined with the present and future human intervention between the water bodies and the embankment, makes the likelihood of encroachment very remote.

Seismicity

The Vitro site is located along the Wasatch Front in an active seismotectonic area, and the embankment would be subject to future seismic hazard. A seismic evaluation of the embankment has been performed (SH&B, 1983; Appendix H).

In the event of a Maximum Credible Earthquake (MCE), with a return period of 1,000 to 2,000 years, the subsurface sands would be susceptible to liquefaction. This could result in minor cracking (a few inches in width). It would not result in flow slides of the tailings. However, minor repair of the slopes would be required.

Earthquake-induced ground motions of lesser intensity, which would be expected to occur on the average of once every 50 to 400 years, would cause no significant damage to the embankment. Minor cracking may occur. Damage of this nature would require minor repair.

A.4 CONSTRUCTION SEQUENCE - VITRO SITE (ALTERNATIVE 2)

A.4.1 Site preparation

A.4.1.1 Mobilization

To provide for a construction staging area, tailings and other contaminated material would be removed and temporarily stockpiled on the remainder of the site. The staging area would be constructed immediately north of the industrial tract located along 900 West Street north of Utah Highway 171 (Figure A-2).

A.4.1.2 Clearing

To ensure that disposal of the small amounts of organic material does not interfere with the integrity of the embankment and cover, it is proposed to cut grasses, weeds, and low shrubs close to the ground, shred or chip these and other minimum amounts of contaminated organics, and mix them evenly throughout the lower portions of the tailings. No open burning would be conducted during shredding and chipping operations.

A.4.1.3 Storm drainage

All earth disturbing activities would be conducted in such a way as to prevent accelerated erosion and sedimentation during construction. Hay bales, fabric filter fences, fabric sheets, and the like will be used to further minimize erosion and sedimentation. Areas would be reclaimed as soon as feasible after tailings are removed.

A.4.1.4 Sedimentation basins

Sedimentation basins would be the primary means to collect contaminated waste water prior to treatment. Waste waters would result from:

- Decontamination activities including equipment washing and truck washdown.
- Dewatering of contaminated material.
- Runoff from contaminated materials.
- Laundry waste from washing protective clothing.
- Shower and wash basin waste water.

Basins and channels would be sized to retain the 10-year 24-hour storm event of the area tributary to the basins plus other waste waters. Retention would be for at least 24 hours. Embankments, dikes, and inlet/outlet structures would be designed and located to minimize short-circuiting within the basins and to avoid retarding circulation. Basins would be designed with sufficient freeboard and spillway systems to allow discharge of peak flow rates from larger storm events.

A.4.1.5 Waste-water treatment

Waste water from the sources mentioned above would flow to the sedimentation basins which would provide primary settling and flow and contaminant equalization. Some of this flow would be utilized for road and pile wetdown for dust and radon control. The remainder would be treated to acceptable limits and discharged to either Mill Creek or Vitro Ditch.

The principal dry-weather flow at the site will be the ground water from excavation. This flow may be as high as 300 gpm. An additional treatment capacity of 300 gpm will be available for storm-water runoff. The flow from the other sources will be insignificant, totaling only a few thousand gallons per day.

Unit processes which have been selected for treatment of the settled and equalized flow include:

- Multi-media filtration for removal of suspended solids.
- Uranium- and radium-selective ion exchange for control of radium and gross alpha.

Suspended solids which are captured by the filter and later backwashed will be placed in an excavation for solids containment. Solutions from resin regeneration and the ultimate spent resins will be buried on the site for contaminant containment. Neutralizing chemicals (e.g., NaOH or H₂SO₄) and flocculent aids (e.g., polymer) may be mixed with the sedimentation basin inflow, if necessary, for pH and solids control.

The performance specifications for the treatment unit will be detailed in the final design for construction by an experienced manufacturer. The system will include automatic controls for minimal operator attention and be weather-proof, requiring no enclosure. After completion of the remedial action, the treatment system will be decontaminated and salvaged or buried on the site.

A.4.2 Fugitive dust control

Dust generated by excavation, earth movement, vehicle use, stockpiling, seeding, and similar activities would be controlled and minimized by the use of a water-based surfactant sprayed under moderately high pressure (from trucks and hoses). The source for dust suppression water would be potable water. In addition, hoses would be available for areas of excavation.

A.4.3 Demolition

No complete structures remain on the site with the exception of the water tower and tank. Numerous foundations remain on the site in the former mill area. Since this area would become part of the embankment, those portions of the foundations that would interfere with the construction or integrity of the embankment would be demolished and incorporated, without nesting, into the internal portions of the embankment. Tailings would be distributed and compacted between and against the rubble to prevent settlement.

A.4.4 Preloading (see note to Table A-1)

After excavation and stockpiling of tailings and contaminated materials, 3,000,000 cy of non-contaminated material would be trucked in to cover the 53-acre disposal site for preloading. The preload would stay in place for approximately 2.5 years (determination of the time would be based on field measurements of settlement to determine the amount and rate of settlement). Once settlement has slowed and the amount of settlement that would take place due to the construction of the embankment has taken place, 2,000,000 cy of the preload material would be hauled away for disposal. The remaining material would be used in the construction of the liner system and for fill around the site.

A.4.5 Liner system construction

The embankment liner system would isolate the contaminated materials from the ground water. It would be constructed of three layers: a subbase layer, a base layer, and a liner (Figure A-3). The subbase is designed to raise the embankment out of the ground water. Prior to subbase emplacement, residual radioactive materials would be excavated. The base layer (about 3 feet thick) would provide a capillary break between the subbase and the liner. It would also serve as a solid base for the compaction of the liner. The liner (2 feet thick) would reduce the transport of contaminants from the embankment into the ground water. Water which has infiltrated through the embankment cover would be filtered by the liner. The liner would have a greater permeability than the cover to prevent water build-up within the embankment.

A.4.6 Embankment construction

The embankment would be constructed in the southcentral and southeast portions of the present site. All residual radioactive material from the existing site and material from vicinity properties remedial action would be consolidated into the embankment.

Tailings would be dewatered as required for material handling. This would be accomplished in layers by scraping, trenching and drying, excavating the dewatered material until a new level is reached which is too wet for handling, and repeating the process. The dewatering water would be pumped or allowed to gravity flow to the sedimentation basins.

Pockets of slimes would be mixed with drier sandy tailings during placement in the embankment to provide a stable working surface for construction equipment and to help reduce the effects of differential settlement in the tailings. For purposes of reducing radon emissions and providing a capillary break, sandy tailings would be identified and incorporated into the upper portion of the embankment.

The purpose of the upper capillary break would be to limit or eliminate upward migration of moisture-transported contaminants. The benefits of placement of sandy tailings in the upper portion of the embankment would outweigh the disadvantage of the slight increase of net infiltration into the tailings.

A.4.7 Restoration

During the relocation of tailings into the embankment, large portions of the existing site would be excavated to below ground level. These areas would be restored with uncontaminated borrow to the approximate elevation of the surrounding terrain and contoured to provide surface drainage.

A.4.8 Existing utilities

Numerous utilities, including an overhead power line, a buried telephone cable, water lines, gas lines, and a sewer drain exist adjacent to or under 3300 South Street. These lines would be left in place. A 42-inch sewer line traverses the present site along the west side of the South Vitro Ditch and access road. This line would be protected during construction and left in service. The artesian wells, which are located in the embankment area, would be plugged and abandoned. All wells or holes to be abandoned would be sealed so as to prevent future contamination of ground water.

A.4.9 Revegetation

All areas of the site disturbed by the remedial action except for the embankment cover would be prepared and seeded with native grasses.

A.4.10 Fencing

After remedial action, permanent fencing would be placed around the embankment. The fence would be 6-foot chain link with barbed wire topworks. A gate would be installed for access from 3300 South Street.

A.4.11 Temporary facilities

During construction operations, temporary facilities would be required for construction workers and supervisory, engineering, administrative, security, and monitoring personnel. The facilities would consist of office space, showers and change facilities for all personnel working on the site, and facilities for laundering contaminated clothing.

A.4.11.1 Security

Fencing is required to ensure site security during the construction period. Portions of the existing fencing would be used during construction if possible. All other existing fencing would be removed and replaced with a new fence surrounding the entire site. No vehicle would be allowed to exit the site without monitoring at the decontamination station located at or near the staging area.

A.4.11.2 Water supply

An 8-inch water line runs along 900 West Street. This would supply showers, laundry, vehicle wash when needed, and drinking water.

A.4.11.3 Waste water

Portable construction toilets would be used. Waste water from showers, wash basins, and laundry would gravity flow to a holding tank. Wash water from the vehicle wash area would be held in a pit. These waters would be used for dust suppression or would be pumped to the sedimentation basin for treatment and discharge.

A.4.11.4 Transportation

To ease traffic congestion due to the remedial action along 900 West Street and 3300 South Street, mitigations such as upgrading intersections, traffic signals, and flagmen would be employed as required.

A.4.12 Borrow area

A local borrow area for embankment cover and restoration material has been identified within about 10 miles of the Vitro site. It is located along 5400 South Street in the southwest Salt Lake County area and is locally operated by Moulton Excavating, Inc.

A.5 RELOCATION TO SOUTH CLIVE (ALTERNATIVE 3)--PROPOSED ACTION

A.5.1 Major elements of the design

The principal feature of this design concept is the relocation of the tailings and other contaminated material to a disposal site located near Clive, Utah (Figure A-4).

This alternative considers two modes for transporting (train, truck) tailings and other contaminated materials from the Vitro site to the South Clive site. The major construction activities for the proposed action are listed separately below for the train and truck transportation modes.

A.5.1.1 Train Transportation

- Preparation of both sites, and construction of waste-water sedimentation basins to protect against release of contaminants. Security fencing would be installed at the Vitro site.
- Construction of drainage control measures to direct generated waste-water and storm-water runoff to the waste-water sedimentation basins during construction activities.
- Installation of measures to control erosion and sediment from disturbed areas during construction.
- Installation and operation of a waste-water treatment facility at the Vitro site to protect against inadvertent contaminant release during construction.
- Protection of surface and subsurface utilities at the Vitro site during construction.
- Construction of a railroad loadout spur on the Vitro site.
- Construction of a railroad spur and offloading facility at the South Clive site.
- Upgrading of the existing frontage road from the Aragonite exit of I-80 to the Clive overpass and construction of an access road from the I-80 overpass to the disposal site.
- Demolition and disposal of structures and rubble.
- Excavation and loading of tailings and other contaminated material into train cars.
- Excavation and construction of the embankment at the South Clive site.
- Relocation of the tailings from the offloading facility to the embankment.

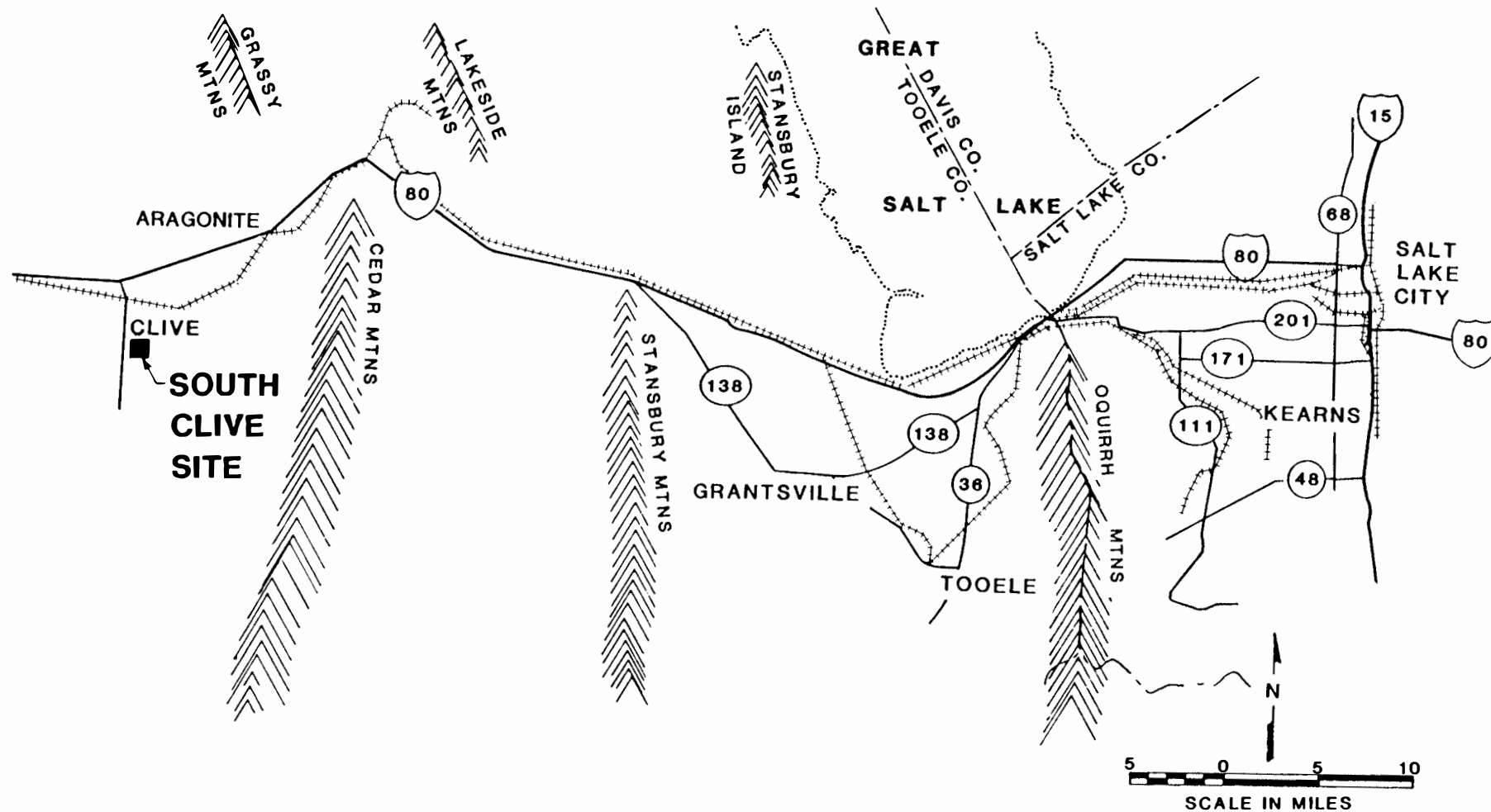


FIGURE A-4
SOUTH CLIVE VICINITY MAP

- Construction of the cover system over the tailings to inhibit water infiltration and radon exhalation.
- Emplacement of erosion protection on the embankment.
- Installation of a permanent fence around the disposal site.
- Demolition of railroad spurs at both sites.
- Restoration of the excavated areas at the Vitro site with backfill and vegetation.

A.5.1.2 Truck Transportation

- Preparation of both sites, and construction of waste-water sedimentation basins to protect against release of contaminants. Security fencing would be installed at the Vitro site.
- Construction of drainage control measures to direct generated waste-water and storm-water runoff to the sedimentation basins during construction activities.
- Installation of measures to control erosion and sedimentation from disturbed areas during construction.
- Installation and operation of a waste-water treatment facility at the Vitro site to protect against inadvertent contaminant release during construction.
- Protection of surface and subsurface utilities at the Vitro site during construction.
- Upgrading of the existing frontage road from the Aragonite exit of I-80 to the Clive overpass and construction of an access road from the I-80 overpass to the disposal site.
- Demolition and disposal of structures and rubble.
- Excavation and loading of tailings and other contaminated material into trucks.
- Excavation and construction of the embankment at the South Clive site.
- Construction of the final cover system over the tailings to inhibit water infiltration and radon exhalation.
- Emplacement of erosion protection on the embankment.
- Installation of a permanent fence around the disposal site.
- Restoration of the excavated areas at the Vitro site with backfill and vegetation.

A.5.2 Description of final condition

The disposal site is located about 85 road miles west of Salt Lake City and about 1.5 miles south of the Clive siding of the Union Pacific System. The total available site, which is one full section or 640 acres, is a relatively flat area at about 4,300 feet above sea level along the eastern edge of the Great Salt Lake Desert. The site is sparsely vegetated with grasses and small bushes. Site access is by a frontage road from the Aragonite exit of I-80 about 7 miles east of Clive.

The completed embankment would be partially below grade, extending approximately 1100 feet by 2200 feet (Figure A-5). The tailings would extend from approximately 6 feet below grade to approximately 27 feet above grade. Material excavated for partial below grade disposal would be used for cover. The final covered embankment would be 34 feet above the surrounding terrain. The embankment would have maximum side slopes of 20 percent and a slightly convex top. The top and sides would be covered with pit run rock for erosion protection. The unpaved access road from I-80 would remain. A chain link fence with warning signs would enclose the site.

The excavated areas at the Vitro site would be restored with clean soil to the original approximate ground level, contoured for surface drainage, and revegetated (Figure A-6). The Vitro site would be available for uses permitted by local zoning ordinances.

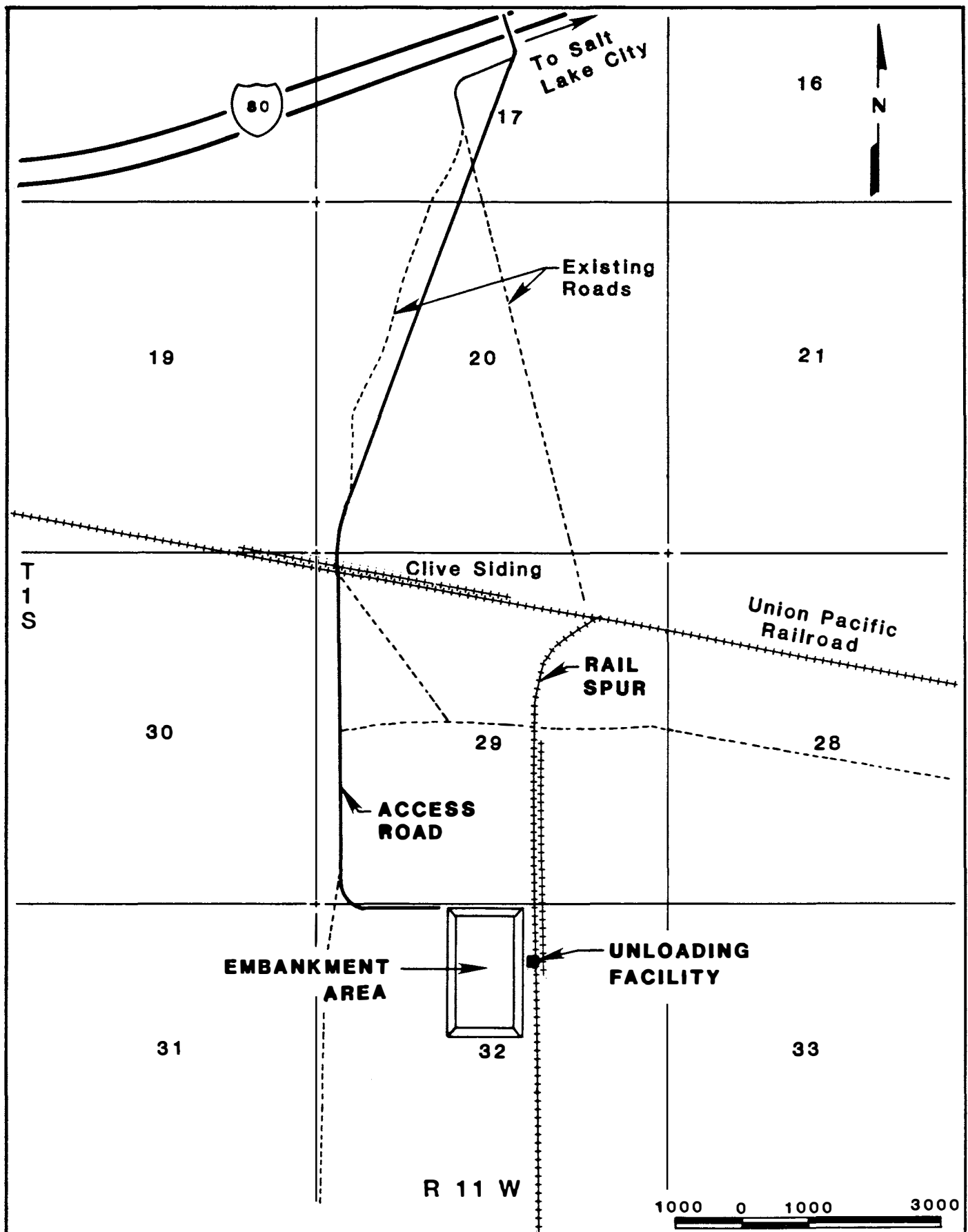


FIGURE A-5
PLOT PLAN FOR SOUTH CLIVE

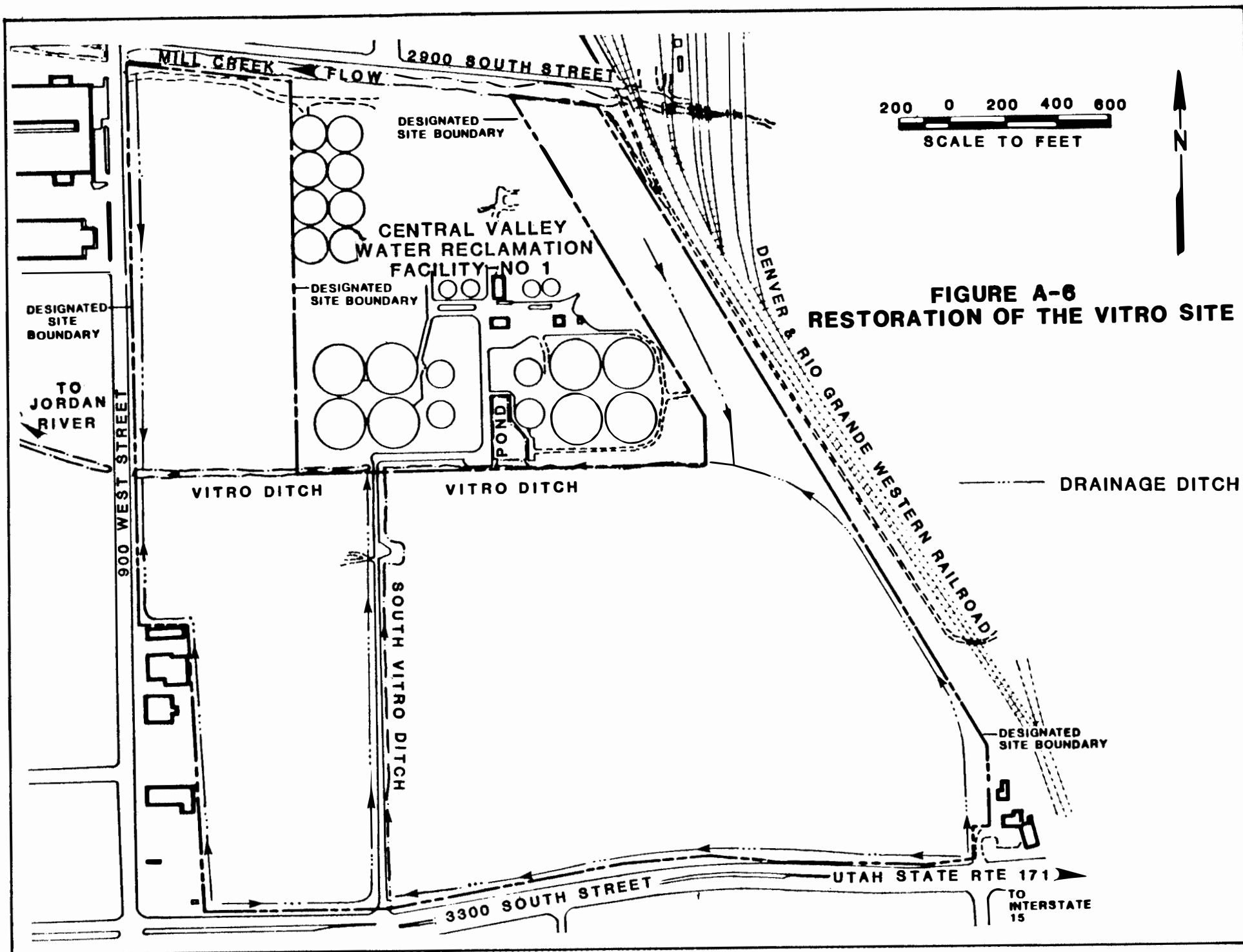


FIGURE A-6
RESTORATION OF THE VITRO SITE

A.6 DESIGN FEATURES - SOUTH CLIVE (ALTERNATIVE 3)

A.6.1 Introduction

Included in this section is a description of the major features of the conceptual design for the proposed action. The details of the conceptual design can be found in the Remedial Action Plan (DOE, 1984).

Tables A-2 and A-3 summarize earthwork volumes described in the following sections. Figure A-5 illustrates the site concept.

A.6.2 Design Considerations

The remedial action was designed to withstand the forces of nature for a long period of time (1000 years), and provide radon control and required ground-water protection consistent with the EPA standards. Several factors that could affect the effectiveness of the embankment were investigated and are discussed below.

A.6.2.1 Cover

The cover would be constructed of two basic layers: a lower compacted earthen layer to act as a radon and water infiltration barrier and an upper rock layer for erosion protection. The cover would also:

- Act as a barrier against inadvertent human intrusion.
- Act as a barrier to discourage intrusion by burrowing animals.
- Act as a barrier to discourage root intrusion.

A typical cross section through the embankment is shown in Figure A-7. Additional details are available in the Remedial Action Plan (DOE, 1984).

Radon control

Control of radon emissions from the embankment would be accomplished by the placement of a compacted soil cover over the tailings and other contaminated material. In addition, the relocation of the tailings would promote natural mixing of slimes and sands which results in a more even distribution of tailings. However, the major factor in the reduction of emissions would be the clean cover material.

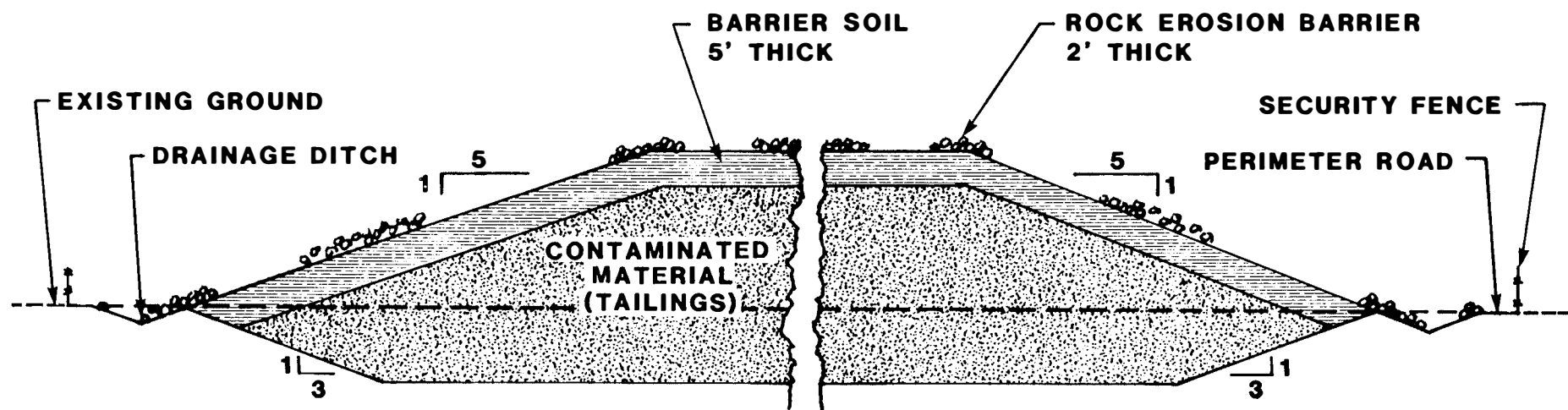
Data on the distribution of radium in the tailings, on the properties of the cover material, and on the anticipated depth of excavation in areas to be restored were analyzed in order to develop an estimate of cover thickness. Radon emissions before and after the remedial action were calculated using the RAECO model (see Section A.3.2.1 for an explanation of RAECO). Based upon these data and analyses, the radon and water infiltration barrier would be constructed of approximately 5 feet of soil from the embankment excavation. Radon emissions after remedial action are calculated to be 20 pCi/m² sec.

Table A-2. Earthwork volume summary--train relocation to South Clive

Item description	Estimated volume (cubic yards)
Vitro site:	
Rail spur construction	
Excavation of contaminated materials	180,000
Subgrade and subballast (select fill)	94,000
Contaminated materials	
Tailings and contaminated subsoils	2,220,000
Windblown and vicinity properties	150,000
Rubble	80,000
Restoration (select fill)	945,000
South Clive site:	
Access road construction	
Road subgrade (compacted fill)	27,000
Gravel surface	31,000
Rail spur construction	
Subgrade (compacted fill)	98,000
Subballast (select compacted fill)	10,000
Embankment construction	2,450,000
Cover	
Radon barrier	460,000
Erosion barrier, ditches, and perimeter roads (pit run rock)	202,000

Table A-3. Earthwork volume summary--truck relocation to South Clive

Item description	Estimated volume (cubic yards)
Vitro site:	
Contaminated materials	
Tailings and contaminated subsoils	2,220,000
Windblown and vicinity properties	150,000
Rubble	80,000
Restoration (select fill)	1,040,000
South Clive site:	
Access road construction	
Road subgrade (compacted fill)	27,000
Gravel surface	44,000
Embankment construction	2,450,000
Cover	
Radon barrier (excavated from embankment)	460,000
Erosion barrier, ditches, and perimeter roads (imported pit run rock)	202,000



NO HORIZONTAL OR VERTICAL SCALE

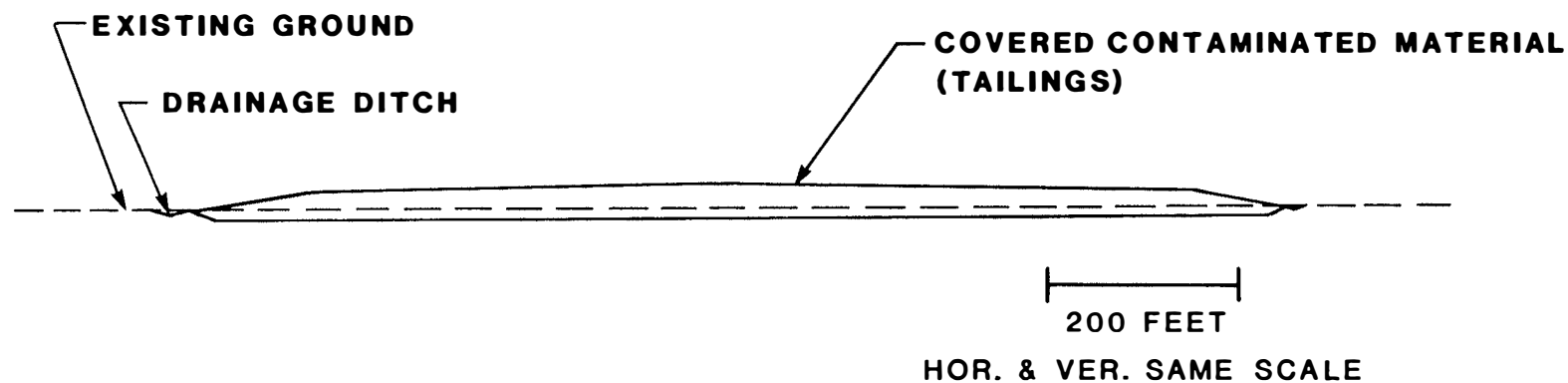


FIGURE A-7
TYPICAL SECTION OF THE EMBANKMENT
SOUTH CLIVE SITE

Ground-water protection

Stabilizing and covering the tailings and other contaminated materials at a minimum of 15 feet above the water table would reduce the potential for leaching of soluble contaminants and subsequent migration via the ground-water regime. Further, the embankment cover includes a low permeability soil, and coupled with low precipitation (i.e., no leachate or driving force for leachate production), would result in essentially no infiltration into the tailings.

Some seepage from the embankment would be expected as a result of the redistribution of moisture within the tailings. The existing ground-water conditions would limit the impact of this seepage because of the extremely poor quality of the water (Appendix D), and the absence of any uses (current or anticipated) of the ground water near the site. Additionally, the volume of seepage would be small, also limiting the potential for degradation of the ground water.

A.6.2.2 Long-term stability

Water erosion

To protect the embankment from the effects of water erosion, the embankment slopes would be limited to 20 percent. The top of the embankment would be convex with gentle (2 percent or less) slopes to promote drainage.

To ensure that the remedial action would withstand water erosion during the design life, the surfaces of the radon barrier cover would be graded and the corners rounded, and the entire embankment radon barrier would be covered with a rock erosion barrier.

Over its design life, the embankment cover may be subjected to severe rainfall events. The most severe potential rainfall event is a PMP which would have a peak 5-minute intensity of approximately 30 inches/hour on the embankment. To protect against the erosive effects of a PMP, the side slopes of the embankment would be covered with a 2-foot-thick layer of 5-inch mean diameter pit run rock; the top of the embankment, which has much gentler slopes, would be covered with a 2-foot-thick layer of 1.5-inch mean diameter pit run rock.

Wind erosion

Because of the long open reach in the Clive area, wind velocities at the site must be considered. The rock layer used to protect against water erosion would also provide protection against wind erosion.

Flood protection

Flooding at the South Clive site would result from the collection of runoff (sheet flow) due to precipitation on the Cedar Mountains east of the site. There are no bodies of water in the area. The PMF peak flow past the embankment resulting from a 6-hour Probable Maximum Precipitation estimated (PMP) of 9.7 inches over the 46-square-mile drainage area was calculated

Hansen et al., 1977) and USGS topographic maps. The 1-hour PMP was used in calculating the PMP because the 6-hour general PMP for the 46-square-mile drainage area is of lesser intensity (2.45 vs 3.66 inches) (USDOI, 1977). The peak flood depths and velocities were found using flood control channel hydraulic design methods (COE, 1970). The results of the analysis indicate that the PMF would have a peak flow of 83,000 cfs and maximum depth adjacent to the embankment of approximately 5.5 feet. The velocity of the overland flow would be approximately 2 fps and the peak velocity (at the toe of the embankment slope) would be approximately 10 fps.

Rip rap design methods (Simons and Senturk, 1976) were then used to determine the stability of the erosion barrier during passage of the PMF. The pit run rock layer on the embankment would provide protection from the flood waters.

Other stability concerns

No perennial rivers or streams occur near the South Clive site. Therefore, stream encroachment into the stabilized embankment is of no concern.

Seismically induced liquefaction of the subsoils and resultant effects to the embankment are also of little concern. First, the ground water is at least 20 feet below the surface and below several layers of unsaturated silty sands. Second, these sand layers are of medium to high density. These factors, combined with the relatively high static overburden pressure to the saturated soil layers, indicate that significant liquefaction due to an MCE (3,000-15,000 years recurrence interval) is improbable; at most, self-healing "cracks" may result. Additional details are available in Appendix H of this FEIS.

A.7 CONSTRUCTION SEQUENCE - SOUTH CLIVE (ALTERNATIVE 3)

A.7.1 Vitro site work

A.7.1.1 Mobilization

To provide for a construction staging area, tailings and other contaminated material would be removed and temporarily stockpiled. The staging area would be constructed adjacent to the industrial buildings along 900 West Street (Figure A-8).

A.7.1.2 Clearing

To ensure that disposal of small amounts of organic material does not interfere with the embankment and cover at the disposal site, it is proposed to cut grasses, weeds, and low shrubs close to the ground, shred or chip these and other minimum amounts of contaminated organics, and mix them evenly with the tailings. There would be no open burning and care would be taken to prevent material from becoming airborne.

A.7.1.3 Erosion and sediment controls

All earth-disturbing activities would be conducted in such a way as to prevent accelerated erosion and sedimentation during construction. Areas would be reclaimed as soon as feasible after tailings are removed.

A.7.1.4 Storm drainage and waste-water sedimentation basins

Basins and channels would be sized to retain runoff from the 10-year 24-hour storm event plus other waste waters. Retention would be for at least 24 hours. Embankments, dikes, and inlet/outlet structures would be designed and located to minimize short-circuiting within the basins and to avoid retarding circulation. Basins would be designed with sufficient freeboard and spillway systems to allow discharge of peak flow rates from larger storm events.

Sedimentation basins would be the primary means to collect contaminated waste water prior to treatment. Waste waters would result from:

- Decontamination activities including equipment washing and truck/train washdown.
- Dewatering of contaminated material.
- Runoff from contaminated materials.
- Laundry waste from washing protective clothing.
- Shower and wash basin waste water.

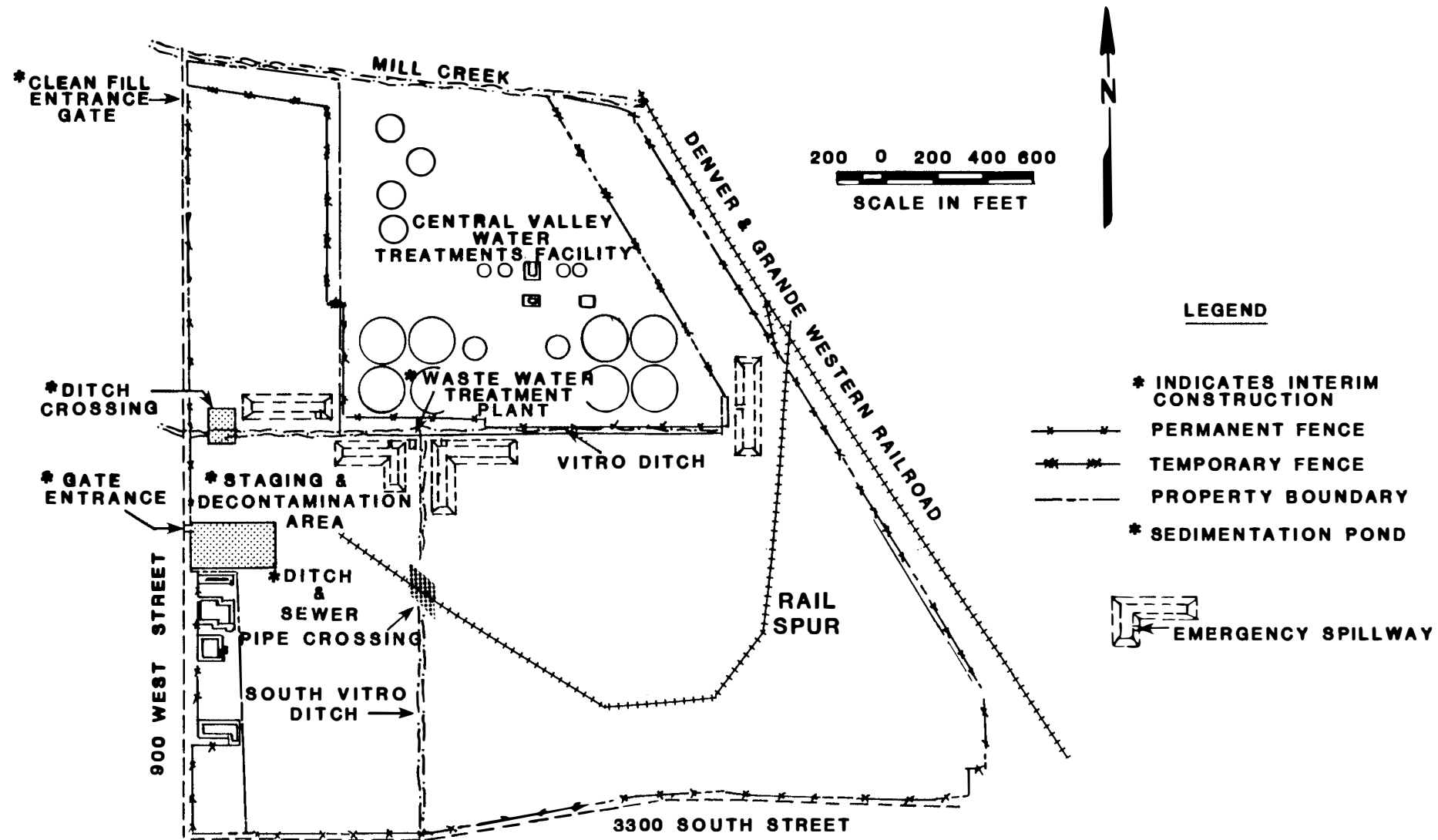


FIGURE A-8
PLOT PLAN VITRO SITE

A.7.1.5 Dewatering

Ground water at the Vitro site is near the surface and at times rises into the tailings. To facilitate handling, the tailings would require dewatering.

Dewatering would be accomplished in layers by plowing or trenching and drying (by evaporation), excavating the dewatered material until a new level is reached which is too wet for handling, and repeating the process. Water would be pumped or gravity flow to the sedimentation basins.

A.7.1.6 Waste-water treatment

Waste water from the sources mentioned above would flow to the sedimentation basins which would provide primary settling and flow and contaminant equalization. Some of this flow would be utilized for road and pile wetdown for dust and radon control. The remainder would be treated to acceptable limits and discharged to either Mill Creek or Vitro Ditch. The flows and treatment scheme would be the same as discussed for Alternative 2 (Section A.4.1.5). The contaminants from the treatment plant would be transported to the South Clive site for final disposal.

A.7.1.7 Fugitive dust control

Dust generated by excavation, earth movement, vehicle use, stockpiling, seeding, and similar activities would be controlled and minimized by the use of a water-based surfactant sprayed under moderately high pressure (from trucks and hoses). The source for dust suppression water would be potable water. In addition, hoses would be available for areas of excavation.

A.7.1.8 Demolition

Existing foundations on the Vitro site would be demolished and combined with the rubble from vicinity properties for disposal in the embankment at South Clive. Rubble would be placed in the lower levels of the disposal embankment. Pieces would not be nested. Tailings would be spread and tamped between and against the rubble so that voids would not occur presently or in the future.

A.7.1.9 Railroad construction (train transport mode)

Transport of the tailings and other contaminated material to the South Clive site by railroad would require the construction of approximately 3800 feet of railroad spur on the Vitro site. The spur would originate at an existing spur at the Roper rail yard, follow the existing railbed to the mill site, turn about 120°, and angle through the site (Figure A-8).

To prepare for the railroad bed, tailings and any contaminated subbase would be removed from the railroad route and stockpiled. Since it is proposed to load the cars directly with a front-end loader, the railroad route through the tailings would be excavated to a width sufficient for the railroad plus a working area for loading from both sides of the train.

A.7.1.10 Excavation and loading

Train

Material within easy working distance of the railroad would be excavated and loaded with front-end loaders. Material beyond a reasonable working distance would be dewatered as necessary, excavated with scrapers or other standard earth moving equipment, transported to the railroad spur, and spread along both sides of the spur for the full length of the train and at an optimum working distance from the train. From there it would be loaded with front-end loader(s).

Truck

The material would be dewatered as necessary, excavated, and loaded with front-end loaders and backhoes into trucks.

A.7.1.11 Transportation

Train

Tailings and other contaminated material would be hauled from the Vitro site to the South Clive site by train. The concept is based on transporting 5400 tons per day (TPD).

Tailings would be transported with one train per day. Two trains of 54, 100-ton capacity cars would be required. One would be loaded at the Vitro site daily while the other is being unloaded at the South Clive site. The loaded train would be covered, decontaminated, and hauled to the South Clive site in the evening. The locomotive engines would leave the loaded train at the South Clive site and return to the Vitro site with the unloaded train by morning.

Fifty of the railroad cars (per unit train) would be rotary-coupled gondola cars which would be water and sand tight. Large pieces of rubble or other contaminated material which cannot be handled by the offloading system at the South Clive site would be transported in four side-dump railcars fitted with door seals to prevent release of contaminated materials.

To prevent windblown contamination during transport, railcars would be covered with a tarpaulin or canopy, or with a sprayed latex seal.

Truck

Tailings and other contaminated materials would be hauled to the South Clive site by truck. The concept is based on hauling 5400 tons per day. Seventy-seven, 35-ton capacity trucks would be required. The trucks would make two round trips per day. They would be loaded, covered, and decontaminated at the Vitro site in the morning, driven to the South Clive site, unloaded and decontaminated, and returned to the Vitro site in the afternoon to obtain a second load for disposal at South Clive. Each round trip would take 4.5 to 5 hours.

The trucks would be 35-ton capacity trucks and trailers fitted with door seals to prevent leakage. To prevent windblown contamination during transport, the trucks would be covered with a sprayed latex seal, tarpaulin, or canopy.

A.7.1.12 Restoration

After removal of the contaminated material from the Vitro site, all areas of excavation would be restored to the approximate original contours (in concurrence with CVWRF) and released for unrestricted use (Figure A-6). The site would be restored by importing, spreading, and compacting clean fill material (see Section A.4.11 for source of fill).

A.7.1.13 Existing utilities

Since the Vitro site would be decontaminated and released for unrestricted use, the existing 42-inch sewer line and all other surface and underground utilities would be protected in place during construction or temporarily removed and replaced in kind.

A.7.1.14 Temporary facilities

During construction operations, temporary facilities would be required for construction workers and supervisors, engineering, administrative, security and monitoring personnel, and equipment maintenance and repair. The facilities would consist of office space, showers and change facilities for all personnel working on the site, as well as facilities for laundering clothing.

Security

The entire site would be fenced during construction. Access would be controlled and no parking would be permitted on the site. Construction vehicles would remain on the site. Trucks bringing construction materials from off the site would be monitored and decontaminated as required prior to exit. A security staff would be on the site 24 hours per day.

Water supply

An 8-inch water line runs along 900 West Street. This would supply showers, laundry, vehicle wash when needed, and drinking water.

Waste water

Portable construction toilets would be used. Waste water from showers, hand basins, and laundry would gravity flow to a holding tank. Wash water from the vehicle wash area would be held in a pit. These waters would be disposed of on the site by a mobile irrigation system, or treated.

A.7.2 South Clive site work

A.7.2.1 Mobilization

A construction staging area would be constructed at the South Clive site and temporary facilities installed (Figure A-5).

A.7.2.2 Clearing

Low brush would be cleared only from areas to receive embankment materials. If burning is not allowed, brush would be mulched and added to the topsoil.

A.7.2.3 Erosion and sediment controls

All earth disturbing activities would be conducted in such a way as to prevent accelerated erosion and sedimentation during construction.

A.7.2.4 Storm drainage and waste-water retention basins

Basins and channels would be sized to retain runoff from the 10-year 24-hour storm event of the area tributary to the basins plus other waste waters. Retention would be for at least 24 hours.

Retention basins would be the primary means to collect contaminated waste water for evaporation. Waste waters would result from:

- Decontamination activities including equipment washing and truck/train washdown.
- Dewatering of contaminated material.
- Runoff from contaminated materials.
- Laundry waste from washing protective clothing.
- Shower and wash basin waste water.

A.7.2.5 Fugitive dust control

Dust generated by excavation, earth movement, vehicle use, stockpiling, seeding, and similar activities would be controlled and minimized by the use of a water-based surfactant sprayed under moderately high pressure (from trucks and hoses). The source for dust suppression water would be ground water.

A.7.2.6 Roads

Road access to the site would be via the Aragonite exit off I-80, along the north frontage road west alongside I-80 for about 7 miles, to the overpass across I-80, and thence by about 3 miles of new access road (Figure A-5).

The existing frontage road between the Aragonite exit and the Clive overpass is a graded, graveled, county road and would require upgrading to carry the increased weight and frequency of traffic.

From the Clive overpass, approximately 3 miles of new access road would be constructed to the disposal site.

A.7.2.7 Rail car unloading (train transport mode)

Approximately 13,800 feet of railroad spur would be constructed to provide rail access to the offloading facility (Figure A-5).

The offloading facility would consist of a car positioner, rotary dump, receiving hopper, and stacking conveyor system. The car positioner would advance a car over the rotary dump mechanism, rotate the car about the axis of its end couplers, and dump the contents into a receiving hopper.

The conveyor system would remove tailings from the hopper beneath the rotary dump for deposition in stockpiles. The system would consist of feeders, an incline conveyor, and a radial stacker. The radial stacker would discharge into two 5000-ton stockpiles, one being deposited while the other is being transported to the embankment. Rubble and other materials that arrive at the South Clive site in side-dump cars would be dumped alongside the track. After unloading, the train would be checked for contamination, decontaminated as necessary, and returned to the Vitro site for loading.

A.7.2.8 Embankment construction

The tailings and other contaminated materials would be placed in an embankment constructed largely above grade. Materials for the radon barrier would be excavated, the contaminated material placed and compacted, and the radon barrier cover and erosion cover placed over the tailings and other contaminated materials.

Tailings would be placed about 15 feet above the ground-water table and the cover would be contoured and compacted to minimize water infiltration. Tailings and other contaminated material would be placed in and over the excavated area. For the transport by train option, tailings would be removed from the stockpiles created by the radial stacker with dozers and scrapers, transported to the excavation, spread, and compacted. For the transport by truck option, trucks would drive into the excavation and spread their load for compaction.

A.7.2.9 Cover construction

The cover would be constructed of two basic layers: A lower compacted earthen layer, and an upper rock layer. The earthen layer would be excavated with scrapers from the portion of the embankment area under construction and compacted over already completed portions of the embankment in a continuous cut and cover operation. The rock layer, for erosion protection, would be brought in by truck, spread, and compacted.

A.7.2.10 Restoration

The site would be returned to its approximate natural condition. Excess excavated material would be wasted around the disposal area. A site access road and drainage ditch would surround the embankment. The railroad and offloading facility would be dismantled, decontaminated, and salvaged.

A.7.2.11 Fencing

The embankment area would be secured by a 6-foot-high chain link fence with barbed wire topworks. A locked gate would be installed for access to the site.

A.7.2.12 Temporary facilities

During construction operations, temporary facilities would be required for construction workers and supervisors, engineering, administrative, security and monitoring personnel, and maintenance and repair services. The facilities would consist of office space and showers and change facilities for all personnel working on the site, as well as facilities for laundering clothing.

Access would be controlled and construction vehicles would remain on the site. Trucks bringing construction materials from off the site would be monitored and decontaminated as required prior to exit. All vehicles leaving the site would be checked for any contaminated material which is subject to release on public thoroughfares. A paved washdown area would be provided to remove all such contamination. Wash water would be collected and treated. A security staff would be on the site 24 hours per day.

There is no developed water supply at the disposal site. Brackish water, adequate for equipment decontamination, compaction, and dust control on the site would be developed from an on-site well. A holding pond would be constructed for storage of developed water. Potable water would be hauled from the nearest source.

Portable construction toilets would be used. Waste water from showers, hand basins, and laundry would gravity flow to a holding tank. Wash water from the vehicle wash area would be held in a pit. These waters would be used for dust suppression or disposed of on the site by a mobile irrigation system.

No electricity, gas, or other utilities are available at the disposal site. Electricity would be supplied by portable generators. Telephone service would be by radio telephone.

A.8 EQUIPMENT, PERSONNEL, ENERGY CONSUMPTION,
AND FUEL ESTIMATES, ALTERNATIVES 2 AND 3

A.8.1 Vitro site--introduction

As discussed in Sections A.2 through A.4, stabilization on the Vitro site (Alternative 2) consists of relocating all of the tailings and contaminated material into an embankment on the southcentral and southeast areas of the existing site. The embankment would occupy approximately 53 acres. The remainder of the site would be decontaminated, restored to approximate grade, and released for unrestricted use.

The construction activities are divided into phases. Each of the phases are described in the following subsections.

A.8.1.1 Site preparation

Tailings, rubble, and other contaminated material presently exist on portions of the area which would be utilized for the embankment. To provide a stable foundation for the tailings embankment, it would be necessary to relocate and recompact tailings presently in the embankment area, and to demolish and relocate foundations and other rubble in this area. The proposed construction staging area is presently covered with tailings and these would be removed and relocated as part of the site preparation.

The site preparation activity would require about 20 working days to complete and would utilize the following equipment.

<u>Type of equipment</u>	<u>Number</u>
D-8 dozer	3
Mobile crane	1
Truck	1
Grader	1
Front end loader	1

A.8.1.2 Tailings relocation

To install a liner system, tailings and contaminated material in the embankment area would be removed, a liner system installed, and the contaminated material replaced and recompactd on the liner system. Although the tailings and contaminated material relocation and liner placement would be two separate operations, they would progress concurrently and thus some of the equipment would be utilized for both activities.

This activity includes relocation of all of the tailings and contaminated material presently located in the embankment area. These materials are subdivided into three general categories depending upon degree of saturation.

Dry material	80,000 cy
Damp material	505,000 cy
Wet material	<u>265,000 cy</u>
Total	850,000 cy

Dry material is defined as loose tailings that can be relocated with heavy earth-moving equipment without special preparation. Damp material is defined as loose material that would require furrowing and dewatering prior to relocation with heavy earth-moving equipment. Wet material would require dewatering prior to excavation with a dragline or backhoe for relocation.

This activity would require approximately 50 working days (10 weeks) and the following equipment.

<u>Type of equipment</u>	<u>Number</u>
D-8 dozer	6
Scraper (20 cy capacity)	6
Backhoe (4 cy capacity)	2
Water truck	2
Compactor	2

A.8.1.3 Liner system placement

This activity includes placement of a base layer, subbase layer, and the liner. Material would be hauled from an off-site borrow location, placed, and compacted. This activity would require the placement of 710,000 cy of subbase and liner material. Liner system placement would require 220 working days (44 weeks) and the following equipment.

<u>Type of equipment</u>	<u>Number</u>
D-8 dozer	4
Backhoe (4 cy capacity)	1
Trucks (18.5 cy capacity)	35
Compactor	2
Grader	2
Water truck	2

A.8.1.4 Tailings consolidation

This activity includes relocation of tailings from the remainder of the site to the embankment area. These tailings are subdivided into three categories.

Dry material	90,000 cy
Damp material	875,000 cy
Wet material	<u>405,000 cy</u>
Total	1,370,000 cy

This activity would require 200 working days (40 weeks) and require the following equipment.

<u>Type of equipment</u>	<u>Number</u>
D-8 dozer	6
Scraper (20 cy capacity)	7
Truck (12 cy capacity)	6
Backhoe (4 cy capacity)	2
Grader	2
Compactor	2
Water truck	2

A.8.1.5 Cover installation

This activity includes the placement of the cover over the finished embankment. The cover material is divided into two categories: a radon barrier and an erosion barrier. All cover materials would be acquired from an off-site borrow location, hauled to the site, spread, and compacted.

Radon barrier cover	290,000 cy
Erosion barrier cover	155,000 cy

This activity would require 140 working days (28 weeks) to complete and the following equipment.

<u>Type of equipment</u>	<u>Number</u>
Trucks (18.5 cy capacity)	35
D-8 dozer	4
Grader	2
Compactor	2
Water truck	2

A.8.1.6 Site restoration

This activity includes the placement of restoration material. During the relocation, tailings and contaminated material would be excavated to depths below the elevation of the surrounding terrain. This excavated material would be replaced with clean fill to restore the area and to provide drainage. The restoration material would be acquired from an off-site borrow location, hauled to the site, spread, and compacted. The area would be revegetated. The quantity of fill required for restoration and revegetation is estimated to be 640,000 cy of random fill and 70,000 cy of select fill.

This activity would require 220 working days (44 weeks) to complete and the following equipment.

<u>Type of equipment</u>	<u>Number</u>
Trucks (18.5 cy capacity)	35
Water trucks	2
D-8 dozer	4
Compactors	2
Grader	1

A.8.1.7 Summary of personnel, energy consumption, and fuel estimates

Tables A-4 through A-6 contain a summary of personnel requirements, and energy and water consumption.

A.8.2 South Clive site--introduction

As discussed in Sections A.5 through A.7, the proposed action (Alternative 3) consists of relocating the tailings and other contaminated material from the Vitro site to the South Clive site. The embankment would occupy about 55 acres. The Vitro site would be decontaminated, restored to approximate grade, and released for unrestricted use.

Construction activities are divided into phases. Each phase is described below by mode of transportation.

A.8.2.1 Site preparation--train option

Vitro site

A construction staging area, site drainage system, waste-water retention basins, and a rail spur would be constructed during the site preparation phase. The staging and rail spur area would be cleared of 180,000 cy of contaminated materials and filled with 95,000 cy of compacted clean soils from an off-site borrow location. A rail spur 3,800 feet long, and a turn out and switch would be installed.

The site preparation activity on the Vitro site would require about 35 working days to complete and would utilize the following equipment.

<u>Type of equipment</u>	<u>Number</u>
D-8 dozer	4
Backhoe (4 cy capacity)	1
Trucks (18.5 cy capacity)	32
Grader	1
Compactor	1
Water truck	1

South Clive Site

A construction staging area, site drainage system, waste-water sedimentation basin, rail spur, rail unloading system, and access road would be constructed during the site preparation phase. The 7-mile frontage road along I-80 would be upgraded by adding 41,000 cy of gravel. A 2.3-mile access road from I-80 to the site and a 2.6-mile rail spur with four switches would be built of 125,000 cy of compacted adjacent soils, geotextile fabric, and

Table A-4. Personnel requirements and exposure type - stabilization in place.

	Number of days	Hours per day	No exposure ¹		On-site exposure ²		Total	
			Number people	Hrs (000s) exposure	Number people	Hrs (000s) exposure	Number people	Hrs (000s) exposure
<u>Site preparation</u>								
Equipment operators	20	8			6	1		
Truck drivers	20	8			1			
Maintenance personnel	20	8			1			
Miscellaneous personnel	20	8			4	1		
Supervisor/foremen	20	8			2			
TOTAL PERSONNEL			0		14		14	
TOTAL EXPOSURE HOURS (000s)						2		2
<u>Tailings relocation</u>								
Equipment operators	50	8			16	6		
Truck drivers	50	8			2	1		
Maintenance personnel	50	8			2	1		
Miscellaneous personnel	50	8						
Supervisor/foremen	50	8			3	1		
TOTAL PERSONNEL			0		23		23	
TOTAL EXPOSURE HOURS (000s)						9		9
<u>Liner system placement</u>								
Equipment operators	220	8			9	16		
Truck drivers	220	8	35	62				
Maintenance personnel	220	8			4	7		
Miscellaneous personnel	220	8						
Supervisor/foremen	220	8			3	5		
TOTAL PERSONNEL			35		16		51	
TOTAL EXPOSURE HOURS (000s)				62		28		90
<u>Tailings consolidation</u>								
Equipment operators	200	8			19	30		
Truck drivers	200	8			8	13		
Maintenance personnel	200	8			3	5		
Miscellaneous personnel	200	8				0		
Supervisor/foremen	200	8			3	5		
TOTAL PERSONNEL			0		33		33	
TOTAL EXPOSURE HOURS (000s)						53		53
<u>Cover installation</u>								
Equipment operators	140	8			8	9		
Truck drivers	140	8	35	39				
Maintenance personnel	140	8			4	4		
Miscellaneous personnel	140	8						
Supervisor/foremen	140	8			3	3		
TOTAL PERSONNEL			35		15		50	
TOTAL EXPOSURE HOURS (000s)				39		17		56
<u>Site restoration</u>								
Equipment operators	220	8			7	12		
Truck drivers	220	8	35	62				
Maintenance personnel	220	8			4	7		
Miscellaneous personnel	220	8						
Supervisor/foremen	220	8			3	5		
TOTAL PERSONNEL			35		14		49	
TOTAL EXPOSURE HOURS (000s)				62		25		86
<u>General Supervision</u>								
Equipment operators	600	8			1	5		
Field service personnel	600	8			7	34		
Security personnel	600	8			4	19		
Office personnel	600	8			2	10		
Monitoring personnel	600	8			6	29		
TOTAL PERSONNEL			0		20		20	
TOTAL EXPOSURE HOURS (000s)						58		96
TOTAL EXPOSURE HOURS (000s)			162		231		393	

¹Limited exposure to remedial action workers transporting uncontaminated fill.²Exposure to remedial action workers on the site.

Table A-5. Energy consumption - stabilization in place

Construction phase	Fuel (gal)	Electricity Kwh.
Site preparation	20,000	-0-
Tailings relocation	150,000	-0-
Liner system placement	450,000	-0-
Tailings consolidation	500,000	-0-
Cover installation	500,000	-0-
Restoration	800,000	-0-
General supervision	<u>100,000</u>	<u>400,000</u>
Total	2,520,000	400,000

Table A-6. Water consumption - stabilization in place

Construction Phase	gallons
Site work (general)	1,000,000
Tailings relocation	400,000
Tailings consolidation	1,200,000
Liner system placement	3,000,000
Cover installation	2,700,000
Restoration	1,600,000
Miscellaneous	<u>1,100,000</u>
Total	11,000,000

20,000 cy of gravel. The components of the rotary dump, hopper, and stacking conveyor unloading facility would be prefabricated off the site and assembled on the site.

The site preparation activity would require about 35 working days to complete and would utilize the following equipment.

<u>Type of equipment</u>	<u>Number</u>
D-8 dozer w/scarifier	1
Scraper	2
Compactor	1
Trucks (18.5 cy capacity)	8
Grader	1
Water truck	1

A.8.2.2 Site preparation--truck option

Vitro site

Site preparation would be the same as for the rail option without the rail spur construction. Approximately 10 working days and the following equipment would be required.

<u>Type of equipment</u>	<u>Number</u>
D-8 dozer	1
Backhoe (4 cy capacity)	1
Trucks (18.5 cy capacity)	8
Grader	1
Compactor	1
Water truck	1

South Clive site

Site preparation would be the same as for the rail option, without the rail spur and offloading facility construction. Approximately 25 working days and the following equipment would be required.

<u>Type of equipment</u>	<u>Number</u>
D-8 dozer w/scarifier	1
Scraper	1
Compactor	1
Trucks (18.5 cy capacity)	12
Grader	1
Water Truck	1

A.8.2.3 Tailings relocation--train option

This activity includes relocation of all of the tailings and contaminated material presently located at the Vitro site, 100,000 cy of contaminated vicinity properties, and 50,000 cy of windblown contaminated soils to the South Clive site. Tailings are subdivided into three general categories depending upon degree of saturation.

Dry material	170,000 cy
Damp material	1,380,000 cy
Wet material	<u>670,000 cy</u>
Total	2,220,000 cy

Dry material is defined as loose tailings that can be relocated with scrapers without special preparation. Damp material is defined as loose material that would require furrowing and dewatering prior to relocation with scrapers. Wet material would require dewatering prior to excavation with a dragline or backhoe for relocation with haul trucks. The windblown contaminated soils are generally dry. These materials would be excavated,

transported, and deposited beside the rail spur. Front end loaders would then place the tailings and fine-grained contaminated materials in the gondola cars. Rubble and vicinity property materials (180,000 cy) would be reduced in size, as necessary, with a mobile crane and wrecker ball, excavated with a dozer, and loaded into the side-dump cars with front end loaders.

This activity would require approximately 635 working days (127 weeks) and the following equipment.

<u>Type of equipment</u>	<u>Number</u>
Mobile crane (20 days only)	1
D-8 dozer	2
Scraper (20 cy capacity)	3
Backhoe (4 cy capacity)	1
On-site haul trucks (12 cy cap)	3
Water truck	1
Front end loaders	2
Rail cars (100 ton capacity)	108
Grader	1

A.8.2.4 Tailings relocation--truck option

The activity would be the same as the train option except that the contaminated materials would be loaded directly into 35-ton capacity trucks with front end loaders. Each truck would make two trips per day (9-10 hours per day). This activity would require approximately 635 working days (127 weeks) and the following equipment.

<u>Type of equipment</u>	<u>Number</u>
Mobile crane (20 days only)	1
Front end loader	2
Backhoe (4 cy capacity)	1
D-8 dozer	1
Trucks (35-ton capacity)	77
Grader	1
Water truck	1

A.8.2.5 Embankment and cover construction--train option

The embankment would be constructed in a continuous cut and cover operation. The existing soils would be excavated for use in covering already completed portions of the embankment. The bottom of the excavation would be compacted in preparation for placement of the contaminated materials which would then be compacted in lifts to the design elevation. Approximately 2,270,000 cy of contaminated materials would be transported from the rail stockpile to the embankment with scrapers and 180,000 cy of rubble by trucks. The radon barrier would require 460,000 cy of compacted soil and the erosion barrier would require 202,000 cy of rock from an off-site borrow area.

The embankment and cover construction would be concurrent with the tailings relocation and would require 640 working days (128 weeks) and the following equipment.

<u>Type of equipment</u>	<u>Numbers</u>
Scraper	6
D-8 dozer	2
Front end loader	1
Compactor	1
Water truck	1
On-site trucks (12 cy capacity)	1
Off-site trucks (18.5 cy capacity)	3
Grader	1

A.8.2.6 Embankment and cover construction--truck option

The activity would be the same as in the train option except all of the contaminated materials would be deposited directly on the embankment.

The embankment and cover construction would require 640 working days (128 weeks) and the following equipment.

<u>Type of equipment</u>	<u>Number</u>
Scraper	1
D-8 dozer	2
Compactor	1
Water truck	1
Off-site trucks (18.5 cy capacity)	3
Grader	1

A.8.2.7 Site restoration--train option

Vitro site

This activity includes the placement of restoration material (select fill). During the relocation, tailings and contaminated material would be excavated to depths below the elevation of the surrounding terrain. This excavated material would be replaced with clean fill to restore the area and to provide drainage. The restoration material would be acquired from an off-site borrow location, hauled to the site, spread, and compacted. The area would be revegetated. The quantity of fill required for restoration and revegetation is estimated to be 1,040,000 cy of select fill. Approximately 95,000 cy of clean fill would have been brought in for the rail spur and staging area, thus 945,000 cy would be brought in the restoration phase.

This activity would require 625 working days (125 weeks) to complete and the following equipment.

<u>Type of equipment</u>	<u>Number</u>
Trucks (18.5 cy capacity)	17
Water truck	1
D-8 dozer	1
Compactors	1
Grader	1

South Clive Site

After all of the tailings and contaminated materials have been relocated from the Vitro site to the South Clive site the rail spur track and offloading facility would be decontaminated and salvaged. The rail spur subbase would be recontoured to approximately the original grade. The embankment construction equipment would be used a short time in this task. The access road would remain.

A.8.2.8 Site restoration--truck option

Vitro Site

The activity would be the same as in the train option except that restoration fill required would be greater than the amount for the rail spur.

The site restoration would require 615 working days (123 weeks) and the following equipment.

<u>Type of equipment</u>	<u>Number</u>
Trucks (18.5 cy capacity)	19
Water truck	1
D-8 dozer	1
Compactor	1
Grader	1

South Clive Site

No restoration activities would be required at the South Clive site.

A.8.2.9 Summary of personnel, energy consumption, and fuel estimates

Tables A-7 through A-11 contain a summary of personnel requirements, and energy and water consumption for Alternative 3.

Table A-7. Personnel requirements and exposure - train option - relocation to South Clive.

	Number of Days	Hours Per Day	No Exposure ¹		On Site Exposure ²		Exposure During Haul ³		Total	
			Number People	Hrs (000s) Exposure	Number People	Hrs (000s) Exposure	Number People	Hrs (000s) Exposure	Number People	Hrs (000s) Exposure
<u>Site preparation - Vitro</u>										
Equipment operators	35	8			11	3				
Truck drivers	35	8	32	9						
Maintenance personnel	35	8			2	1				
Miscellaneous personnel	20	8			22	4				
Supervisor/foremen	35	8			8	2				
TOTAL PERSONNEL			32		43				75	
TOTAL EXPOSURE HOURS (000s)				9		9				18
<u>Site preparation - Clive</u>										
Equipment operators	35	8	9	3						
Truck drivers	35	8	8	2						
Maintenance personnel	35	8	2	1						
Miscellaneous personnel	20	8	28	4						
Supervisor/foremen	35	8	8	2						
TOTAL PERSONNEL			55						55	
TOTAL EXPOSURE HOURS (000s)				12						12
<u>Tailings relocation - Vitro</u>										
Equipment Operators	635	8			9	46	5			
Equipment operators	20	8			1			25		
Truck drivers	635	8			3	15				
Maintenance personnel	635	8			2	10				
Miscellaneous personnel	635	8			11	56				
Supervisor/foremen	635	8			4	20				
TOTAL PERSONNEL					30		5		35	
TOTAL EXPOSURE HOURS (000s)						147		25		173
<u>Embankment construction - Clive</u>										
Equipment operators	640	8			13	67				
Truck drivers	640	8	3	15	1	5				
Maintenance personnel	640	8			2	10				
Miscellaneous personnel	640	8			8	41				
Supervisor/foremen	640	8			4	20				
TOTAL PERSONNEL			3		28				31	
TOTAL EXPOSURE HOURS (000s)				15		143 *				159
<u>Site restoration - Vitro</u>										
Equipment operators	625	8			4	20				
Truck drivers	625	8	17	85						
Maintenance personnel	625	8			1	5				
Miscellaneous personnel	625	8								
Supervisor/foremen	625	8			2	10				
TOTAL PERSONNEL			17		7				24	
TOTAL EXPOSURE HOURS (000s)				85		35				120
TOTAL EXPOSURE HOURS (000s)				121		335		25		482

¹Limited exposure to remedial action workers transporting uncontaminated fill.

²Exposure to remedial action workers on the site.

³Exposure to remedial action workers transporting tailings.

Talbe A-8. Personnel requirements and exposure - truck option - relocation to South Clive.

	Number of Days	Hours Per Day	No Exposure ¹		On Site Exposure ²		Exposure During Haul ³		Total	
			Number People	Hrs (000s) Exposure	Number People	Hrs (000s) Exposure	Number People	Hrs (000s) Exposure	Number People	Hrs (000s) Exposure
<u>Site preparation - Vitro</u>										
Equipment operators	10	8			5					
Truck drivers	10	8	8	1						
Maintenance personnel	10	8			1					
Miscellaneous personnel	10	8			9	2				
Supervisor/foremen	10	8			4					
TOTAL PERSONNEL			8		19				27	
TOTAL EXPOSURE HOURS (000s)				1		2				2
<u>Site preparation - Clive</u>										
Equipment operators	25	8	5	1						
Truck drivers	25	8	12	2						
Maintenance personnel	25	8	1	1						
Miscellaneous personnel	25	8	6	1						
Supervisor/foremen	25	8	4	1						
TOTAL PERSONNEL			28						28	
TOTAL EXPOSURE HOURS (000s)				6						6
<u>Tailings relocation - Vitro</u>										
Equipment operators	635	8			6	30				
Equipment operators	20	8			1					
Truck drivers	635	8					77	489		
Maintenance personnel	635	8			2	10				
Miscellaneous personnel	635	8			15	76				
Supervisor/foremen	635	8			4	20				
TOTAL PERSONNEL					28		77		105	
TOTAL EXPOSURE HOURS (000s)						137		489		626
<u>Embankment construction - Clive</u>										
Equipment operators	640	8			5	26				
Truck drivers	640	8	3	15		0				
Maintenance personnel	640	8			1	5				
Miscellaneous personnel	640	8			9	46				
Supervisor/foremen	640	8			4	20				
TOTAL PERSONNEL			3		19				22	
TOTAL EXPOSURE HOURS (000s)				15		97				113
<u>Site restoration - Vitro</u>										
Equipment operators	615	8			4	20				
Truck drivers	615	8	19	93						
Maintenance personnel	615	8			1	5				
Miscellaneous personnel	615	8								
Supervisor/foremen	615	8			2	10				
TOTAL PERSONNEL			19		7				26	
TOTAL EXPOSURE HOURS (000s)				93		35				128
TOTAL EXPOSURE HOURS (000s)				115		271		489		875

¹Limited exposure to remedial action workers transporting uncontaminated fill.

²Exposure to remedial action workers on the site.

³Exposure to remedial action workers transporting tailings.

Table A-9. Energy consumption--train option

Construction phase	Fuel (gal)	Electricity (Kwh)
Site preparation	180,000	--
Tailings relocation	3,420,000	--
Embankment construction	2,000,000	--
Restoration	1,070,000	--
General supervision	300,000	800,000
Total	6,970,000	800,000

Table A-10. Energy consumption--truck option

Construction phase	Fuel (gal)	Electricity (Kwh)
Site preparation	51,000	
Tailings relocation	4,940,000	
Embankment construction	690,000	
Restoration	1,140,000	
General supervision	300,000	800,000
Total	7,121,000	800,000

Table A-11. Summary of water use--gallons

Activity	Train		Truck	
	Vitro	Clive	Vitro	Clive
Site prep	2,600,000	1,400,000	--	300,000
Relocation	400,000	400,000	1,500,000	1,500,000
Embankment		4,700,000		4,700,000
Restoration	6,100,000		6,700,000	
Dust control	2,700,000	2,700,000	2,700,000	2,700,000
Total	11,800,000	9,200,000	10,900,000	9,200,000
Total Option	21,000,000		20,100,000	

A.9 CAPITAL COST ESTIMATES

A.9.1 Vitro site--Alternative 2

A cost estimate has been prepared, based upon the conceptual design described in this Appendix. The conceptual design cost estimate is \$31.24 million and is summarized in Table A-12. This represents the preliminary cost estimate for cost-sharing purposes. A detailed breakdown of the remedial action construction costs is presented in Table A-13. These costs do not include the vicinity property work.

Table A-12. Site cost estimate summary (1983 - \$000)
Alternative 2

Item	Costs
<u>Site acquisition</u>	
Mineral value	0
Land value	<u>5,000</u>
TOTAL SITE ACQUISITION	5,000
Remedial Action (RA)	
Processing site	
Site preparation	1,550
Liner system	4,230
Site grading	8,370
Cover	1,370
Erosion protection	930
Decontamination facilities	60
Restoration	3,960
Fencing	80
Supervisory & field services	<u>3,600</u>
TOTAL REMEDIAL ACTION	24,150
<u>Engineering/construction management</u>	
Engineering	630
Construction management	<u>1,110</u>
TOTAL ENGINEERING/CONSTRUCTION MANAGEMENT	1,740
MAINTENANCE AND SURVEILLANCE	<u>350</u>
TOTAL COST ESTIMATE	\$31,240*

*Based upon the State of Utah engineering analyses and cost estimates for the preload system, the cost for Alternative 2 would increase to \$42.0 million.

Table A-13. Cost estimate--detailed
Alternative 2

Item	Cost (\$000)
SITE PREPARATION	
1. Mobilization (lump sum)	60
2. Staging area (lump sum)	20
• Laydown and parking facilities	
3. Roads	80
• Construct and maintain temporary roads	
• Concrete protection pads over utilities	
4. Clearing and grubbing (lump sum)	10
5. Dewatering	140
• Temporary ditches, gravel liners	
• Sump pumps and lines	
• Retention ponds	
• Permanent ditches	
6. Waste-water treatment facility	860
7. Demolition	380
• Stack, concrete foundations	
• Telephone and power lines (relocate)	
• Water and gas lines (relocate)	
Total site preparation	
	\$1,550
TAILINGS PILE	
	8,370
1. Relocate, grade, and compact (on-site materials)	
• Dry	(170,000 cy)
• Dewatered	(1,380,000 cy)
• Wet	(670,000 cy)
• Rubble	(80,000 cy)
• Off-site materials	(150,000 cy)
2. Liner system	4,230
• Subbase preparation	(220,000 cy)
• Base preparation	(300,000 cy)
• Liner preparation	(190,000 cy)

Table A-13. (continued)

Item	Cost (\$000)
RADON COVER	1,370
1. Compacted borrow (290,000 cy) • Purchase, haul, spread, and compact	
EROSION COVER	930
1. Pit run rock • Purchase, haul, spread, (155,000 cy) and compact	
DECONTAMINATION (lump sum)	60
1. Driveway washdown facility	
SITE RESTORATION	3,960
1. Fill material (640,000 cy) • Purchase, haul, spread, and compact	
Select fill material (70,000 cy) • Purchase, haul, spread, and compact	
2. Seeding (75 Ac)	
FENCING (lump sum) (7,000 LF)	80
SUPERVISORY AND FIELD SERVICES	
1. Field staff 1,000 • Project manager • Project engineer • Construction engineer • Safety engineer • Schedules/cost engineer • Secretary	
2. Field services 1,060 • Additional labor • Security • Survey crew • Quality control	

Table A-13. (continued)

Item	Cost (\$000)
3. Field health services • Health physics manager • Access control technician • Truck monitor • Laboratory services • Equipment and miscellaneous	1,070
4. Temporary facilities • Field office • Field office expenses • Change and shower unit • Temporary utilities • Temporary sanitary facilities • Insurance • Consumable supplies • Laundry and operation • Mobile equipment • Fencing, barricades, signs, and miscellaneous	<u>470</u>
Supervisory and Field Services Total:	3,600
Total Preliminary Cost Estimate	<u>\$24,150</u>

A.9.2 South Clive site--Alternative 3 (proposed action)

A cost estimate has been prepared, based upon the conceptual design described in this Appendix. The conceptual design cost estimate is \$63.78 (train) or 67.68 (truck) million and is summarized in Tables A-14 and A-15. This represents the preliminary cost estimate for cost-sharing purposes. A detailed breakdown of the remedial action construction costs is presented in Tables A-16 (train) and A-17 (truck). These costs do not include the vicinity property work.

Table A-14. Site cost estimate summary (1983 - \$000)
Alternative 3 - train transportation

Item	Costs
<u>Site acquisition</u>	
Mineral value	0
Land value	<u>80</u>
TOTAL SITE ACQUISITION	80
<u>Remedial action (RA)</u>	
Work at Salt Lake City	
Site preparation	2,520
Decontamination	330
Site relocation	33,400
Site restoration	5,270
Supervisory and field services	3,980
	45,500
Work at Clive	
Site preparation	2,820
Cover	1,250
Erosion protection	1,430
Decontamination	330
Site relocation	6,460
Fencing	90
Supervisory and field services	3,020
	<u>15,400</u>
TOTAL REMEDIAL ACTION	60,900
<u>Engineering/construction management</u>	
Engineering	1,150
Construction management	<u>1,560</u>
TOTAL ENGINEERING/CONSTRUCTION MANAGEMENT	2,710
MAINTENANCE AND SURVEILLANCE	<u>90</u>
TOTAL COST ESTIMATE	\$63,780

Table A-15. Site cost estimate summary (1983 - \$000)
Alternative 3 - truck transportation

Item	Costs
<u>Site acquisition</u>	
Mineral value	0
Land value	<u>80</u>
TOTAL SITE ACQUISITION	80
<u>Remedial action (RA)</u>	
Work at Salt Lake City	
Site preparation	1,490
Decontamination	120
Site relocation	41,300
Site restoration	5,270
Supervisory and field services	4,320
	52,500
Work at Clive	
Site preparation	3,510
Cover	1,250
Erosion protection	1,430
Decontamination	120
Site relocation	2,680
Fencing	90
Supervisory and field services	3,220
	<u>12,300</u>
TOTAL REMEDIAL ACTION	64,800
<u>Engineering/construction management</u>	
Engineering	1,150
Construction management	<u>1,560</u>
TOTAL ENGINEERING/CONSTRUCTION MANAGEMENT	2,710
MAINTENANCE AND SURVEILLANCE	<u>90</u>
TOTAL COST ESTIMATE	\$67,680

Table A-16. Cost estimate--detailed
Alternative 3 - train transportation

Item	Cost (\$000)
<u>WORK AT SALT LAKE CITY</u>	
SITE PREPARATION	
1. Mobilization (lump sum)	60
2. Staging area (lump sum)	20
• Laydown and parking facilities	
3. Utility protection	20
• Concrete protection pads over utilities	
4. Clearing and grubbing (lump sum)	10
5. Dewatering	140
• Temporary ditches, gravel liners	
• Sump pumps and lines	
• Retention ponds	
• Permanent ditches	
6. Waste-water treatment facility	860
7. Demolition	380
• Stack, concrete foundations	
• Telephone and power lines (relocate)	
• Water and gas lines (relocate)	
8. Temporary railroad spur	<u>1,030</u>
• Construct base, install new and used track, maintenance and salvage	
Total site preparation	\$2,520
DECONTAMINATION (lump sum)	330
1. Equipment and truck wash-down facility	
2. Train wash-down facility	
SITE RELOCATION	
1. Excavate and load contaminated material (2,450,000 cy)	8,810
2. Transportation: cars, maintenance, hauling, covers	24,590

Table A-16. (continued)

Item	Cost (\$000)
SITE RESTORATION	
1. Fill material (825,000 cy)	5,270
• Purchase, haul, spread, and compact	
Select fill material (120,000 cy)	
• Purchase, haul, spread, and compact	
2. Seeding (128 Ac)	
SUPERVISORY AND FIELD SERVICES	
1. Field staff	1,190
• Project manager	
• Project engineer	
• Construction engineer	
• Safety engineer	
• Schedules/cost engineer	
• Secretary	
2. Field services	1,090
• Additional labor	
• Security	
• Survey crew	
• Quality control	
3. Field health services	1,140
• Health physics manager	
• Access control technician	
• Laboratory services	
• Equipment and miscellaneous	
4. Temporary facilities	<u>560</u>
• Field office	
• Field office expenses	
• Change and shower unit	
• Temporary utilities	
• Temporary sanitary facilities	
• Insurance	
• Consumable supplies	
• Laundry and operation	
• Mobile equipment	
• Fencing, barricades, signs and miscellaneous	
Supervisory and field services total:	3,980

Table A-16. (continued)

Item	Cost (\$000)
<u>WORK AT CLIVE</u>	
SITE PREPARATION	
1. Mobilization (lump sum)	60
2. Staging area (lump sum)	20
• Laydown and parking facilities	
3. Roads	1,070
• Construct and maintain temporary roads	
• Construct permanent roads	
4. Dewatering	190
• Temporary ditches, gravel liners	
• Retention ponds	
• Permanent ditches	
5. Water well	120
6. Temporary railroad spur	<u>1,360</u>
Total site preparation	\$2,820
RADON COVER	1,250
1. Compacted on site soils (570,000 cy)	
• Excavate, spread, and compact	
EROSION COVER	1,430
1. Pit run rock (190,000 cy)	
• Excavate, haul, spread	
DECONTAMINATION (lump sum)	330
1. Equipment and truck wash-down facility	
2. Train wash-down facility	
SITE RELOCATION	
1. Haul tailings from radial stacker; spread and compact (2,450,000 cy)	4,290
2. Off-loading facility	2,170

Table A-16. (continued)

Item	Cost (\$000)
FENCING (7,500 LF)	90
SUPERVISORY AND FIELD SERVICES	
1. Field staff • Construction engineer	260
2. Field services • Additional labor • Security • Survey crew • Quality control	1,260
3. Field health services • Health physics manager • Access control technician • Laboratory services • Equipment and miscellaneous	810
4. Temporary facilities • Field office • Field office expenses • Change and shower unit • Temporary utilities • Temporary sanitary facilities • Insurance • Consumable supplies • Laundry and operation • Mobile equipment • Fencing, barricades, signs and miscellaneous	<u>690</u>
Supervisory and field services total:	<u>3,020</u>
Total preliminary cost estimate	\$60,900

Table A-17. Cost estimate--detailed
Alternative 3 - truck transportation

Item	Cost (\$000)
<u>WORK AT SALT LAKE CITY</u>	
SITE PREPARATION	
1. Mobilization (lump sum)	60
2. Staging area (lump sum)	20
• Laydown and parking facilities	
3. Utility protection	20
• Concrete protection pads over utilities	
4. Clearing and grubbing (lump sum)	10
5. Dewatering	140
• Temporary ditches, gravel liners	
• Sump pumps and lines	
• Retention ponds	
• Permanent ditches	
6. Waste-water treatment facility	860
7. Demolition	<u>380</u>
• Stack, concrete foundations	
• Telephone and power lines (relocate)	
• Water and gas lines (relocate)	
Total site preparation	\$1,490
DECONTAMINATION (lump sum)	120
1. Equipment and truck wash-down facility	
SITE RELOCATION	
1. Excavate and load contaminated material (2,450,000 cy)	4,510
2. Transportation: trucks, maintenance, hauling, covers	36,790

Table A-17. (continued)

Item	Cost (\$000)
SITE RESTORATION	
1. Fill material (825,000 cy)	5,270
• Purchase, haul, spread, and compact	
Select fill material (120,000 cy)	
• Purchase, haul, spread, and compact	
2. Seeding (128 Ac)	
SUPERVISORY AND FIELD SERVICES	
1. Field staff	1,190
• Project manager	
• Project engineer	
• Construction engineer	
• Safety engineer	
• Schedules/cost engineer	
• Secretary	
2. Field services	1,090
• Additional labor	
• Security	
• Survey crew	
• Quality control	
3. Field health services	1,500
• Health physics manager	
• Access control technician	
• Truck monitor	
• Laboratory services	
• Equipment and miscellaneous	
4. Temporary facilities	<u>540</u>
• Field office	
• Field office expenses	
• Change and shower unit	
• Temporary utilities	
• Temporary sanitary facilities	
• Insurance	
• Consumable supplies	
• Laundry and operation	
• Mobile equipment	
• Fencing, barricades, signs and miscellaneous	
Supervisory and field services total:	4,320

Table A-17. (continued)

Item	Cost (\$000)
<u>WORK AT CLIVE</u>	
SITE PREPARATION	
1. Mobilization (lump sum)	60
2. Staging area (lump sum) • Laydown and parking facilities	20
3. Roads • Construct and maintain temporary roads • Construct permanent roads	3,120
4. Water well	120
5. Dewatering • Temporary ditches, gravel liners • Retention ponds • Permanent ditches	<u>190</u>
Total site preparation	\$3,510
RADON COVER	
1,250	
1. Compacted on-site soils (570,000 cy) • Excavate, spread, and compact	
EROSION COVER	
1,430	
1. Pit run rock (190,000 cy) • Excavate, haul, spread	
DECONTAMINATION (lump sum)	
120	
1. Equipment and truck wash-down facility	
SITE RELOCATION	
1. Haul tailings to embankment area (2,450,000 cy)	2,680
FENCING (7,500 LF)	
90	

Table A-17. (continued)

Item	Cost (\$000)
SUPERVISORY AND FIELD SERVICES	
1. Field staff • Construction engineer	260
2. Field services • Additional labor • Security • Survey crew • Quality control	1,260
3. Field health services • Health physics manager • Access control technician • Truck monitor • Laboratory services • Equipment and miscellaneous	1,010
4. Temporary facilities • Field office • Field office expenses • Change and shower unit • Temporary utilities • Temporary sanitary facilities • Insurance • Consumable supplies • Laundry and operation • Mobile equipment • Fencing, barricades, signs and miscellaneous	<u>690</u>
Supervisory and field services total:	<u>3,220</u>
Total preliminary cost estimate	\$64,800

References for Appendix A

- COE (U.S. Army Corps of Engineers), 1970. Engineering and Design, Hydraulic Design of Flood Control Channels, EM1110-2-1601, Office of the Chief of Engineers, Washington, D.C.
- (COE, 1970)
- DOE (U.S. Department of Energy), 1984. Remedial Action Plan and Site Conceptual Design for Stabilization of the Inactive Uranium Mill Tailings Site at Salt Lake City, Utah for the U. S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico. UMTRA--DOE/AL-050502.0141.
- Hansen, et al. (Hansen, E. M., Francis K. Schwarz, and John T. Riedel), 1977. Probable Maximum Precipitation Estimates, Colorado River and Great Basin Drainages, Hydrometeorological Report No. 49, Prepared by the National Weather Service Office of Hydrology for the U.S. Department of Commerce and U.S. Department of the Army, Silver Spring, Maryland.
- Rogers et al., (Rogers, V. C., G. M. Sanquist, and K. K. Nielson), 1981. Radon Attenuation Effectiveness and Cost Optimism of Composite Covers for Uranium Mill Tailings, UMTRA-DOE/ALO-165, prepared by Rogers and Associates Engineering Corp., Salt Lake City, Utah, for the U.S. Department of Energy, UMTRA Project Office, Albuquerque, New Mexico.
- SH&B (Sergent, Hauskins, & Beckwith), 1983. "Evaluation of Potential Earthquake Effects, Vitro Site, Salt Lake City, Utah," unpublished report prepared by Sergent, Hauskins, & Beckwith, Phoenix, Arizona, for the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.
- Simons and Senturk (Simons, D. B. and F. Senturk) 1976. Sediment Transport Technology, Water Resources Publication, Fort Collins, Colorado.
- USDOI (U.S. Department of the Interior), 1977. Design of Small Dams, Bureau of Reclamation, Water Resources Technical Publication, Washington, D.C.
- Walski, T. M., J. M. Morgan, A. C. Gibson, and P. R. Schroeder, 1982. "Draft User Guide for the Hydrologic Evaluation of Landfill Performance (HELP) Model," Municipal Environmental Research Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio.

Appendix B

THE SELECTION OF AN OFF-SITE DISPOSAL SITE

TABLE OF CONTENTS

	<u>Page</u>
B.1 BACKGROUND	B-3
B.2 HISTORY	B-5
B.2.1 The FBDU engineering assessments	B-5
B.2.2 Site selection by the State of Utah	B-12
B.2.3 Site evaluations by the DOE	B-14
B.3 CONCLUSIONS	B-17
References for Appendix B	B-19

LIST OF TABLES

	<u>Page</u>
B-1 Twenty-nine sites evaluated as repositories for the Vitro tailings in Phase II-Title I Engineering Assessment	B-6
B-2 FBDU site selection criteria	B-9
B-3 Sites considered by Vitro tailings site selection committee (VTSSC)	B-13
B-4 Relative rankings of state-nominated areas	B-14

Appendix B

THE SELECTION OF AN OFF-SITE DISPOSAL SITE

The impacts of transporting the Vitro tailings and other contaminated material to an off-site location are described in this document in terms of a new disposal site approximately 1 mile south of Clive, Utah. This appendix provides a background for and history of the events that led to the choice of the South Clive site as the off-site alternative.

B.1 BACKGROUND

On March 12, 1974, the subcommittee on Raw Materials of the Joint Committee on Atomic Energy (JCAE), Congress of the United States, held hearings on two identical bills submitted by Senator Frank E. Moss and Representative Wayne Owens of Utah. The bills, S. 2566 and H.R. 11378, provided for the assessment of an appropriate remedial action to limit the exposure of individuals to radiation from uranium mill tailings at the Vitro site in Salt Lake City, Utah. These bills also provided for a cooperative arrangement between the Atomic Energy Commission (AEC) and the State of Utah in making the assessment.

During the JCAE hearings, Dr. William D. Rowe of the U.S. Environmental Protection Agency (EPA) pointed out that there were other inactive uranium mill sites that shared the problems of the Vitro site; he recommended a generic approach to the problem of abandoned uranium mill tailings, with first priority being given to addressing the most critical tailings sites. Similar recommendations were made by Dr. James L. Liverman who testified for the AEC: he proposed that a comprehensive study should be made of all abandoned tailings piles, rather than treating potential problems on a piece-meal basis. This comprehensive study would be a cooperative two-phase undertaking by the concerned states and appropriate Federal agencies such as the AEC and EPA. Phase I of this undertaking would involve identifications of sites that might require remedial action, and determination of the need for corrective action through observations of each site's condition, ownership, proximity to populated areas, and prospects for increased population near the site. A preliminary report of Phase-I work would serve as a basis for determining if a detailed engineering assessment (Phase-II) was necessary for each mill site. The Phase-II engineering, if necessary, would include evaluation of the problems, examination of alternative solutions, preparation of cost estimates and of detailed plans, and specifications for alternative remedial-action measures.

The Phase-I assessment began in May 1974, with teams consisting of representatives of the AEC, the EPA, and the affected states visiting 21 of the known inactive millsites. A Phase-I report was presented to the JCAE in October 1974 (AEC, 1974). Based on the findings of that report, a decision was made by the AEC to proceed with the Phase-II engineering assessments at 17 sites, including the Vitro site at Salt Lake City.

B.2 HISTORY

B.2.1 The FBDU engineering assessments

An active search for alternate disposal sites for the Vitro mill tailings began in 1975. On May 5, 1975, the U.S. Energy Research and Development Administration (ERDA), formed by the Energy Reorganization Act of 1974 which abolished the AEC, selected Ford, Bacon & Davis Utah Inc. (FBDU) of Salt Lake City to provide architect-engineering services for Phase-II assessments of the 17 mill sites mentioned in the Phase-I report (AEC, 1974). FBDU began work on June 23, 1975, giving first consideration to the Vitro site. The architect-engineering services contract specified, among other things, that FBDU would determine the adequacy and the environmental suitability of sites at which mill tailings could be disposed.

The original Phase-II report on the Vitro site in Salt Lake City was published in April 1976 (FBDU, 1976). Altogether 29 potential disposal sites or areas were mentioned in this report; these sites are listed in Table B-1. The 29 sites were either nominated by state agencies, Federal agencies, private individuals, or were chosen by FBDU on the basis of their knowledge of suitable areas in the vicinity of Salt Lake City. Because of transportation costs, only those locations within 150 miles of Salt Lake City were initially considered.

Very early in their work on the engineering assessments, FBDU developed 29 criteria for determining the suitability of sites proposed for storage of mill tailings (personal communication, Mr. Robert Overmyer, FBDU, October 5, 1981). These 29 criteria, listed in Table B-2 in their original form as a field "score sheet," were logically developed from general principles of radiation protection that had been adopted by ERDA. It should be emphasized that in 1975 there were no Federal standards or guidelines specifically directed towards the cleanup of uranium mill sites or disposal of uranium mill tailings. Some guidelines for cleanup of habitable structures contaminated with tailings had been published by the U.S. Surgeon General for use in the Grand Junction, Colorado remedial program (10 CFR 12), but these guidelines did not directly apply to the problems of mill tailings disposal. Consequently, ERDA and FBDU had to create their own guidelines in order to proceed with the engineering assessments. In brief, these ad-hoc guidelines had three objectives: (1) to reduce residual gamma radiation to levels which would be as low as practicable; (2) where cleanup was necessary, to reduce the radium content of the soil to no more than twice the radium background in the area; (3) to meet applicable state and Federal standards for the radium-226 content of ground or surface waters. Other desirable goals, such as preservation of local ecosystems, the minimization of project costs, and making best use of lands, were factored into the development of the 29 site-selection criteria.

The site-selection criteria were used to score and rank the 29 sites shown in Table B-1; the highest-scoring site was ranked first, the next-highest-scoring site was ranked second, and so on. In obtaining a total score for each site, the scores for each criterion (a number in the range 1 to 10) were simply added, and equal weights were given to the 29 criteria. The results of this ranking are specified in Table B-1 for the top-ranking 15

Table B-1. Twenty-nine sites evaluated as repositories for the Vitro tailings in Phase II-Title I Engineering Assessment

Salt Lake Valley sites	FBDU site identification number	FBDU rank ^a
Salt Lake International Airport Fill for proposed runway expansion Township 1 North, Range 1 West	4 ^c	7 ^b
Freeway Interchange (I-80:40th W) South of Salt Lake International Airport #1 Township 1 South, Range 2 West	5 ^c	8 ^b
Kennecott Tailings Area 2 miles north of Magna, Utah Township 1 South, Range 2 West	6	-
Butterfield Canyon 5 miles south, southwest of Lark, Utah Township 1/2 South, Range 1 West	14	14
Magna Lake Bed North and east of Kennecott Tailings Pond Township 1 South, Range 2 West	28 ^c	-
Magna Area State Land 2 miles east of Magna, Utah Township 1 South, Range 2 West	24 ^c	12
Lark Copper Tailings Site 1/2 mile east of Lark, Utah Township 3 South, Range 2 West	25	15
Oquirrh Foothills 12 miles west of Midvale, Utah Township 3 South, Range 2 West	29 ^c	-
<u>Great Salt Lake Desert sites</u>		
1 mile south of Clive, Utah Township 1-1/2 South, Range 11 West	1 ^c	2
Natural Depression 8 miles north of Clive, Utah Township 1/2 North, Range 12 West	2 ^c	1
Natural Depression Township 1 North, Range 15 West	11	-
Newfoundland Range Basin Township 5-1/2 North, Range 14 West	12	-

Table B-1 (continued)

Great Salt Lake Desert sites	FBDU site identification number	FBDU rank ^a
Dugway Proving Grounds 5 miles west of Camels Back Ridge Township 8 South, Range 11 West	17	-
6 miles northwest of Knolls, Utah Salt Lake Baseline, Range 12 West	22	-
12 miles northwest of Knolls, Utah Township 1 North, Range 13 West	23	-
1 mile south of Low, Utah	27	-
<u>Other locations</u>		
North Skull Valley 3 miles west of Delle, Utah Salt Lake Baseline, Range 9 West	3 ^c	3
Rush Valley 20 miles south of Tooele Army Depot Township 7 South, Range 5 West	7	6
Ripple Valley 5 miles southeast of Porter Well, Utah Salt Lake Baseline, Range 10 West	8	-
Cedar Mountain Foothills 10 miles east of Clive, Utah Township 1-1/2 South, Range 10 West	9	-
Cedar Mountain Foothills 10 miles west of Delle, Utah Salt Lake Baseline, Range 9 West	10	5
Black Mountain Lakeside Mining District 7 miles north of Delle, Utah Township 1/2 North, Range 8 West	20	10
Point of the Mountain 3 miles north of Lehi, Utah Township 2 North, Range 10 West	26	13
Puddle Valley 5 miles east of Grassy Mountain Well Township 2 North, Range 10 West	13	-

Table B-1 (continued)

Other locations	FBDU site identification number	FBDU rank ^a
Puddle Valley Northwest of Delle, Utah Township 1 North, Range 9 West	21	9
Hell's Kitchen Ranch 40 acre natural basin Township 17 South, Range 1/2 West	16	-
Rush Valley 4 miles south of Tooele Army Depot Township 7 South, Range 4 West	18	4
Camp Williams State Military Reservation Tickville Gulch, 8 miles west of Lehi Township 3 South, Range 3 West	19	11
Ripple Valley 7 miles southwest of Porter Well, Utah Township 1/2 South, Range 11 West	15	-

^aRanks are specified for only the top-ranking 15 sites.

^bNo longer available as of 1981, since developments are already underway or are completed.

^cAlternative disposal sites selected for cost studies (FBDU, 1976).

Table B-2. FBDU site selection criteria

Criteria	1	2	3	4	Point values		6	7	8	9	10
					5						
HYDROLOGY & GEOLOGICAL CONSIDERATIONS											
Rainfall	More than 30"ann.	<27"ann.	<24"ann.	<21"ann.	<18"ann.	<15"ann.	<12"ann.	<9"ann.	<6"ann.		Less than 3"ann.
Evidence of flooding	Common occur.				50% Chance						Negligible
Run-off characteristics	Gully erosion		Sheet erosion			Rills evident					No erosional features
Drainage distance from site to rivers, lakes & lower elev.	Within 1 mile	>2	>3	>4	>5	>6	>7	>8	>9		Over 10 miles
Wells or springs in area	Within 1 mile	>2	>3	>4	>5	>6	>7	>8	>9		Over 10 miles
Water table location	Water table >20'	>40'	>60'	>80'	>100'	>120'	>140'	>160'	>180'		Water table over 200'
Possibility of mud or rock slides, faults, avalanches	Common occur.										Negligible
Potential for agriculture & grazing, soil charc.	Good topsoil										No topsoil, rocky
Density of vegetative cover	100%	90%	70%	50%	30%	20%	15%	10%	5%		No vegetation
Type of underlying unconsolid. strata	Sand & gravel										Heavy clay
Wind erosion	Flat and windy										Protected from wind
Ability to isolate the site	Impossible				Good						Presently isolated

Table B-2 (continued)

Criteria	1	2	3	4	Point values		7	8	9	10
					5	6				
Stabilization potential	Impos- sible				Good					Excellent
Dip of underlying strata	Folded	20°	10°	8°	6°	4°	3°	2°	1°	Flat
Extent of faulting	Evident offsets			Evident Frac- turing			Occas- sional joints			Undis- turbed
Type of bedrock	Limestone			Sandstone			Shales			Granite
Ground water quality	Potable		Suitable for live- stock		Suitable for industry					Very poor quality
ECOLOGICAL CONSIDERATIONS										
Wildlife population	Yearlong habitat		Seasonal use		Shelter area					Negli- gible
Proximity to population	>2 miles	>4	>6	>8	>10	>12	>14	>16	>18	Over 20 miles
Current use of land	Rangeland									Waste- land
Aesthetic consideration	Naturally beaut.									Nonde- script
Probable future land use	Human habitat				Agricul- tural					None
ECONOMIC CONSIDERATIONS										
Natural resources in area	Abundant									Negli- gible
Highway accessibility	Less than 10 mi	>9 miles	>8 miles	>7 miles	>6 miles	>5 miles	>4 miles	>3 miles	>2 miles	>1 mile

Table B-2 (continued)

Criteria	Point values									
	1	2	3	4	5	6	7	8	9	10
Proximity to railroad	Less than 20 mi	>18 miles	>16 miles	>14 miles	>12 miles	>10 miles	>8 miles	>6 miles	>4 miles	>2 miles
Miles from tailings site	Over 150 miles	<135	<120	<105	<90	<75	<60	<45	<30	30 miles
Estimated current value/acre	\$360	\$360	\$320	\$280	\$240	\$200	\$160	\$120	\$80	Less than \$40
Maintenance required for tailings in this area	Semi-annual	Annual	Every 2 years	Every 3 years	4	5	6	7	8	None
Source of fill for SLC site	None									Unlimited

sites. It is seen that areas in the Great Salt Lake Desert, or in the series of valleys west of the Salt Lake Valley, rank the highest. The highest-ranking sites in the Salt Lake Valley, such as the runway expansion at Salt Lake Airport and the Interstate-80 Exchange, would also be acceptable; but the latter are no longer at a stage of development where joint utilization for tailings disposal is practicable (FBDU, 1981).

B.2.2 Site selection by the State of Utah

In November of 1978, Congress passed PL95-604, "The Uranium Mill Tailings Radiation Control Act of 1978" (UMTRCA). Title I of PL95-604 authorized the U.S. Department of Energy (DOE), successor to ERDA, to enter into cooperative agreements with affected states and Indian tribes in order to establish assessment and remedial action programs at inactive uranium mill tailings sites; the Federal government would pay 90 percent of remedial-action costs and the affected state would pay the remainder. The UMTRCA also stipulated that the affected state would acquire mill tailings disposal sites during remedial-action operations, but that ownership of these sites would revert to the Federal government after completion of the remedial action.

In November 1979, 25 former uranium-milling sites including the Vitro site in Salt Lake City, Utah, were designated for remedial action under PL95-604. In early 1980, Utah's governor directed the State Division of Environmental Health to recommend a final disposal site for the Vitro tailings. A committee of eight members, representing all pertinent Bureaus in the Division of Environmental Health and the Utah Geological and Mineral Office, was established to make the requisite studies and recommendations. The committee, called the "Vitro Tailings Site Selection Committee" (VTSSC) began work with the consideration of sites proposed in previous studies. The 29 sites mentioned in the 1976 engineering assessment (FBDU, 1976, and Table B-1) were studied, and all but the 3 top-ranking candidates were eliminated. Eight new candidates were added to obtain the 11 sites listed on Table B-3. All of the sites in the Salt Lake Valley were eliminated in this first round of site screening.

The VTSSC adopted the following rules for conducting its second and final round of screening: (1) each committee member would evaluate only those aspects of the site representative of his particular expertise; (2) the technical criteria used by FBDU (see Table B-2) would be used with possible changes in relative weighting of these criteria; (3) each committee member would submit a report to the Chairman who would summarize the committee recommendations; (4) only physical acceptability of the sites would be evaluated on the basis of direct observations and a review of information from reports of previous investigations; and (5) each committee member was to consider three separate options. The three options were: Option-I sites, the use of which was judged to entail no economic or political complications; Option-II sites, those sites requiring further evaluations to determine if transport of the tailings to them would be economical; and Option-III sites at which reprocessing of the tailings might be possible, subject to favorable outcomes of evaluations of the political and economic factors involved with reprocessing. The VTSSC eventually declined evaluation of Option-II and Option-III sites (VTSSC, 1980), pending an economic evaluation by the DOE (see Section C.2, Appendix C).

Table B-3. Sites considered by Vitro tailings
site selection committee (VTSSC)

VTSSC site no.	Location	FBDU site no. ^a
Option-I sites ^b		
1	One mile south of Clive, Tooele County	1
2	Eight miles north of Clive, (Natural Depression), Tooele County	2
3	Three miles west of Delle, Tooele County	3
4	Boulder Creek, Tooele County	
Option-II sites ^b		
5	Three miles north of Woodside, Carbon County	
6	Nine miles south of Crescent Junction, Grand County	
Option-III sites ^b		
A	North of Crescent Junction, Grand County	
B	Sager's Flat, Grand County	
C	Northwest of Whitehouse, Grand County	
D	West of Cisco, Grand County	
E	North of Cisco, Grand County	

^aSee Table B-1.

^bOption-I sites: Use of these would entail no economic or political complications.

Option-II sites: Use of these might require economic evaluations to determine if costs are competitive with Option-I sites.

Option-III sites: Use of these might include reprocessing to recover the uranium and other mineral values. In addition to economic evaluations, agreements with the DOE, the State of Utah, and property owners would be required.

A report by the VTSSC was submitted to the Governor of Utah on June 20, 1980 (VTSSC, 1980). The Committee recommended the FBDU site No. 2, a natural depression 8 miles north of Clive in Tooele County, as a primary site for final disposal of the tailings at the Vitro site. As secondary sites, the committee recommended FBDU site No. 1, one mile south of Clive, Tooele County, and FBDU site No. 3, 3 miles west of Delle, Tooele County. The Governor of Utah endorsed these recommendations in a letter to the DOE on January 6, 1981.

After the VTSSC report had been submitted, the Utah Department of Health recommended consideration of a fourth area not previously included in the State's site-selection process. In a letter to the DOE dated July 23, 1981, the Utah Department of Health requested that DOE evaluate an area on the extreme northeast corner of the Wendover Bombing and Gunnery Range, about 3 miles south of FBDU site No. 1. The DOE notified the U.S. Department of Defense (DOD) that it would consider part of the Wendover Bombing Range as a location for disposal of uranium mill tailings, and requested permission to perform studies and tests on the land in question. Officials of the DOD declined approving use of the Wendover Bombing Range lands on September 4, 1981, stating that the lands would be needed to support operational requirements and that they believed the lands would in any case be environmentally unsuited for the proposed use.

B.2.3 Site evaluations by the DOE

In April 1981, a DOE contractor made an independent analysis of the three Option-I sites recommended by the State of Utah. At the conclusion of this evaluation, the DOE determined that the area 1 mile south of Clive, Tooele County (FBDU site No. 1) was the superior of the three areas proposed by the State. The relative rankings of the three sites according to 7 environmental and geotechnical disciplines are shown in Table B-4.

Table B-4. Relative rankings of state-nominated areas

Discipline	FBDU Site No. 1	FBDU Site No. 2	FBDU Site No. 3
Vegetation	2	1	3
Wildlife	1	2	3
Soils & reclamation	2	3	1
Hydrology & water quality	1	2	3
Meteorology & air quality	1	2	3
Human resources	1	3	2
Geotechnical engineering	<u>1</u>	<u>3</u>	<u>2</u>
Composite score	9	16	17

A summary of the evaluation of the three state-nominated areas, and reasons for rejecting FBDU sites Nos. 2 and 3, are provided in Appendix C where considered-but-rejected alternatives are discussed.

The Option-II and Option-III sites proposed by the State's site-selection committee were evaluated by the DOE and then rejected because of their distance being at least 150 miles by road or rail from the Vitro site; evaluations of these options and reasons for rejecting them are also contained in Appendix C.

The possibility that there are technically suitable disposal areas nearer to the Vitro site than the three state-nominated areas was also considered. At the request of the DOE, Sandia National Laboratories (SNL) reviewed all the sites that had so far been proposed as alternative disposal sites, and in September 1981 the DOE determined that (1) there are presently no more-isolated locations for disposal of the Vitro tailings within 17 road-miles of the Vitro site other than the former Vitro site itself, and (2) there may be technically suitable disposal areas west of the Salt Lake Valley other than the three state-nominated areas, but the use of such areas would offer little or no environmental or economic advantages beyond the advantages to be realized in the use of one of the state-nominated areas. Therefore, the DOE determined that it was not reasonable to examine these Salt Lake Valley areas further. The bases for these conclusions are outlined in Appendix C.

B.3 CONCLUSIONS

The DOE has chosen the area approximately one mile south of Clive, Utah as the candidate for use as an alternative disposal site for the Vitro tailings and other contaminated material. This choice is in accord with site nominations made by the State of Utah, and can be justified by the results of over 7 years of study directed towards finding suitable alternate areas for long-term storage of the Vitro site wastes. The impacts of a remedial action at the Vitro site that would include the transportation of mill tailings and wastes to the area south of Clive, Utah, are assessed in the body of this document.

REFERENCES FOR APPENDIX B

AEC (U.S. Atomic Energy Commission), 1974. Phase-I Summary Report, October 1974.

FBDU (Ford, Bacon & Davis Utah Inc.), 1976. Phase-II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Vitro Site, Salt Lake City, Utah, GJT-1, prepared for U.S. Energy Research and Development Administration, Grand Junction, Colorado.

FBDU (Ford, Bacon & Davis Utah Inc.), 1981. Engineering Assessment of Inactive Uranium Mill Tailings, Vitro Site, Salt Lake City, Utah, DOE/UMT-0102, prepared for U.S. Department of Energy, Albuquerque Operations Office, Albuquerque, New Mexico.

VTSSC (Vitro Tailings Site Selection Committee), 1980. "Vitro Tailings Site Selection Committee Report," dated June 20; signed by Blaine N. Howard (Chairman), Earl Peirce, Fitzhugh Davis, Dan Blake, Robert Cunliffe, and Dane Finerfrock; copies available on request to Uranium Mill Tailings Remedial Actions Project Office, DOE Albuquerque Operations Office, Albuquerque, New Mexico.

Appendix C

ALTERNATIVES THAT WERE CONSIDERED BUT REJECTED

TABLE OF CONTENTS

	<u>Page</u>
C.1 STATE-RECOMMENDED ALTERNATE DISPOSAL AREAS	C-3
C.1.1 The prime area	C-4
C.1.2 The second alternate area	C-6
C.2 ALTERNATE DISPOSAL AREAS IN CARBON AND GRAND COUNTIES, UTAH . . .	C-9
C.2.1 Stabilization north of Woodside	C-9
C.2.2 Stabilization south of Crescent Junction	C-11
C.3 ALTERNATIVE DISPOSAL AREAS IN THE SALT LAKE VALLEY	C-13
C.3.1 Lack of isolated areas within the Salt Lake Valley	C-13
C.3.2 Lack of technically suitable areas in the mountains . . .	C-14
C.4 ALTERNATIVES INVOLVING REPROCESSING OF THE VITRO MILL TAILINGS . .	C-15
References for Appendix C	C-19

LIST OF FIGURES

	<u>Page</u>
C-1 Vicinity map, Woodside area	C-10

Appendix C

ALTERNATIVES THAT WERE CONSIDERED BUT REJECTED

The alternatives for remedial actions at the Vitro site that were considered during the development of this EIS but were determined to be unreasonable are described in this appendix, and reasons given for their rejection. The considered-but-rejected alternatives can be divided into four classes: (1) alternatives involving disposal of the Vitro wastes at other locations considered by the State of Utah (excluding the South Clive site); (2) alternatives involving disposal at sites in Carbon County; (3) alternatives involving disposal of the Vitro wastes at locations within or near the Salt Lake Valley; (4) alternatives that would involve the reprocessing of the Vitro mill tailings to extract residual mineral values.

C.1 STATE-RECOMMENDED ALTERNATE DISPOSAL AREAS

The State of Utah found three areas acceptable for long-term disposal of the mill tailings and other residues from the Vitro site (see Section B.2.2, Appendix B). They are named and located as follows.

- o The Prime Area is the so-called great depression located approximately 8 miles north of Clive, Tooele County, Utah. This area consists of three sections of public domain: Sections 8, 17, and 20 of T1N, R12W.
- o The First Alternate Area is a parcel of state land located approximately one mile south of Clive, Tooele County, Utah within Section 32 of T1S, R11W. This area is referred to throughout this EIS as the "South Clive site."
- o The Second Alternate Area is a section of state land located approximately 3 miles west of Delle, Tooele County, Utah: Section 2 of T1S, R9W.

The firm of Dames & Moore was contracted by the DOE to perform an independent evaluation of the suitability of the three areas for disposal of uranium mill tailings; the evaluation was made in April of 1981 by specialists in geohydrology, surface-water hydrology, soils and reclamation, plant ecology, wildlife ecology, meteorology and air quality, human resources, and geotechnical engineering. Evaluations were based on available literature, knowledge of the region, site reconnaissance, and professional judgement. It was assumed that the disposal of the mill tailings would be, according to current practice, subgrade in lined trenches or cells. Factors considered by the specialists were oriented toward achieving the standards then proposed by the EPA for disposal of mill tailings under Title I of UMTRCA (46 FR 2556-2563). Specific factors considered included the following:

- o Potential for geologic hazards, erosion potential, or subsidence.
- o Economics of the transport and stabilization of contaminated materials, including transportation distance, access to existing rail and highway systems, construction of the retention system, and availability of cover materials.
- o Geohydrology, including general depth to ground water and potential for impacts on ground-water quality.
- o Surface-water hydrology, including proximity to and potential for impacts on intermittent and perennial drainages, drainage basin characteristics, and flood potential.
- o Local meteorological conditions and potential for impacts on air quality.
- o Topography as related to transportation, engineering, and long-term stabilization (erosional versus depositional environment).

- o Present and potential land use, general productivity.
- o Existing and potential vegetation, value as wildlife habitat and/or rangeland.
- o Importance of area to plant and wildlife species of concern (endangered, threatened, ecologically important).
- o Potential for reclamation.
- o Proximity and potential for visual impacts to human residences and public use areas.
- o Engineering restrictions and construction problems imposed by geotechnical conditions.

The evaluation led to the elimination by the DOE of two of the three areas that the State had found to be acceptable--the Prime Area and the Second Alternate Area. The DOE found that these are not reasonable alternative areas (see Appendix B). A description of each of these areas and reasons for their elimination are given below.

C.1.1 The Prime Area

The Prime Area is an elongated natural depression in the Great Salt Lake desert. The depression is up to about 10 feet in depth, approximately 1 mile in width, and extends both north and south beyond the three sections of concern. The depression is bounded to the east and west by what appear to be old sand dune ridges that are sparsely covered with shadscale, winterfat, nuttall saltbush, koschia, and other salt-tolerant species of plants.

Geohydrology and surface waters. During the site reconnaissance, (April 1981), the ground-water table was within 3 feet of the depression's floor, which is a mud flat composed of salt-encrusted silt and clay underlain by Lake Bonneville lakebed depositions. Periodically there is standing water in the depression and there would thus be a very high potential for impact on ground-water quality if the disposal site were located there. Otherwise, this depression has no clear-cut disadvantages from a surface hydrology standpoint. It would not be subject to erosion from runoff and would have a very low potential for flood damage.

Soils and reclamation. The general lack of an on-site source of rock and gravel to protect the reclaimed surface from wind erosion coupled with an anticipated difficulty in establishing a vegetative cover would increase the cost of reclamation; the latter would make reclamation success questionable. The depression is a depositional environment since it receives run-in from the adjacent ridge slopes. Upon drying, however, the deposition of material carried in by water would be countered by wind erosion. The net effect of these two opposing actions would be most influenced by moisture conditions which, in turn, will reflect precipitation patterns and fluctuations in Great Salt Lake water levels.

Wildlife and plants. The depression floor is nearly devoid of vegetation. As evidenced by the presence of several desiccated individuals on the depression floor the day after heavy precipitation, the mud flat contains a population of Great Basin Spadefoot Toads; otherwise, very limited wildlife habitat exists on this area. No endangered or threatened species are known from this vicinity.

Meteorology and air quality. The depression is the farthest from Interstate 80 of the three areas (about 5 miles). Since about 40 percent of all winds greater than 12 mph are from the south, emissions would be blown away from the highway. However, soil erosion and drifting in the vicinity of the depression indicate that blow dust and wind erosion could be serious local problems; use of the area would involve about 10 miles of unpaved haul roads (compared to approximately 2.5 and 0.8 miles at the other two areas).

The railroad line lies 0.5 mile south of I-80. If contaminated material were transported by rail, a transfer point for transport to the depression would be required which could produce emissions that would impact highway traffic.

The nearest Class I air quality area (Capital Reef National Park) is approximately 200 miles south of the area.

Human resources. The issues that are of consequence to the choice of the best among the three nominated areas are transportation costs (construction of new rail or roads, total cost of transportation) and visual impacts to travelers on I-80 and/or nearby residents. The Prime Area would involve the longest (rail or highway) distance from Salt Lake City and the greatest transportation cost for haulage from the rail or highway to the disposal area. Visual impacts would be concentrated near Clive where material would be transloaded from the existing rail or highway to the connecting rail spur or haul road. The depression is sufficiently far from the existing railroad and I-80 (8-10 miles) to prevent on-site activities being visible to travelers. Of historical interest, the Donner Trail passes to the north of this depression.

Geotechnical engineering. Use of the depression would present major construction problems relative to excavation of pits or trenches in the soft silty clays and transport of contaminated materials from the adjacent alluvial ridges onto the mud flat. Periodic inundation of the site and the shallow water table would further complicate engineering design and construction. Excavated clay from the depression would be suitable for use as an impermeable cover over the disposal trenches or pits. A bottom liner would be unnecessary to control vertical seepage. The nearest gravels for cover are about 5 miles away in the Grayback Hills to the east.

Reasons for elimination. The Prime Area was ranked second after the South Clive Area owing mainly to its disadvantages in terms of reclamation, transportation, and geotechnical engineering, all of which would lead to increased costs of implementation with no increase in environmental benefits over those offered by use of the South Clive Area. Another major problem with use of the Prime Area would be the necessity for transporting the tailings

from a railhead near Clive, across Interstate 80, and into the Prime Area. The most economical means of carrying the material over this path would be truck transport. A direct truck route that crossed Interstate 80 would lead to serious and frequent traffic interruptions; on the other hand, use of an existing overpass west of Clive would necessitate the upgrading or construction of frontage roads and an extra transport distance of about 15 miles.

For these reasons, and the fact that an alternative involving the Prime Area would be too close on the spectrum of alternatives to one involving the South Clive site, the DOE has determined that the Prime Area alternative is unreasonable.

C.1.2 The Second Alternate Area

This area, about 3 miles west of Delle, is in the Skull Valley portion of the old lakebed deposits of Lake Bonneville. The topsoil is poorly developed and varies from sandy to clayey silt. There is some topographic relief in the area and defined runoff channels are present, particularly on the eastern portion of the section. The area is used for recreation (hunting and target shooting, motorcycle riding) and is traversed by an access road to the Cedar Mountains, which are also used for recreation.

Geohydrology and surface waters. Based upon the literature, the upper water table is approximately 150 feet beneath the ground surface. However, the area is clearly the worst from the viewpoint of surface hydrology. Because of its location relative to surrounding terrain and the size of the drainage basin, it is susceptible to sufficient velocity and volume of runoff to be hazardous to a disposal system. This is evidenced by the existence of defined drainage channels. A relatively large depression in the eastern part of this area is not enclosed but, rather, is a portion of a major drainage system through Skull Valley. Thus, there would be a serious potential for contamination of down-gradient water quality.

Soils and reclamation. Because of its proximity to the Cedar Mountains, this area is exposed to lower wind velocities than the other two areas. There is consequently less potential for wind erosion. As on the other areas, the soils are highly alkaline; the soil texture is less than 18 percent clay. Of the three areas, soils on this area offer the greatest potential for development of winter sheep range through proper management. As elsewhere, rock and gravel would have to be imported for cover material. Because of the relatively favorable soils and availability of suitable plant materials for revegetation, this area would be the easiest to reclaim of the three evaluated.

Wildlife and plants. Because ecological conditions on this area are the most diverse of those evaluated, it is rated as being the most valuable as wild-life habitat. In addition, the presence of prairie dogs is not only academically of interest (since they were not known to occur in this vicinity) but represents potential habitat for endangered species. (However, no endangered or threatened species are known from this vicinity.) The area is used for recreational hunting more than are the other two. No wetlands are present.

Vegetation on the area varies from what is essentially a greasewood flat on the northwestern portion of the section to a sparse grassland to the east; the existing vegetation is similar to that on the South Clive site but is more diverse and includes less of the noxious weed Halogeton.

Meteorology and air quality. Assuming transportation emissions would be proportional to distance, this area is most favorable in being the closest to the Vitro site. However, the nearest residences are within 2 miles of the area and would potentially be impacted by fugitive emissions. In addition, the access road to the Cedar Mountains passes along and through this area; travelers on this would be impacted by fugitive emissions. Finally, the area is both south of and the closest to I-80 (less than 1 mile); because about 40 percent of the winds stronger than 12 mph blow from southerly directions, fugitive emissions would be carried across the highway.

Human resources. Because the existing railroad is on the opposite side (north) of I-80, transloading material from the railroad would require a crossing, increasing transportation costs. This would be partially offset by the fact that this area is about 25 miles closer to the Vitro site than the others. The overall cost advantage of the Delle area would be minimal. Because of its proximity to I-80 and to Delle, the use of this area would be more visible than at the other two areas.

Geotechnical engineering. From an engineering viewpoint, this area is similar to the South Clive site except for access problems imposed by the railroad being north of I-80; the latter problem is common to this area and the Prime Area.

Based upon the literature, the upper water table is deeper than at the First Alternate Area but the difference is not that significant relative to construction and operation of a disposal site. Construction problems would be minimal. Clay capping material could be obtained through excavation of trenches; a bottom liner would not be necessary. A gravel source is less than 1 mile from the area.

Reasons for elimination. The Second Alternate Area was ranked only slightly below the Prime Area, and, hence, third after the South Clive site, owing mainly to its value as wildlife habitat, its proximity to the highway and the settlement of Delle, and its unfavorable surface hydrology. As stated above, the Second Alternate Area shares the same kind of access problem with the Prime Area--the tailings would have to be transported from the rail head across I-80 to reach the disposal site. Thus, the DOE has concluded that an alternative involving the Second Alternative Area would be unreasonable for the same reasons that an alternative involving the Prime Area was determined to be unreasonable.

C.2 ALTERNATE DISPOSAL AREAS IN CARBON AND GRAND COUNTIES, UTAH

The State of Utah's site-selection team considered two disposal areas in Carbon and Grand Counties, respectively, but declined to evaluate them in detail (VTSSC, 1980). These areas were (1) an area 3 miles north of Woodside, Carbon County, Utah, and (2) an area 9 miles south of Crescent Junction, Grand County, Utah. The following is a brief discussion of these alternate disposal areas and the major environmental and economic factors that caused them to be rejected as reasonable alternate areas for the disposal of Vitro mill tailings and residues.

C.2.1 Stabilization north of Woodside

The Woodside site that was considered is located approximately 156 road miles southeast of Salt Lake City in Emery County, Utah, as shown on Figure C-1. Consideration was given to this area in response to a proposal submitted to the State of Utah that recommended the use of an existing fleet of trucks that were currently (1980) hauling coal from the Emery and Carbon County areas to the Kennecott copper mill near Salt Lake City. After the State of Utah had suggested this site, a preliminary analysis was made by DOE contractors of environmental and economic factors affecting its suitability. From this evaluation, it was concluded by the DOE that the Woodside site could not be considered a reasonable alternative disposal site.

General description of the area. The Woodside site, approximately 6.5 square miles in size, is located on a level, sparsely vegetated pediment near the base of the Book Cliffs. The site area itself appears to be suitable for the deposition of the Vitro tailings according to preliminary evaluations in which the geologic, hydrologic, and environmental setting of the site were considered (FBDU, 1981). The site is isolated from major population centers and is easily accessible by highway. It is public domain administered by the U.S. Bureau of Land Management. The stabilization alternatives proposed in the conceptual plan and engineering evaluation for the South Clive site (see Section 3.2.4 and Appendix A) would be suitable for the Woodside site.

Reasons for rejection. Although the Woodside site appears to be physically suitable for the stabilization of tailings, the primary concern associated with using this site involves the transportation of materials. One transportation proposal presented to the State consisted of using coal hauling trucks to transport the Vitro tailings to the Woodside site (VTSSC, 1980). The trucks currently haul coal from mines in Carbon and Emery Counties to the Kennecott mill near Salt Lake City. It was recommended in the proposal that, once unloaded, the trucks would be diverted to the Vitro site and loaded with tailings for their return trip. After discussions with local trucking contractors, a preliminary cost estimate was prepared. The estimate was prepared assuming a 9-year transporting period (250 working days per year) requiring an average of 39 truckloads per day. The estimated cost of transportation for this period was \$14.09 per ton which included the cost of fitting trucks with the required seals and covers. This cost is well in excess of the \$8.50 per ton (\$0.10 per ton mile) estimated for truck transportation to the South Clive site and, thus, from the economic standpoint alone does not represent a reasonable alternative. Furthermore, the

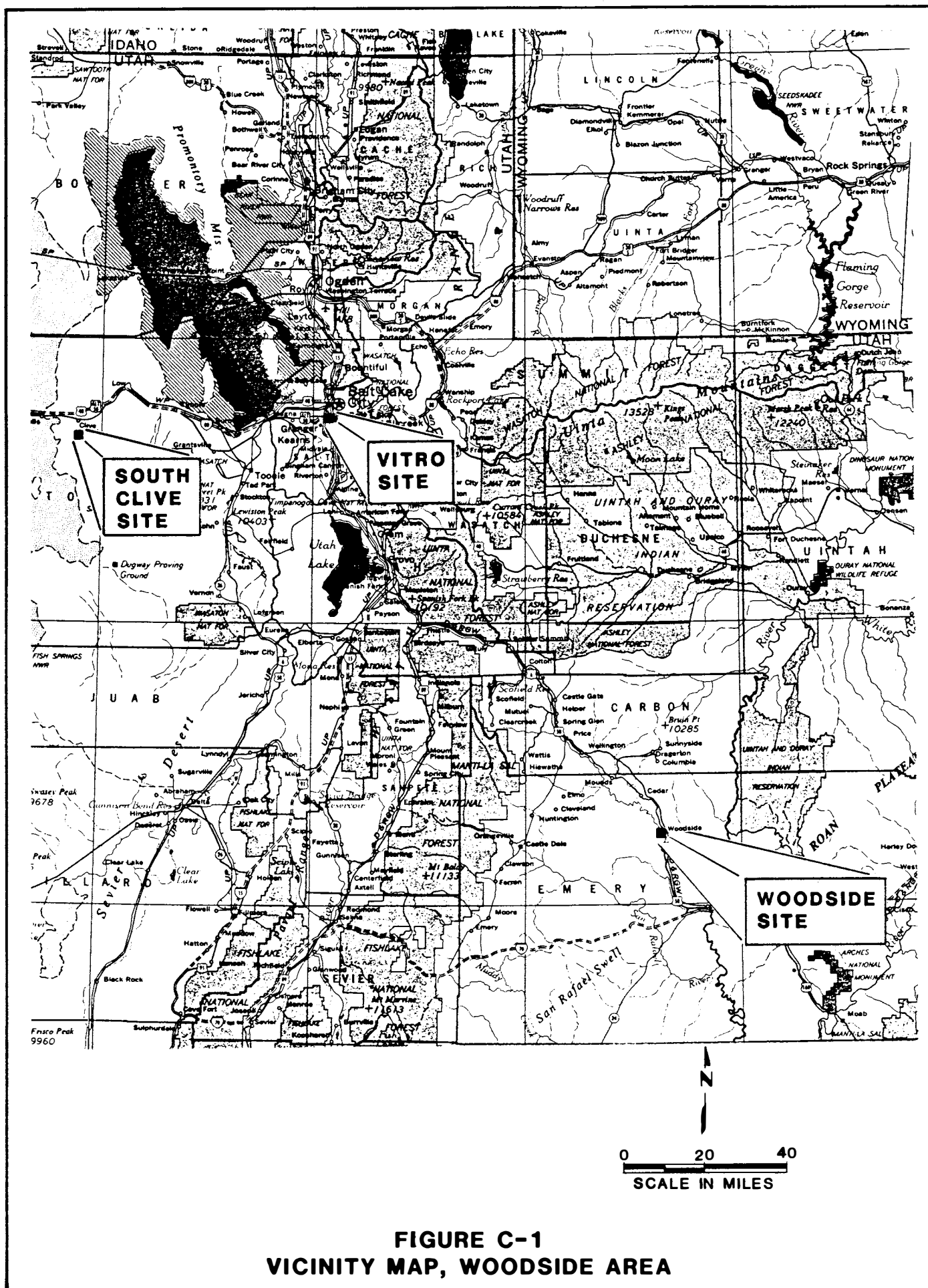


**FIGURE C-1
VICINITY MAP, WOODSIDE AREA**

9-year transporting period would exceed the 7 years (after publication of final EPA standards) allowed for remedial actions by PL95-604, Title I.

An additional concern that decreases the practicality of this alternative is the increased transport distance and the consequent increased potential for the occurrence of a traffic accident involving a truck filled with contaminated tailings. The transport distance estimated for the Woodside site is approximately 156 miles compared to a distance of about 85 miles for the South Clive site. Further, as shown on Figure C-1, the shortest route between the Vitro site and Woodside is via Highway 6, which crosses the Wasatch Mountain Range at Soldier Pass. During the winter months this pass is periodically snow packed and slippery, thus significantly increasing general trucking hazards.

C.2.2 Stabilization south of Crescent Junction

The Crescent Junction area is 9 miles south of Crescent Junction, Grand County, Utah. It is about 11 square miles of pediment near the base of the Booker Cliffs, and is similar to the Woodside area except that it lies approximately 215 road miles from Salt Lake City. Though the State ranked the Crescent Junction area higher than the Woodside area in terms of technical suitability for uranium mill tailings disposal, the State also disqualified the area. Apparently, use of the area for uranium mill tailings disposal would conflict with a proposed land exchange between the Division of State Lands and the Bureau of Land Management (VTSSC, 1980).

The DOE did not perform cost estimates for transportation to the Crescent Junction area, but since the area is some 60 miles farther from Salt Lake City than the Woodside area the reasons for rejecting the Woodside area would also apply with increased force to the rejection of the Crescent Junction area. Therefore, transport of the tailings and other contaminated material to the Crescent Junction area would not be a reasonable alternative.

C.3 ALTERNATIVE DISPOSAL AREAS IN THE SALT LAKE VALLEY

The State of Utah did not recommend any areas within the Salt Lake Valley for alternative disposal sites for the Vitro mill tailings and other residues. The possibility that suitable areas exist in the Salt Lake Valley or on its periphery was briefly studied in September 1981 by the DOE's contractor, Sandia National Laboratories, and based on results of that study, the DOE concluded that (1) there are presently no suitable locations for disposal of the Vitro tailings within the Salt Lake Valley more isolated than the Vitro site itself, and (2) there may be technically suitable disposal areas west of the Salt Lake Valley other than the three state-nominated areas, but use of such areas would offer little or no environmental or economic benefit beyond the benefits to be realized in the use of one of the state-nominated areas. This section briefly documents the bases for these two conclusions.

C.3.1 Lack of isolated areas within the Salt Lake Valley

The Salt Lake Valley is assumed to be that region bounded on the east by the foothills of the Wasatch Mountains, on the north by the Great Salt Lake, on the west by the Great Salt Lake and the foothills of the Oquirrh Mountains, and on the south by the foothills of the Traverse Mountains. The Vitro site is located in the northwest quadrant of this valley, and straight-line distances from it to other points in the valley vary up to about 17 miles; road mileage between any two points is usually larger than the straight-line mileage. Railroads connecting to the Vitro site are limited to a narrow north-to-south corridor that roughly bisects the region and lies on the western side of its most urbanized parts. An east-to-west railroad corridor joins the north-to-south corridor at a point just north of metropolitan Salt Lake City and runs westward along the southern margin of the Great Salt Lake. No railroads cross the Wasatch mountains east of the Salt Lake Valley; I-80 is the main route crossing the Wasatch range east of the city.

The lands east of the north-south railroad corridor are, in general, heavily populated and privately owned; no areas there could be construed as being isolated or would be acceptable to the Salt Lake Valley residents as a site for the disposal of uranium mill tailings. The lands west of the north-south railroad corridor are less densely populated, although most of these are in various stages of development. The immediate vicinity of the Vitro site is fairly typical of the type and degree of development of this western half of the region: land is used for businesses (retail, manufacturing, light industry) and residences or, in the extreme west of the region, for agriculture and mining (gravel pits, copper mine facilities). It is thus possible that locations as isolated and as technically suitable for tailings disposal as the Vitro site could be found in this western half of the valley. From the standpoint of the major physical factors that determine disposal site suitability (topography, geology, hydrology, and climate) all locations in the western half would be roughly equivalent.

The equivalence of the physical factors that determine site suitability, however, suggests that there would be no environmental benefit in moving the tailings from their present location to a new one in the western half of the valley unless the new location afforded unique opportunities for stabilization

of the tailings at reasonable costs and with minimum interference with planned land use. A few such locations have been considered in the past in connection with public construction projects such as interstate highway exchanges or airport runway extensions; but as of September 1981 these projects were no longer available and further projects of this kind are not foreseen to occur within the time span allowed for completion of remedial actions under the UMTRCA. For these reasons, the DOE determined that an alternative involving disposal at a location in the Salt Lake Valley other than the Vitro site would be unreasonable.

C.3.2 Lack of technically suitable areas in the mountains

Suitably isolated sites for disposal of the Vitro tailings might be found in the Wasatch Mountains bordering the Salt Lake Valley on the east or in the Oquirrh Mountains to the west. However, these mountains are of high relief, and there are few roads leading into them that could support a safe and efficient transport of the large amounts of material that would be moved during remedial action at the Vitro site. Railroad access to locations within the Wasatch Range is possible only by a long and roundabout route through Provo, Utah. Rail access to the Oquirrh is apparently limited to routes owned by the Kennecott Corporation.

It would be difficult and expensive to construct an engineered waste containment in these mountains that would meet the EPA disposal standards. The large relief combined with relatively high precipitation make erosion a problem; there is also the risk of long-term contamination of useful ground waters, since both mountain ranges are recharge areas for the deeper ground waters of the Salt Lake Valley. Thus, the cost of placing the Vitro tailings in these mountains would probably be excessive because of the additional engineering required to build a waste depository under these adverse conditions. In short, the DOE sees neither environmental nor economic advantages in placing an alternative disposal site within the Wasatch or Oquirrh Mountains, and has determined that such alternatives are not reasonable.

C.4 ALTERNATIVES INVOLVING REPROCESSING OF THE VITRO MILL TAILINGS

In alternatives of this kind, the higher-grade tailings at the Vitro site would first be reprocessed to recover residual minerals of economic value; then the residues (still retaining most of the original radioactive elements) would be placed in an engineered structure for long-term disposal. In principle, at least two basic alternatives are practicable: (A) on-site reprocessing of the Vitro tailings followed by on-site stabilization of the residues; (B) transfer of the wastes to a new site and decontamination of the Vitro site, followed by the reprocessing of the wastes and stabilization of the residues at the new site.

These alternatives involving reprocessing cannot be entirely rejected until all procedures for determining the practicability of reprocessing have been completed. By law (PL95-604, Title I, Section 108(b)), the DOE must solicit expressions of interest regarding the remilling of residual radioactive materials at designated inactive processing sites and, upon receipt of any expressions of interest, must determine whether the proposals are practicable. The determination of practicability includes an assay of the tailings to determine their residual mineral contents. The DOE has complied with these requirements by publishing a request for expressions of interest in the Federal Register, "Commerce and Business Daily," and in local newspapers. Several expressions of general interest were received; and an assay program was begun in 1981. The Vitro tailings pile was sampled for assay in May 1981. The results of the assay program are available in DOE (1982).

Summary of investigations at Vitro site, Salt Lake City, Utah

Project Description:

The primary objectives of these investigations were to:

- o Determine the total quantity of uranium bearing material at the site.
- o Determine the total quantity of uranium, vanadium, and molybdenum present in the material at the site.
- o Determine the extractability of uranium, vanadium, and molybdenum by leaching methods.
- o Evaluate the economics of reprocessing the tailings for recovery of any or all of these three metals.
- o Obtain data on the concentration of various trace metals normally associated with uranium mill tailings, including Ra-226.

In order to accomplish these objectives it was necessary to drill and sample the entire tailings deposit at the site. A sufficient number of samples was required to assure a statistical accuracy of 90 percent with a minimum 12 percent confidence interval. A total of 104 holes (samples) were taken at the site. Samples of each 2.5-foot interval were taken to provide moisture determinations throughout the pile. Where possible, each hole was drilled a minimum of 5 feet into the subbase material to investigate the amount of uranium migration into the substrate.

All samples were transported to the Tucson laboratories of Mountain States Research and Development (MSRD) where they were dried, analyzed, and prepared into composite charges for leach testing. Approximately 10 percent of the samples were taken with Shelby tube samplers so that bulk density determinations could be made on the tailings.

Using survey data for the drill holes, hole depths, moisture data, bulk density data, and chemical analyses, the volume, tonnage, and metal content of the tailings and subbase material were calculated.

Laboratory leach testing was conducted on composite test charges to determine optimum conditions and methods for leaching of the uranium, vanadium, and molybdenum. These data were then used to develop process flowsheets and major equipment lists, from which the capital cost could be estimated for a treatment plant.

Based upon total recoverable value of the three metals, the capital cost of the plant, and the estimated cost of operating the plant, a final evaluation as to the profitability of reprocessing the tails was made.

Site Description:

The Vitro site is located in the Salt Lake City Metropolitan area and is bordered on the south by 33rd South Street and on the west by 9th West. The immediate vicinity is zoned for light industry.

The tailings were deposited in five separate and distinct areas covering approximately 75 acres. Section A, located in the northwest portion of the area is surrounded by berms and during recent years has been used for discard and storage of sewage plant effluent. A major part of the section is extremely soft and has a high water content.

Section E is located on the eastern portion of the site and is low-lying with no distinct boundaries. This section had some of the highest grade material found, probably due to its proximity to the mill and discharges of higher grade material during emergency situations as well as use for ore storage.

The other three sections are easily distinguishable and, with the exception of the heavy rubble cover on Section C, present no particular handling problem.

The tailings are typical of beneficiated ore, being sandy in nature and relatively fine. Screen analyses indicate they are 100 percent minus 10 mesh and over 50 percent minus 200-mesh.

A drilling and sampling program was conducted at the site to provide the physical and analytical data required to determine the total quantity of tailings and uranium-bearing subbase material at the site and the total content of uranium, vanadium, and molybdenum. From these data the following statistics were developed:

Tailings, wet tons	2,755,711
Water, %	20.21
Tailings, dry tons	2,198,668
U ₃ O ₈ , %	.0150
pounds	659,452
V ₂ O ₅ , %	.0955
pounds	4,198,565
Mo, %	.0173
pounds	62,458
Subbase, wet tons	739,047
Water, %	3.39
Subbase, dry tons	566,157
U ₃ O ₈ , %	.0116
pounds	131,440
Total material, wet tons	3,494,758
Water, %	20.89
Total material, dry tons	2,764,825
U ₃ O ₈ , %	.0143
pounds	790,892

Amenability Testing:

Laboratory testing was conducted at MSRD's laboratories on composited samples from the site. Testing was conducted on samples representing each section and for the entire site. Testing procedures included:

- o Agitation leach with sulfuric acid.
- o Agitation leach with carbonate solution.
- o Extended acid agitation leach.
- o Column leach with acid.

The tailings were generally unresponsive to alkaline leaching with low extractions of uranium and vanadium.

Agitation leaching with acid indicated uranium extractions in the 55 percent range could be expected. Hence, column leach testing was conducted with acid only. The best overall results were obtained with the column acid leach process, which is indicative of what can be attained in the heap leach process. Analysis of the test results indicated that extraction for uranium, vanadium, and molybdenum, respectively, of 75 percent, 30 percent, and 55 percent could be expected in a heap leach operation on this material.

Accordingly, flowsheets were developed for a process plant to treat the pregnant leach solutions from heap leaching to recover uranium, vanadium, and molybdenum as marketable products.

Economic Evaluation:

Although a total of 2,764,825 dry short tons (DST) of uranium-bearing material was identified at the site, only 1,192,940 DST were considered to be

acceptable feed for processing by reason of its grade and/or response to treatment. The material considered not acceptable is located such that it could be either left in place or bypass the plant during mining operations.

The process plant was sized to treat the 1,992,940 DST of tailings plus subbase material at a rate of 750,000 dry short tons per year with a project life of approximately 2.7 years. During this period the production would be as tabulated below:

Product	Total lbs	Unit Price	Total
U ₃ O ₈	567,968	\$23.00	\$13,063,264
V ₂ O ₅	1,168,831	3.00	3,506,493
Mo	390,161	8.50	3,316,369
TOTAL VALUE			\$19,886,126

Evidently, reprocessing of the Vitro site tailings is not economic at present-day prices (unit prices given above) as shown by the following estimates:

Plant Capital Cost	\$16,060,000
Operating Cost	27,419,000
Total Project Cost	\$43,479,000
Less Salvage Value	<u>782,000</u>
Total Direct Cost	\$42,697,000
Marketable Production	\$19,886,126
Profit or (Loss)	(\$22,810,900)

The \$23 million loss would be added to the costs of stabilizing the residues that remain after reprocessing is completed. Therefore, reprocessing does not represent a reasonable alternative at this time.

REFERENCES FOR APPENDIX C

- DOE (U.S. Department of Energy), 1982. Economic Evaluation of Inactive Uranium Mill Tailings, Vitro Site, Salt Lake City, Utah. UMTRA-DOE/ALO-171.
- FBDU (Ford, Bacon and Davis Utah Inc.), 1981. Engineering Assessment of Inactive Uranium Mill Tailings, Vitro Site, Salt Lake City, Utah, DOE/UMT-0102, prepared for U.S. Department of Energy, Albuquerque Operations Office, Albuquerque, New Mexico.
- VTSSC (Vitro Tailings Site Selection Committee), 1980. "Vitro Tailings Site Selection Committee Report," dated June 20; signed by Blaine N. Howard (Chairman), Earl Peirce, Fitzhugh Davis, Dan Blake, Robert Cunliffe, and Dane Finerfrock; copies available on request to Uranium Mill Tailings Remedial Action Project Office, DOE Albuquerque Operations Office, Albuquerque, New Mexico 87185.

Appendix D

Hydrological and Water Quality Information

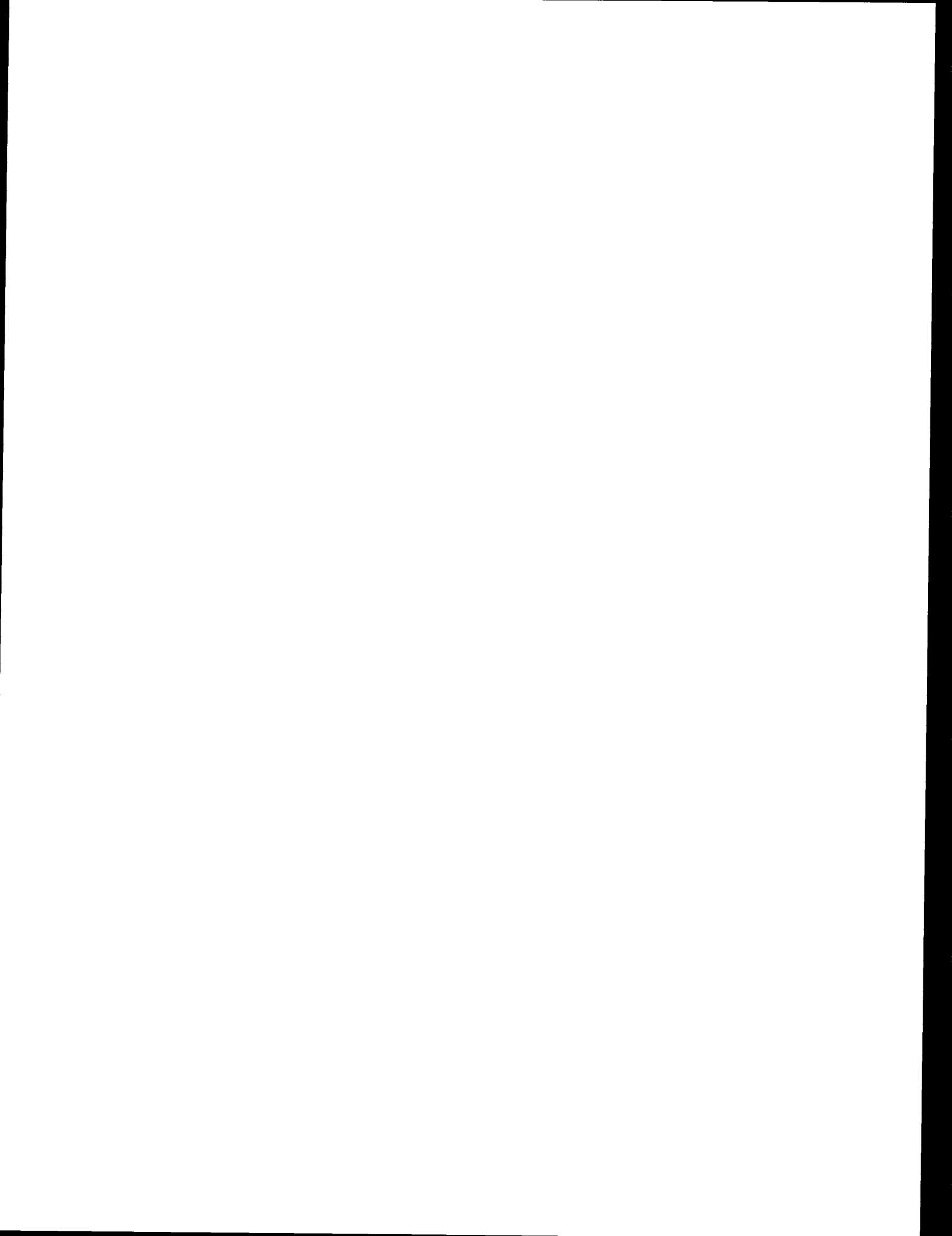


Table of Contents

	<u>Page</u>
D.1 INTRODUCTION.....	D-1
D.1.1 Vitro site.....	D-1
D.1.2 South Clive site.....	D-1
D.2 EXISTING CONDITIONS, PROBLEM STATEMENT, AND METHODS OF CALCULATION - VITRO SITE.....	D-3
D.2.1 Existing conditions.....	D-3
D.2.2 Problem statement.....	D-3
D.2.3 Methods of calculation.....	D-8
D.3 HYDROLOGY AND GROUND-WATER CHEMISTRY - VITRO SITE.....	D-9
D.3.1 Description of existing subsurface and ground-water setting.....	D-9
D.3.1.1 Data sources.....	D-9
D.3.1.2 Stratigraphic and hydrologic setting.....	D-23
D.3.2 Description of existing ground-water chemistry.....	D-36
D.3.2.1 Field sampling of ground water.....	D-36
D.3.2.2 Field test results.....	D-36
D.3.2.3 Laboratory testing and unconfined aquifer results.....	D-36
D.3.2.4 Laboratory testing and confined aquifer results	D-39
D.3.2.5 Confined aquifer hydrodynamics and ground-water quality impacts.....	D-40
D.3.3 Geohydrologic data analysis.....	D-42
D.3.3.1 Hydrodynamic data collection.....	D-42
D.3.3.2 Hydrodynamic data analysis and results.....	D-42
D.3.4 Description of Illinois State Water Survey model modifications and additions.....	D-47
D.3.4.1 Calibration of the hydrodynamic model.....	D-51
D.3.5 Analysis of water quality, geochemistry, and solute transport.....	D-63
D.3.5.1 The present condition.....	D-65
D.3.5.2 Post-remedial action.....	D-75
D.3.6 Aquifer restoration analysis.....	D-78
D.3.6.1 Boundaries of contamination.....	D-78
D.3.6.2 Potentially affected water supplies.....	D-78
D.3.6.3 Aquifer restoration techniques.....	D-83
D.3.6.4 Comparison of benefits and costs.....	D-86
D.4 CONCLUSIONS AND SUMMARY - VITRO SITE.....	D-89
D.5 GEOHYDROLOGY - SOUTH CLIVE SITE.....	D-91
D.5.1 Existing geohydrology.....	D-91
D.5.2 Data sources.....	D-95
D.5.3 Existing water quality.....	D-101
D.5.4 Water uses.....	D-101

Table of Contents
(continued)

	<u>Page</u>
D.6 CONCLUSION AND SUMMARY - SOUTH CLIVE SITE.....	D-119
D.7 SURFACE-WATER QUALITY, TRANSPORTATION ROUTE.....	D-121
References for Appendix D.....	D-141

List of Figures

	<u>Page</u>
D-1 Generalized ground-water hydrogeology for the southern Salt Lake City area.....	D-4
D-2 Potentiometric surface map of the confined (artesian) aquifer for the southern Salt Lake area.....	D-5
D-3 Historic water levels in the unconfined aquifer, South Salt Lake site, measured April 1982.....	D-6
D-4 Location map of sampling wells on or near South Salt Lake site.....	D-10
D-5 Generalized geologic cross-section for the area west of the tailings pile, South Salt Lake site.....	D-33
D-6 Generalized stratigraphic cross-section along north side of the tailings pile, South Salt Lake site.....	D-34
D-7 Generalized stratigraphic cross-section along south side of the tailings pile, South Salt Lake site.....	D-35
D-8 Ground-water flow direction, South Salt Lake site.....	D-52
D-9 Finite-difference grid representing the South Salt Lake site vicinity.....	D-54
D-10 Cross-sectional representation of calculation of flux to stream, South Salt Lake site.....	D-55
D-11 Revised 50 x 41 finite-difference grid representing the South Salt Lake site vicinity.....	D-58
D-12 Water levels in the unconfined aquifer, South Salt Lake site, measured September 1983.....	D-71
D-13 Aquifer restoration descriptive map, South Salt Lake site.....	D-79
D-14 Idealized stratigraphic relationship near South Clive site.....	D-92
D-15 Water table contour map at the South Clive site April 2, 1982.....	D-93
D-16 East-west soil profile, center of South Clive disposal site.....	D-97
D-17 East-west soil profile, south of South Clive disposal site.....	D-98
D-18 East-west soil profile, north of South Clive disposal site.....	D-99
D-19 North-south soil profile, center of Clive disposal site.....	D-100
D-20 South Clive watershed.....	D-103
D-21 Locations of surface-water quality sampling stations.....	D-122

List of Tables

	<u>Page</u>
D-1 EPA National Interim Drinking Water Standards.....	D-7
D-2 Well completion data, Vitro site, TAC (1983) wells.....	D-11
D-3 Well construction details, Vitro site.....	D-12
D-4 Ground-water quality, 1982.....	D-14
D-5 Ground-water quality, 1983.....	D-24
D-6 Ground-water quality, State of Utah samples, 1983.....	D-29
D-7 Summary of background data, unconfined aquifer.....	D-37
D-8 Classification of dissolved solids, based on abundance in potable water.....	D-38
D-9 Summary of on-site data, unconfined aquifer.....	D-38
D-10 Summary of downgradient data, unconfined aquifer.....	D-39
D-11 Summary of confined aquifer data.....	D-40
D-12 Major pumpage of the artesian aquifer in the vicinity of the Vitro site.....	D-41
D-13 Results of on-site slug tests (cm/sec).....	D-43
D-14 Results of pump test on deep well #15, South Salt Lake site.....	D-45
D-15 Values calculated from pump test results on deep well #15 west of South Salt Lake site.....	D-48
D-16 Variable grid spacing (36 x 28 nodes).....	D-56
D-17 Variable grid spacing (50 x 41 nodes).....	D-57
D-18 Calibration of unconfined system, present case.....	D-59
D-19 Calibration of unconfined system, historic case.....	D-60
D-20 Fluxes in unconfined system after remedial action.....	D-61
D-21 Calibration of confined system, present case.....	D-62
D-22 Analysis of surface-water samples.....	D-67
D-23 Speciation of metals as determined by PHREEQE.....	D-68

List of Tables (Continued)

	<u>Page</u>
D-24 Analysis of tailings pile water.....	D-69
D-25 Comparison of measured and calculated uranium concentrations.....	D-72
D-26 Possible mixing of ground waters during pumping.....	D-74
D-27 Predicted maximum downgradient contaminant concentration in the unconfined aquifer, post-remedial action with a liner.....	D-77
D-28 Calculated worst-case change of water quality in Jordan River.....	D-80
D-29 Estimated capital costs ground-water removal and treatment, Vitro site.....	D-85
D-30 Estimated annual operating costs for ground-water removal and treatment, Vitro site.....	D-86
D-31 Summary of benefit-cost analysis.....	D-87
D-32 Ground-water elevations at the South Clive site.....	D-94
D-33 Well construction details - South Clive site.....	D-96
D-34 Pump tests - South Clive site.....	D-102
D-35 Chemical ground-water quality - South Clive site.....	D-104
D-36 Records of selected wells in the South Clive area.....	D-116
D-37 Surface-water sampling locations.....	D-121
D-38 Surface-water quality - Vitro to South Clive transportation route.....	D-123

D.1 INTRODUCTION

D.1.1 Vitro site

In this appendix the hydrodynamics, geochemistry, and solute transport affecting the ground water underlying the Vitro site and the surrounding area are analyzed. The hydrodynamic analysis includes:

- Assessment of historic conditions.
- Assessment of present conditions.
- Prediction of post-remedial action conditions.

Static water-level measurements, aquifer tests, and numerical methods were used for the analysis of the hydrodynamic characteristics of the unconfined aquifer, the confining layer, and the confined aquifer.

The geochemical analysis includes supporting data and descriptions and explanations for the chemical changes between:

- Layer 1 (tailings and tailings water) and Layer 2 (tailings, soil, water, and ground water) of the pile.
- Layer 2 and the underlying ground water.
- The underlying ground water and downgradient unconfined ground water.
- Upgradient unconfined ground water and downgradient unconfined ground water.
- Upgradient confined ground water and downgradient confined ground water.
- Uncontaminated surface water and contaminated surface water.

The solute transport analyses were used to:

- Support the explanations for measured downgradient concentrations of uranium and sulfate.
- Predict the time of entry into the ground water and the concentrations of sulfate, uranium, arsenic, and molybdenum following remedial action.

D.1.2 South Clive site

Starting in section D.5 of this Appendix, the ground-water regime of the South Clive site and the surrounding area are analyzed. The analysis includes:

- Assessment of hydrologic setting.
- Assessment of existing water quality.
- Assessment of potential for recharge on site.
- Assessment of existing and potential water uses.

D.2 EXISTING CONDITIONS, PROBLEM STATEMENT, AND METHODS OF CALCULATION - VITRO SITE

D.2.1 Existing conditions

The Vitro site is located within the Jordan River Valley in South Salt Lake, Utah. The ground-water regime is generally characterized by two aquifer systems, a near-surface unconfined system and a deeper confined system. The unconfined system is principally recharged by upward flow from the confined aquifer and surface infiltration (Figure D-1). The confined system is recharged by infiltration into porous materials on the flanks of the Wasatch Mountains to the east and the Oquirrh Mountains to the west. Near the site, both aquifers flow generally toward the west-northwest (Figures D-2 and D-3). The unconfined aquifer discharges into surface-water courses such as Mill Creek, the Jordan River, and the Great Salt Lake.

The background water quality (chemistry) in the vicinity of the Vitro site is substantially different for each of the two aquifer systems. The upper unconfined aquifer water is characterized by a brackish quality with high total dissolved solids, generally 2000 ppm or greater, and sulfates on the order of 800 ppm or greater. [The unconfined water quality generally improves with depth and approaches the quality of the confined ground water.] Due to its [marginal] quality and minimal yields to wells, this water has very limited use for domestic or agricultural purposes. The confined aquifer water generally has dissolved solids values of about 300 ppm and a sulfate content of about 20 ppm. The confined aquifer is an important source of domestic, agricultural, and industrial water supply in the Salt Lake Valley. (Table D-1, EPA National Interim Drinking Water Standards).

Elevated levels of sodium, sulfate, chloride, total dissolved solids, and uranium have been found in the unconfined aquifer ground water downgradient (west-northwest) and beneath the tailings pile, as compared to the upgradient conditions of the same aquifer. No elevated levels of molybdenum (Mo), selenium (Se), radium (Ra-226 and Ra-228), vanadium (V), thorium (Th-230), and lead 210 (Pb-210) have been found downgradient of the pile boundary. Samples from upgradient wells contained higher concentrations of arsenic (As) than samples from downgradient wells. Elevated levels of molybdenum have been found in discharge water from the excavation at the Central Valley Water Reclamation Facility (CVWRF).

None of the radioactive constituents and metals listed above, which would be associated with the tailings pile, were found in levels above background in the confined aquifer water. However, higher levels of sulfate and chloride were found in samples of the confined aquifer beneath and downgradient of the pile boundary than were found in samples taken from upgradient wells.

D.2.2 Problem statement

The purpose of this study is to evaluate the present and projected characteristics of the ground-water flow regime. From this evaluation, a determination will be made of the projected changes in the water levels, and present and future rates and concentrations of contaminant migration. The following items have been analyzed:

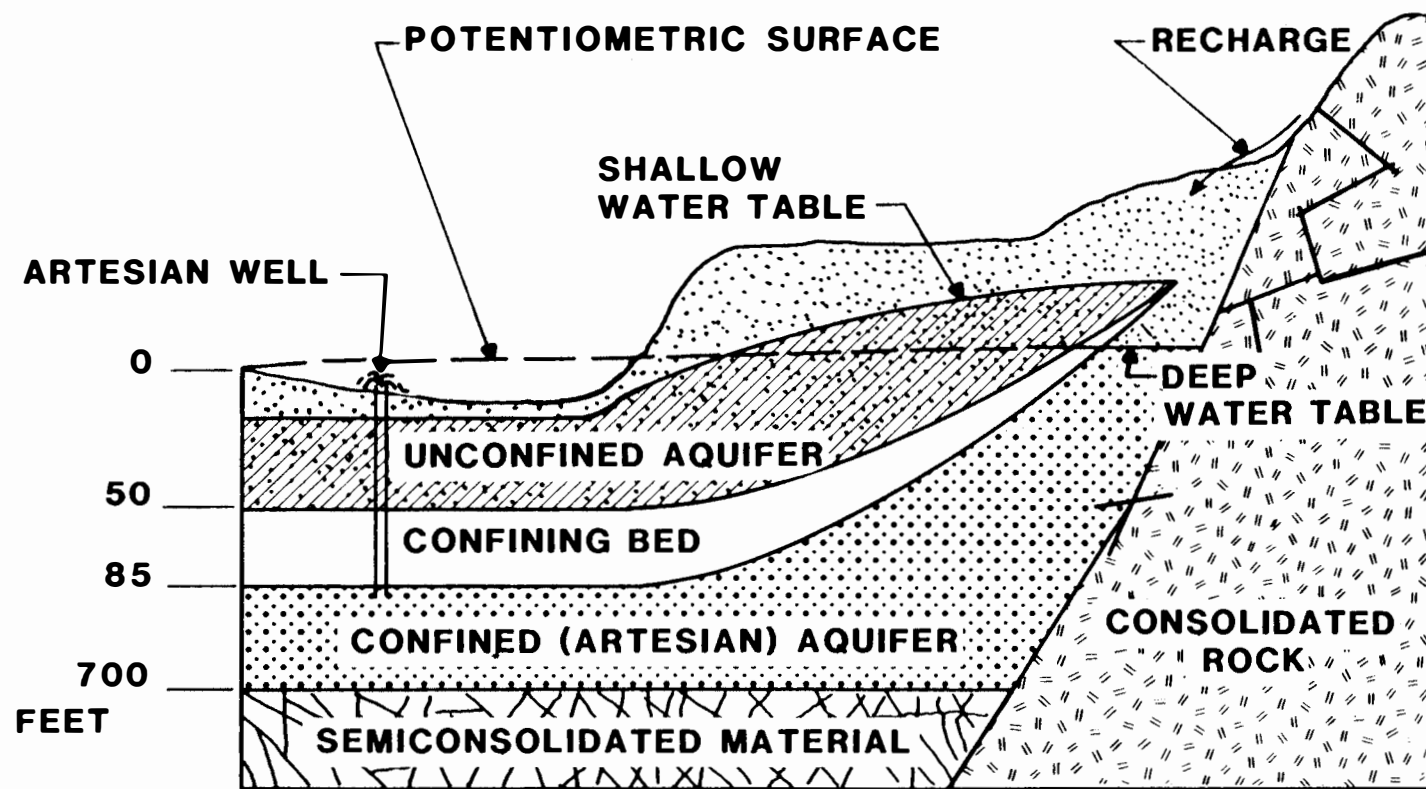
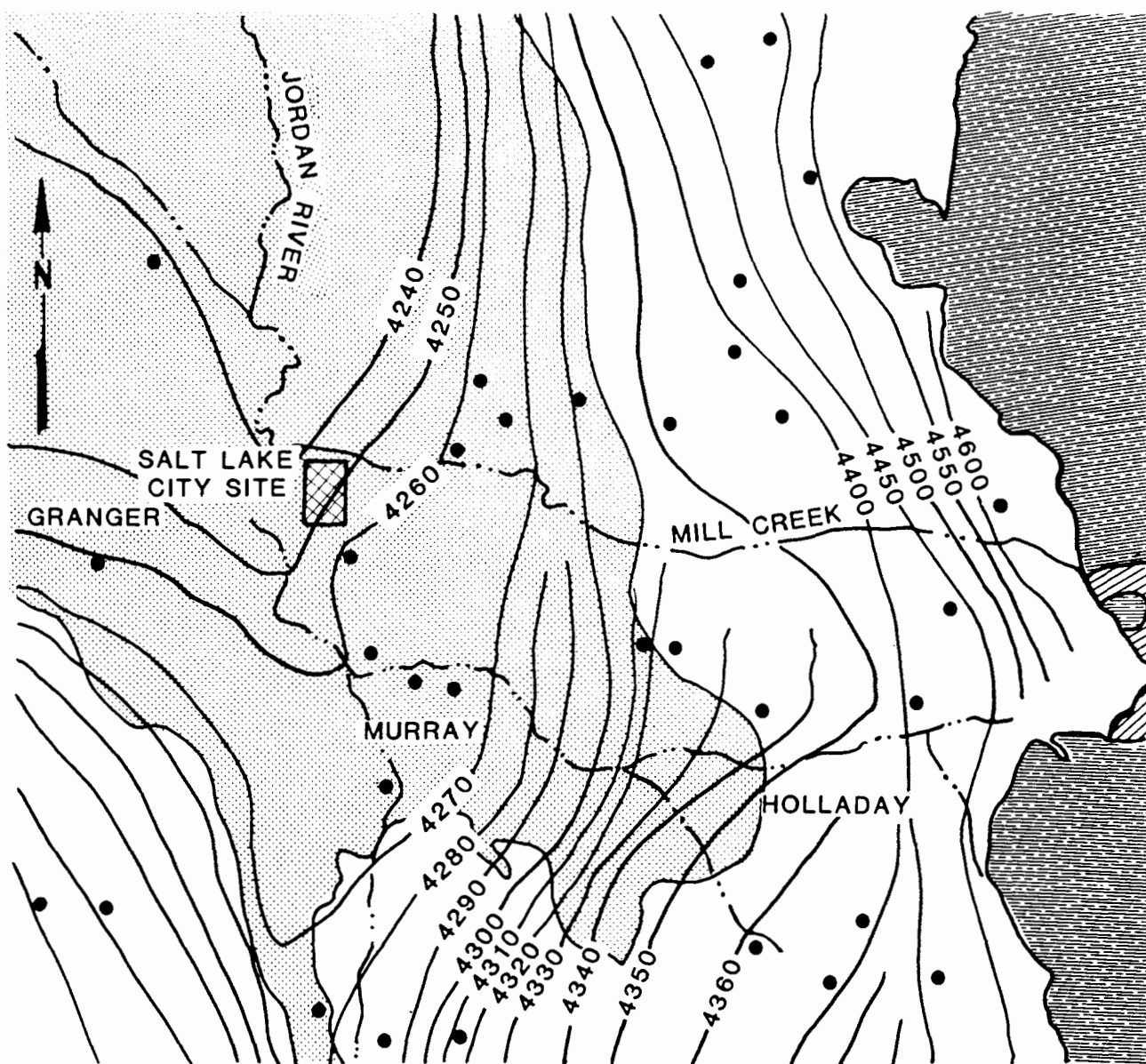


FIGURE D-1
GENERALIZED GROUNDWATER HYDROGEOLOGY
FOR THE SOUTHERN SALT LAKE CITY AREA



 VALLEY FILL
PERMEABILITY VARIABLE

 ROCKS OF MODERATELY
HIGH AND HIGHEST
PERMEABILITY

 ROCKS OF MODERATELY
LOW AND LOWEST
PERMEABILITY

 AREA OF ARTESIAN FLOW-
FEBRUARY, 1969

 4250 WATER-LEVEL CONTOUR

NOTE

ADAPED FROM HELY, MOWER,
AND HARR, 1971.

FIGURE D-2
POTENTIOMETRIC SURFACE MAP OF THE CONFINED (ARTESIAN)
AQUIFER FOR THE SOUTHERN SALT LAKE AREA

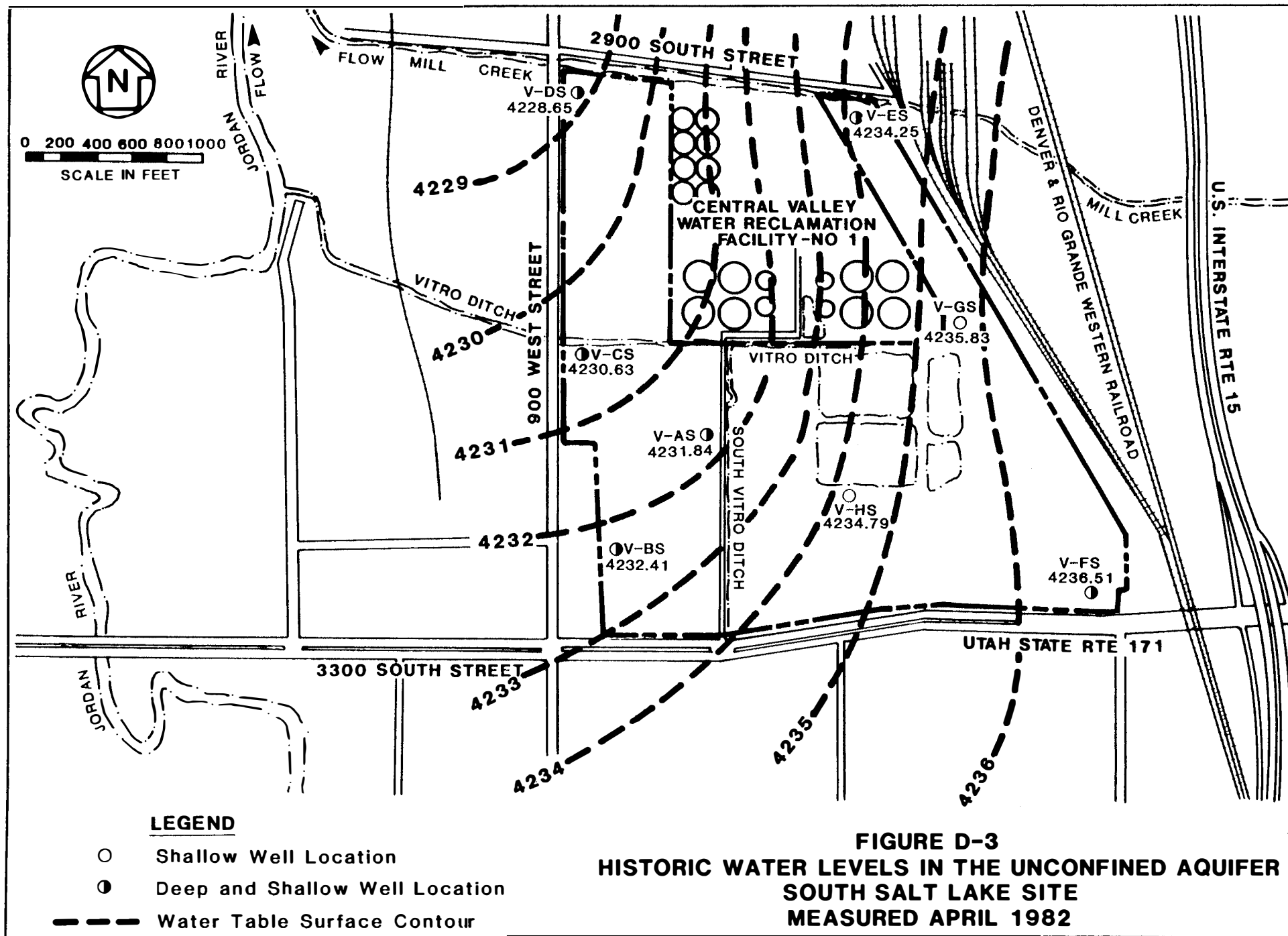


Table D-1. EPA National Interim Drinking Water Standards (40 CFR 141, 143)

Parameter	Drinking water standards ^a	
	primary	secondary
Arsenic	0.05	--
Barium	1.0	--
Cadmium	0.01	--
Chromium	0.05	--
Copper	--	1.0
Fluoride	1.4-2.4	--
Lead	0.05	--
Mercury	0.002	--
Nitrate	10.0	--
Selenium	0.01	--
Silver	0.05	--
Zinc	--	5.0
Chloride	--	250.0
Iron	--	0.3
Manganese	--	0.05
pH	--	6.5-8.5
Sulfate	--	250
TDS	--	500
Uranium (Health Advisory level) (in picocuries per liter)	10.0	--
Radium 226-228 combined (in picocuries per liter)	5.0	--
Gross alpha (in picocuries per liter)	15.0	--
Gross beta (in picocuries per liter)	50.0	--

^aAll values in mg/l unless otherwise noted.

- Numerical simulation of the steady-state water levels as compared to measured water levels (both aquifer systems).
- Calibration of present and historic rates and concentrations of contaminant migration, using total uranium and sulfate (i.e. the most representative mobile contaminants) as the key indicators in both systems.
- Prediction of post-remedial action, steady-state water level elevations for the unconfined aquifer.
- Prediction of post-remedial action rates and concentrations of contaminant migration (total uranium, sulfate, arsenic, and molybdenum).

D.2.3 Methods of calculation

- Detailed field investigations involving water-level monitoring, pump testing, and water sampling of both the unconfined system and the confined system were carried out by the TAC (1983) and Dames and Moore (1982). The data were analyzed for aquifer parameters such as hydraulic conductivity, transmissivity, storativity, and vertical and lateral hydraulic gradients[].
- The Illinois State Water Survey finite difference hydrodynamic flow model was used to simulate the hydrodynamic setting and predict the changes in the ground-water regime after remedial action (Prickett and Lonquist, 1971). Input, output, calculation of the error tolerance, and several other parts of the program were modified or enhanced. The details of the modeling effort are presented in Sections D.3.4 and D.3.5.
- Contaminant migration was analyzed using the existing data base (TAC, 1983; Dames and Moore, 1982; and Markos and Bush, 1982) and the Prakash (1982) equations. The existing data were used to determine the lateral and vertical contaminant migration parameters, which were subsequently used to predict post-remedial action conditions.
- The ground-water chemistry was analyzed on the basis of chemical equilibria relations. The existing data were used to predict the migration from the tailings pile and subsequent precipitation of these constituents. The PHREEQE geochemical model (Parkhurst et al., 1980) was used to determine speciation.

D.3 HYDROLOGY AND GROUND-WATER CHEMISTRY - VITRO SITE

D.3.1 Description of existing subsurface and ground-water setting

D.3.1.1 Data sources.

Subsurface explorations, monitoring well installation, hydrologic investigations involving pump testing of both aquifers, water-level monitoring, and sampling for water-quality testing have been carried out by various investigators at and near the Vitro site and in the Jordan River Valley. These investigators include Hely, Mower, and Harr (1971), Markos and Bush (1982), Dames and Moore (1982), and the TAC (1983). In addition, several studies using published data have been presented for the Salt Lake area in other references.

Several monitoring wells have been drilled (in 1982 and 1983) on and around the site both in the unconfined aquifer and the confined aquifer. During the first drilling program, 12 wells were completed in the shallow system (completion depths 50-60 feet) and 7 wells were completed in the deep system (completion depths 70-80 feet), (DOE, 1983). These wells are located within the Vitro site boundary, roughly defined as the quadrangle formed by 3300 South Street, 900 West Street, Mill Creek, and the Denver and Rio Grande Western Railroad.

During the second drilling program, 10 well points, 24 monitor wells, and 1 pump well were completed in the unconfined system. The 24 monitor wells are grouped in 8 nests with 3 wells per nest. Five monitor wells and one pump well were completed in the confined aquifer system. Also, two wells were completed to depths of 65.7 feet to 67.7 feet and 53.6 feet to 55.6 feet. These wells were used to isolate the confining layer between the unconfined and confined systems. Figure D-4 shows the location of the wells drilled in 1982 and in 1983 (TAC 1983), and Tables D-2 and D-3 describe the installation details for each well.

The first field testing program, in 1982, included a pump test on shallow, on-site well V-CS1 and 2 slug tests on well V-BS, 2 slug tests on well V-BD, 3 slug tests on well V-DS and 1 slug test each on wells V-ES, V-ED, V-FS, V-GS, and V-HS (Dames and Moore, 1982). The second field testing program, in 1983, included a pump test on deep, off-site well No. 15, and another pump test on shallow, off-site well No. 14.

The first water-quality sampling program, in 1978 and 1979, included 7 surface-water samples, 2 from the Jordan River, 2 from Mill Creek and 1 each from Vitro Ditch, South Vitro Ditch, and the marsh east of the site. Also, 14 borehole water-samples were taken from the tailings pile (Markos and Bush, 1982).

The second water-quality sampling program, in 1982, included 17 samples, taken on various dates, from a total of 15 on-site wells. This program included 11 samples from 9 shallow wells and 6 samples from 6 deep wells. Each of the 17 samples was analyzed for 70 different constituents or parameters (DOE, 1983) (Table D-4).

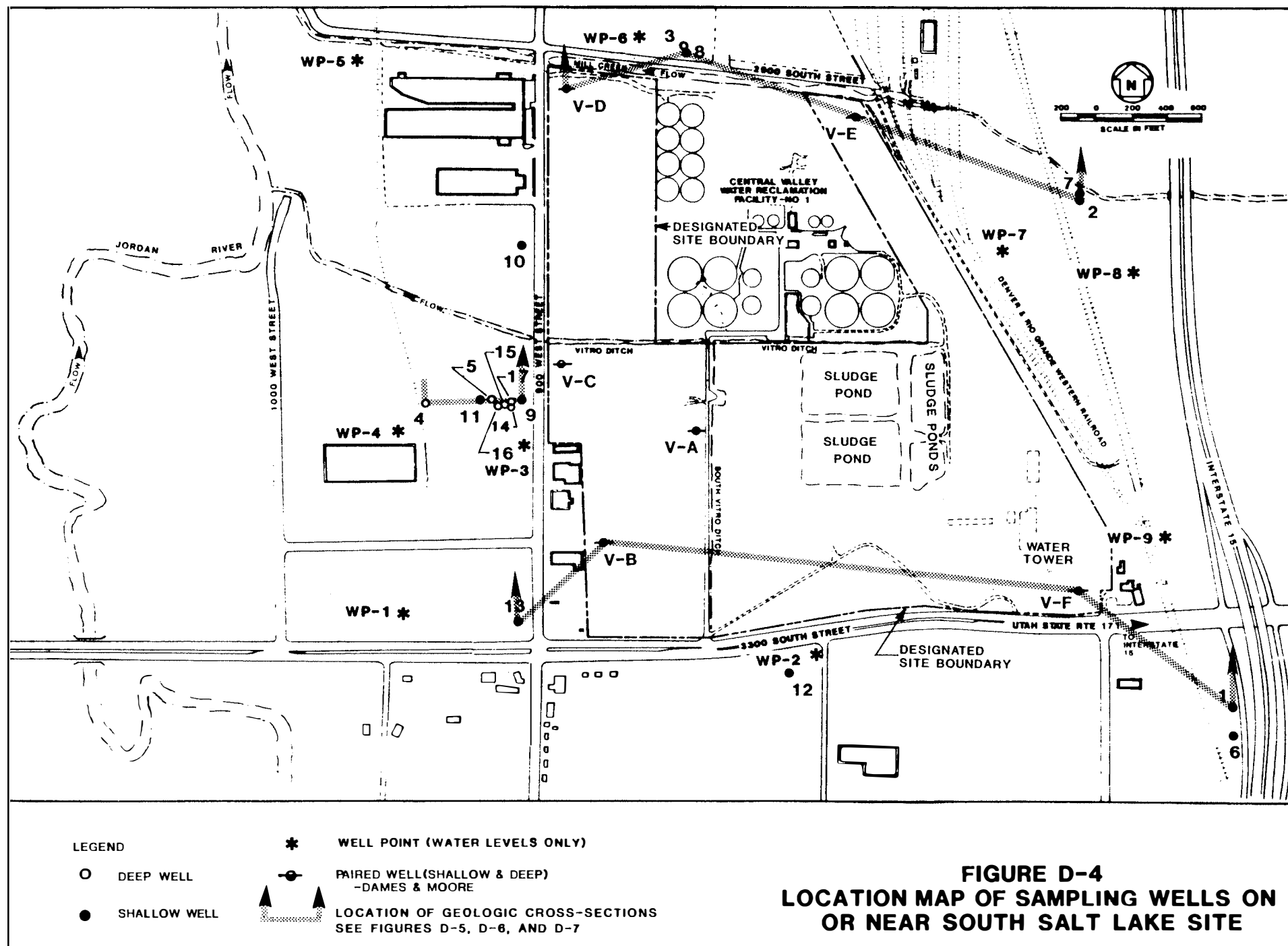


Table D-2. Well completion data, Vitro site, TAC (1983) wells

TAC well No.	Total ^a depth Ft.	Screened ^a interval Ft.	Blank ^a interval Ft.	Ground elev. Ft.	Collar elev. Ft.	Location ^b
1	115	100-110	0-100	4244.96	4246.47	U
2	135	119-129	0-119	4238.07	4239.07	U
3	125	110-120	0-110	4234.13	4235.74	C
4	137	105-115	0-105	4234.37	4235.62	D
5	132	115.5-125.5	0-115.5	4234.92	4237.41	D
6A	31.5	26-28	0-26	4244.61	4246.42	U
6B	20	17-19	0-17	4244.68	4246.51	U
6C	10	7-9	0-7	4244.71	4246.46	U
7A	35	26-28	0-26	4237.97	4240.30	U
7B	25	15-17	0-15	4238.02	4240.53	U
7C	15	8-10	0-8	4237.98	4239.81	U
8A	40	26-28	0-26	4233.13	4236.20	C
8B	35	19-21	0-19	4233.13	4235.40	C
8C	10	6-8	0-6	4233.13	4235.53	C
9A	35	27-29	0-27	4233.17	4234.80	D
9B	25	16-18	0-16	4232.97	4235.05	D
9C	15	6-8	0-6	4233.02	4235.73	D
10A	36.5	26-28	0-26	4234.60	4236.95	D
10B	20	14.5-16.5	0-14.5	4234.65	4236.67	D
10C	10	6-8	0-6	4234.55	4236.80	D
11A	31.5	24-26	0-24	4234.52	4236.54	D
11B	20	17-19	0-17	4234.62	4236.34	D
11C	15	6-8	0-6	4234.82	4236.54	D
12A	31.5	26-28	0-26	4235.90	4238.04	C
12B	20	17-19	0-17	4236.06	4237.87	C
12C	10	6.5-8.5	0-6.5	4235.95	4237.96	C
13A	31.5	26-28	0-26	4235.70	4238.41	D
13B	20	16-18	0-16	4235.75	4238.23	D
13C	10	6-8	0-6	4235.75	4237.95	D
14	41.5	18-38	0-18	4233.27	4235.40	D
15	133	102-112	0-102	4233.73	4235.20	D
16	71	66-68	0-66	4234.47	4236.80	D
17	60	54-57	0-54	4233.40	4235.80	D
WP-1	9	7-9	0-7	4235.52	4237.42	C
WP-2	6	4-6	0-4	4233.87	4236.20	D
WP-3	8.5	6.5-8.5	0-6.5	4233.37	4235.79	D
WP-4	7	5-7	0-5	4233.35	4235.70	D
WP-5	8.5	6.5-8.5	0-6.5	4232.09	4234.29	D
WP-6	9.5	7.5-9.5	0-7.5	4231.18	4233.31	D
WP-7	10	8-10	0-8	4236.68	4238.47	C
WP-8	7	5-7	0-5	4236.62	4237.71	U
WP-9	10	8-10	0-8	4238.02	4239.29	U
WP-10	10	8-10	0-8	4236.25	4237.90	U

^aAll depths from ground surface.^bWhere: U = upgradient
C = crossgradient
D = downgradient

Table D-3. Well construction details, Vitro site

Well number ^a	Blank interval (ft) ^b	Screened interval (ft)	Sand pack interval (ft)	Grout seal interval (ft)	Bentonite seal interval (ft)
V-Ad1 obs. N	+2.0 - 98.0	98.0 - 128.0	65.0		
s. N	+2.5 - 97.5	97.5 - 127.5	92.0 - 137.0	0.0 - 90.0	90.0 - 92.0
	127.5 - 130.5				
V-AD3 pumping	+2.0 - 98.0	98.0 - 128.0	96.0 - 130.0	0.0 - 91.0	91.0 - 96.0
V-AS1 obs. N	+1.5 - 13.4	13.4 - 18.7	12.5 - 19.7	0.0 - 11.0	11.0 - 12.5
	18.7 - 19.7				
V-AS2 pumping	+2.0 - 13.0	13.0 - 19.0	12.0 - 22.0	0.0 - 11.0	11.0 - 12.0
	19.0 - 22.0				
V-AS3 obs. S	+2.0 - 10.0	10.0 - 20.0	9.0 - 22.0	0.0 - 8.5	8.5 - 9.0
	20.0 - 22.0				
V-BD	+3.0 - 85.0	85.0 - 95.0	82.0 - 97.0	0.0 - 80.0	80.0 - 82.0
	95.0 - 98.0				
V-BS	+2.0 - 15.0	15.0 - 20.0	14.5 - 25.0	0.0 - 13.5	13.5 - 14.5
	20.0 - 25.0				
V-CD	+2.0 - 105.0	105.0 - 115.0	80.0 - 118.0	0.0 - 80.0	None
	115.0 - 118.0				
V-CS pumping	0.0 - 14.5	14.5 - 37.5	Unknown	Unknown	Unknown
	37.5 - 39.5				
V-CS obs. N	0.0 - 17.0	17.0 - 27.0	None	Unknown	Unknown
	27.0 - 29.0	29.0 - 39.0			
	39.0 - 42.0				
V-CS obs. S	0.0 - 11.5	11.5 - 26.5	Unknown	Unknown	Unknown
	26.5 - 28.5	28.5 - 38.5			
	38.5 - 41.5				
V-DD	+1.5 - 80.0	80.0 - 90.0	75.0 - 90.0	0.0 - 73.0	73.0 - 75.0
V-DS	1.3 - 13.0	13.0 - 23.0	12.0 - 27.0	0.0 - 11.5	11.5 - 12.0
	23.0 - 25.0				
V-ED	+2.6 - 74.0	74.0 - 89.0	70.0 - 92.0	0.0 - 63.0	63.0 - 70.0
	89.0 - 92.0				
V-ES	+1.6 - 14.5	14.5 - 29.5	13.0 - 30.0	0.0 - 11.0	11.0 - 13.0
	29.5 - 31.0				

Table D-3. (Continued)

Well number ^a	Blank interval (ft) ^b	Screened interval (ft)	Sand pack interval (ft)	Grout seal interval (ft)	Bentonite seal interval (ft)
V-FS	0.0 - 30.0	30.0 - 40.0	27.0 - 40.0	0.0 - 25.0	25.0 - 27.0
V-FD	0.0 - 81.5	81.5 - 91.5	63.0 - 91.5	0.0 - 63.0	
V-GS	+1.5 - 25.0 35.0 - 36.5	25.0 - 35.0	23.0 - 35.0	0.0 - 21.0	21.0 - 23.0
V-HS	+3.0 - 35.0	35.0 - 45.0	Unknown	Unknown	Unknown

^aFor well locations, see Figure D-4 (all wells located on the site).

^b"+" denotes portion of well above ground surface.

Ref. DOE 1983

Table D-4. Ground-water quality, 1982

Parameter ^b	Well number ^a						
	V-HS	V-CD	V-ED	V-DD	V-CS	V-DS	V-ES
Date sampled	2/9/82	4/22/82	4/22/82	4/22/82	4/22/82	4/22/82	4/22/82
Aluminum (Al)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Arsenic (As)	0.02	< 0.01	0.02	< 0.01	0.05	0.10	< 0.01
Arsenic - total (As)	0.02	< 0.01	0.02	< 0.01	0.05	0.10	0.02
Barium (Ba)	< 0.1	0.3	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Barium - total (Ba)	0.5	0.3	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Boron (B)	0.68	0.21	0.35	0.20	0.98	1.31	0.92
Cadmium (Cd)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Cadmium - total (Cd)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Chromium (Cr)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Chromium - total (Cr)	0.08	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Cobalt (Co)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Copper (Cu)	0.05	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Copper - total (Cu)	0.16	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Iron (Fe)	0.11	0.51	0.45	0.12	21.0	54.0	< 0.05
Iron - total (Fe)	44.0	0.56	0.92	0.52	23.00	58.00	0.24
Lead (Pb)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Lead - total (Pb)	0.3	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Magnesium (Mg)	320	50.0	23.0	22.0	210	390	290
Manganese (Mn)	0.64	0.31	0.15	0.06	1.43	3.88	0.12
Manganese - total (Mn)	1.85	0.29	0.13	0.06	1.37	4.02	0.14
Mercury - total (Hg)	0.5	0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
(in micrograms per liter)							
Molybdenum (Mo)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Nickel (Ni)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Potassium (K)	140	13.0	25.0	12.0	38.0	24.0	44.0
Selenium (Se)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Selenium - total (Se)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.02
Silver (Ag)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Silver - total (Ag)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Sodium (Na)	2,000	27.0	76.0	30.0	340	240	420
Sodium - total (Na)	2,000	27.00	76.0	30.0	340	240	420
Strontium (Sr)	1.79	0.90	0.23	0.33	2.11	5.50	3.16
Vanadium (V)	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Zinc (Zn)	0.02	0.01	< 0.01	0.02	0.01	0.05	0.02
Zinc - total (Zn)	0.25	0.01	0.01	0.02	0.01	0.05	0.02

Table D-4. (continued)

Parameter ^b	Well number ^a							
	V-HS	V-AD	V-AS	V-GS	V-FD	V-BS	V-FS	V-BD
Date sampled	4/14/82	4/15/82	4/15/82	4/15/82	4/15/82	4/21/82	4/21/82	4/21/82
Aluminum (Al)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Arsenic (As)	0.05	< 0.01	0.09	0.05	< 0.01	< 0.05	0.09	0.01
Arsenic - total (As)	0.05	< 0.01	0.09	0.05	< 0.01	0.05	0.09	0.01
Barium (Ba)	0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Barium - total (Ba)	0.2	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.1	< 0.1
Boron (B)	0.84	0.14	2.09	0.41	0.10	1.96	0.26	0.18
Cadmium (Cd)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Cadmium - total (Cd)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Chromium (Cr)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Chromium - total (Cr)	0.03	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.05	< 0.01
Cobalt (Co)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Copper (Cu)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Copper - total (Cu)	0.09	< 0.01	< 0.01	0.06	< 0.01	0.04	0.30	< 0.01
Iron (Fe)	0.19	0.58	< 0.05	0.46	0.18	12.0	0.18	0.61
Iron - total (Fe)	20.20	< 0.70	0.33	15.10	0.20	18.00	70.00	0.90
Lead (Pb)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Lead - total (Pb)	< 0.05	0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.14	0.05
Magnesium (Mg)	260	23.0	670	39.0	21.0	530	35.0	33.0
Manganese (Mn)	0.36	0.13	0.07	0.07	0.03	1.77	0.17	0.18
Manganese - total (Mn)	0.91	0.13	0.07	0.37	0.04	1.85	1.60	0.16
Mercury - total (Hg)	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	0.3	< 0.3	< 0.3
(in micrograms per liter)								
Molybdenum (Mo)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Nickel (Ni)	< 0.05	0.05	0.10	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Potassium (K)	110	9.10	110	34.0	5.70	130	26.0	11.0
Selenium (Se)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Selenium - total (Se)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Silver (Ag)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Silver - total (Ag)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Sodium (Na)	1,500	19.0	1,470	72.0	15.0	820	22.0	24.0
Sodium - total (Na)	1,500	19.0	1,470	72.0	15.0	820	22.0	24.0
Strontium (Sr)	1.65	0.27	11.10	0.19	0.30	8.60	0.13	0.46
Vanadium (V)	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Zinc (Zn)	0.11	0.04	0.32	0.10	0.15	0.05	0.01	0.02
Zinc - total (Zn)	0.19	0.04	0.35	0.16	0.15	0.05	0.37	0.02

Table D-4. (continued)

Parameter ^b	Well number ^a						
	V-HS	V-CD	V-ED	V-DD	V-CS	V-DS	V-ES
Date sampled	2/9/82	4/22/82	4/22/82	4/22/82	4/22/82	4/22/82	4/22/82
Ammonia (NH ₃ -N) (un-ionized)	0.10	0.11	0.18	0.13	0.05	0.05	0.05
Bicarbonate (HCO ₃)	586	225	443	352	604	1,186	377
Carbonate (CO ₃)	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Calcium (Ca)	150	120	28.0	48.0	220	550	210
Chloride (Cl)	2,686	156	21.7	11.7	332	319	501
Chloride - total (Cl)	2,853	158	24.9	12.8	354	323	507
Conductivity - field (in micromhos per centimeter)	22,000	1,200	640	500	4,100	5,200	5,000
Cyanide - total (CN)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Fluoride (F)	1.36	0.22	0.35	0.27	3.33	0.79	0.62
Fluoride - total (F)	1.36	0.23	0.36	0.29	3.34	0.79	0.63
Hydroxide (OH)	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Nitrate (NO ₃ -N)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	15.3
Nitrate - total (NO ₃)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	15.3
pH - field	7.8	7.8	7.8	8.0	6.9	6.6	7.6
pH - lab @25°C	8.30	8.00	8.01	8.20	7.50	7.25	8.08
Phenol	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.005
Phosphate - total (PO ₄ -P)	0.38	0.38	0.69	0.48	1.69	0.49	0.32
Redox potential (EH) (in millivolts)	102	178	210	218	149	121	131
Salinity - field (0/00)	-	-	-	-	-	-	-
Sulfate (SO ₄)	1,822	205	5	5	1,272	2,210	1,598
Sulfate - total (SO ₄)	1,914	206	5.4	5	1,340	2,212	1,639
Sulfide (H ₂ S)	< 0.05	< 0.05	0.09	0.07	0.08	< 0.05	< 0.05
Temperature - field (°C)	10.3	12.2	13.3	11.7	13.3	12.2	12.2
Total alkalinity (as CaCO ₃)	501	202	384	303	521	1,017	328
Total dissolved solids as calcium)	7,449	750	406	320	2,876	4,304	3,470
Total hardness (as CaCO ₃)	1,691	505	164	210	1,413	2,978	1,718
Total organic carbon	9	10	17	11	16	27	14

Table D-4. (continued)

Parameter ^b	Well number ^a	
	V-AS-2	V-AS-2
Date sampled	7/18/82	11/8/82
Ammonia (NH ₃ -N) (un-ionized)	0.14	1.44
Bicarbonate (HCO ₃)	1,525	1,144
Carbonate (CO ₃)	1	1
Calcium (Ca)	470	410
Chloride (Cl)	122	721.3
Chloride - total (Cl)	128.6	720.1
Conductivity - field (in micromhos per centimeter)	2,000	9,200
Cyanide - total (CN)	0.005	0.05
Fluoride (F)	2.90	3.5
Fluoride - total (F)	2.9	3.7
Hydroxide (OH)	0.5	0.5
Nitrate (NO ₃ -N)	0.1	0.1
Nitrate - total (NO ₃)	0.1	0.5
pH - field	7.1	7.14
pH - lab @25°C	7.43	7.63
Phenol	0.005	0.005
Phosphate - total (PO ₄ -P)	0.38	0.17
Redox potential (EH) (in millivolts)	117	189
Salinity - field (0/00)	-	-
Sulfate (SO ₄)	6,008	3,917
Sulfate - total (SO ₄)	6,016.0	3,950
Sulfide (H ₂ S)	0.05	0.06
Temperature - field (°C)	15.0	13.5
Total alkalinity (as CaCO ₃)	1,293	962
Total dissolved solids (as calcium)	10,592	8,096
Total hardness (as CaCO ₃)	4,178	3,247
Total organic carbon	11	7

Table D-4. (continued)

Parameter ^b	Well number ^a							
	V-HS	V-AD	V-AS	V-GS	V-FD	V-BS	V-FS	V-BD
Date sampled	4/14/82	4/15/82	4/15/82	4/15/82	4/15/82	4/21/82	4/21/82	4/21/82
Ammonia (NH ₃ -N) (un-ionized)	0.33	0.14	< 0.05	0.31	0.13	< 0.05	0.11	0.12
Bicarbonate (HCO ₃)	556	309	1,507	385	290	1,229	354	279
Carbonate (CO ₃)	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Calcium (Ca)	95.0	55.0	390	30.0	62.0	410	28.0	90.0
Chloride (Cl)	2,245	29.6	918	110	16.1	736	13.9	90.1
Chloride - total (Cl)	1,508	29.6	918	110	16.1	747	15.0	91.2
Conductivity - field (in micromhos per centimeter)	18,000	620	17,000	1,050	570	8,000	630	1,000
Cyanide - total (CN)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Fluoride (F)	0.62	0.11	2.09	0.45	0.12	6.01	0.59	0.26
Fluoride - total (F)	0.47	0.11	2.10	0.45	0.14	6.10	0.60	0.26
Hydroxide (OH)	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Nitrate (NO ₃ -N)	0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.1	0.1	0.1
Nitrate - total (NO ₃)	0.2	< 0.1	< 0.1	< 0.1	< 0.1	0.1	0.2	0.1
pH - field	7.8	7.9	7.1	8.0	8.2	6.7	7.8	7.9
pH - lab @25°C	7.72	7.80	7.20	8.12	8.20	6.60	7.80	7.70
Phenol	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Phosphate - total (PO ₄ -P)	1.77	0.44	0.30	1.84	0.38	0.34	0.17	0.58
Redox potential (EH) (in millivolts)	114	209	130	182	228	122	224	181
Salinity - field (0/00)	-	-	-	-	-	-	-	-
Sulfate (SO ₄)	1,236	< 5	4,612	23.0	44.4	3,008	< 5	96.3
Sulfate - total (SO ₄)	567	8.2	4,642	41.2	46.9	3,020	< 5	96.7
Sulfide (H ₂ S)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Temperature - field (°C)	13.3	12.2	11.7	11.7	12.2	12.8	11.7	13.3
Total alkalinity (as CaCO ₃)	485	273	1,275	335	253	1,047	369	248
Total dissolved solids (as calcium)	6,002	316	9,473	544	323	6,600	310	510
Total hardness (as CaCO ₃)	1,307	232	3,731	235	241	3,205	213	360
Total organic carbon	26	10	14	14	30	25	10	12

Table D-4. (continued)

Parameter ^b	Well number ^a	
	V-AS	V-AS
Date sampled	7/18/82	11/8/82
Aluminum (Al)	< 0.01	< 0.1
Arsenic (As)	0.08	0.034
Arsenic - total (As)	0.10	0.048
Barium (Ba)	< 0.1	< 0.1
Barium - total (Ba)	< 0.1	< 0.1
Boron (B)	1.75	1.28
Cadmium (Cd)	< 0.01	< 0.01
Cadmium - total (Cd)	< 0.01	< 0.01
Chromium (Cr)	< 0.01	< 0.01
Chromium - total (Cr)	< 0.01	< 0.01
Cobalt (Co)	0.1	< 0.05
Copper (Cu)	< 0.01	< 0.01
Copper - total (Cu)	< 0.01	< 0.01
Iron (Fe)	0.13	0.13
Iron - total (Fe)	0.24	2.18
Lead (Pb)	< 0.05	< 0.01
Lead - total (Pb)	< 0.05	< 0.01
Magnesium (Mg)	730	540
Manganese (Mn)	0.06	0.05
Manganese - total (Mn)	0.07	0.11
Mercury - total (Hg)	< 0.3	< 0.3
(in micrograms per liter)		
Molybdenum (Mo)	0.2	0.1
Nickel (Ni)	< 0.05	< 0.05
Potassium (K)	120	110
Selenium (Se)	< 0.01	< 0.01
Selenium - total (Se)	< 0.01	< 0.01
Silver (Ag)	< 0.01	< 0.01
Silver - total (Ag)	< 0.01	< 0.01
Sodium (Na)	1,600	1,120
Sodium - total (Na)	1,600	1,090
Strontium (Sr)	10.00	9.5
Vanadium (V)	< 0.5	< 0.1
Zinc (Zn)	< 0.01	0.01
Zinc - total (Zn)	< 0.01	0.01

Table D-4. (continued)

Parameter ^c	Well number ^a						
	V-HS	V-CD	V-ED	V-DD	V-CS	V-DS	V-ES
Date sampled	2/9/82	4/22/82	4/22/82	4/22/82	4/22/82	4/22/82	4/22/82
Gross alpha, total	0.0+39.7	0.7+5.6	11.8+6.5	0.0+3.0	77.0+35.0	3.7+30.0	21.0+28.0
Gross beta, total	71.4+173	10.6+6.7	25.6+5.0	10.6+4.2	39.0+39.0	36.0+38.0	52.0+39.0
Radium-226, total	3.8+0.4	0.9+0.2	4.5+0.4	0.5+0.1	7.4+0.5	1.1+0.2	1.0+0.2
Radium-228, total	8.7+3.3	0.0+2.3	0.6+2.6	0.0+2.7	2.0+2.4	0.0+2.4	0.7+2.7
Thorium-230, total	1.5+1.4	0.4+0.8	1.8+1.4	0.1+0.7	6.7+2.1	0.0+0.5	0.0+0.5
Lead-210, total	0.9+1.3	0.0+1.3	4.2+1.4	0.0+1.1	2.4+1.2	1.2+1.2	1.6+1.2
Polonium-210, total	1.7+1.7	0.7+0.5	2.0+0.6	0.3+0.4	2.0+0.7	2.1+0.7	0.5+0.3
Uranium (U ₃ l ₈), dissolved	16.9	< 0.7	0.7	< 0.7	93.4	10.2	26.4
Uranium (U ₃ O ₈), total	26.4	< 0.7	0.7	< 0.7	115.1	16.2	31.1

Table D-4. (continued)

Parameter ^c	Well number ^a							
	V-HS	V-AD	V-AS	V-GS	V-FD	V-BS	V-FS	V-BD
Date sampled	4/14/82	4/15/82	4/15/82	4/15/82	4/15/82	4/21/82	4/21/82	4/21/82
Gross alpha, total	24.3+2.7	0.0+3.2	232+113	85.2+28.7	0.0+2.7	1,181+167	39.0+21.0	23.0+9.0
Gross beta, total	128+83.2	5.0+4.1	79.4+83.8	78.5+12.1	2.8+4.0	370.0+82.0	70.0+22.0	11.0+6.0
Radium-226, total	8.0+0.6	0.5+0.1	1.6+0.3	7.2+0.7	0.3+0.1	114+2.1	4.6+0.4	9.1+0.6
Radium-228, total	1.2+3.6	0.0+2.1	0.0+4.0	2.5+3.7	2.0+2.2	0.0+2.7	0.2+2.6	0.0+2.4
Thorium-230, total	2.7+1.6	0.2+0.3	0.9+0.8	4.7+1.8	0.2+0.3	28.9+2.5	1.8+1.4	0.0+1.1
Lead-210, total	19.9+2.0	0.3+1.2	6.6+1.5	6.7+1.6	0.5+1.4	161+4.5	7.0+1.3	3.2+1.1
Polonium-210, total	7.7+1.1	0.4+0.4	2.8+1.1	11.8+2.3	0.5+0.4	76.9+5.2	3.7+0.9	1.6+0.7
Uranium (U ₃ O ₈), dissolved	2.7	< 0.7	83.9	4.1	< 0.7	249.1	2.7	< 0.7
Uranium (U ₃ O ₈), total	3.4	< 0.7	83.9	10.2	< 0.7	744.7	6.1	< 0.7

Table D-4. (continued)

Parameter ^c	Well number ^a	
	V-AS	V-AS
Date sampled	7/18/82	11/8/82
Gross alpha, total	183+114	281.8+78.9
Gross beta, total	84.1+72.8	117.9+54.1
Radium-226, total	1.9+0.3	7.3+0.5
Radium-228, total	0.4+2.1	3.9+3.1
Thorium-230, total	4.8+1.0	8.3+2.8
Lead-210, total	1.2+1.0	4.7+2.5
Polonium-210, total	0.8+0.7	10.3+2.0
Uranium (U ₃ O ₈) dissolved	254.6	160.8
Uranium (U ₃ O ₈), total	278.1	191.0

^aFor well locations, see Figure D-4.

^bAll values in mg/l on a dissolved basis, unless otherwise noted.

^cValues in pCi/l.

Ref. DOE 1983

Although Eh was measured in the field and reported on Table D-4, these values were not used in the geochemical modeling with PHREEQE (see Section D.3.5). The measured values may not be accurate because dissolved oxygen may have been greater than 0.01 mg/l. Dissolved oxygen was not measured. For the geochemical modeling, discussed in Section D.3.5, redox potential was estimated on the basis of a general understanding of the geochemical system.

The third sampling program, through September, 1983, included a total of 52 samples, taken on various dates, from 33 different wells and the CVWRF excavation. It was comprised of 33 samples from 22 shallow wells, 15 samples from 9 deep wells, 2 samples from 2 wells completed in or adjacent to the aquitard between the confined and unconfined systems, and 2 samples from the excavation. Five to 34 constituents were analyzed per sample (TAC, 1983). The sampled wells, the dates of sampling, and the analyses are shown in Table D-5. The State of Utah (1983) obtained 32 sample splits with samples collected during the 1983 program. These samples were analyzed for 13 to 18 parameters (Table D-6).

A set of standardized procedures was used for gathering, preserving, shipping, handling within the laboratory, and analyzing samples. Details of these procedures are available at the DOE Uranium Mill Tailings Remedial Action (UMTRA) Project office in Albuquerque, New Mexico. The determination of the concentration of most of the chemical constituents was done according to the analytical procedures of the United States Environmental Protection Agency (1979).

The following discussion summarizes the current understanding and interpretation of the stratigraphy, geohydrology, and ground-water chemistry in the general vicinity of the Vitro site.

D.3.1.2 Stratigraphic and hydrologic setting.

The general stratigraphy of the Jordan River Valley in the vicinity of the site consists of several hundred feet of unconsolidated to poorly consolidated alluvial and lacustrine deposits of interbedded and highly lenticular sands, silty sands, silts, and clays. The fine-grained deposits were laid down in the lake environment of the prehistoric Lake Bonneville. The coarser-grained soils were deposited as alluvium, probably along the margins of this prehistoric lake as the levels fluctuated and lowered to its present condition, the Great Salt Lake.

The field investigations in the vicinity of the Vitro site indicate that approximately the upper 85 feet of subsoil consists of interbedded fine sand, silty sand, clay, and silt. These beds are often laterally discontinuous and vary in thickness from a few inches to several feet. Generally, the upper 50 to 70 feet of this complex profile form the unconfined aquifer system. This unconfined aquifer generally overlies a stratum of interbedded layers of low-permeability clays and silts. Because materials of the unconfined aquifer are very similar to the underlying aquitard, the thickness of the unconfined aquifer varies and can only be estimated. Potentiometers installed between 10 and 60 feet below the ground surface revealed water levels at, slightly below,

Table D-5. Ground-water quality, 1983

Parameter ^b	Well number ^a									
	6A	6B(split)	6C	7C	10C	9A	9B(split)	9C	13C	Excavation
NO ₃	<1.0	1.0/1.7	1.0	1.0	110	1.0	1.0/1.9	1.0	3.0	2.0
Al	0.024	0.054/1.68	0.036	0.02	0.056	0.025	0.038/9.26	0.019	0.021	0.026
As	0.12	0.052/0.1	0.05	0.065	0.05	0.05	0.05/ 0.01	0.05	0.5	0.05
Ba	<0.5	0.5/ 0.01	0.5	0.5	0.5	0.5	0.5/ 0.01	0.5	0.5	0.5
Cd	<0.01	0.01/ 0.001	0.01	0.01	0.01	0.01	0.01/ 0.001	0.01	0.01	0.01
Cr	<0.05	0.05/ 0.05	0.05	0.05	0.05	0.05	0.05/ 0.05	0.05	0.05	0.05
Cu	<0.02	0.02/0.46	0.02	0.02	0.02	0.02	0.02/ 0.01	0.02	0.02	0.02
Fe	.028	0.066/0.70	0.036	3.7	0.042	8.9	33/41	0.1	0.012	1.6
Pb	<0.5	0.05/ 0.001	0.05	0.05	0.05	0.05	0.05/ 0.05	0.05	0.05	0.05
Hg	<0.002	0.002/ 0.002	0.002	0.002	0.002	0.002	0.003/0.1	0.002	0.002	0.002
Mo	<0.01	0.01/ 0.01	0.01	0.012	0.018	0.01	0.01/ 0.01	0.012	0.045	1.2
Ni	<0.5	0.5/ 0.1	0.05	0.5	0.5	0.5	0.5/ 0.1	0.5	0.5	0.5
Ca	31	140/0.13	560	290	620	230	440/504	430	23	330
Se	<0.01	0.01/ 0.01	0.01	0.01	0.01	0.01	0.01/ 0.01	0.01	0.01	0.01
Ag	<0.05	0.05/ 0.05	0.05	0.05	0.05	0.05	0.05/ 0.01	0.05	0.05	0.05
Zn	<0.5	0.5/ 0.1	0.5	0.5	0.5	0.5	0.5/ 0.01	0.5	0.5	0.5
Cl	230	1200. 1.0	4900	630	1200	4300	4200/880	2800	590	460
TDS	930	4010/3768	16100	4250	12300	14500	18300/17950	15800	2320	4340
SO ₄	21	980/865	4300	1400	5200	4800	6600/7050	6600	250	1600
Na	180	1100/450	3000	450	920	3100	3200/1357	2400	760	550
Mg	76	160/178	700	330	1000	880	1300/233	1200	14	280
K	52	49/40	67	22	51	160	190/435	200	97	50
V	<0.01	0.01/ 0.1	0.01	0.01	0.01	0.01	0.01/5.56	0.01	0.04	0.01
Th-230 (pCi/l)	<1.0	1.0/ 1+1.0	1.0	1.0	1.0	1.0	1.0/ 1+1.0	1.0	1.0	1.0
Pb-210 (pCi/l)	<1.5	1.5/ 1.5+1.5	1.5	1.5	1.5	1.5	1.5/ 1/5+1/5	1.5	1.5	1.5
U(NAT)	0.003	0.0045/ 0.1	0.04	0.022	0.11	0.038	0.092/ 0.1	2.24	0.021	0.248
Gross A (pCi/l)	<80	200/ 5+2.5	600	200	400	600	600/ 5+2.5	800	200	200
Gross B (pCi/l)	<20	500/ 5+2.5	2000	500	1000	2000	2000/ 5+2.5	2000	500	500
Ra-226 (pCi/l)	<1.0	1.0/ 1+1.0	1.0	1.2	1.0	1.2	1.4/ 1+1.0	13.0	1.0	1.2
Ra-228 (pCi/l)	<2	2 / 1+1.0	2	2	2	2	2 / 1+1.0	2	2	2
Alkalinity	550	580/383	580	400	720	900	965/798	780	680	--
pH (s.u.)	7.48	7.35	7.01	7.26	6.92	6.97	6.58	6.85	7.98	6.85
temp (°C)	12	11	9	17	11	11.5	11.5	10	8	13
Cond (μmhos/cm) ^e	1200	4050	12500	4150	7800	12500	13500	10500	2375	3950
date sampled	4/13	4/13	4/13	3/30	3/29	4/10	4/10	4/10	4/5	3/30

Note: right-hand halves of split samples represent analyses done by a laboratory which was later found to report inconsistent results.

Table D-5. (continued)

Parameter ^b	Well number ^a								
	14 ^c	14 ^d	16	17	4	V-BD	V-BS (split)	V-DS	V-DD
NO ₃	--	--	--	--	--	--	--/ 0.2	--	--
Al	<0.01	<0.01	--	--	--	<0.01	0.07/ 9.94	<0.01	<0.01
As	<0.01	<0.01	--	--	--	<0.01	0.05/<0.002	0.04	<0.01
Ba	0.02	0.02	--	--	--	0.34	0.02/ 0.08	0.02	0.12
Cd	<0.01	<0.01	--	--	--	<0.01	<0.01/ 0.04	<0.01	<0.01
Cr	<0.01	<0.01	--	--	--	<0.01	<0.01/ 0.13	<0.01	<0.01
Cu	<0.01	<0.01	--	--	--	<0.01	0.01/ 0.85	<0.01	<0.01
Fe	10.3	25	1.3	0.6	4.6	0.2	<21/<6.11	6.5	0.13
Pb	0.01	<0.01	--	--	--	<0.01	<0.01/<0.001	<0.01	<0.01
Hq	<0.002	<0.002	--	--	--	<0.002	0.002/<0.002	<0.002	<0.002
Mo	<0.02	<0.02	--	--	--	<0.01	0.08/<0.005	<0.01	<0.01
Ni	<0.05	<0.05	--	--	--	<0.05	<0.05/ 0.39	0.05	<0.05
Ca	400	<400	41	44	250	75	470/ 460	390	47
Se	<0.01	<0.01	--	--	--	<0.01	<0.01/<0.002	<0.01	<0.01
Aq	<0.01	0.01	--	--	--	<0.01	<0.01/<0.76	<0.01	<0.01
Zn	0.1	0.15	--	--	--	<1	<1/<0.01	<1	<1
Cl	3600	3800	11	13	410	76	560/11.4	160	13
TDS	20000	20000	350	420	1800	510	6900/2904	2900	325
SO ₄	7500	7800	5	7	590	73	3200/750	1300	<15
Na	3400	4000	26	29	86	20	700/ 45	200	30
Mg	1320	1325	25	28	100	30	525/ 160	186	23
K	166	167	19	20	22	12	121/ 31	17	13
V	0.02	<0.01	--	--	--	<0.01	<0.01/ 0.31	<0.01	<0.01
Th 230 (pCi/l)	<1.0	<1.0	--	--	--	<1.0	<1.0/<1+1.0	<1.0	<1.0
Pb 210 (pCi/l)	<1.5	<1.5	--	--	--	<1.5	<1.5/<1.5+1.5	<1.5	<1.5
U (ppm)	0.12	0.12	<0.003	<0.003	0.003	<0.003	0.33/<0.1	0.54	<0.003
Gross A (pCi/l)	<200	<200	--	--	--	<15	290/<5+2.5	350	<15
Gross B (pCi/l)	<600	<600	--	--	--	<50	370/<5+2.5	210	<50
Ra-226 (pCi/l)	<1.0	<1.0	--	--	--	<1.0	14/<1+1.0	<1.0	2.8
Ra-228 (pCi/)	--	--	--	--	--	--	--/<1+1.0	--	--
Alkalinity	1000	1080	310	294	280	240	1090/ 674	594	280
Sr 8.4	8.4	--	--	--	0.76	8.4/ --	4.5	0.44	--
pH (s.u.)	6.66	6.66	7.68	7.85	6.68	7.65	6.51	6.78	7.7
temp (°C)	11.5	11.5	14	21	12.5	12.5	13.2	14	12.0
cond (mhos/ cm) ^e	14500	14800	420	550	1680	580	5300	2450	398
date sampled	6/2	6/2	6/30	6/30	6/29	6/6	6/10	6/7	6/6

Table D-5. (continued)

Parameter ^b	Well number ^a								
	8B	12C	5	1(split)	3	2	V-CD	15***	15****
NO ₃	<1	2	<1	<1/3.32	1	1	8	--	--
Al	<0.01	<0.01	<0.01	<0.01/0.52	0.01	0.01	0.01	0.01	0.01
As	<0.01	0.02	<0.01	0.03/0.57	0.01	0.01	0.01	0.01	0.01
Ba	<1.0	<1.0	<1.0	<1.0/0.14	1.0	1.0	1.0	1.0	1.0
Cd	<0.01	<0.01	<0.01	<0.01/<0.01	0.01	0.01	0.01	0.01	0.01
Cr	<0.01	<0.01	<0.01	<0.01/<0.05	0.01	0.01	0.01	0.01	0.01
Cu	0.02	<0.01	<0.01	<0.01/<0.02	0.01	0.01	0.01	0.01	0.01
Fe	14	0.02	0.62	0.21	0.32	0.61	0.22	1.3	0.04
Pb	<0.05	<0.05	<0.05	<0.05/<0.05	0.05	0.05	0.05	0.05	0.05
Hg	<0.002	<0.002	<0.002	0.002	0.002	0.002	0.002	0.002	0.002
Mo	0.02	0.02	<0.01	<0.01/<0.01	0.01	0.01	0.01	0.01	0.01
Ni	<1	<1	<1	<1/0.1	1	1	1	1	1
Ca	480	160	80	80/49.14	50	50	140	180	180
Se	<0.01	<0.01	<0.01	0.01/ 0.01	0.01	0.01	0.01	0.01	0.01
Ag	<0.01	<0.01	<0.01	0.01	0.01	0.01	0.01	0.01	0.01
Zn	<1.0	<1.0	<1.0	0.1/ 0.1	1.0	1.0	1.0	1.0	1.0
Cl	1200	320	85	10	13	10	220	310	310
TDS	5800	1654	580	330/388	300	288	864	1242	1343
SO ₄	2000	410	110	10/4.0	20	10	230	340	340
Na	650	140	26	14/6.57	19	30	24	42	43
Mg	300	130	40	23/23.0	20	20	62	80	80
K	15	39	13	8.4/0.01	5.6	10	14	15	15
V	<0.01	0.01	<0.01	0.02/ 0.06	0.01	0.01	0.01	0.01	0.01
Th-230 (pCi/l)	<1.0	<1.0	<1.0	1.0/1.0+1.0	1.0	1.0	1.0	1.0	1.0
Pb-210 (pCi/l)	<1.5	<1.5	3	1.5/1.5+1.5	2	2	1.5	1.5	1.5
U (ppm)	0.013	0.017	<0.003	0.011/ 0.1	0.003	0.003	0.003	0.003	0.003
Gross A (pCi/l)	<300	<45	<45	30/5.0+2.5	30	30	20	100	100
Gross B (pCi/l)	<300	<50	<50	50/5.0+2.5	50	50	50	100	100
Ra-226 (pCi/l)	2.1	<1	<1.0	1.0/1.0+1.0	2.0	1.0	1	1	1
Ra-228 (pCi/l)	--	--	2	2/1.0+1.0	--	--	--	--	--
Alkalinity	--	520	--	--	--	--	195	200	200
pH (s.u.)	6.85	7.08	7.21	7.73	7.78	7.25	7.35	7.49	7.46
temp (°C)	9	10	13	15	12	12	130	17	14
cond (mhos/cm) ^e	4350	1650	700	385	352	370	1000	1210	1600
date sampled	5/11	5/17	5/5	5/5	5/11	5/12	5/17	5/21	5/23

Table D-5. (continued)

Parameter ^b	Well number ^a														
	6A	6B	6C	7A	7B	7C	9A	9B	9C	10A	10B	10C	11A	11B	11C
NO ₃	--	--	--	--	--	--	--	--	--	--	0.9	--	--	--	--
Al	--	--	--	<0.01	0.03	<0.01	--	--	--	<0.01	<0.01	<0.01	--	--	--
As	--	--	--	0.06	0.07	0.06	--	--	--	<0.01	<0.01	<0.01	--	--	--
Ba	--	--	--	0.07	0.05	0.05	--	--	--	0.03	0.03	0.03	--	--	--
Cd	--	--	--	<0.01	<0.01	<0.01	--	--	--	<0.01	<0.01	<0.01	--	--	--
Cr	--	--	--	<0.01	<0.01	<0.01	--	--	--	<0.01	<0.01	<0.01	--	--	--
Cu	--	--	--	<0.01	<0.01	<0.01	--	--	--	<0.01	<0.01	0.01	--	--	--
Fe	--	--	--	0.04	1.4	3.2	--	--	--	6.4	17.5	<0.01	12	16	0.28
Pb	--	--	--	<0.01	<0.01	<0.01	--	--	--	<0.01	<0.01	<0.01	--	--	--
Hg	--	--	--	<0.002	<0.002	<0.002	--	--	--	<0.002	<0.002	<0.002	--	--	--
Mo	--	--	--	0.02	0.01	0.02	--	--	--	<0.01	<0.01	<0.01	--	--	--
Ni	--	--	--	<0.05	<0.05	<0.05	--	--	--	<0.05	<0.05	<0.05	--	--	--
Ca	--	--	--	30	165	315	--	--	--	350	625	800	--	--	--
Se	--	--	--	<0.01	<0.01	<0.01	--	--	--	<0.01	<0.01	<0.01	--	--	--
Ag	--	--	--	<0.01	<0.01	<0.01	--	--	--	<0.01	<0.01	<0.01	--	--	--
Zn	--	--	--	<1	<1	<1	--	--	--	<1	<1	<1	--	--	--
Cl	--	--	--	78	330	860	--	--	--	2400	520	1400	5400	4900	3300
TDS	1000	5800	16000	810	2200	4600	8900	19000	17000	18000	7500	7700	21000	20000	20000
SO ₄	--	--	--	110	820	2000	--	--	--	7100	3300	6600	7500	7500	6300
Na	--	--	--	170	300	500	--	--	--	2800	500	1100	--	--	--
Mg	--	--	--	46	182	385	--	--	--	1325	535	1130	--	--	--
K	--	--	--	28	27	20	--	--	--	123	42	52	--	--	--
V	--	--	--	<0.01	<0.01	<0.01	--	--	--	<0.01	<0.01	0.01	--	--	--
Th 230 (pCi/l)	--	--	--	<1.0	<1.0	<1.0	--	--	--	<1.0	<1.0	<1.0	--	--	--
Pb 210 (pCi/l)	--	--	--	2	<1.5	<1.5	--	--	--	3	<1.5	2	--	--	--
U (ppm)	--	--	--	<0.003	0.012	0.02	0.025	0.13	2.12	0.01	0.014	0.11	0.14	0.57	1.87
Gross A (pCi/l)	--	--	--	<20	<120	<100	--	--	--	<200	<200	<200	--	--	--
Gross B (pCi/l)	--	--	--	<60	<350	<300	--	--	--	<600	<600	<600	--	--	--
Ra-226 (pCi/l)	--	--	--	3.2	<1.0	14	--	--	--	1.5	<1.0	<1.0	2.0	2.1	3.2
Ra-228 (pCi/l)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sr	--	--	--	0.43	1.9	8.4	--	--	--	6.9	7.6	11	--	--	--
Alkalinity	530	510	560	456	400	400	650	1400	900	1000	870	770	840	870	840
pH (s.u.)	7.6	7.41	7.2	7.55	7.47	7.47	7.46	6.77	6.79	7.05	6.60	6.88	6.96	6.93	6.90
temp (°C)	16	16	17	14	21	20.5	18.	18.3	15.0	12	13	12	13.0	12.0	13
cond (mhos/cm) ^e	1380	6500	16000	950	2500	5000	9500	15900	12700	12000	5400	8800	17300	15900	13500
date sampled	6/10	6/10	560	6/9	6/9	6/9	6/9	6/9	6/9	6/8	6/7	6/7	6/9	6/9	6/9

Table D-5. (continued)

Parameter ^b	Excavation drain	V-FS	4	5	15	private well
As	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Fe	4.4	0.22	2.4	0.12	2.1	4.2
Mo	0.87	<0.01	<0.01	<0.01	<0.01	<0.01
Ca	300	26	220	80	180	81
cl	560	11	310	100	270	410
TDS	4722	340	1513	628	1120	2038
SO ₄	2100	<5	510	140	390	680
Mg	310	35	94	42	79	240
K	55	30	28	16	18	23
Mn	1.1	0.05	0.60	0.35	0.45	0.75
Pb-210 (PCi/l)			<1.5	<1.5	1.8	
u (ppm)	0.240	0.003	<0.003	<0.003	<0.003	<0.003
Alkalinity	640	290	260	250	200	245
pH (S.u.)	6.95	7.38	7.25	7.34	7.38	7.25
temp (°C)	18	15	14.0	13.5	13.2	15.0
Cond (mhos/ cm) ^e	4150	425	1610	700	1230	2090
date sampled (1983)	8/22	8/24	8/22	8/22	8/23	8/26

Note: private artesian well located at 3181 So. 1100 W. St.

^aFor well locations see Figure D-4.

^bAll values in milligrams per liter on a dissolved basis, except as noted.

^cMiddle of pump test.

^dEnd of pump test.

^eNot corrected to 25°C.

Table D-6. Ground-water quality, State of Utah samples, 1983

Parameter ^{b,c}	Well number ^a												
	Excavation drain	15	15	14	14	13C	12C	11C	11B	11A	9C	9B	10C
As	0.007	<0.0005	<0.0005	0.003	0.003	0.525	0.020	0.012	0.035	0.013	0.003	0.001	0.011
Ba		0.37	0.30	<0.05	<0.05	0.07	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05
Cd		<0.001	<0.001	0.005	0.004	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001
Cr	<0.005	<0.005	<0.006	0.005	<0.005	0.005	<0.005	0.015	0.030	0.030	<0.005	0.005	0.006
Cu	<0.010	0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.10	<0.010	<0.010	0.010	0.015
Fe	2.30	0.08	1.50	14.80	<0.03	<0.03	<0.03	0.40	21.40	18.40	0.49	0.03	0.36
Pb	<0.006	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.013	<0.005	0.006	<0.005	0.005	0.005
Hg	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	0.0001
Mo		<0.200	<0.200										
Ni	0.037	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.185	0.385	0.430	0.077	0.074	0.044
Se	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0005	0.0005
Zn	0.015	0.005	0.005	0.005	110.	0.005	0.020	0.010	0.015	0.015	0.050	0.020	0.005
Mn	0.725	0.420	0.415	1.670	1.740	0.010	0.700	0.815	1.655	1.285	1.180	3.145	0.360
Ag	0.002	0.002	0.002	0.004		0.002	0.002	0.005	0.006	0.006	0.002	0.003	0.002
Gr. Alpha (pCi/l)	109.	7.	7.	124.	362.		6.	303.	142.	63.	819.	63.	59.
Gr. Beta (pCi/l)	---	11.	36.	42.	127.		10.	763.	1093.	770.	513.	10.	---
Ra-226 (pCi/l)	<0.5	<0.5	1.	<0.5	<0.5		<0.5	1.	<0.5	<0.5	<0.5	1.	<0.5
U (pCi/l)	193.	0.	1.	112.	78.		16.	693.	110.	78.	1350.	59.	84.
Date (1983)	5/30	5/23	5/21	6/2	6/2	4/6	5/17	6/9	6/9	6/9	4/8	4/8	3/29

Table D-6. (continued)

Parameter ^{b,c}	Well number ^a											
	10C	10B	10A	8B	7C	7A	7C	7B	6A	6A	5	3
As	0.021	0.014	0.004	0.003	0.070	0.245	0.162	0.245	0.014	0.133	0.0015	0.001
Ba	<0.05	<0.05	<0.05	<0.05	0.05	0.07	0.06	<0.05	<0.05	0.28	0.22	0.10
Cd	0.002	0.002	0.004	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cr	0.014	0.011	0.013	<0.005	<0.005	0.006	0.006	0.007	0.005	<0.005	<0.005	<0.005
Cu	0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Fe	<0.03	18.50	2.65	14.00	5.00	0.03	3.40	1.30	8.90	0.20	0.54	0.24
Pb	0.008	0.005	0.006	<0.005	<0.005	<0.005	<0.007	<0.005	0.005	<0.005	<0.005	<0.005
Hg	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Mo												
Ni	0.086	0.053	<0.010	0.019	0.053	<0.010	<0.010	0.10	0.086	<0.010	<0.010	<0.010
Se	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Zn	0.005	<0.005	<0.005	<0.005	0.005	<0.005	0.005	0.005	0.040	<0.005	<0.005	<0.005
Mn	0.590	2.590	0.865	0.515	0.600	0.060	<0.415	0.275	1.010	0.160	0.335	0.065
Ag	0.004	<0.002	0.006	<0.002	<0.002	<0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Gr. Alphas (pCi/l)	0.42	21.	19.	5.			25.	56.				
Gr. Beta (pCi/l)	156.	56.	420.	<10.			298.	308.				
Ra-226 (pCi/l)	<0.5	<0.5	1.	0.			<0.5	0.				
U (pCi/l)	68.	15.	2.	9.			4.	14.				
Date (1983)	6/7	6/7	6/8	5/11	3/30	6/9	6/8	6/8	4/9	4/13	5/9	5/11

^aFor well locations see Figure D-4.^bAll values in mg/l on a dissolved basis except as noted.^cAll samples represent splits from samples of same date and well shown in Table D-5.

or slightly above the ground surface. Thus, in the vicinity of the tailings pile, the unconfined aquifer appears to be about 60 feet thick. The interbedded strata of this aquifer system produce water at variable rates. Results of water-sample collection for quality testing and a pump test indicate that water yields can be much less than 1 gpm for the silts and clays and greater than 10 gpm for the fine sands and silty sands. (Detailed well logs of the recent investigation by the TAC (1983) for the shallow wells are available at the UMTRA Project office in Albuquerque, New Mexico).

The major sources of recharge to the unconfined aquifer are infiltration of precipitation and upward leakage from the confined aquifer. This aquifer generally discharges into the surface-water drainages such as the Jordan River, Mill Creek, and the Great Salt Lake. However, dewatering of a temporary excavation near the CVWRF treatment plant has temporarily modified the discharge patterns of the unconfined aquifer (see Section D.3.4.1 for details). A highway drain below the Denver & Rio Grande Western Railroad overpass of 3300 South Street locally influences flow in the unconfined aquifer. The ground water which enters the drain is pumped out of a sump into a culvert which discharges into the head of South Vitro Ditch. Ground-water levels in the area indicate that there is a ground-water divide (Bear, 1979) between the site and the highway drain. The presence of the ground-water divide means that there is little or no potential for the migration of contaminants from the site to the drain.

Water levels in the unconfined aquifer range from 10 feet or more below the ground surface (where affected by the CVWRF excavation or highway drain) to 1 foot or more above ground surface. Topographic depressions and drainages allow surface expressions of the water table. Topographic "lows" to the east of the site are perennial marshy areas.

The stratigraphy below a depth of about 85 feet also consists of interbedded silts, clays, and sands. The sand layers are generally coarser-grained than the overlying beds described above. In some instances the sand layers contain considerable amounts of gravel.

Recent work by Dames and Moore (1982) and the TAC (1983) included monitoring and pump wells to a maximum depth of about 130 feet below the ground surface. The wells that penetrated to a depth of about 70 feet or greater, below the ground surface, encountered ground water under significant artesian pressure. The hydraulic head levels ranged from about 7.5 feet above land surface for the well at 70 feet to 15 feet above land surface for the wells at a depth of about 130 feet. Near the Jordan River, it is reported that this artesian aquifer system extends to depths of 500 to 800 feet below the ground surface (Hely et al., 1971).

Flow rates from 2-inch open piezometers in the confined aquifer ranged from a few gpm to several tens of gpm (TAC, 1983). Pump testing of an 8-inch well produced a sustained quantity of about 300 gpm, of which about 150 gpm was artesian flow. Even though the producing sand layers of the confined aquifer are separated by clay and silt layers, monitoring of potentiometers at various depths in the aquifer during a long-term pump test indicated that the sand layers are hydraulically connected. (Detailed well logs of the recent investigation by the TAC (1983) for the deeper wells are also available at the UMTRA Project office.)

The major source of recharge to the confined aquifer is infiltration of precipitation and snowmelt in the flanks of the Wasatch and Oquirrh Mountains. Beneath the site, the water in this aquifer flows toward the northwest. Natural discharge is upwards to the unconfined aquifer system. Artificial discharge occurs with pumping of wells completed in the confined aquifer system.

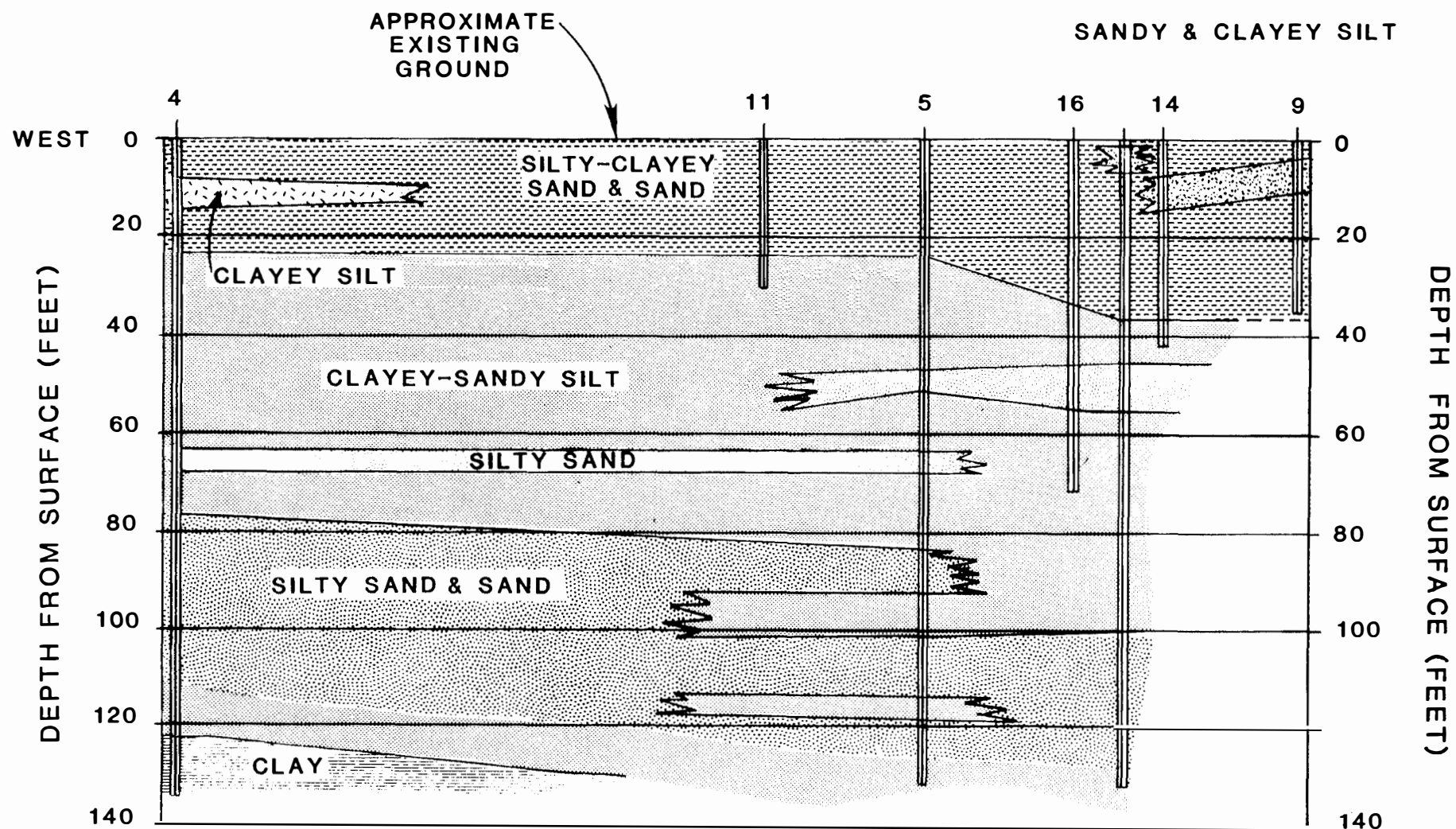
Based on the well logs, simplified subsurface cross-sections, Figures D-5, D-6, and D-7 were constructed to illustrate the conditions described above. It should be noted that the subsurface strata consist of numerous laterally discontinuous layers of silt, clay, and sand of variable thickness.

The relationship of the two aquifer systems with regard to recharge, discharge, and movement of ground water, as determined by a recent pump test by the TAC (1983) and a previous study by Hely et al., (1971) are described in detail in a subsequent section of this appendix.

Available records indicate that eight wells were drilled on the Vitro site in the period 1943-1961 (State of Utah). The wells were screened between 500 and 800 feet below ground surface. All but one of the wells were constructed as flowing wells; the remaining well was equipped with a pump. Five of the flowing wells can still be found on the site, with shut-off valves in working condition.

A small pool at the head of the Vitro ditch may be the site of another well. Water flows from the pool through a culvert to Vitro Ditch at a rate of about 1 cubic foot per second (Weber, 1983). Such high volume, localized discharge would not be expected from spring flow through the fluvial-pluvial sediments at the site. A possible explanation for the discharge would be artesian flow through a partially destroyed well completed in the confined aquifer. During remedial action, this area should be excavated and, if present, the well or wells would be sealed properly.

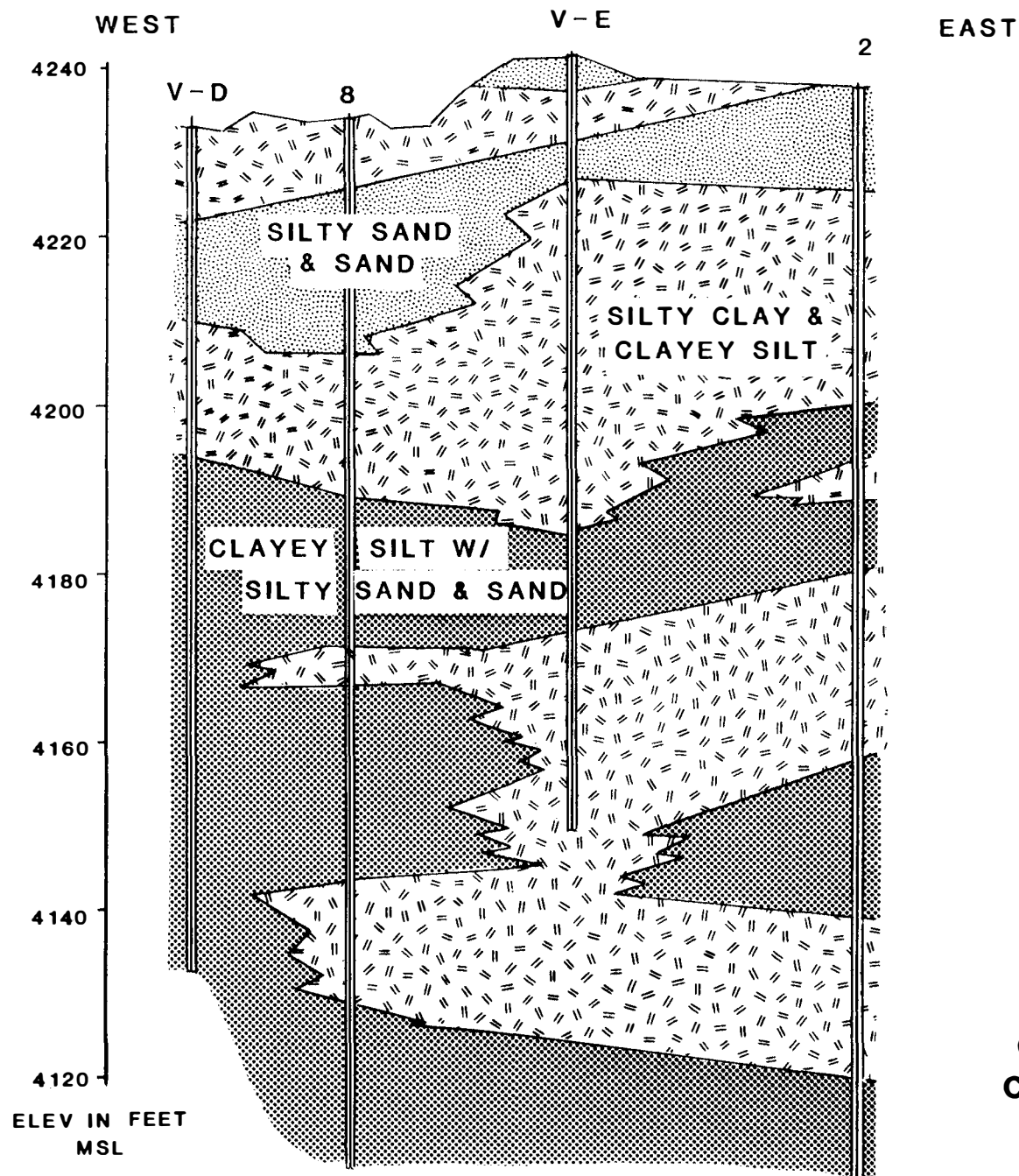
The existing monitoring wells in the confined aquifer represent a potential pathway for communication between the two aquifers. This communication could mean either loss of usable water from the confined aquifer or, in the event of a reversal of the upward hydraulic head gradient, downward migration of contaminants. During the remedial action these wells, and the remaining wells for the mill would be plugged and sealed.



1. ALL STRATIGRAPHIC LINES
ARE APPROXIMATE ONLY

2. LOCATIONS OF GEOLOGIC
CROSS-SECTIONS SEE
FIGURE D-4

FIGURE D-5
GENERALIZED GEOLOGIC CROSS-SECTION FOR THE
AREA WEST OF THE TAILINGS PILE, SOUTH SALT LAKE SITE



1. ALL STRATIGRAPHIC LINES ARE APPROXIMATE ONLY
2. LOCATIONS OF GEOLOGIC CROSS-SECTIONS SEE FIGURE D-4

FIGURE D-6
GENERALIZED STRATIGRAPHIC
CROSS SECTION ALONG NORTH
SIDE OF THE TAILINGS PILE,
SOUTH SALT LAKE SITE

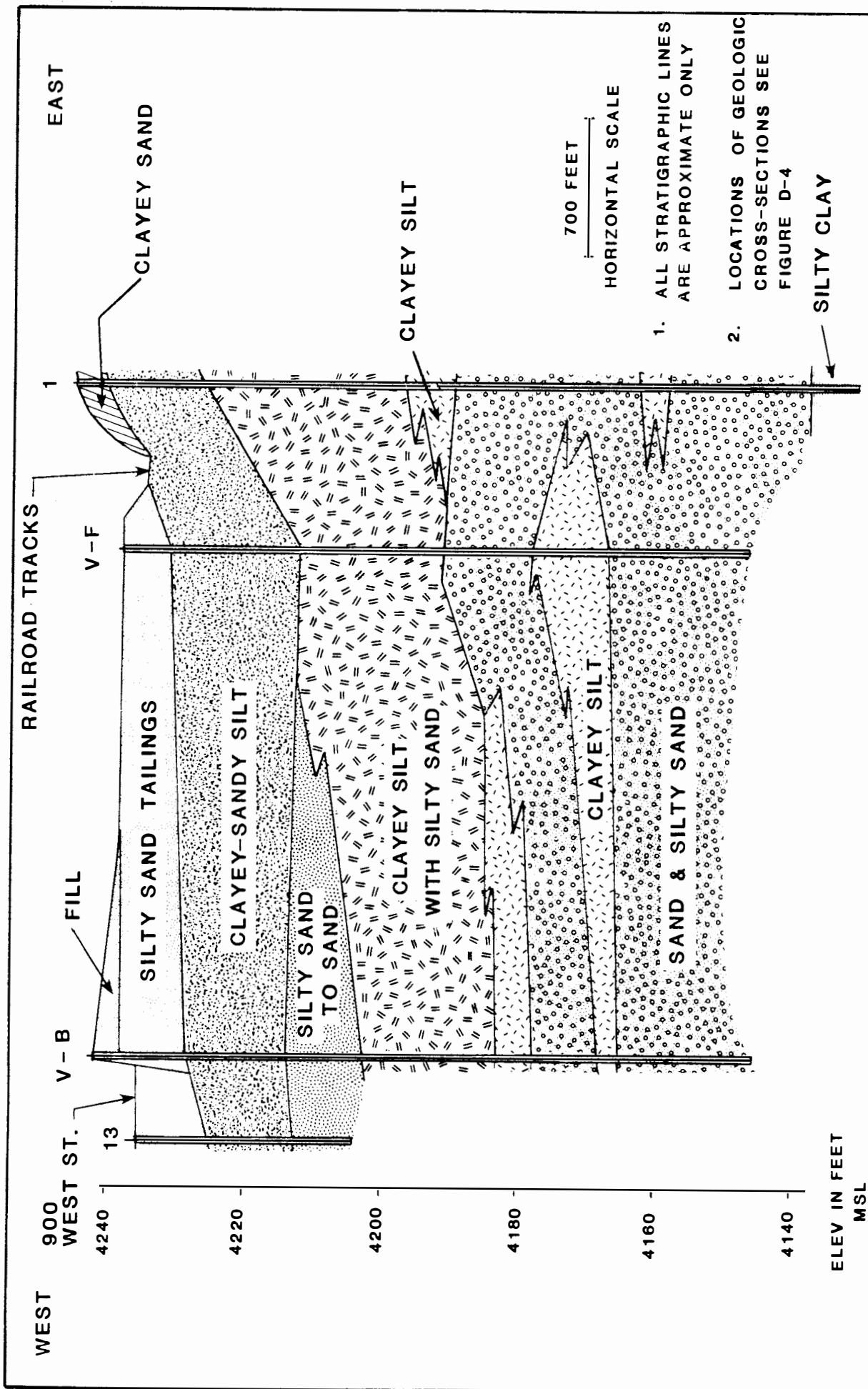


FIGURE D-7
GENERALIZED STRATIGRAPHIC CROSS-SECTION ALONG
SOUTH SIDE OF THE TAILINGS PILE, SOUTH SALT LAKE SITE

D.3.2 Description of existing ground-water chemistry

D.3.2.1 Field sampling of ground water.

Water from the shallow and artesian wells was obtained with a small diameter electric peristaltic pump. The samples were filtered through an in-line system having disposable 0.45 micron filter membranes. The water was then placed in several containers, preserved as per specifications provided by the testing laboratories (Bendix Field Engineering Corporation, Grand Junction, Colorado; and AnaCor Laboratories, Albuquerque, New Mexico) and placed in shipping containers with ice. Field testing of the samples included: alkalinity, pH, Ec (specific conductance), and temperature. Sufficient water was withdrawn from each well until the Ec and temperature values were stable.

D.3.2.2 Field test results.

Field determined Ec values ($\mu\text{mhos per cm}$) reflect the general water quality with regard to dissolved solids. The field Ec values for upgradient wells in the unconfined aquifer generally ranged from about 1000 to 4000 $\mu\text{mhos/cm}$ with one anomalously high value of about 12,500 $\mu\text{mhos/cm}$ at the 10-foot depth in well No. 6, located southeast and upgradient of the pile (Table D-5). Ec values for the shallow wells downgradient were consistently about 11,000 to 13,000 $\mu\text{mhos/cm}$. This increase in Ec values reflects an increase in dissolved solids downgradient (west and northwest) of the tailings pile as compared to the shallow wells upgradient.

The field alkalinity values, a measure of dissolved carbonates and bicarbonates, are lower upgradient than downgradient from the pile boundary. Upgradient alkalinity values range from 400 to 580 mg/l. Downgradient alkalinity values range from 680 to 1400 mg/l.

Field Ec values for the artesian wells were typically about 350 upgradient and 2,000 $\mu\text{mhos/cm}$ downgradient of the pile and the alkalinity values were about 300 mg/l both upgradient and downgradient of the site (Table D-5). These conditions indicate a much lower level of dissolved solids as compared to the overlying unconfined aquifer water and an increase downgradient in the confined aquifer.

D.3.2.3 Laboratory testing and unconfined aquifer results.

Water samples were tested for several chemical constituents including major cations, anions, trace metals, total dissolved solids, Th-230, Pb-210, U, V, gross alpha, and gross beta. The results of the chemical analyses are shown in Tables D-4, D-5, D-6.

Standardized procedures were used for each of the steps in the water-quality sample program as detailed in Section D.3.1.1.

For this Appendix, the discussion of ground-water quality and contaminant migration is divided according to location with respect to the tailings, and according to the type of contaminant. Separate discussions are provided for the water quality upgradient, downgradient, and beneath the tailings. Contaminants are discussed according to classification as major constituents

(predominantly SO₄ and TDS), minor constituents (As, Cd, Se, Cr, Mo), or radionuclides (U, Ra-226, Th-230, Pb-210).

Background water quality. The background water quality was established from wells upgradient and cross gradient to the site. The shallow wells revealed the following typical background values for the parameters listed above (not including well No. 6C at 10-foot depth). To further screen the upgradient samples to better represent unconfined, background water quality, only those wells with TDS between 1000 and 2000 mg/l are considered (Table D-7).

Table D-7. Summary of background data - unconfined aquifer

Constituent	Measured concentrations (upgradient and cross- gradient wells) (mg/l)	Background measured concentration (wells 7A, 6A, and 12C) (mg/l)
As	<0.05 to 0.245	0.02 to 0.12
Mo	<0.01 to 0.02	<0.01 to 0.02
U	0.003 to 0.022	<0.003 to 0.017
Ra-226	<1.0 to 1.2 pCi/l	<1.0 to 3.2 pCi/l
Gross a	<80 to 200 pCi/l	<20 to <80 pCi/l
Cl	13.9 to 1200	78 to 320
SO ₄	<5 to 2000	21 to 410
TDS	310 to 4250	810 to 1654
Cd	<0.01 to 0.01	<0.01
Fe	0.02 to 14.0	0.02 to 0.04
Se	<0.01	<0.01
V	<0.01	<0.01
Th-230	<1.0 pCi/l	<1.0 pCi/l
Pb-210	<1.5 pCi/l	<1.5 pCi/l

As noted earlier, the 10-foot-deep sample from well No. 6 is anomalously high as compared to the other background sample concentrations and previous work by Hely, Mower, and Harr (1971). The source of the very high TDS and certain anions and cations in this upgradient well is not certain, but is not considered to be associated with the tailings.

On-site water quality. The water quality below the pile is characterized by high concentrations of chlorides, iron, sulfates, TDS, molybdenum, uranium, Ra-226, Th-230, and other major constituents (see Table D-8 for classification of constituents). The concentration of arsenic remains within the background range, and vanadium is not found in elevated levels. Water quality under the site is summarized in Table D-9.

Downgradient water quality. The water-quality of the unconfined aquifer downgradient (northwest to west) of the pile is characterized by elevated levels of sulfates, chlorides, iron, TDS, and total uranium as compared to the background water-quality data. Radium, arsenic, vanadium and thorium are not found in concentrations above background levels, except one analysis for well

Table D-8. Classification of dissolved solids, based on abundance in potable water^a

<u>Major Constituents</u>	
Sodium	Bicarbonate
Calcium	Sulfate
Magnesium	Chloride
Silica	
<u>Secondary Constituents</u>	
Iron	Carbonate
Strontium	Nitrate
Potassium	Fluoride
Boron	
<u>Minor Constituents</u>	
Aluminum	Manganese
Arsenic	Molybdenum
Barium	Nickel
Cadmium	Selenium
Chromium	Uranium
Copper	Vanadium
Lead	Zinc
<u>Trace Constituents</u>	
Mercury	Thorium
Radium	Silver

^aAfter Davis and DeWiest (1965)

Table D-9. Summary of on-site data, unconfined aquifer

Parameter (dissolved)	Measured concentrations
As	<0.01 to 0.19 mg/l
Cd	<0.01 to 0.003 mg/l
Cl	13.9 to 2686 mg/l
Fe	<0.05 to 54.0 mg/l
Mo	<0.1 to 0.2 mg/l
Se	<0.01 mg/l
SO ₄	23.0 to 6008 mg/l
TDS	544 to 10,592 mg/l
U	0.004 to 0.61 mg/l
V	<0.5 mg/l
Ra-226	1.0 $\pm$ 0.2 to 114 $\pm$ 2.1 pCi/l
Th-230	0.0 $\pm$ 0.5 to 28.9 $\pm$ 2.5 pCi/l
Pb-210	0.9 $\pm$ 1.3 to 161 $\pm$ 4.5 pCi/l
Gross alpha	0.0 $\pm$ 39.7 to 1181 $\pm$ 167 pCi/l

No. 13C with a vanadium concentration of 0.04 mg/l and an arsenic concentration of 0.5 mg/l.

The downgradient water quality in the unconfined aquifer is summarized in Table D-10.

Table D-10. Summary of downgradient data, unconfined aquifer

Parameter (dissolved)	Measured concentrations
As	0.05 to 0.525 ^a mg/l
Cd	0.005 to <0.01 mg/l
Cl	590 to 4,200 mg/l
Fe	0.012 to 33 mg/l
Mo	0.01 to 0.045 mg/l
Se	0.01 mg/l
SO ₄	250 to 7,000 mg/l
TDS	2,300 to 21,000 mg/l
U	0.02 to 4.05 mg/l
V	0.01 to 0.04 mg/l
Ra-226	1.0 to 1.4 pCi/l
Th-230	1.0 pCi/l
Pb-210	1.5 pCi/l
Gross alpha	200 to <400 pCi/l

^aAnomalously high concentration from Well No. 13C

Well No. 13 is located southwest of the Vitro site. Water-quality from this well was included in the above table because it is located west of the pile area. However, the ground-water flow direction in the southwest corner of the pile is generally toward the northwest and thus the ground-water quality at well No. 13 was probably not measurably influenced by the pile. This is reflected in the water-quality data for well No. 13, which are very similar to the background quality summarized in Table D-10.

Summary of results. As shown above, the major influence of the tailings pile on the unconfined aquifer west of the site has been the past contribution of measurable amounts of TDS, chloride, sulfate, iron, and uranium. The background water quality of the unconfined aquifer is characteristically brackish with high levels of TDS, chloride, sulfate, and other nonradioactive constituents that make the water from this system nonpotable. Because the water of this aquifer throughout much of the Jordan River Valley is unsuitable for potable use without extensive treatment, the impacts of very limited quantities of additional dissolved solids and uranium after remedial action, immediately downgradient of the pile, are expected to be minimal.

D.3.2.4 Laboratory testing and confined aquifer results.

The water quality of the confined system contains elevated levels of chloride, sulfate and iron downgradient and beneath the tailings pile as compared to the upgradient, background samples (Table D-8).

The following is representative of typical water-quality data for wells penetrating the artesian aquifer upgradient, downgradient, and beneath the tailings pile.

Table D-11. Summary of confined aquifer data

Parameter (dissolved)	Upgradient (well No. 1)	Downgradient (well No. 5)	Beneath pile (well CD)
As	0.03 mg/l	0.0015 mg/l	<0.01 mg/l
Cd	0.01 mg/l	<0.001 mg/l	<0.01 mg/l
Cl	10 mg/l	85 mg/l	220 mg/l
Fe	0.21 mg/l	0.62 mg/l	0.22 mg/l
Mo	0.01 mg/l	<0.01 mg/l	<0.01 mg/l
Se	0.01 mg/l	<0.01 mg/l	<0.01 mg/l
SO ₄	10 mg/l	110 mg/l	230 mg/l
TDS	330 mg/l	580 mg/l	864 mg/l
U	0.01 mg/l	<0.003 mg/l	<0.003 mg/l
V	0.06 mg/l	0.01 mg/l	0.01 mg/l
Ra-226	1.0 pCi/l	<1.0 pCi/l	<1.0 pCi/l
Th-230	1.0 pCi/l	<1.0 pCi/l	<1.0 pCi/l
Pb-210	1.5 pCi/l	3.0 pCi/l	1.5 pCi/l
Gross alpha	30 pCi/l	<45 pCi/l	20 pCi/l
Ec (field)	385 μ mhos/cm	700 μ mhos/cm	1080 μ mhos/cm

The three wells listed above were sampled as part of the TAC (1983) study. Complete data summaries are shown in Tables D-4, D-5, D-6.

D.3.2.5 Confined aquifer hydrodynamics and ground-water quality impacts.

The relatively good water quality of the artesian (confined) aquifer is maintained by the upward gradient of the aquifer which prevents downward migration of the brackish unconfined aquifer water. Current utilization (pumping) of the confined aquifer in the Salt Lake City area has not significantly reduced the areal extent of the flowing artesian conditions which are present in the valley or the head levels of the aquifer as compared to levels measured in the early 1900's (Hintze and Miller, 1975). Thus, this upward gradient has been and is currently maintained in the Salt Lake area. Much heavier utilization of the artesian aquifer would reduce the head levels and possibly reverse the upward gradient. This condition would then cause downward flow of the brackish unconfined aquifer waters. The presence of the several feet of confining clay and silt layers would retard flow to very low velocities if the vertical gradient were reversed; however, the downward driving force would be present.

The location and volume of pumpage necessary to reverse the upward gradient near the Vitro site can be estimated by examining present pumpage of the artesian aquifer. Available data from the U.S. Geological Survey (1983) indicate that pumpage within two miles of the Vitro site averaged 462 gallons per minute in 1982 (Table D-12). Data of the TAC (1983) and the DOE (1983) indicate that an upward gradient is present and has been maintained in recent years. These data indicate that heavy pumpage in close proximity, probably less than 1/2 mile radial distance, of the Vitro site would be necessary to locally reverse the upward gradient.

Table D-12. Major pumpage of the artesian aquifer in the vicinity of the Vitro site

Well Number ^a	Owner	Approx. distance from site (In feet)
(C-1-1)25caa	Public supply well	1600-2400
(C-1-1)25abc	Public supply well	2400-3300
(C-1-1)35add	Salt Lake County Water Conservation Dis.	5700-6400
(C-1-1)35dab	City of South Salt Lake	3700-4400
(C-1-1)35ddc	City of South Salt Lake	5700-6400

Well Number							
Annual Pumpage in acre- feet/yr (gpm)	<u>25caa</u>	<u>25abc</u>	<u>35cdd</u>	<u>35dab</u>	<u>35ddc</u>	<u>Total</u>	<u>Year</u>
						325(201)	1970
			56(35)	985(611)		1366(847)	1971
			83(51)	1135(704)		1543(957)	1972
			73(45)	1057(655)		1455(902)	1973
	320(198)		48(30)	785(487)		1478(916)	1974
	678(420)		0	1026(636)		2029(1258)	1975
	527(327)		2.3(1.4)	1233(764)		2087(1294)	1976
	280(174)		53(33)	905(561)		1563(969)	1977
	272(169)		0	985(611)		1582(981)	1978
	52(32)		0	1329(824)		138(856)	1979
	77(48)		0	1454(901)		1531(949)	1980
	41(25)		0	821(509)		862(534)	1981
	178(110)			568(352)		746(462)	1982

^aWells numbered according to location as explained in Hely, Mower, and Harr (1971)

The migration of the unconfined aquifer water to the lower confined aquifer would increase the total dissolved solids levels in localized and downgradient portions of the confined aquifer. This condition would degrade the artesian water and it could eventually make the artesian water nonpotable. This scenario should restrict the long-term, heavy utilization of the confined aquifer, irrespective of the contamination noted in the upper aquifer system associated with the tailings pile.

The evidence of elevated iron, chlorides, and sulfates in the confined aquifer beneath and downgradient of the pile may reflect past utilization of the confined aquifer. Past heavy pumping of this aquifer at one or more locations near or upgradient of the tailings pile and mill site may have lowered the head levels of the artesian system and allowed downgradient migration of unconfined ground water.

Based on recent pump test results (TAC, 1983), the influence of this industrial pumping probably extended several hundreds of feet from the production wells. The vertical gradient was reversed most noticeably at the production wells, providing a driving mechanism for movement of mobile constituents such as sulfates and chlorides. These constituents are present in high levels in the unconfined aquifer both in background water samples and in the vicinity of the pile. Water-quality of samples collected during the pump test (TAC, 1983) of the confined aquifer revealed increased levels of iron, sulfates, chlorides, and TDS when compared to an artesian water sample taken at a nearby well prior to the pump test (Table D-5, wells No. 15 and 5).

In summary, data indicate that contamination from the brackish unconfined aquifer will occur if the underlying confined system is depressurized by sustained pumping at volumes large enough to depress the head levels below the head levels of the unconfined ground-water system. It should be noted that no significant evidence of levels above background for heavy metals and radionuclides were found in the confined aquifer beneath or downgradient of the tailings pile. These constituents are less mobile than the sulfates and chlorides and probably were adsorbed or precipitated in the clay and silt layers of the unconfined aquifer and aquitard.

D.3.3 Geohydrologic data analysis

D.3.3.1 Hydrodynamic data collection.

Subsurface explorations, monitoring well installation, hydrologic investigations involving pump testing of both aquifers, water-level monitoring, and sampling for water-quality analyses have been carried out by various investigators at and near the Vitro site and in the Jordan River Valley area. These investigators include Hely, Mower, and Harr (1971), Markos and Bush (1982), Dames and Moore (1982), and the TAC (1983). Details of these programs are presented in Section D.3.1.1. The well locations are shown in Figure D-4. The pump tests were all constant discharge, wherein declines in water level are measured periodically at various observation wells. Slug tests were performed by instantaneous removal of a slug of water from a well, followed by the measurement of the recovery of the water level in the well. Results of hydrodynamic testing are discussed below.

D.3.3.2 Hydrodynamic data analysis and results.

Pump Test Unconfined Aquifer. The pump test on shallow well V-CS1 was run for about 4.5 hours at a pumping rate of about 11 gpm (Dames and Moore, 1982). The total drawdowns at the observation wells were slight:

- 0.58 feet at the pumped well.
- 0.20 feet at observation well V-CS2 which is 9.6 feet from the pumped well.
- 0.14 feet at observation well V-CS3 which is 20.0 feet from the pumped well.

The drawdown and recovery data at well V-CS2 were analyzed to supply values of transmissivity and storativity of the unconfined aquifer and saturated tailings material at the site. Using the Theis' Recovery method (Davis and DeWiest, 1965), a value of transmissivity = $6684 \text{ ft}^2/\text{day}$ was calculated. Using the Jacob's method (Davis and DeWiest, 1965) on the drawdown data yielded a value of transmissivity = $7455 \text{ ft}^2/\text{day}$. Using the Jacob's method with a transmissivity value of $7059 \text{ ft}^2/\text{day}$ (the geometric mean of the results for the drawdown and recovery data) yielded a value of storativity = 0.026. No corrections of drawdowns for water table conditions were needed because the total drawdown was much less than the saturated thickness of the aquifer. A check on the value of (u), the well function, showed that the Jacob's method was valid at times greater than 10 minutes. These results may be inaccurate due to the low pumping rate, approximately 11 gpm, and short duration of the test, about 270 minutes, resulting in relatively slight total drawdowns.

The on-site slug test data were analyzed with 3 methods; the Hvorslev, the Cooper, Bredehoeft and Papadopulos, and the Ferris and Knowles (Table D-13). The calculated values of hydraulic conductivity range from 0.0 to $6.4 \times 10^{-3} \text{ cm/sec}$. Assuming a saturated thickness of 38 feet, the transmissivity value of $7059 \text{ ft}^2/\text{day}$ from the pump test analysis indicates a hydraulic conductivity of $6.5 \times 10^{-2} \text{ cm/sec}$.

Table D-13. Results of on-site slug tests (cm/sec.)

Well	Hydraulic conductivity ^a method 1	Hydraulic conductivity ^b method 2	Hydraulic conductivity ^c method 3
V-BS	4.0×10^{-4}	1.8×10^{-3}	1.9×10^{-4}
V-BS	3.5×10^{-4}	1.3×10^{-3}	1.0×10^{-4}
V-BD	1.6×10^{-3}	6.4×10^{-3}	7.0×10^{-5}
V-BD	1.2×10^{-3}	4.8×10^{-3}	1.6×10^{-3}
V-DS	0.	0.	1.3×10^{-3}
V-DS	0.	0.	1.3×10^{-3}
V-DS	0.	0.	1.4×10^{-3}
V-ES	8.8×10^{-5}	1.2×10^{-4}	2.3×10^{-5}
V-ED	5.4×10^{-5}	7.7×10^{-5}	2.6×10^{-5}
V-FS	3.3×10^{-5}	3.5×10^{-5}	9.3×10^{-6}
V-GS	2.6×10^{-5}	2.4×10^{-5}	1.1×10^{-5}
V-HS	1.6×10^{-5}	5.2×10^{-5}	8.4×10^{-6}

^aMethod 1 is Hvorslev (1951).

^bMethod 2 is Cooper, Bredehoeft, and Papadopulos (1967).

^cMethod 3 is Ferris and Knowles (1963).

The pump test on shallow, off-site well No. 14 was run for about 24 hours at a pumping rate of about 11 gpm. No drawdown was recorded at any of the observation wells (TAC, 1983). The lack of drawdown was probably caused by recharge from surface flooding (May, 1983) of the area and the relatively low pumping rate. A total drawdown of about 15.98 feet was recorded at the pump well. Pump well recovery data were analyzed to obtain values of transmissivity and hydraulic conductivity. Actual residual drawdowns were corrected for dewatering. The calculated value of transmissivity from this analysis was 768 ft²/day. Assuming a saturated thickness of 38 feet, the saturated thickness above the bottom of the well screen, the hydraulic conductivity is 20.1 ft/day or 7.1×10^{-3} cm/sec.

The United States Geological Survey published values of transmissivity and specific yields for the shallow aquifer, estimated from lithologic logs (Hely et al., 1971). The transmissivity values range from 1300 to 4000 ft²/day. At the area around the Vitro site, transmissivity is estimated as 2700 ft²/day. The specific yield of the unconfined aquifer ranges from 0.10 to 0.20.

Pump test - confined aquifer. The pump test on deep, off-site well No. 15 was run for about 91 hours at a pump rate of approximately 300 gpm. Water levels were measured at the pump well, 6 other deep wells, 24 shallow wells, and 2 intermediate wells during the pump test and recovery period (TAC, 1983). Table D-14 lists the completion intervals, radial distances from the pump well, drawdowns at the time the well was shut down and the land surface elevation for all 33 observation wells.

In the analysis of drawdown data, no corrections were needed for barometric response of the aquifer, aquifer recharge-discharge trends, aquifer boundaries, and off-site water use. During the pump test, barometric pressure varied from a low of 30.00 inches of mercury at 4:00 a.m. on May 21 to high of 30.14 inches of mercury at 6:00 p.m. on May 20, 1983. At the beginning of the test, 2:30 p.m. on May 19, the barometric pressure was 30.08 inches of mercury and at the end of the pumping period, 9:45 a.m. on May 23, the barometric pressure was 30.07 inches of mercury. These values were abstracted from a barometric chart recording station at the United States Geological Survey's office at 1700 South, 1745 West in Salt Lake City.

The maximum change in barometric pressure was 0.14 inches of mercury which converts to 0.16 feet of water. The change from the beginning to the end of the pump test was 0.01 inches of mercury or 0.01 feet of water. Assuming an aquifer barometric efficiency of 100 percent, these values would represent the change in measured water level due to the change in atmospheric pressure. These small corrections were considered insignificant in the analyses of drawdown data. Static water levels were measured for up to one and a half months at the deep wells prior to the pump test. The maximum change through this period was +0.3 feet at well No. 3 from May 6 to May 19, 1983. Due to this minimal rise, corrections of drawdown data for aquifer recharge-discharge trends, aquifer boundaries, and off-site water use were not needed.

Table D-14. Results of pump test on deep well #15
South Salt Lake site

Well identification	Depth of completion interval (ft.)	Radial distance from well #15 (ft.)	Drawdown at well shutdown (ft.)	Land surface elevation (ft. msl)
CD	105.0-115.0	550	3.40	--
1	99.8-109.8	4440	1.04	4245.0
2	119.0-129.0	3420	1.87	4238.1
3	110.2-120.2	2000	2.15	4234.1
4	105.1-115.1	500	4.08	4234.4
5	115.5-125.5	100	3.42	4234.9
6A	26.4-28.4	4510	0.26	4244.6
6B	16.7-18.7	4510	0.70	4244.7
6C	6.7-8.7	4510	0.84	4244.7
7A	26.2-28.2	3420	-0.01	4238.0
7B	15.3-17.3	3420	0.17	4238.0
7C	7.6-9.6	3420	0.17	4238.0
8A	26.4-28.4	2220	-0.07	4233.1
8B	18.7-20.7	2220	-0.05	4233.0
8C	6.8-8.1	2220	Dry	4233.1
9A	216.9-28.9	70	0.12	4233.2
9B	15.7-17.7	70	0.18	4233.0
9C	5.8-7.8	70	0.19	4233.0
10A	26.1-28.1	870	0.08	4234.6
10B	14.5-16.5	870	0.03	4234.7
10C	6.3-8.3	870	0.08	4234.6
11A	24.3-26.3	150	0.27	4234.5
11B	16.8-18.8	150	0.27	4234.6
11C	6.1-8.1	150	0.26	4234.8
12A	26.4-28.4	2200	-0.05	4235.9
12B	16.7-18.7	2200	-0.25	4236.1
12C	6.5-8.5	2200	1.31	4236.0
13A	25.7-27.7	1220	0.39	4235.7
13B	16.2-18.2	1220	0.34	4235.8
13C	6.2-8.2	1220	0.01	4235.7
15	102.1-112.1	0	58.69	4233.7
16	65.7-67.7	20	0.51	4234.5
17	53.6-55.6	20	-1.04	4233.4

Qualitative information can be gained from the response of various wells to the pump test. Most of the shallow wells (wells Nos. 6A to 13C) show drawdown through the pumping period, but 6 shallow wells show a recovery (negative values on Table D-14). Generally, the A series shallow wells show less drawdown than the B series and the B series wells show less drawdown than the C series. Because the A wells are the deepest and the C wells are the shallowest, it would normally be expected that the deeper A wells would show more drawdown. It is difficult to determine if the non-normal shallow well response is due only to the pumping of well No. 15 or if the response is due to the combination of the pumping and some other unknown local stress or stresses attributable to environmental influences (Todd, 1980).

Well No. 17 is screened at a depth of about 54 to 56 feet, in the top of a clayey silt layer. This silt layer appears to be approximately 15 feet thick with sand partings. Well No. 16 is screened at a depth of about 66 to 68 feet near the base of the clayey silt layer. Because the hydraulic head differential across this layer is approximately 8 feet, this layer is believed to be the confining layer separating the unconfined and confined systems.

The hydraulic heads at wells No. 16 and No. 17 responded oppositely to the pumping of well No. 15. Well No. 17 showed a rise of 1.04 feet during the 91-hour pump test. This response was probably due to compaction of the underlying confining layer and aquifer. The hydraulic head at well No. 16 rose about 0.10 feet at the onset of the test, but eventually dropped 0.51 feet. The data from wells No. 16 and 17 were somewhat compromised because the sand filter packs extended from the screened intervals in the clayey silt layer into the overlying sand layer. Nonetheless, the hydraulic head measured in well No. 16 is substantially greater than that measured in well No. 17. Therefore, it is concluded that the changes of water level at well No. 16 represent the response of the confining layer. This response was used to calculate a value of vertical hydraulic conductivity of the aquitard.

All the deep observation wells showed definite drawdown in response to the pump test. The heterogeneity and layering of the materials composing the confined aquifer system are exhibited by the various responses of the deep wells. For instance, the final drawdown at well No. 5 was 3.42 feet, while the final drawdown at well No. 4 was 4.08 feet, even though well No. 5 is 100 feet from the pump well, while well No. 4 is 500 feet from the pump well. Both wells are located west of the pump well. Well No. 4 is completed at approximately the same depth as the pump well, while well No. 5 is 10 feet deeper. The response at well No. 2 also exhibits the effects of heterogeneity or layering. The logarithmic plot of drawdown versus time used to analyze the test results (Lohman, 1972) shows an abrupt increase in the rate of drawdown about 200 minutes into the pump test. Well No. 2 is completed about 12 feet deeper than well No. 15.

Values of transmissivity and storativity of the confined aquifer and values of vertical hydraulic conductivity for the overlying aquitard were calculated from the response to pumping at deep observation wells Nos. 1 through 5 and CD using the Hantush Modified method (Lohman, 1972). Also, values of vertical hydraulic conductivity through the confining layer were calculated using the "Ratio Method" (Neuman and Witherspoon, 1972). The values of vertical hydraulic conductivity were obtained by assuming a specific storage for the confining layer of 0.0125 ft^{-1} . Without assuming a specific storage, the "Ratio Method" and the geometric mean values from the Hantush Modified method were solved simultaneously. The results were a specific storage of $6.6 \times 10^{-4} \text{ ft}^{-1}$ and vertical hydraulic conductivity of $3.1 \times 10^{-3} \text{ ft/day}$. Table D-15 lists these calculated values and values for the same parameters that were published by the United States Geological Survey (Hely et al., 1971). The field data, assumptions, and calculations that were summarized in this section are available at the UMTRA Project Office in Albuquerque, New Mexico.

D.3.4 Description of Illinois State Water Survey model modifications and additions

The Illinois State Water Survey finite difference hydrodynamic model (Prickett and Lonquist, 1971) has a wide range of applications and has been pre-qualified for use on low-level waste disposal sites by the United States Nuclear Regulatory Commission. The code solves the partial differential equation governing the transient, two-dimensional flow of ground water in a confined, heterogeneous aquifer with axidirectional anisotropy. This equation is

$$\partial/\partial x [T(x) \partial h/\partial x] + \partial/\partial y [T(y) \partial h/\partial y] = S \partial h/\partial t + Q, \text{ where}$$

$T(x)$ = transmissivity in x direction (L^2/T)

$T(y)$ = transmissivity in y direction (L^2/T)

h = hydraulic head (L)

t = time (T)

S = storage coefficient

Q = net ground-water withdrawal rate per unit area (L/T)

x, y = rectangular coordinates. The code has been augmented and can also simulate:

- Unconfined conditions
- Conversion from unconfined to confined conditions
- Conversion from confined to unconfined conditions
- Leaky confined conditions
- Induced infiltration from a stream or pond
- Ground-water evapotranspiration
- Variable pumping rates

The code is applicable to the simulations of two-dimesional, heterogeneous, isotropic, steady-state ground-water flow as applied to the Vitro site and surrounding area.

Table D-15. Values calculated from pump test results on deep well #15 west of South Salt Lake site

Observation well identification	Method used	Transmissivity (ft ² /day)	Storativity	Vertical hydraulic conductivity (ft/day)
1	Modified Hantush	867	2.7×10^{-6}	1.5×10^{-5}
2	Modified Hantush	1482	4.8×10^{-5}	1.7×10^{-5}
3	Modified Hantush	2298	1.8×10^{-4}	6.5×10^{-5}
4	Modified Hantush	7660	3.8×10^{-4}	1.5×10^{-6}
5	Modified Hantush	3535	2.4×10^{-4}	0.98
CD	Modified Hantush	4596	1.6×10^{-4}	7.8×10^{-4}
16	Ratio	----	-----	5.8×10^{-2}
All Above Wells	Ratio and Modified Hantush	----	-----	3.1×10^{-3}
Geometric Mean	--	2676	8.4×10^{-5}	--
N/A	U.S.G.S Estimate	9000	1.0×10^{-4}	1.6×10^{-2} and 4.9×10^{-2}

For the Vitro site, the model is used to predict the past, present, and future hydrodynamics of the site and vicinity. To facilitate its use on this project, modifications and additions have been made to the code. These include:

- Renumbering of statement labels to make the program more readable.
- Increased flexibility for input and output procedures.
- Variably-spaced grid option.
- Redefinition of convergence criteria.
- Calculation of global mass balance and mass fluxes.
- Added statements to avoid infinite value errors.
- Slight reorganization to allow more efficient compilation.

The modifications to the input and output procedures have no effect on the numerical calculations of the code. The new input procedures allow for the reading of a complete data file of nodal parameters. The file contains a line for each node which includes the I and J coordinates (column and row designations) followed by the 13 hydraulic parameters. These parameters, in the order that they appear on each line, are:

1. T2 - Transmissivity in X direction, in L^2/T .
2. T1 - Transmissivity in Y direction (for isotropic case $T2 = T1$).
3. SF1--Artesian storage factor (storativity multiplied by the area represented by the node), in L^2 .
4. H--Initial estimate of hydraulic head at the node, in L.
5. Q--Constant rate of vertical recharge or withdrawal for the area represented by the node, in L^3/T ; for nodes along the boundary this may also represent constant lateral flux.
6. R--Vertical permeability factor between the modeled aquifer and a stream bed, vadose zone, or contiguous aquitard (the vertical hydraulic conductivity divided by the thickness of the stream bed, vadose zone, or contiguous aquitard multiplied by the area represented by the node), in L^3/T .
7. RH--Elevation of land or stream surface for problems involving seepage from a stream or evapotranspiration; or hydraulic head in adjacent aquifer for problems involving leakage through an aquitard, in L.
8. RD--Elevation of bottom of stream or water level below which evapotranspiration ceases, in L.
9. SF2--Water table storage factor (specific yield multiplied by the area represented by the node), in L^2 .
10. CH--Elevation of the top of the principle aquifer, in L.
11. P2--Hydraulic conductivity in the X direction, in L/T .
12. P1--Hydraulic conductivity in the Y direction, in L/T (for isotropic problems $P2=P1$).
13. BOT--Bottom of the principle aquifer, in L.

Data manipulation is made more efficient for a heterogeneous setting by allowing explicit reading of all parameter values in the data file. Computer codes to manipulate these data can be written and executed easily. The only modification to the output is creation of a data file with all the calculated hydraulic head values in a format that can be input to a contouring program, thus allowing computer-generated potentiometric surface and water-table maps. These modifications to the input and output capabilities of the code do not affect the calculations in any way.

The variably-spaced grid option was necessary for an accurate representation of the unconfined flow regime at the Vitro site without using an excessive number of nodes. A detailed discussion of the finite-difference grid representations is presented in section D.3.4.1. The subroutine for this option, VARGRID, was verified on a transient problem with a pumping well in the center of an area. Also, computer codes were developed to interpolate nodal parameters from a variable-spaced grid to an equally-spaced grid and vice-versa. These codes, the subroutine VARGRID, and the input and output for the test case are available at the UMTRA Project Office in Albuquerque, New Mexico.

The modification to the convergence criteria does not affect the calculations of the computer code. Originally, the absolute differences between calculated hydraulic head at each node were computed and summed at the midpoint and end of each iteration. The modification was made to calculate and sum only the absolute differences at the end of each iteration. It was found that in most cases with a large grid, heterogeneous material properties, and inclusion of vertical leakage, the error criterion would converge asymptotically to some value greater than zero. The choice of the value to set the convergence criteria is subjective and should ensure that an adequate number of iterations have been executed to reach a relatively smooth solution. The modified convergence criteria allowed convergence to a more consistent asymptote for a given problem than did the original convergence criteria. In addition to modifying the computation of the convergence criteria, a parameter to end the computations after a given number of iterations was added to limit computer time and costs while executing a nonconvergent or slowly converging problem.

For each hydrodynamic situation simulated, a subroutine was added to calculate global mass balance and each flux into or out of the principle aquifer. These subroutines were added to ensure mass balance and to assess the relative significance of the various sources of inflow and outflow to the aquifer being modeled. These subroutines are discussed in detail in section D.3.4.1. Annotated versions of these subroutines and all modifications to the original code are available at the UMTRA Project office in Albuquerque, New Mexico.

D.3.4.1 Calibration of the hydrodynamic model

The Illinois State Water Survey hydrodynamic code was used to calibrate two steady-state hydrogeologic settings for the unconfined aquifer and one setting for the confined aquifer. For each setting, the model of the Vitro site and adjacent areas was calibrated in two ways. First, calculated hydraulic heads were compared to field measured water levels. A residual (measured head minus calculated head at a given point) of ± 4 feet was adequate because this represents the range of annual water-level fluctuations. Second, the mass balance of the system was calculated and calibrated, i.e., inflows balanced against outflows. The calibration techniques and results are discussed in detail for each of the three calibrated cases.

Calibration of unconfined aquifer--present case. Recent water level measurements in the unconfined aquifer on and adjacent to the Vitro site reveal that:

- The present water table is below Mill Creek, Vitro Ditch, and South Vitro Ditch. These surface water courses are presently recharging the ground water.
- Shallow ground water flows radially toward the CVWRF excavation.

Prior to dewatering of the CVWRF excavation, shallow ground water discharged into Mill Creek, Vitro Ditch, and South Vitro Ditch. They were surface expressions of the water table. These shallow ground-water flows were toward the Jordan River and Mill Creek (Figure D-8).

To enhance calibration of the unconfined aquifer system, a subroutine to the Illinois State Water Survey code was written to calculate the various fluxes of water into and out of the area being modeled. This subroutine allowed calculation of the global mass balance. The fluxes calculated include:

- Infiltration from the surface.
- Upward leakage from the underlying artesian aquifer.
- Vertical seepage from Mill Creek, Vitro Ditch, and South Vitro Ditch.
- Lateral flow to or from the Jordan River.
- Lateral flow to the CVWRF excavation.
- Lateral flow into and out of the area being modeled.

Infiltration and upward leakage were summed and modeled as a constant rate across the entire modeled area. The constant recharge parameter, Q , for each node not along the boundary of the grid was assigned a value representing the sum of infiltration and upward vertical leakage in terms of ft^3/day . This was implemented by assigning an identical flux to each internal node, in terms of ft/day and allowing the subroutine VARGRID to multiply the flux by

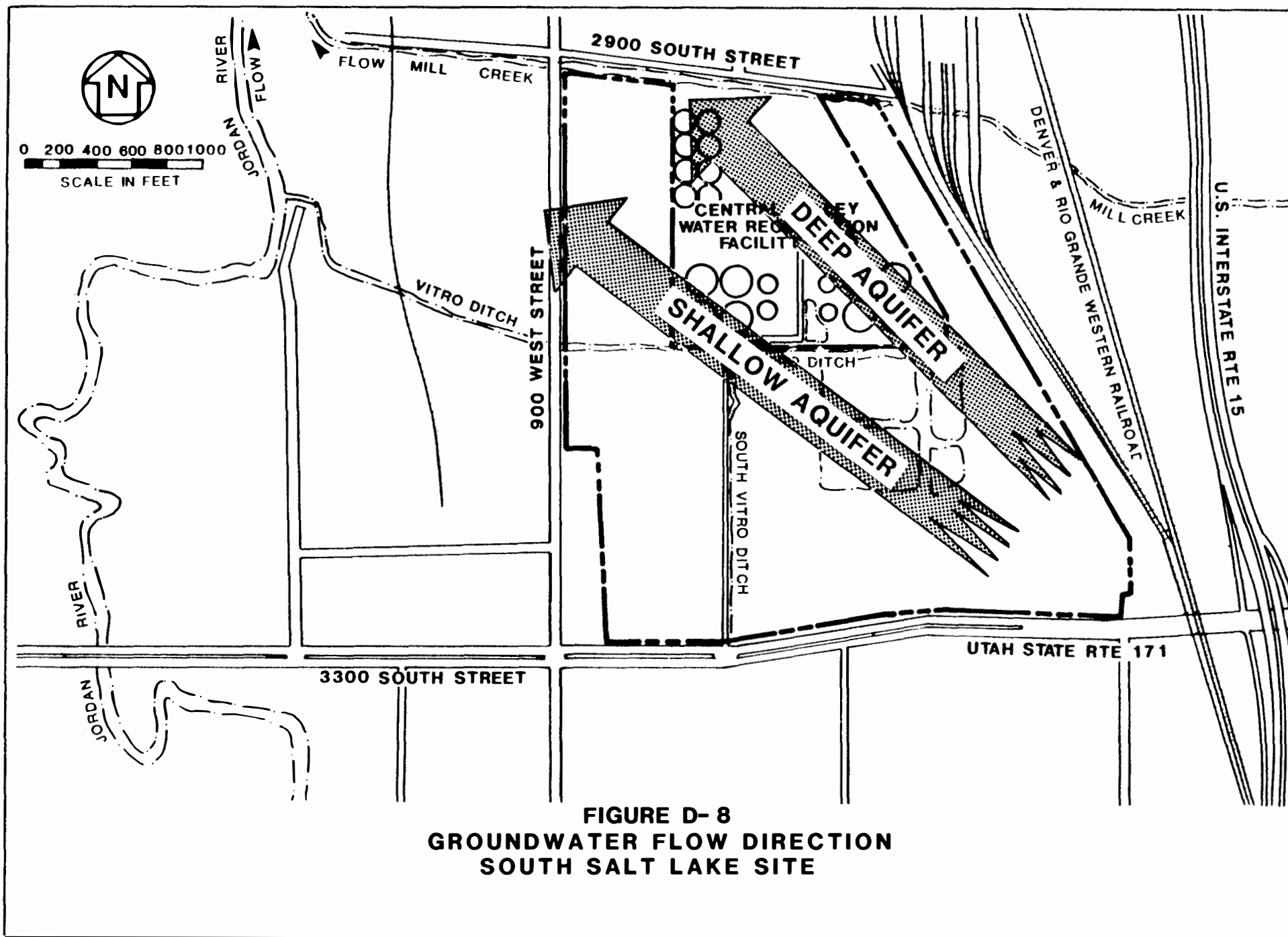


**FIGURE D-8
GROUNDWATER FLOW DIRECTION
SOUTH SALT LAKE SITE**

the area represented by the node. The value of flux from infiltration was 2.4 in/year (5.5×10^{-4} ft/day) (from Hely et al., 1971). Upward, vertical leakage was adjusted and a value of 2.25 in/yr (5.1×10^{-4} ft/day) provided the best calibration.

Seepage from Mill Creek and the Vitro Ditches was modeled with the use of the R, RH and RD nodal parameters (see Prickett and Lonquist, 1971). The R values represent the vertical hydraulic conductivity of the material between the surface water body and the water table multiplied by the width of the stream channel multiplied by the length represented by the node in the direction of the stream. For Mill Creek, the width of the stream channel was estimated as 15 feet and the calibrated hydraulic conductivity was 1.5 ft/day. For the Vitro Ditches, the width of the stream channel was estimated as 10 feet and the calibrated hydraulic conductivity was 0.8 ft/day. The values of RD, (the bottom elevation of the streams) were derived from topographic maps and interpolated between assigned points. The values of RH, (the elevation of the stream surface) were assigned values of RD plus 2.0 ft. for Mill Creek and RD plus 1.5 ft. for the Vitro Ditches.

The flows to the Jordan River and to the CVWRF excavation were calculated with Darcy's Law. For each node representing the Jordan River or the boundary of the CVWRF excavation, the flow was approximated by (Figures D-9 and D-10):

$$Q = \frac{(h_n - h_o)}{r} K_{no}db \text{ where:}$$

Q = Volumetric flow rate (ft³/day).

h_n = Calculated hydraulic head at the node (n) adjacent to the river or excavation (ft).

h_o = Calculated hydraulic head at the node (o) representing the river or excavation boundary.

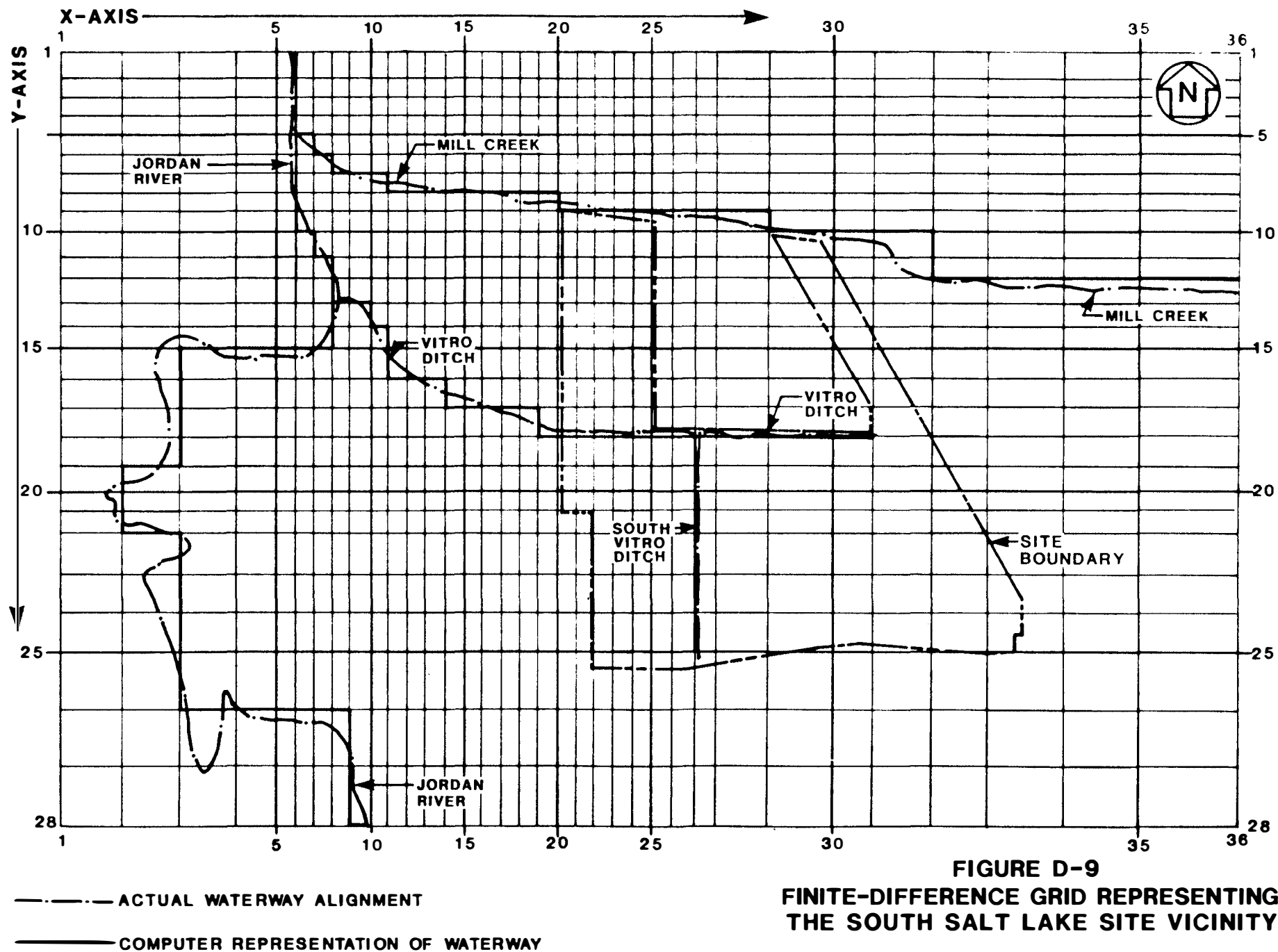
r = The distance between nodes N and O.

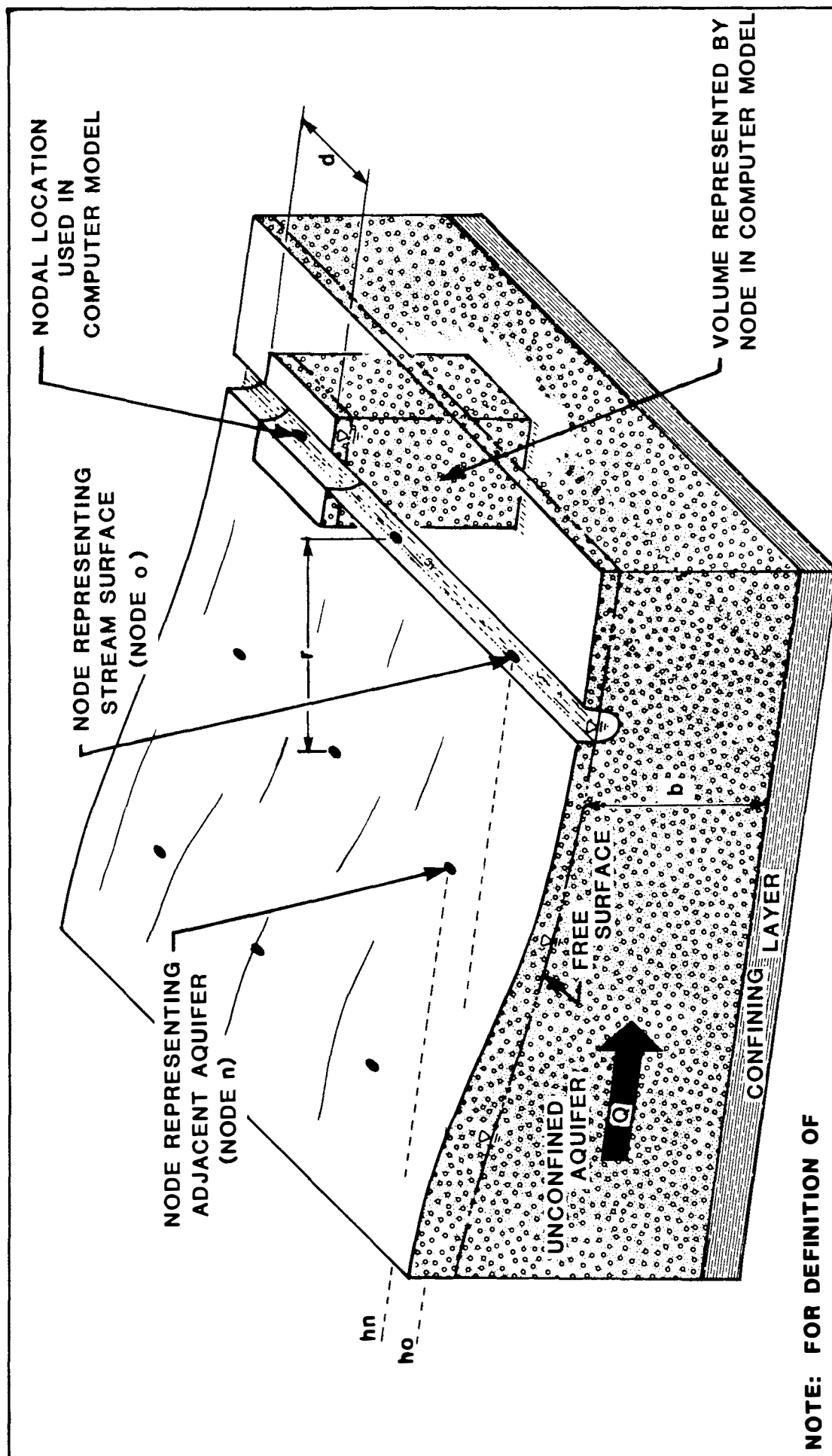
K_{no} = The value of hydraulic conductivity for flow between nodes N and O.

d = The width represented by nodes N and O.

b = The difference between average hydraulic heads and the average bottom of the aquifer at nodes N and O.

The computer code automatically sets the boundaries of the grid as impermeable. To model the boundaries as constant flux with a flux other than zero, the constant flux values are assigned in the recharge/withdrawal array, Q. The calibrated value of volumetric flux into the area being modeled was 52,062 ft³/day.





NOTE: FOR DEFINITION OF VARIABLES SEE TEXT.

FIGURE D-10
CROSS-SECTIONAL REPRESENTATION OF
CALCULATION OF FLUX TO STREAM
SOUTH SALT LAKE SITE

The unconfined aquifer at the Vitro site and adjacent area, present case, was modeled initially on a variably-spaced grid with 36 columns and 28 rows of nodes (Table D-16). The storage factors (SF2) for the nodes representing the Jordan River and the CVWRF excavation were set to 1×10^{200} . The extremely high values allowed these nodes to have a large enough storage capacity so that the hydraulic heads would remain constant. The storage factors at the other nodes were set to low values, on the order of 1×10^{-20} , to allow steady-state calculations. These low values caused the finite-difference analog of $S \frac{dh}{dt}$ to be inconsequential in the results of the iterative, finite-difference calculations.

Table D-16. Variable grid spacing (36 x 28 nodes)

Column designation ^a	Width (in feet)	Row designation ^b	Width (in feet)
1-3 ^c	390.6	1	182.3
4	260.4	2-9	130.2
5-26	130.2	10-13	162.8
27	162.8	14	130.2
28	312.5	15	221.4
29	481.8	16-18	195.3
30	260.4	19-21	156.3
31	377.6	22-24	260.4
32	390.6	25-27	390.6
33-34	520.8		
35	722.8		

^aColumn N is space between nodes (N-1,J) and (N,J).

^bRow M is space between nodes (I,M-1) and (I,M).

^cColumn designation 1-3 means columns 1 through 3.

Because the unconfined system was modeled as isotropic and heterogeneous, for each node, the hydraulic conductivity in the x direction was set equal to the hydraulic conductivity in the y direction but the values from node to node varied.

The most representative field determination of hydraulic conductivity for the unconfined aquifer was the pump test performed and analyzed by the TAC (see Section D.3.3.2). The value of hydraulic conductivity obtained from this test was 20.1 ft/day. The calibration was most successful by assigning hydraulic conductivities of 15 ft/day to nodes representing the Jordan River meander belt, 30 ft/day to 50 ft/day along Mill Creek, and 20 ft/day to 35 ft/day for all other nodes with lower values near the Jordan River increasing to higher values to the east. Although these values were chosen to enhance calibration, their spatial distribution is also consistent with the depositional history of the shallow alluvial materials. As the materials were deposited in the lacustrine environments of Lake Bonneville and the Great Salt

Lake, the heavier, coarser-grained particles probably settled further away from the center of the basin, while finer-grained particles would settle closer to the center of the basin. Coarser-grained, more permeable material probably underlies Mill Creek and the high hydraulic conductivities were necessary to attain a mass balance and calculated hydraulic head that matched the measured values. The values of CH, top of aquifer, were set to approximate land surface elevation and the values of BOT, bottom of aquifer, were set to about 60 feet below land surface.

After numerous runs with the 36 by 28 nodal grid, it was found that this spacing of nodes did not provide sufficient detail in the areas with steep hydraulic gradients to adequately calibrate the model. The major inflow and outflow occurs in a relatively small area, bounded by Mill Creek and the Vitro Ditches, which includes the CVWRF excavation. The major area of concern was around the excavation, particularly the Mill Creek side. It was found that to accurately calculate flux using Darcy's Law, the nodes adjacent to the excavation must be close to the nodes representing the excavation boundary, otherwise the linear approximation of the hydraulic gradient is not accurate. The second grid has more nodes located in the critical area around the excavation. This grid contains 50 columns and 41 rows of nodes, approximately doubling the number of nodes contained in the first grid (Table D-17, Figure D-11).

Table D-17. Variable grid spacing (50 x 41 nodes)

Column designation ^a	Width (in feet)	Row designation ^b	Width (in feet)
1-5 ^c	390.6	1	312.5
6-8	234.4	2	187.5
9-12	156.3	3-5	156.3
13	78.1	6	78.1
14-16	46.9	7-12	46.9
17-18	78.1	13	78.1
19	46.9	14-16	156.3
20-26	78.1	17-18	78.1
27-34	46.9	19-20	46.9
35-37	78.1	21-22	78.1
38-45	156.3	23-34	156.3
46-48	468.75	35	78.1
49	625.	36	46.9
		37	78.1
		38	156.3
		39-40	390.6

^aColumn N is space between nodes (N-1,J) and (N,J)

^bRow M is space between nodes (I,M-1) and (I,M)

^cColumn designation 1-5 means columns 1 through 5.

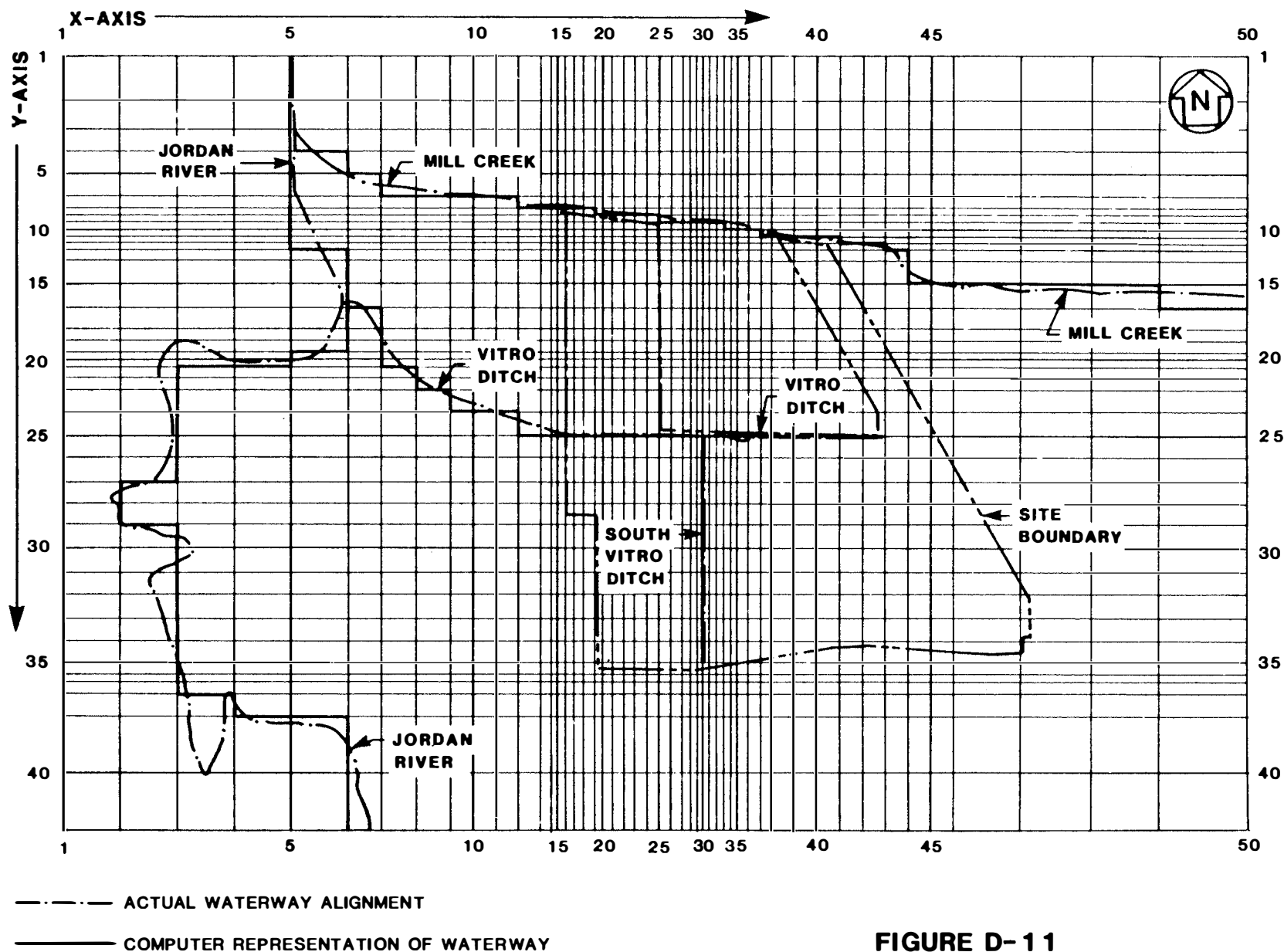


FIGURE D-11
REVISED 50 x 41 FINITE-DIFFERENCE GRID
REPRESENTING THE SOUTH SALT LAKE SITE VICINITY

During the calibration process, it was found that the hydraulic head distribution was more sensitive to changes in lateral hydraulic conductivity than to changes in infiltration, upward leakage, and seepage from the surface water bodies. The mass balance was relatively insensitive to changes in infiltration and upward leakage but was sensitive to changes in seepage from the creek and ditches. Table D-18 contains the results of the calibration of the unconfined system for present, steady-state conditions. The excavation has been and is currently being dewatered. The calculated value of flow rate to the CVWRF excavation is 54,718 ft³/day or 284 gpm. The measured flow rate from the excavation discharge pipe is approximately 300 gpm. The relative error in the mass balance is about -1 percent computed with a relative error of (inflow-outflow)/(inflow+outflow). The calibration of residual hydraulic heads, measured hydraulic head minus calculated hydraulic head, had absolute values of less than 3.1 feet.

Table D-18. Calibration of unconfined system, present case

Well designation	ISWS nodal location		Measured ^a water levels (ft)	Calculated water levels (ft)	Difference (ft) ^b
	<u>X</u>	<u>Y</u>			
7	47	18	4235.55	4232.45	+3.10
13	13	38	4233.79	4231.64	+2.15
9	13	28	4231.68	4230.53	+1.15
11	11	28	4231.61	4230.85	+0.76
6	49	40	4243.44	4242.79	+0.65
10	13	22	4230.01	4229.41	+0.60
12	38	39	4233.53	4233.56	-0.03
8	27	9	4226.42	4228.48	-2.06

Fluxes^b(in ft³/day)

Sum of infiltration and upward leakage	+35,192.
Seepage to Mill Creek	+ 4,765.
Seepage from Vitro Ditches	+ 1,195.
Flow to Jordan River	-40,587.
Flow across boundaries	+52,062.
Flow to CVWRF excavation	-54,718.
Net mass balance error	+ 2,091.
% Percent relative error: (inflow-outflow)/ (inflow + outflow)	-1%

^aaverage of well triplet completed to different intervals

^bplus is flow into modeled aquifer; minus is flow out of modeled aquifer

Calibration of unconfined system--historic case. The historic case refers to the unconfined hydrodynamics prior to the existence of the CVWRF excavation. The same values of infiltration, upward leakage, and hydraulic conductivity used for the present case were used also for the historic case. The differences between the two simulations were in boundary conditions. In the historic case, Mill Creek and the Vitro Ditches were designated constant head boundaries ($SF2=1 \times 10^{200}$). In the present case they were modeled as contributors of seepage to the unconfined system. Water levels measured (Dames and Moore, 1982) before the excavation at wells close to the creek and ditches, confirm that the surface water bodies are surface representations of the water table. The fluxes to Mill Creek and the ditches were calculated with Darcy's Law in the same manner as described in the previous section of this document. The constant head designation of the CVWRF excavation was eliminated, i.e., the values of SF2 were changed from 1×10^{200} to 1×10^{-20} . The fluxes (values of Q) for nodes on the grid boundary were adjusted to properly calibrate the mass balance. Results of the calibration are shown on Table D-19. The relative mass balance error is 1.5 percent and the maximum absolute difference of measured head minus calculated head at a given point is 2.7 feet. The total calculated flux through the system is about 64,000 ft³/day, (calculated by summing the flux in or out) while in the present case with the CVWRF excavation causing steep hydraulic gradients, the total calculated flux is about 94,000 ft³/day. In the historic case, much of the ground-water discharge from the site is to Mill Creek.

Table D-19. Calibration of unconfined system-historic case

Well designation	ISWS nodal location		Measured ^a water levels (ft)	Calculated water levels (ft)	Difference (ft) ^a
	<u>X</u>	<u>Y</u>			
V-CS	15	26	4230.63	4230.69	-0.06
V-AS	26	28	4231.84	4231.66	+0.18
V-GS	43	24	4235.83	4235.26	+0.57
V-ES	40	14	4234.25	4233.56	+0.69
V-BS	21	32	4232.41	4230.66	+2.15
V-HS	37	31	4234.79	4232.41	+2.38
V-FS	47	34	4236.51	4233.82	+2.69

³
Fluxes^a(in ft /day)

Sum of infiltration and upward leakage	+35,192.
Seepage to Mill Creek	-57,841.
Seepage from Vitro Ditches	+13,196.
Flow to Jordan River	- 4,853.
Flow across boundaries	+16,252.
Net mass balance error	+1,945.
Percent Relative Error (inflow-outflow)/ (inflow + outflow)	1.5%

^aplus is flow into modeled aquifer; minus is flow out of modeled aquifer

Prediction of unconfined system--post-remedial action. Two minor changes were made to the unconfined system, historic case, to predict the post-remedial action water levels in the unconfined system. First, the rate of infiltration for the area of the covered embankment was reduced from 2.4 inches/year to 1.3 inches/year. Second, the lateral flow into the modeled area was raised about 2 percent to account for more inflow due to steeper hydraulic gradients caused by less infiltration. Table D-20 lists the various calculated fluxes. The calculated hydraulic heads were slightly lower than those calculated for the historic case. There was no calculated water level rise anywhere on the modeled area.

Table D-20. Fluxes in unconfined system after remedial action

Fluxes^a(in ft³/day)

Sum of infiltration and upward leakage	+33,819.
Seepage to Mill Creek	-57,711.
Seepage from Vitro Ditches	+13,643.
Flow to Jordan River	- 4,874.
Flow across boundaries	+15,683.
Net mass balance error	+ 560.
Percent Relative Error (inflow - outflow)/ (inflow + outflow)	0.4%

^aplus is flow into modeled aquifer; minus is flow out of modeled aquifer

Calibration of confined system--present case. The confined system was modeled on the second unconfined system grid (50x41 grid). The following parameter values were used:

1. SFl=Artesian Storage Factor-- 8.4×10^{-5} x area represented by the node. The storativity of 8.4×10^{-5} was derived from the pump test analysis (see Section D.3.3.2).
2. Q = Constant leakage or constant flux across boundary of grid--This value was set to 0.0 for internal nodes. It was set to negative values on the south and east borders of the grid and positive values on the north and west borders of the grid. Negative values indicate flow into the aquifer; positive values indicate flow out of the aquifer. These values were chosen to simulate the potentiometric surface configuration and fluxes observed in the field.

3. Perm = The hydraulic conductivity in the X and Y directions for each node were set to the same value to simulate isotropic conditions. The values varied from 6.5 ft/day in the southeast portion of the grid to 21.7 ft/day on the northwest portion of the grid with an arithmetic mean of 13.3 ft/day and a geometric mean of 14.1 ft/day. These values corresponded to the lower values calculated with the pump test analysis (see Section D.3.3.2). These values were chosen and varied as described to enhance calibration of measured to computed hydraulic head. The recharge factor R chosen was $3.4 \times 10^{-5} \text{ day}^{-1}$ which equals a vertical hydraulic conductivity of $3.4 \times 10^{-4} \text{ ft/day}$ through the aquitard divided by the 10-foot thickness of the aquitard. This value of vertical hydraulic conductivity is within the range calculated from the pump test results. The values of hydraulic head in the overlying aquifer, RH, were those values from the calibrated, unconfined system, present case. The aquifer thickness, CH-BOT, was set to a value of 70 feet.

Table D-21 shows the results of the calibration of the confined system. The relative mass balance error is about 0.1 percent. The largest difference between calculated and observed hydraulic heads is 4.8 feet. All the calculated values are lower than the corresponding measured values, but the measured values in 1981 by Dames and Moore were about 3 feet lower than the values measured in 1983. The calculated upward leakage is about 15,000 ft^3/day which equals 1.5 inches/year. The value calculated with the calibration of the unconfined system was 2.25 inches/year. These two values confirm that the upward leakage is about equal to the recharge from infiltration, which was estimated as 2.4 inches/year.

Table D-21. Calibration of confined system, present case

Well designation	ISWS nodal location		Measured water levels (ft)	Calculated water levels (ft)	Difference (ft) ^a
	<u>X</u>	<u>Y</u>			
2	47	17	4248.9	4244.1	+4.8
4	8	27	4246.8	4242.7	+4.1
5	11	27	4247.2	4243.2	+4.0
3	26	5	4246.8	4243.7	+3.2
1	49	40	4249.1	4248.8	+0.3

Fluxes^a (in ft^3/day)

Upward leakage	-15,236.
Flow across boundaries	+15,218.
Net mass balance error	- 18.
Percent relative error (inflow - outflow)/ (inflow + outflow)	0.1%

^aplus is flow into modeled aquifer; minus is flow out of modeled aquifer

D.3.5 Analysis of water quality, geochemistry, and solute transport

Chemical data representing the tailings pile water and unconfined ground water were analyzed using the geochemical model PHREEQE (Parkhurst et al., 1980). This model uses thermodynamic relationships to determine aqueous and solid speciation. PHREEQE allows calculation of the form(s) in which a metal exists while in solution and the mineral which co-exists with the solute and controls its concentrations.

The equations used by PHREEQE are as follows:

1. Electrical neutrality (one equation).

$$\sum_{i=1}^I z_i \cdot m_i = 0$$

2. Conservation of electrons (one equation). The sum of the OPV of aqueous species equals initial total plus contribution from phases other than aqueous. This equation is only used in determining the speciation in reaction solutions, not initial solutions.

$$\sum_{i=1}^I v_i \cdot m_i = \text{OPV} + \sum_{p=1}^P u_p \cdot \text{MIN}_p$$

3. Mass balance (one equation for each element except H and O). The sum of aqueous species equals initial total plus contribution from phases other than aqueous.

$$\sum_{i=1}^I c_{i,j} \cdot m_i = \text{TOT}_j + \sum_{p=1}^P b_{p,j} \cdot \text{MIN}_p \quad \text{for each } j$$

4. Mineral equilibrium (one equation for each mineral phase).

$$\sum_{i=1}^J b_{p,j} \cdot \log(a_j) = \log(K_p) \quad \text{for each } p$$

5. Mass action equations for aqueous species (one for each aqueous species other than master species; written as association reactions).

$$\log(a_i) = \log(K_i) + \sum_{j=1}^J c_{i,j} \cdot \log(a_j)$$

where

- a_i activity of the i^{th} ion pair.
- a_j activity of the j^{th} master species.
- $b_{p,j}$ stoichiometric coefficient of the j^{th} master species in the p^{th} mineral (zero if master species is not present in mass action equation for the i^{th} species).
- $c_{i,j}$ stoichiometric coefficient of the j^{th} master species in the i^{th} aqueous species (zero if master species is not present in mass action equation for the i^{th} species).
- I number of aqueous species.
- J number of master species.
- K_i equilibrium constant for the mass action equation for the i^{th} aqueous species.
- K_p equilibrium constant for the mass action equation for the p^{th} phase.
- m_i molality of the i^{th} aqueous species.
- MIN_p moles of the p^{th} mineral transferred into (+) or out of (-) in the aqueous phase.
- OPV $\sum_{i=1}^I v_i \cdot m_i$, calculated from the speciation of the initial solution or the mixture of two initial solutions.
- P number of mineral phases.
- TOT_j Total concentration of the element corresponding to the j^{th} master species preceding any mineral dissolution or precipitation.
- u_p sum of the OPV's of the constituents in the p^{th} mineral.]
 EX. $\mu_{\text{FeS}_2} = 0$ and $\mu_{\text{Fe}(\text{OH})_3} = +3$
- v_i Operational valence (OPV) of the i^{th} aqueous species. The numerical values are assigned arbitrarily for bookkeeping convenience; they are self-consistent in terms of correctly defining electron transfer in redox reactions, but may or may not correspond to the true chemical valence for the entities involved.

$v_i = 0$ for "non-redox" species (those whose valence does not change within the stability range for water).

$= 0$ for H^+ ,

$= 0$ for OH^- ,

= -2 for H (aq) ,

= +4 for O (aq) ,

= the formal elemental valence for aqueous redox species
(or the sum of the formal valences of the constituents of
an aqueous complex, excluding H and O). Ex. $v_{\text{Fe}^{2+}} =$
 $+2$, $v_{\text{SO}_4^{2-}} = +6$, and $v_{\text{FeSO}_4^0} = +8$.

z_i charge on the i^{th} species.

PHREEQE solves a set of nonlinear equations using a combination of two techniques:

- o a continued fraction approach, as in Wigley (1977), is used for mass balance equations
- o a modified Newton-Raphson technique is used for all other equations

PHREEQE is an equilibrium model and does not account for reaction kinetics. Solute transport was simulated with steady-state unidirectional solutions to the advection-dispersion equations found in Prakash, 1982.

D.3.5.1 The Present Condition

Surface and ground waters on and near the Vitro site have been contaminated by the tailings pile. A sample was defined as being contaminated if it satisfied any of the following criteria:

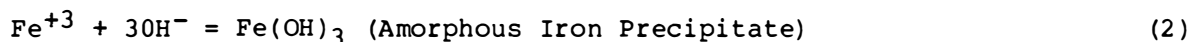
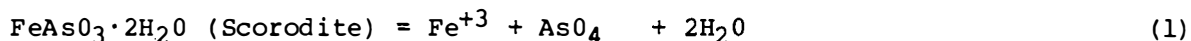
- It contained metals associated with the tailings pile in concentrations higher than the highest concentration found in uncontaminated (background) samples.
- The pH of the sample was lower than the lowest found in background samples.
- It contained higher concentrations of calcium (Ca^{+2}) or bicarbonate (HCO_3^-) than the highest concentrations found in background samples.

These criteria are broad and may encompass samples which have not been contaminated by water derived from the tailings pile.

As far as its effect upon water quality is concerned, the tailings pile is composed of two geochemically distinct layers. The top layer is composed of tailings and pile water (Layer 1). It rests upon a mixture of tailings, soil, and ground water (Layer 2). These layers are about 10 feet and 3 feet thick, respectively. Layer 2 contains bands of iron (Fe) and sulfate (SO_4^{--}) precipitates which are the result of tailings water moving into the chemical environment of the ground-water system (Markos and Bush, 1982).

Determination of speciation in Layer 1 using PHREEQE can be found in Table D-23. Chemical data from both tailings layers are presented in Table D-24. These data illustrate that ground water in contact with tailings contains higher concentrations of As, Cd, Mo, Pb and U than does the tailings water. It follows that the chemical mechanisms occurring in Layer 2 are different from those in Layer 1 and are responsible for the greatest portion of aqueous contamination found in the site area. An explanation of the higher concentrations in Layer 2 follows.

When tailings water is mixed with ground water, the chemical environment changes drastically. Acidity decreases by a factor of several hundred and Eh (oxidation-reduction potential) decreases by several hundred millivolts (Markos and Bush, 1982). The acidic tailings water dissolves soil calcium carbonate (CaCO_3). This causes Fe and SO_4 compounds to precipitate which in turn causes metal-bearing minerals in the tailings to dissolve more rapidly than they do in tailings Layer 1. An example of this process is the dissolution of the arsenic mineral, scorodite:



Reaction (2) causes Reaction (1) to be driven to the right, resulting in increased concentrations of dissolved arsenic. Amorphous iron has the ability to retard the movement of arsenic and other metals by sorbtion, co-precipitation, and occlusion (Markos and Bush, 1982). The concentration of arsenic depends upon which mechanism is faster, dissolution or retardation. In the water of Layer 2, dissolution is the faster. The implication is that if the tailings are placed above the water table, levels of contamination will be greatly reduced because the dissolution will not occur at appreciable rates.

On the other hand, concentrations of barium and chromium are lower in Layer 2 than in Layer 1. The movement of these metals may be highly retarded in tailings Layer 1, or, they may be rapidly sorbed in Layer 2. Recent research indicates that both mechanisms are operating (PNL, 1983). This is supported by the speciation information presented in Table D-22. Both barium and chromium exist as multi-valent cations in Layer 1. They remain cations as pH is increased. Therefore, their movement is retarded.

Surface Water and CVWRF Excavation

Data from samples of surface water are presented in Table D-22. The Jordan River and Mill Creek are considered to represent background conditions. The CVWRF excavation, Vitro Ditch, South Vitro Ditch, and the marsh east of the site are contaminated due to tailings sliding or blowing into these waters, or shallow ground-water flow beneath the pile to the surface water. The excavation and the ditches are bordered by tailings. The marsh is within the area identified as containing wind blown tailings (Douglas and Hans, 1975). As with the tailings water of Layer 2, some surface water samples have concentrations higher than the concentrations in Layer 1. These metals are cadmium (Cd), molybdenum (Mo) and uranium (U). Tables D-23 and D-24 show that mixtures of tailings and background waters contain high

Table D-22. Analyses of surface water samples

	Background (4 samples) ^a	Excavation (2 samples)	Vitro Ditch (3 samples)	South Vitro Ditch (4 samples)	Marsh
pH	7.9	6.8	7.2	7.6	8.8
As	0.01	0.007	0.01	0.03	0.07
Ba	NA	ND	0.074	NA	0.021
Cd	ND	ND	ND	ND	0.36
Cr	0.01	ND	0.02	0.02	0.05
Mo	0.01	1.2	0.84	0.37	0.62
Pb	0.08	0.006	0.12	0.08	0.14
U	0.0042	0.58	1.0	0.10	0.0014
^b Se	ND	ND	ND	ND	0.43

NA = Not Analyzed

ND = Not Detected

^aWhere more than one sample has been taken, the highest concentration found is reported

^bNo Se has been detected in any water sample from the tailings pile.

Note: All data reported as mg/l except pH.

Table D-23. Speciation of metals as determined by PHREEQE

	Tailings pile (upper level)		Shallow ground water (contaminated)		Shallow ground water (Background)		Deep ground water (Background)	
	<u>Aqueous</u>	<u>Solid</u>	<u>Aqueous</u>	<u>Solid</u>	<u>Aqueous</u>	<u>Solid</u>	<u>Aqueous</u>	<u>Solid</u>
As	H ₃ AsO ₄	FeAsO ₄ · 2H ₂ O	AsO ₄ ⁻³ , H ₃ AsO ₄	Mn ₃ (AsO ₄) ₂ · 8H ₂ O, NaUO ₂ AsO ₄ · 4H ₂ O, AlAsO ₄ · 2H ₂ O	AsO ₄	Mn ₃ (AsO ₄) ₂ · 8H ₂ O	AsO ₄	Mn ₃ (AsO ₄) ₂ · 8H ₂ O
Ba	Ba ⁺²		Ba ⁺²	BaSO ₄	Ba ⁺²	BaSO ₄	Ba ⁺²	BaSO ₄
Cd	CdSO ₄	CdSO ₄ · H ₂ O	Cd ⁺²	CdCO ₃	Cd ⁺²	CdCO ₃	Cd ⁺²	CdCO ₃
Cr	Cr ⁺³	Cr ₂ O ₃	CrOH ⁺² , Cr(OH) ₂	Cr(OH) ₃	Cr(OH) ₂	Cr(OH) ₃	Cr(OH) ₂	Cr(OH) ₃
Mo	HMoO ₄	PbMoO ₄	MoO ₄	PbMoO ₄	MoO ₄	PbMoO ₄	MoO ₄	PbMoO ₄
Pb	PbSO ₄	PbMoO ₄	PbHCO ₃ · -2	PbMoO ₄	PbHCO ₃ · -2	PbMoO ₄	PbHCO ₃ · -2	PbMoO ₄
U	UO ₂	NaUO ₂ AsO ₄ · 4H ₂ O	UO ₂ (CO ₃) ₂	NaUO ₂ AsO ₄ · 4H ₂ O	UO ₂ (CO ₃)	NaUO ₂ AsO ₄ · 4H ₂ O	UO ₂ (CO ₃) ₂	

^aMost abundant aqueous species reported; where data from more than one well were analyzed, most abundant species in each well is reported. The solid phase believed to control aqueous concentrations is reported.

Table D-24. Analysis of tailings pile water

	Layer 1 (1 sample)	Layer 2 (Highest concentration found in 14 samples)	Average
Eh (Mv)	560	(-25) - (330)	
pH (s.u.)	3.3	(4.9) - (7.1)	
As (mg/l)	0.36	6.14	0.94
Ba (mg/l)	27.0	0.078	0.047
Cd (mg/l)	0.0069	0.22	0.020
Cr (mg/l)	0.06	0.05	0.030
Mo (mg/l)	0.05	7.90	1.14
Pb (mg/l)	0.26	0.28	0.17
U (mg/l)	0.45	75.0	7.61

Note: All data reported as mg/l except as indicated

concentrations of Mo. This is in contrast to contaminated ground waters (Tables D-4, D-5, and D-6) which contain concentrations of Mo at near background levels. This indicates that two different mechanisms are operating. One controls concentrations of Mo in the presence of tailings, the other in the absence of tailings.

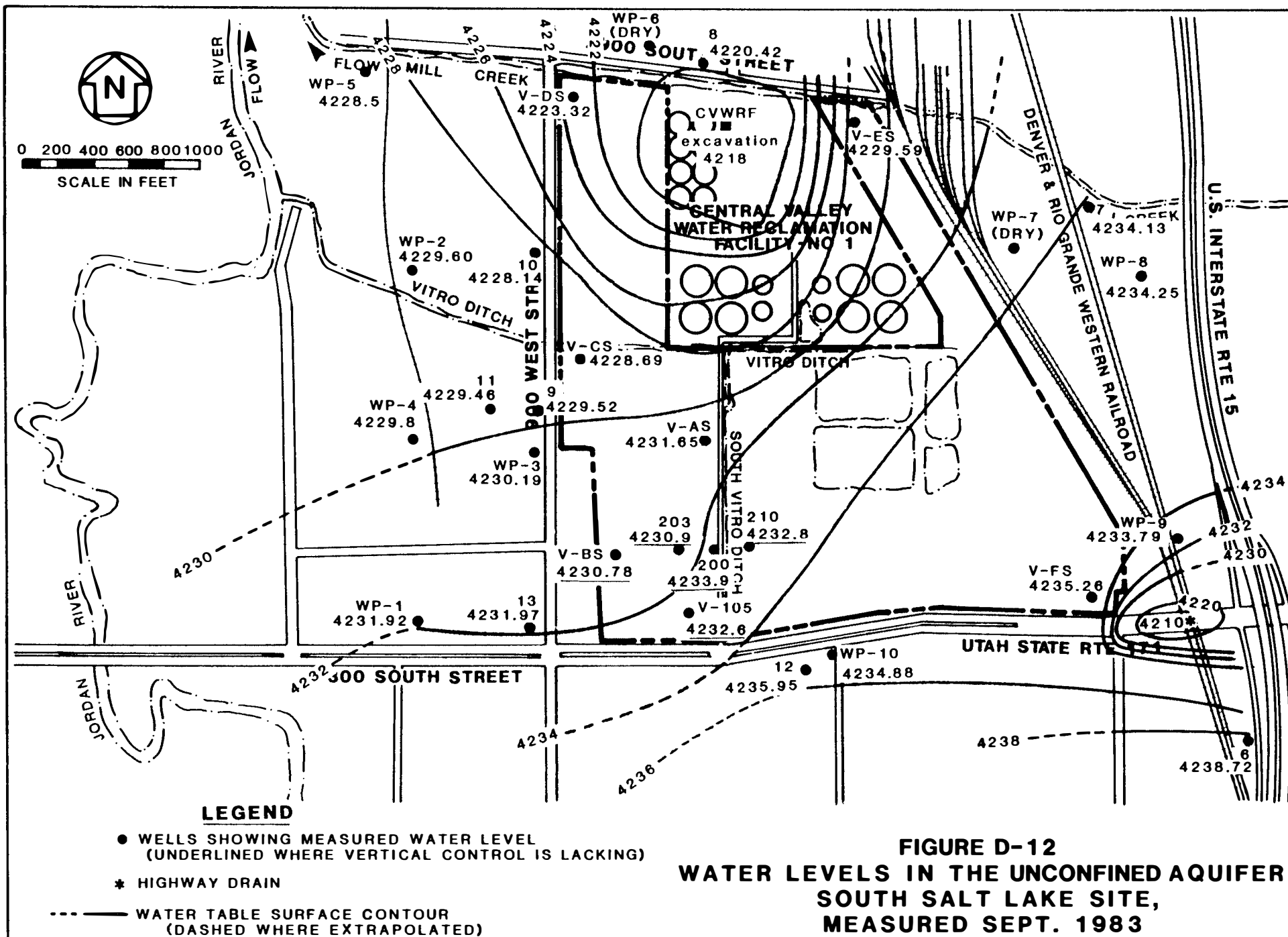
Since the opening of the CVWRF excavation, ground-water flow paths in the vicinity of the mill site have been altered towards the excavation (Figure D-12). The results of the calibrated hydrodynamic model of the present condition show that about one-third of the water flowing into the excavation comes from north of the excavation, while about two-thirds of the water is flowing from the existing tailings areas. The uranium concentration in the excavation drainage water was measured at 0.25 mg/l. Assuming a background concentration of 0.02 mg/l in the uncontaminated water and assuming that the uranium concentration in the shallow ground water entering the excavation is accurately represented by the excavation discharge sample, the average uranium concentration of water in the tailings can be calculated as 0.35 mg/l.

The TDS measured in the CVWRF excavation was 4340 mg/l. Assuming a background concentration of 2,500 mg/l, the calculated average TDS of ground water under the tailings is 5260 mg/l. These calculated concentrations of uranium and TDS may accurately represent present average source concentrations from the tailings pile to the shallow unconfined ground water.

Unconfined Ground Water. Samples from the following wells fit the definition of contamination: 8, 9, 10, 11, 13, 14, VBS, and VDS (Tables D-4, D-5, and D-6). These samples define a plume of contamination at least 3600 ft wide which has advanced at least 400 ft west of the site boundary. Wells 12 and 7 represent background concentrations.

Examination of Tables D-4, D-5, and D-6 yields the following information. In no sample is Ba found in concentrations significantly above background levels, including beneath the pile. This strongly suggests that transport of Ba is highly retarded. Arsenic is found in concentrations above background in only one well, suggesting that transport of arsenic is also quite retarded. Cadmium, chromium, molybdenum, and lead are found in concentrations slightly above background levels in a few cases, indicating that their movement through the aquifer is retarded to some degree. Uranium is found in concentrations above background levels in all but one instance. It is the most mobile of the metals considered.

Retardation of the transport of Ba, Cd, Cr, and Pb is expected because these metals exist as cationic species in the unconfined aquifer (see Tables D-4, D-5, and D-6). As and Mo exist as anions but recent research indicates that both species may be sorbed by Fe and aluminum compounds (PNL, 1983; Markos & Bush, 1982; LeGendre & Runnels, 1975). It has also been suggested that Mo may form long chains of snowflake-like structures (polymers) which are more easily sorbed than MoO_4^{2-} (Bohn, 1975). Whatever the explanation, As and Mo are present in concentrations significantly lower than can be attributed to dilution alone (see Tables D-4, D-5, and D-6).



Uranium is mobile in the ground water beneath the tailings in the form of $\text{UO}_2(\text{CO}_3)_2$. Prior to the excavation, unconfined ground water flowed roughly southeast to northwest through the tailings, and discharged into the Jordan River and Mill Creek. In the downgradient area, the uranium concentrations in water samples from well triplets 9A, 9B, 9C and 11A, 11B, 11C, indicate evidence of a relic contaminant plume. Uranium concentrations at wells 9C and 11C are higher than any uranium concentrations of ground-water samples beneath the tailings pile. Using hydraulic parameters for the calibrated historic hydrogeologic model and the solute transport equations of Prakash (1982), uranium concentrations were calculated and compared to values measured in the wells. The strength and location of the source was varied until results of the simulation agreed with the measured values (Table D-25).

Table D-25. Comparison of measured and calculated uranium concentrations

Well ID	Approximate depth of well screen (ft)	Measured concentration (mg/l)	Calculated concentration (mg/l)
9A	6	0.025	0.013
9B	16	0.13	0.23
9C	26	2.12	2.24
11A	4	0.14	0.053
11B	15	0.57	0.39
11C	24	1.87	1.86

The following input values were used in this calibration of the solute transport equations:

- A point source 700 feet east of 900 West Street, directly east of well series 9 and 11.
- An effluent concentration of 7.76 mg/l released at a constant rate of 1 ft³/day.
- A ground-water velocity of 0.3 ft/day.
- Lateral and vertical dispersivities of 0.00001 ft²/day and 0.007 ft²/day, respectively.

The uranium concentration at downgradient well No. 13 is 0.02 mg/l, about background level, while downgradient well No. 10C has a slightly elevated concentration of 0.11 mg/l. The concentrations at wells Nos. 10 and 13 show that there is selective transport with little spreading of the plume, confirming the low dispersivity of the system in the vicinity of wells 11 and 9. Calibration of the movement of sulfate (see below) showed that the dispersivity of the system as a whole is higher than in the area of wells No. 9 and 11.

The concentration of sulfate downgradient was also modeled using the Prakash equations. The source was modeled as 2 lines, 900 feet long, perpendicular to the direction of flow. The concentrations were set at 6000 mg/l above background concentration representing the highest sulfate level of any sample. This simulation resulted in calculated maximum concentrations of sulfate of 3750 mg/l above background at a distance of 1500 feet west of the pile, 57.4 mg/l above background 4150 feet west of the pile, and 1.2 mg/l above background 4200 feet west of the pile (adjacent to the Jordan River). The Jordan River is considered as an infinite sink for contaminants through the application of image well theory in the Prakash equations. For these line sources, a lateral dispersivity of 4.0 ft²/day and a vertical dispersivity of 0.25 ft²/day were used. The value at 1500 feet west of the pile was close to values measured in that area.

Confined system. Comparing the water quality at upgradient wells Nos. 1 and 2 to downgradient wells Nos. 4 and 5 shows that the downgradient artesian water has elevated TDS but no elevation in the concentrations of radionuclides or trace metals. The average TDS at wells Nos. 1, 2, and 3 is about 300 ppm while the average at wells Nos. 4 and 5 is 1200 ppm. The high concentrations downgradient must represent relic contamination because the natural vertical hydraulic gradient in the area is upward, precluding the downward flow of water from the unconfined to the confined system. The downgradient contamination in the confined system is probably due to downward leakage caused by pumping at the mill site during processing. To obtain process water at the Vitro site, it is estimated that it was necessary to pump from the confined system at an average continuous rate of 190 gpm for 13 years.

It is difficult to determine whether or not water originating in the tailings pile has entered the confined system because the pathway is complicated. First, tailings pile water must enter the unconfined system. All metals will be diluted and immobilized to some degree. Next, the mixture of tailings pile--unconfined ground water must pass through the clay confining layer. Further immobilization will occur because clays have high sorptive capacities (Garrels & Christ, 1965). Finally, the contaminated water enters the confined system where it is diluted once again. The plume of contamination, which is at least 2600 feet wide and has advanced at least 1900 feet west of the site boundary, may be due to downward migration of water from both the unconfined aquifer and the tailings pile or may be due to downward migration from the unconfined aquifer only.

Although these wells contain Ba and Cr in concentrations above background levels, it is unlikely that these metals came from the tailings pile. In the first place, Ba is not found in concentrations above background levels in the unconfined aquifer. Secondly, both metals are sorbed more strongly than U which is not found in concentrations above background levels. Lead-210 has been detected in one of two samples taken from well 5 and one sample from well 15. The concentrations were not significant because they were only slightly above the detection limit of 1.5 pCi/l.

It is difficult to accurately determine the concentration of TDS or individual chemical constituents of the water leaking from the unconfined to the confined aquifer; and the mixing of the natural, confined ground water with the water derived from leakage once the natural hydraulic gradients were restored. To determine the possibility of the downgradient water quality in the confined system being a result of pumpage during milling, the following calculation was performed:

1. Background TDS = 300 mg/l in the confined system.
2. Unconfined ground water leaking into confined system may have contained TDS from 4000 to 40,000 mg/l. The lower values would represent primarily water natural in the unconfined system while the higher values would represent water contaminated with tailings liquor.
3. Downgradient, unconfined ground-water samples contain approximately 600 and 1800 mg/l TDS.
4. Calculate mixing of the two sources of water, unconfined and confined, to produce the measured downgradient contamination, assuming no precipitation/dissolution reactions.

Table D-26 shows that mixing of ground water from the unconfined system with the confined system is a reasonable explanation of the elevated concentrations of dissolved solids found downgradient in the confined system at a depth of 110 to 130 feet below the ground surface.

Table D-26. Possible mixing of ground waters during pumping

Confined ground water TDS (mg/l)	Leaking unconfined ground water TDS (mg/l)	Resultant TDS (mg/l)	Fraction from confined water	Fraction from unconfined water
300	4000	600	0.92	0.08
300	4000	1200	0.76	0.24
300	4000	1800	0.59	0.41
300	20000	600	0.98	0.02
300	20000	1200	0.95	0.05
300	20000	1800	0.92	0.08
300	60000	600	0.99	0.01
300	60000	1200	0.98	0.02
300	60000	1800	0.97	0.03

D.3.5.2 Post-remedial action

Contaminant migration in the unconfined system after remedial action is dependent upon two items: fluid flow after remedial action, and the source of contamination after remedial action. The source of contamination will vary depending upon the location of the tailings with respect to the level of the water table.

Hydrodynamics. The calibrated hydrodynamic model shows that the water levels in the unconfined system will be approximately the same after remedial action and after the CVWRF excavation is closed as historic levels (before the excavation) (Tables D-19 and D-20). The levels will drop slightly under the Vitro site in response to the reduced infiltration in that area (Table D-20). Significantly, there will be no rise in water levels in the area of the tailings, so that the water table will remain about 3 feet below the contaminated material. The restoration of historic ground-water levels means that historic flow patterns will be restored, and the unconfined ground water will again flow southeast to northwest to discharge into the Jordan River and Mill Creek.

The remedial action requires that the tailings material be encapsulated with a cap that will reduce infiltration through the tailings to a maximum of 0.11 feet/year, assuming no vegetation, and a liner that will guarantee that the tailings are a minimum of 3 feet above the water table. The time necessary for contamination to travel from the encapsulation to the ground water can be calculated with equations from Gilbert et al., (1983). The input parameters for uranium are:

- N_e = effective porosity = 0.10 (assumed value)
- K_d = partitioning coefficient = 15 cm³/g (a value of 30 cm³/g for low pH was reported in Gilbert et al., 1983)
- I = infiltration rate = 0.11 ft/yr
- ρ_s = density of liner material = 1.7 g/cm³ (assumed value)
- D = the distance from the encapsulated tailings to the water table = 3 feet

$$\text{The delay time, } T_d = DX(N_e + \rho_s K_d)/I = \\ 3 \text{ ft. } (0.10 + 1.7 \text{ g/cm}^3 \times 15 \text{ cm}^3/\text{g})/0.11 \text{ ft/yr.} = 700 \text{ years}$$

This analysis (700 years) is a worst case assessment for uranium migration, using highly conservative parameter values.

A probable case delay time can be calculated with more likely parameter values.

$$\begin{aligned} N_e &= 0.10 \\ K_d &= 30 \text{ cm}^3/\text{g} \\ I &= 0.33 \text{ ft/yr (value calculated assuming sparse vegetation)} \\ \rho_s &= 1.7 \text{ g/cm}^3 \\ D &= 5 \text{ ft (the design thickness of the liner)} \\ T_d &= DX(N_e + \rho_s K_d)/I = 5 \text{ ft } (0.10 + 1.7 \text{ g/cm}^3 \times 30 \text{ cm}^3/\text{g})/ \\ &\quad 0.033 \text{ ft/yr} = 7700 \text{ yrs} \end{aligned}$$

Partitioning coefficients for the dissolved metals under unmixed tailings pile conditions are available only for uranium (Gilbert et al., 1983). Only qualitative estimates of the effects of retardation can be made for the other metals. Recent research (PNL, 1983) and the information presented in this section indicates that Ba and Cr are highly retarded under tailings piles conditions. This same research indicates that As and Pb will also be highly retarded, while Cd, U, and Mo will be relatively mobile.

The proposed remedial action should cause significant delay (a minimum of 700 years) for trace metal contaminants to enter the ground-water system. Downgradient concentrations were predicted for U, Mo, and As following the 700+ year delay time, using the following assumptions:

- Tailings Layer 1 concentrations were used as source concentrations.
- Effluent release rate = predicted conservative percolation rate of 1.3 inches/year.
- Ground-water seepage velocity = 0.3 ft/day.
- Vertical dispersivity = $0.25 \text{ ft}^2/\text{day}$.
- Lateral dispersivity = $4.0 \text{ ft}^2/\text{day}$.
- The source can be defined as 2 horizontal lines perpendicular to the direction of flow. These lines bound the proposed encapsulation to the east and west and run the length of the proposed encapsulation, north to south.
- The constituents are mobile, i.e., move with the ground water.
- The Jordan River acts as a constant concentration discharge boundary.
- The depth of mixing in the aquifer is 45 feet.

See Table D-27 for the post-remedial action concentrations calculated for U, As and Mo, using the equation from Prakash (1982).

Table D-27. Predicted maximum downgradient contaminant concentration in the unconfined aquifer, post-remedial action, with a liner

Contaminant	Location	Concentration (mg/l)
As	At Source	0.36
As	900 W.	0.008
As	900' west of 900 W.	0.005
As	2100' west of 900 W.	0.002
Mo	At source	0.05
Mo	900 W.	0.001
Mo	900' west of 900W.	0.0007
Mo	2100' west of 900 W.	0.0003
U	At source	0.45
U	900 W.	0.01
U	900' west of 900 W.	0.006
U	2100' west of 900 W.	0.002
SO ₄ = Above background	At source	6600
SO ₄ = Above background	900 W.	144
SO ₄ = Above background	900' west of 900 W.	87
SO ₄ = Above background	2100' west of 900 W.	34

Time necessary for contaminants to travel from base of encapsulation to water table:

SO₄ = >28 Years

U, Mo, As >700 Years

D.3.6 Aquifer Restoration Analysis

D.3.6.1 Boundaries of contamination

A contaminant plume exists in the unconfined aquifer downgradient of the Vitro site (see Section D.3.2 for description of existing ground-water quality). Contamination was detected in samples from well triplets 9, 10, and 11 (see Figure D.13 for well locations). Samples from these wells contained concentrations of total dissolved solids (TDS), uranium (U), sulfate (SO_4^{2-}), sodium (Na^+), chloride (Cl^-), calcium (Ca^{++}), and magnesium (Mg^{++}) significantly higher than samples from upgradient, unconfined wells. A sample from well 13C did not contain these constituents in concentrations higher than upgradient or cross-gradient "C" wells (see Table D.5). A sample from well 17, completed in the top of the confining layer separating the unconfined and confined aquifers, also contained uncontaminated ground water. The natural flow in the unconfined aquifer is to the northwest (Figure D-8). Therefore, the Jordan River and Mill Creek are considered discharge boundaries of the shallow ground water flowing beneath the Vitro site. Based upon the data presented above, the assumed maximum boundaries of contamination have the following dimensions (Figure D-13):

- Plume width of 3,100 feet -- The distance, north-to-south, from well triplet 13 to Mill Creek. A sample from well 13C showed no contamination and Mill Creek is a discharge boundary for shallow ground water.
- Plume length of 1500 to 2600 feet -- The distance from the site boundary to the discharge at the Jordan River.
- Plume thickness of 50 feet -- The depth distance from the water table to the bottom of the unconfined aquifer. Water at the base of the unconfined system is uncontaminated as evidenced by the sample from well 17.

The maximum area of contaminated, unconfined ground water is $7 \times 10^6 \text{ ft}^2$ (Figure D-13). The maximum thickness is 50 feet. Assuming a conservatively high value of porosity of 0.30 (Hely, et al., 1971), the maximum volume of off-site contaminated, unconfined ground water is $1 \times 10^8 \text{ ft}^3$.

Also, to ensure a worst-case analysis, the assumption was made that the quality of all the water contained within the contaminated volume is equal to the poorest quality found in the downgradient, unconfined ground-water samples (Table D-28).

D.3.6.2 Potentially affected water supplies

There are three potentially affected available water supplies (discounting quality or need for treatment):

- Surface water (Jordan River and Mill Creek).
- Unconfined aquifer water.
- Confined aquifer water.

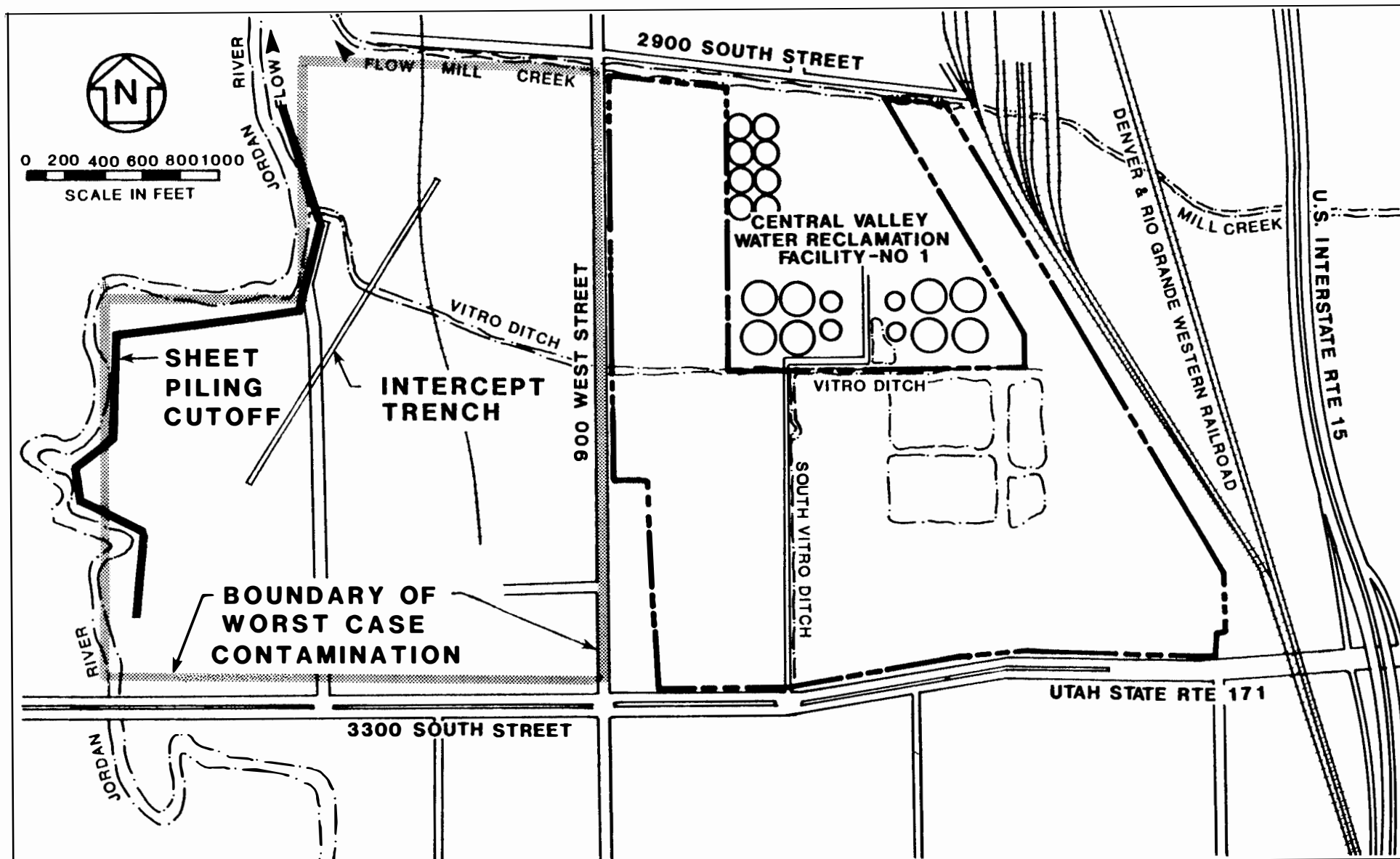


FIGURE D-13
AQUIFER RESTORATION DESCRIPTIVE MAP SOUTH SALT LAKE SITE

Table D-28 Calculated worst-case change of water quality in Jordan River

Parameter	Jordan River current concentration (mg/l)	Unconfined aquifer maximum concentration (mg/l)	Jordan River ^a plus plume concentration (mg/l)	Resultant change in river concentration (mg/l)
TDS	1180	20,000	1270	+90
U	0.7	2.0	0.7	0
SO ₄	368	7,000	400	+32
Na	186	3,100	200	+14
Cl	271	2,500	282	+11
Ca	127	1,000	131	+ 4
Mg	60	1,000	64	+ 4

$$^a \frac{(\text{Concentration in River}) \times (68,000 \text{ gpm}) + (\text{Concentration from Aquifer}) \times (325 \text{ gpm})}{68,325 \text{ gpm}}$$

In this section the benefits of aquifer restoration are described and calculated for each of the three water supplies by considering the loss of use and potential use, given no aquifer restoration. The loss of benefit would extend through the time needed for the contaminated water to travel and discharge to the Jordan River or Mill Creek (period of natural purging). Geochemical retardation was not considered because the contaminants are mobile in the ground water. To bound this time, two methods of calculation were used. First, for a lower bound, a shallow ground-water flux to Mill Creek and the Jordan River of 62,600 ft³/day was considered (see Section D.3.4.1, Table D-20). Given a flux of 62,600 ft³/day (325 gpm), it would require 4.4 years for the entire contaminated volume of 1x10⁸ ft³ to discharge to the surface water streams. For an upper bound, a seepage velocity of 0.3 ft/day was considered (see Section D.3.5.1). Given a maximum travel distance of 2,600 feet, the calculated travel time was 23.7 years. The average discharge through this period would be 11,500 ft³/day (60 gpm).

Effect upon the Jordan River

The worst-case loss of benefit to surface water would occur if all the contaminated unconfined ground-water discharged to the Jordan River. For the reach from the Vitro site to the Great Salt Lake, the Jordan River is

classified for aquatic wildlife (Class 3B) and agricultural beneficial uses (State of Utah, 1978). The 3B classification requires protection for warm water species of game fish and other aquatic life, including the necessary aquatic organisms in their food chain. The agricultural uses include irrigation of crops and stock watering. Generally, warm water fish do not suffer stress from dissolved solids until concentrations reach 2,500 to 3,000 mg/l TDS (USEPA, 1973). Dissolved solids have been determined to be detrimental for irrigation and stock watering only at concentrations greater than 3,000 mg/l.

The average flow of the Jordan River near the Vitro site is 68,000 gpm (State of Utah, 1943-1968). The degradation of the river was calculated with a ground-water discharge of 325 gpm. This maximum discharge rate was used to calculate the maximum degradation of river quality. The river water concentrations displayed on Table D-28 were found in the State of Utah, 1943-1968. The quality of the discharge from the unconfined aquifer to the Jordan River is assumed to be equal to the poorest quality found in the aquifer to determine the worst-case degradation of river quality.

The results of the worst-case degradation calculations are presented on Table D-28. The increase in TDS, SO_4^{--} , Na^+ , Cl^- , Ca^{++} , and Mg^{++} would not change the beneficial uses of the river. The change in river water quality would be insignificant and there would be no loss of benefit because there would be no effect on the river's beneficial uses.

Effect upon the unconfined aquifer

The upper portion of the unconfined aquifer is naturally brackish (see Section D.3.2 and Hely et al., 1971). The water quality improves with depth and approaches the good quality of the underlying confined system. Within a one-half mile radius of the site, there are two wells known to be completed to the unconfined system. These wells are believed to be used for irrigation only. There are no known wells other than monitor wells completed to the unconfined aquifer and within the boundaries of contamination. A maximum loss of benefit could be calculated by assuming all the water within the boundary of contamination in the unconfined aquifer would have been of drinking water quality and the entire volume of water could be used before discharging to Mill Creek or the Jordan River.

The maximum volume of contaminated ground water was calculated as $1 \times 10^8 \text{ ft}^3$, (2,300 acre-feet). The State of Utah states that the cost of water in the Salt Lake area is approximately \$105 per acre-foot (State of Utah, 1983). Therefore, the maximum loss of benefit to the unconfined ground water is \$240,000.

The change in use of the unconfined aquifer due to contamination from the Vitro site would be from marginal irrigation and stock watering to industrial use only in the upper portions and from potable water to industrial use only in the lower portion. It should also be noted that yields from monitoring wells completed in the unconfined system are low (approximately 10 gpm).

Effect upon the confined aquifer

The confined aquifer is an important source of domestic, agricultural, and industrial water supply in the Salt Lake Valley (see Section D.2.1). The State of Utah indicated that within a half-mile radial distance from the Vitro site, there are 7,790 acre-feet per year of total water rights (State of Utah, 1983). Within the areal boundary of contamination in the unconfined system, only two wells are known to be completed to the confined system other than wells associated with the Vitro site. Both of these wells are not being used presently.

An upward, vertical hydraulic gradient protects the confined aquifer from the downward migration of lesser-quality, unconfined ground water. This upward gradient occurs naturally but could be reversed by localized heavy pumping (see Section D.3.2.5). Several samples downgradient of the Vitro site indicate that the confined ground water may have been contaminated. Samples from four wells averaged 1,140 mg/l of TDS; background is about 300 mg/l of TDS.

Although future degradation of the confined aquifer would occur only with localized, heavy pumping, the potential loss is considered. The areal extent of potential contamination in the confined system would be the same as in the unconfined system. The depth of contamination would be dependent on the magnitude of the downward vertical gradient induced by the localized pumping. Because this pumping is hypothetical, the depth of mixing is impossible to predict. A reasonably conservative estimate would be mixing to 160 feet below the ground surface or to the 100 foot depth of the aquifer. This estimate assumes that pumping-induced drawdowns will be less than 170 feet. For this hypothetical case, the volume of contaminated ground water would be 2×10^8 ft³, assuming a porosity of 0.30. This volume is 4,600 acre-feet and, at a value of \$105 per acre-foot (State of Utah, 1983), the loss of resource would be \$480,000.

Spatial apportionment method

A second method of calculating the loss of benefit due to the volume of contamination is to assume that a portion of the water rights claimed within a half-mile radius of the Vitro site is not available during the natural purging of the unconfined aquifer. Contaminated, unconfined ground water cannot be used during the 4.4 to 23.7 year purging period due to contamination. Also, for a worst-case assessment, it is assumed that ground water beneath the contaminated area cannot be used for the full purging period. The ground water upgradient or lying outside of the contaminated boundary is not affected and may be used to fulfill water rights. Apportionment is made as to the percentage of the surrounding water rights that will be reduced or not available. Even though a greater density of water rights are in the area outside the contaminated area, for conservatism it is assumed that water rights are equally distributed throughout the half-mile radius circle.

A circle with a half-mile radius has an area of $2.2 \times 10^7 \text{ ft}^2$. The maximum area of the plume is $6.7 \times 10^6 \text{ ft}^2$ (see Figure D-13). The contaminated area is approximately 30 percent of the area of the circle. There are 7,790 acre-feet per year of total water rights within the area of the circle (State of Utah, 1983). Thirty percent of this would be 2,340 acre-feet. At a value of \$105 per acre-foot, the annual loss of ground water use would be a maximum of \$245,000 per year.

D.3.6.3 Aquifer restoration techniques

There are several methods to remove the contaminants contained within the plume. These include:

- Intercept trench with recharge control.
- Barrier walls and removal by pumping.
- Pumping of Contaminated water and recharging of fresh water using a series of wells.

All of these methods would lead to treatment and disposal of discharge.

Using EPA 1982 as a guideline, the intercept trench with recharge control appears to be the least expensive and most efficient method for the hydrogeologic setting by the Vitro site. The barrier walls with pumping would require a greater capital investment, take more time for cleanup, and cause greater mixing of uncontaminated and contaminated water. The pumping/recharge system is more expensive, would take considerably more time, and may cause differential settlement or fail completely in the highly stratified, unconsolidated unconfined aquifer.

Plume capture methodology

The intercept trench would be placed across the plume, between the Jordan River and 1000 West Street (see Figure D-13). Another intercept trench may be required between the northern end of 100 West Street and well number 4. The location of the trench(es) would be dependent on the result of a site investigation conducted at the beginning of installation of a remedial action program to define and quantify the plume in the area west and north of well number 4. For the purpose of this analysis, it was assumed there would be 1900 lineal feet of trench, four feet wide and to a depth of 50 feet. A trench of this nature would intercept the contaminant plume and passively collect it at a rate of about 500 to 1000 gpm. These values were calculated using the line sink method in Lohman (1972), with transmissivity = 1000 ft^3/day , storativity = 0.3, change in drain state of 50 ft and time = 100 days and 365 days. The trench would be sloped to one end where a sump would collect the captured liquid and the liquid would be pumped to a treatment plant. The bottom of the trench would be sealed with clay.

Recharge from the Jordan River would be controlled by the use of a barrier to prevent Jordan River water from entering the treatment collection system and diluting the effectiveness of the collection and treatment system (Figure D-13). For this analysis, the barrier would be an interlocking steel barrier pile driven into the ground between the intercept trench and the river. This barrier, although not a complete control method, should control a sufficient quantity of recharge to prevent significant dilution in the trench (EPA, 1982).

Plume treatment

The goal of the treatment plant would be to generate an effluent of sufficient quality to discharge to the surface waters of the State of Utah. In addition to the effluent, the treatment plant would generate a sludge that would contain uranium and possibly other radioactive contaminants. (For the purposes of this analysis, it has been assumed that the sludge will require disposal at a low-level hazardous waste disposal site.)

The treatment plant will involve the following processes (Sherwood, 1983):

1. Neutralization to a pH of 8.0 to 9.0 to precipitate most metals and neutralize the residual acid. Sulfate (SO_4^{--}), would remain in solution. The operating costs of the neutralization facilities are based on lime as a neutralization agent.
2. Fixation -- The sludge generated in the neutralization step would be settled and then stabilized by a stabilizing agent, such as CHEMFIX, after dewatering so that it could be handled by normal construction equipment for disposal.
3. Reverse osmosis -- In order to obtain a discharge permit, the treatment plant effluent would be required to meet nondegradation standards (State of Utah, 1978) for the receiving stream (Jordan River). The primary contaminant not meeting the nondegradation standards after treatment would be TDS and sulfate. Reverse osmosis would be used to remove TDS and sulfate to meet the effluent discharge standards.

The capital costs for installation of the ground-water removal system and treatment plant are summarized in Table D-29. This estimate of capital costs does not include:

- Financing costs of the project.
- Right of ways and land acquisition.
- Removal or rerouting of utilities.
- Rerouting and reconstruction of roadways crossed by intercept trench.
- Drainage control of irrigation ditches and canals during construction and operation.

Table D.29 Estimated capital costs, ground-water removal and treatment, Vitro site

Task description	Basis	Unit cost	Task cost (\$) for 500 gpm system	Task cost (\$) for 1000 gpm system
Ground-water investigation to define aquifer	-----	350,000	350,000	350,000
Sheet piling of intercept trench	3800 LF x 50 cy	13.75/sq ft	2,612,500	2,612,500
Excavation of intercept trench	14,000 cy	2.50/cy	35,000	35,000
Clay baseliner	2,000 cy	25.00/cy (in-place)	50,000	50,000
Select washed gravel trench fill	12,000 cy	8.50/cy	102,000	102,000
Recover sheet piling	3800 LF x 50 ft	1.33/sq ft	252,700	252,700
Redrive sheet piles at river	3800 LF x 50 ft	2.72/sq ft	516,800	516,800
Additional sheet piling required at river	400 LF x 50 ft	13.75/sq ft	275,000	275,000
Removal system	Includes pumps & piping to move water 2,500 ft to treatment plant	75,000	75,000	150,000
Neutralization facility	Reaction tank, controller, dewatering, sludge handling	600,000	600,000	1,200,000
Fixation	Mixing tank, dewatering and settling ponds, water control	750,000	750,000	1,500,000
Reverse osmosis	-----	3,200,000	3,200,000	6,400,000
Discharge system	-----	300,000	300,000	600,000
TOTAL CAPITAL COST			8,774,000	14,044,000
^a Salvage value			2,612,000	3,670,000
Net Capital Cost			6,162,000	10,374,000

^aBased on 20% recovery for treatment system and 50% recovery for sheet piling.

The ground water would be captured at a rate of approximately 500 to 1000 gpm and it is estimated that approximately 250 to 500 gpm would be from the plume while the remainder would be ambient, unconfined ground water. At this collection rate, it is estimated that the remedial action will require approximately three to six years to completely remove the 1×10^8 ft³ plume. The annual operating costs are shown in Table D-30. Estimates are given for treatment of discharges of 500 gpm and 1000 gpm on Table D.30.

Table D-30 Estimated annual operating costs for ground-water removal and treatment, Vitro site

System	Operation	Cost (\$)	
		500 gpm - Discharge	1000 gpm
Collection and Removal	Labor	40,000	70,000
	Maintenance materials	50,000	100,000
Treatment and Disposal	Labor	125,000	225,000
	Maintenance materials	115,000	230,000
	Reagents	1,150,000	2,300,000
	Disposal	200,000	350,000
Monitoring and Analytical	Labor	50,000	50,000
	Chemistry	200,000	200,000
Annual Operating Costs		1,930,000	3,525,000

D.3.6.4 Comparison of benefits and costs

Benefits were calculated using two different methods:

- Maximum lost value of degraded or potentially degraded water resource on a volumetric basis.
- Lost value according to spatial apportionment of water rights.

In addition, a range of time required for natural purging of the contamination was considered. This range is 4.4 to 23.7 years. Also, two periods and rates of discharges, 500 gpm discharge for six years and 1000 gpm discharge for three years with trenching are considered. Table D-31 contains the cost-benefit ratios calculated for the eight possibilities.

The total cost is calculated as the capital cost plus the annual cost multiplied by the number of years of required treatment. The benefit using the maximum lost value is the sum of lost value to the unconfined and confined systems (\$240,000 + \$480,000 = \$720,000). The benefit using the spatial

apportionment approach is the difference between the time required for natural purging and the time required for treatment multiplied by the annual loss of benefit (\$245,000). No benefit is considered for the Jordan River because, with dilution, the ground-water contamination does not restrict its use. As shown on Table D-31, the boundary cost-benefit ratios are 4.1 and infinity. Given the conservatism of the analysis, i.e., maximum possible benefits and costs discounted, aquifer restoration seems unwarranted.

Table D-31 Summary of cost-benefit analysis

Lost value volumetric or spatial apportionment	Range in possible time for natural purging	Range in treatment discharges	Total benefit (\$-000)	Total cost (\$-000)	Cost: Benefit ratio
Lost value calculated by volume of contaminated and poten- tially contam- inated water resource	4.4 year natural purging	3-year treatment	720	20900	29
		6-year treatment	720	17700	25
	23.7 year natural purging	3-year treatment	720	20900	29
		6-year treatment	720	17700	25
Lost value calculated by spatial apportion- ment	4.4 year natural purging	3-year treatment	340	20900	61
		6-year treatment	0.0	20900	infinite
	23.7 year natural purging	3-year treatment	5070	20900	4.2
		6-year treatment	4340	17700	4.1

D.3.6.5 Potential use of the unconfined aquifer after remedial action

The highest level of uranium detected in water off the site is 2.24 ppm in shallow well 9C. An individual drinking this water exclusively over a period of years would have an increased risk of developing cancer. (Direct consumption of such water would represent the most significant exposure pathway.) This is considered very unlikely, because the area is not residential, public water supplies are available, and the preferred ground-water source is the deep aquifer. Even if an individual should drink such water, the high level of TDS and sulfates would result in ill effects such as diarrhea and dehydration; such water would not be consumed on a long-term basis. Nonetheless, DOE will review with NRC and the State of Utah the desirability of mitigation measures to limit use of the shallow ground-water system downgradient of the Vitro site.

D.4 CONCLUSIONS AND SUMMARY - VITRO SITE

- Downgradient contamination in the unconfined system represents a relic source and relic plume. The source of the uranium was modeled as a point source of concentration 7.76 mg/l at a distance 700 feet east of the site boundary. Significant contaminant migration appears to have been along a narrow band defined by wells Nos. 9 and 11.
- Present concentrations of contaminant migration from the tailings in the unconfined ground water are best defined by the water sample taken from the CVWRF excavation and consideration of the source of this water. This water sample shows no elevation of concentrations of nitrate, aluminum, arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, zinc, vanadium, thorium-230, lead-210, chloride, sulfate, or total dissolved solids. Uranium and molybdenum do show elevated concentrations.
- The unconfined aquifer has limited use due to poor water quality and low yield.
- Downgradient contamination in the confined system can best be explained by vertical hydraulic gradient reversal during active milling at the Vitro site. No further contamination will occur unless the vertical hydraulic gradient is reversed again.
- Percolation from the surface to the unconfined aquifer is (approximately) equal to the present upward leakage from the confined aquifer to the unconfined aquifer.
- If the saturated soils underlying the embankment are as permeable or more permeable than laterally adjacent soils, then a ground-water mound will not form beneath the embankment.
- With a liner system beneath the embankment, uranium and trace metals will not enter the ground water from the embankment under the worst conditions for at least 700 years.
- With a liner system beneath the embankment, off-site contaminant concentrations due to solute transport from the tailings will be less than any present or proposed drinking water standards.
- Aquifer restoration does not seem warranted given the range of calculated cost:benefit ratios (4.1 to infinity) and the current and predicted future absence of use in the maximum area of possible contamination.
- Although the likelihood of human health impacts from uncontrolled use of the unconfined aquifer downgradient of the Vitro site is considered very small, DOE will review with NRC and the State of Utah the desirability of mitigation measures to limit the use of this ground water.

D.5 GEOHYDROLOGY - SOUTH CLIVE SITE

The South Clive site lies near the periphery of the northern Great Salt Lake Desert. Two ground-water systems are in the vicinity of the site. The largest consists of unconsolidated to partly consolidated valley fill which ranges to more than 1600 feet in thickness. An idealized stratigraphic relationship is shown in Figure D-14. The valley fill aquifer does not transmit water uniformly, exhibiting a wide range in transmissivity. The water quality in the valley fill is generally characterized as briny.

The other ground-water system in the vicinity of the South Clive site is the alluvial fan aquifer which borders much of the floor of the northern Great Salt Lake Desert. The alluvial fan aquifer consists of both surficial deposits and underlying unconsolidated to well-cemented older alluvium. Water in the alluvial fan aquifer is derived from recharge above the desert floor (e.g., the Cedar Mountains to the east of the site) and discharges into the valley fill aquifer. The locally fresh to slightly saline water in the alluvial fan aquifer comprises much of the usable ground water in the northern Great Salt Lake Desert.

D.5.1 Existing geohydrology

The water table at the South Clive site ranges from about 25 to 35 feet below the ground surface, with saturated conditions extending to at least 230 feet deep. The apparent hydraulic gradient is about 2.8 feet per mile, sloping gradually to the north-northeast (Figure D-15). The magnitude and direction was determined from static water levels measured in wells. Given that ground-water recharge occurs from the east and the surface slope is to the southwest, the expected hydraulic gradient should be generally to the west-southwest. There are several possible explanations for the discrepancy between the apparent, measured hydraulic gradient and the expected hydraulic gradient:

- The gradient is shallow and possible surveying errors could cause an apparent reversal of the hydraulic gradient. A new survey has just been completed.
- Wells were completed in different stratigraphic units and the vertical hydraulic gradient may have a great enough magnitude to cause an apparent reversal of the hydraulic gradient (see Figures D-16 through D-19). For example, on Figure D-18, the measured water levels are lower at well SC-4 than SC-10 but SC-4 is completed in the clayey silt as well as an underlying sand with fines while SC-10 is completed in the clayey silt only.
- A localized recharge from precipitation and snowmelt may affect water levels at some wells differently than at other wells.

Measured fluctuations in ground-water elevations over time are generally less than 1 foot (Table D-32).

WEST

EAST

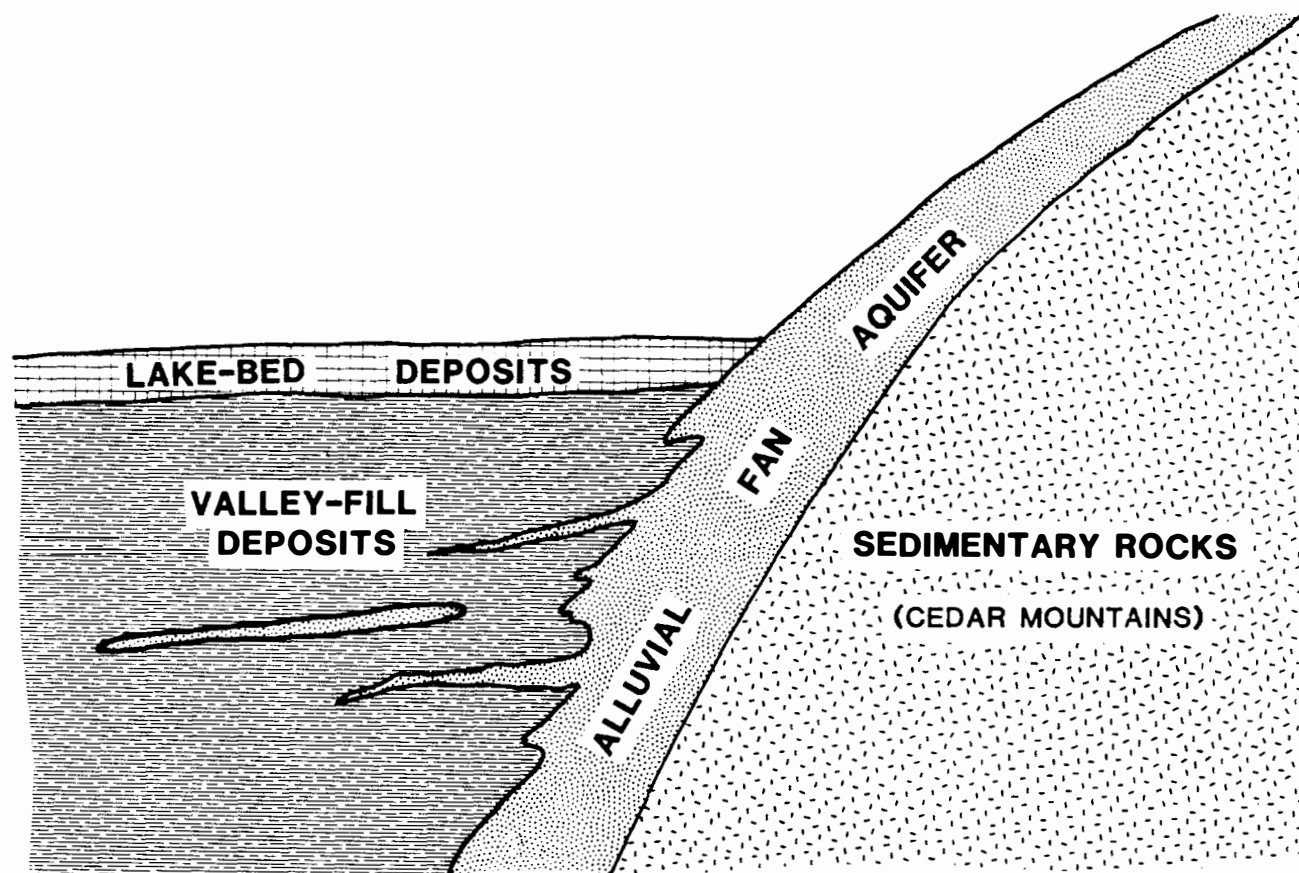


FIGURE D-14
IDEALIZED STRATIGRAPHIC RELATIONSHIP
NEAR SOUTH CLIVE SITE

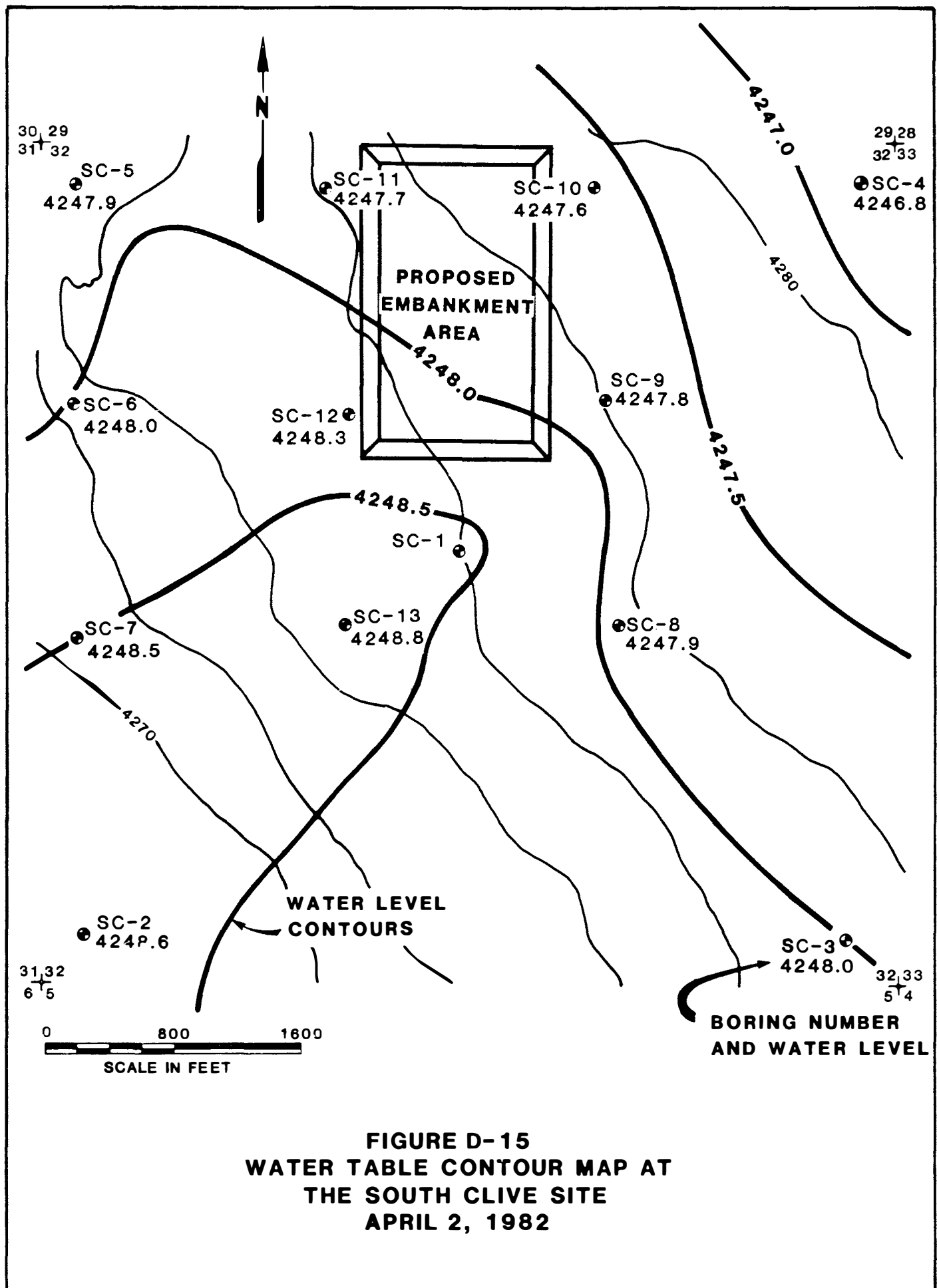


Table D-32. Ground-water elevations at the South Clive site

Boring number	Ground surface elevation ^a (feet)	Elevation top of casing (feet)	Ground-water elevations in feet above MSL ^a												
			Date of measurement												
			9-22-81	9-23-81	9-24-81	9-29-81	9-30-82	2-12-82	2-26-82	3-8-82	3-17-82	4-2-82	7-14-8	9-26-83	10-13-83
SC-1	4276.1	4279.4				4250.1	4247.2	4248.3	4248.2	4248.5	4248.6	4248.3		4248.6	
SC-2	4269.2	4276.6	4248.4				4248.4	4249.1	4248.6	4248.6	4248.6		4248.2	4248.2	4250.2
SC-3	4277.3	4280.5			4248.0		4247.8	4248.0	4248.0	4248.1	4248.0	4247.2		4248.3	
SC-4	4280.7	4284.8				4246.6	4245.8	4246.6	4246.6	4246.0	4246.8	4246.4		4246.7	
SC-5	4273.5	4276.3		4247.4	4247.5		4247.5	4247.4	4247.4	4247.8	4247.9	4247.6	4247.0	4248.0	4248.5
SC-6	4272.6	4276.5						4248.0	4247.8	4248.1	4248.0	4248.0		4248.6	4247.6
SC-7	4270.1	4274.7						4248.6	4248.4	4248.5	4248.5	4248.1		4249.6	4249.1
SC-8	4277.8	4282.9						4247.9	4247.9	4248.0	4247.9	4247.5	4247.8	4248.3	
SC-9	4278.8	4283.2						4247.7	4247.6	4247.7	4247.8	4247.3	4248.3	4247.8	
SC-10	4280.0	4284.1						4247.4	4247.6	4247.6	4247.6	4247.2	4248.0	4248.0	
SC-11	4276.0	4280.8						4247.6	4247.5	4247.1	4247.7	4247.2		4248.0	
SC-12	4274.9	4277.5						4247.5	4247.5	4247.6	4248.3	4248.1		4249.9	
SC-13	4274.4	4279.5						4248.5		4248.6	4248.8			4249.4	

^aMean sea level datum.

Studies of the hydrology of nearby areas indicate that there is minimal potential for significant ground-water recharge on the site. The low annual precipitation and fine-grained lake deposits below about 4600 feet tend to limit infiltration to the underlying ground water (Price and Bolke, 1970). Recharge may be concentrated on the more permeable alluvial fan deposits, and averages only 6 to 10 percent of the total precipitation on the drainage basin (Hood and Waddell, 1968). It is believed that ground water from the alluvial fan deposits recharges the valley fill deposits. The South Clive site is on the periphery of the northern Great Salt Lake Desert hydrologic province, where it is reported that precipitation contributes little, if any, recharge to the shallow system (Stephens, 1974).

D.5.2 Data Sources

Information about subsurface conditions at the site is based on 13 borings in the vicinity of the site (DOE, 1983). The boring locations are the same as the well locations shown in Figure D-15. The borings extended to between 43 and 251 feet below the ground surface. All of the borings were used to install observation wells (Table D-33). Four additional wells were constructed for use during pump tests. Four soil profiles across the site were constructed from well logs (see Figures D-16, D-17, D-18, and D-19).

Table D-33. Well construction details - South Clive site

Well ^a number	Well dia (in)	Blank interval (ft)	Screened interval (ft)	Sand pack interval (ft)	Grout seal interval (ft)	Bentonite seal interval (ft)	Back fill interval
SC-1	2	+3.17 - 219.8	219.8 - 229.8	100.0 - 229.8	0.0 - 68.0	68.0 - 73.0	73.0 - 100.0
SC-2	2	+3.25 - 18.5	18.5 - 48.5	16.0 - 48.5	0.0 - 5.5	none	5.5 - 16.0
SC-3	2	+3.25 - 30.5	30.5 - 50.5	23.0 - 50.5	0.0 - 5.0	none	5.0 - 23.0
SC-4	2	+4.25 - 31.5	31.5 - 51.5	29.5 - 51.5	0.0 - 4.0	none	4.0 - 29.5
SC-5	2	+2.67 - 31.5	31.5 - 51.5	29.0 - 51.5	0.0 - 4.0	none	4.0 - 29.0
[SC-6	1.5	+3.85 - 30.0	30.0 - 45.0	30.0 - 46.0	0.0 - 5.0	none	5.0 - 30.0
SC-7	6	+3.80 - 41.0	41.0 - 56.0	32.0 - 56.0	0.0 - 5.0 10.0 - 31.0	31.0 - 32.0	5.0 - 10.0
SC-7A	1.5	+4.65 - 28.5	28.5 - 43.5	28.0 - 43.5	0.0 - 5.0	none	5.0 - 28.0
SC-7B	1.5	+3.00 - 45.0	46.0 - 55.0	38.0 - 55.0	0.0 - 5.0 17.0 - 37.0	37.0 - 38.0	5.0 - 17.0
SC-8	6	+3.00 - 40.0	40.0 - 55.0	35.0 - 55.0	0.0 - 5.0 14.0 - 34.0	34.0 - 35.0	5.0 - 14.0
SC-8A	1.5	+2.70 - 34.3	34.3 - 49.3	33.0 - 49.3	0.0 - 5.0	none	5.0 - 33.0
SC-8B	1.5	+3.00 - 45.0	45.0 - 55.0	40.0 - 55.0	0.0 - 5.0 12.0 - 39.0	39.0 - 40.0	5.0 - 12.0
SC-9	1.5	+4.35 - 30.0	30.0 - 45.0	28.5 - 45.0	0.0 - 4.0	none	4.0 - 20.5
SC-10	1.5	+3.95 - 33.0	33.0 - 48.0	32.5 - 48.0	0.0 - 4.0	none	4.0 - 32.5
SC-11	1.5	+4.70 - 30.0	30.0 - 45.0	29.0 - 45.0	0.0 - 3.5	none	3.5 - 29.0
SC-12	1.5	+3.25 - 63.0	53.0 - 58.0	47.5 - 58.0	0.0 - 46.5	46.5 - 47.5	-
SC-13	1.5	+5.07 - 52.0	52.0 - 55.0	45.5 - 55.0	-	43.0 - 45.5	0.0 - 43.0

^aFor well locations see Figure D-15.

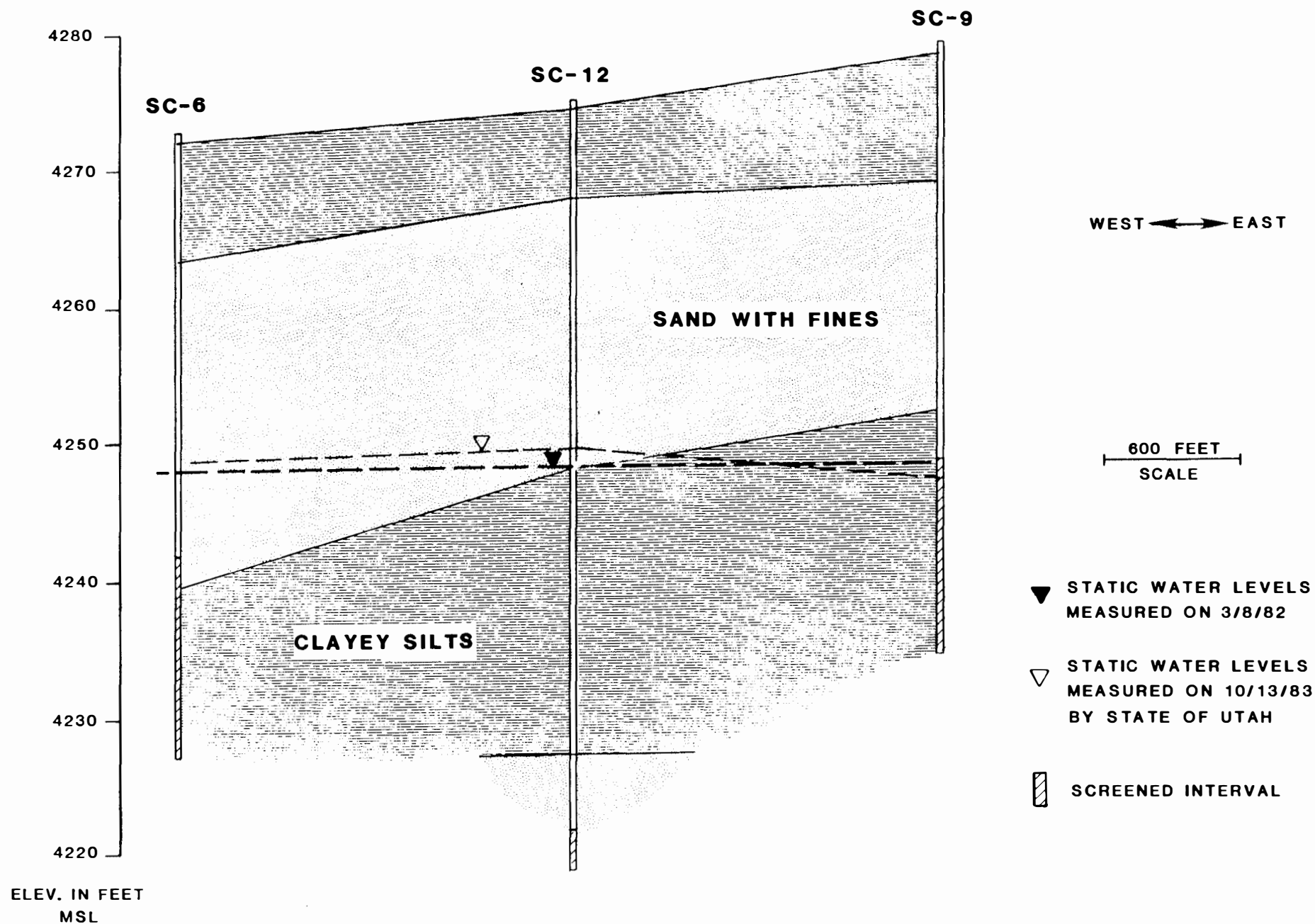


FIGURE D-16
EAST-WEST SOIL PROFILE CENTER OF SOUTH CLIVE DISPOSAL SITE

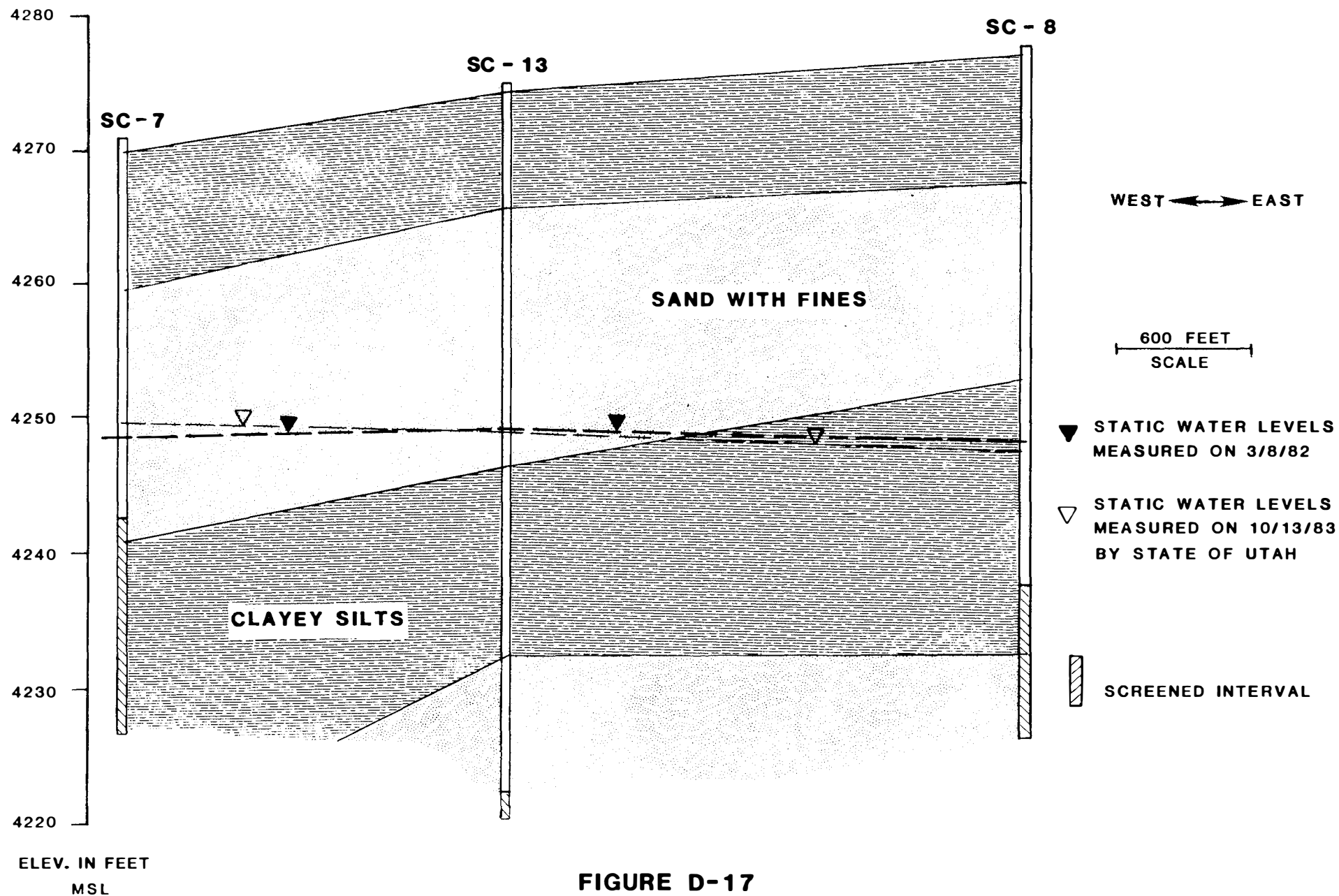


FIGURE D-17
EAST-WEST SOIL PROFILE SOUTH OF SOUTH CLIVE DISPOSAL SITE

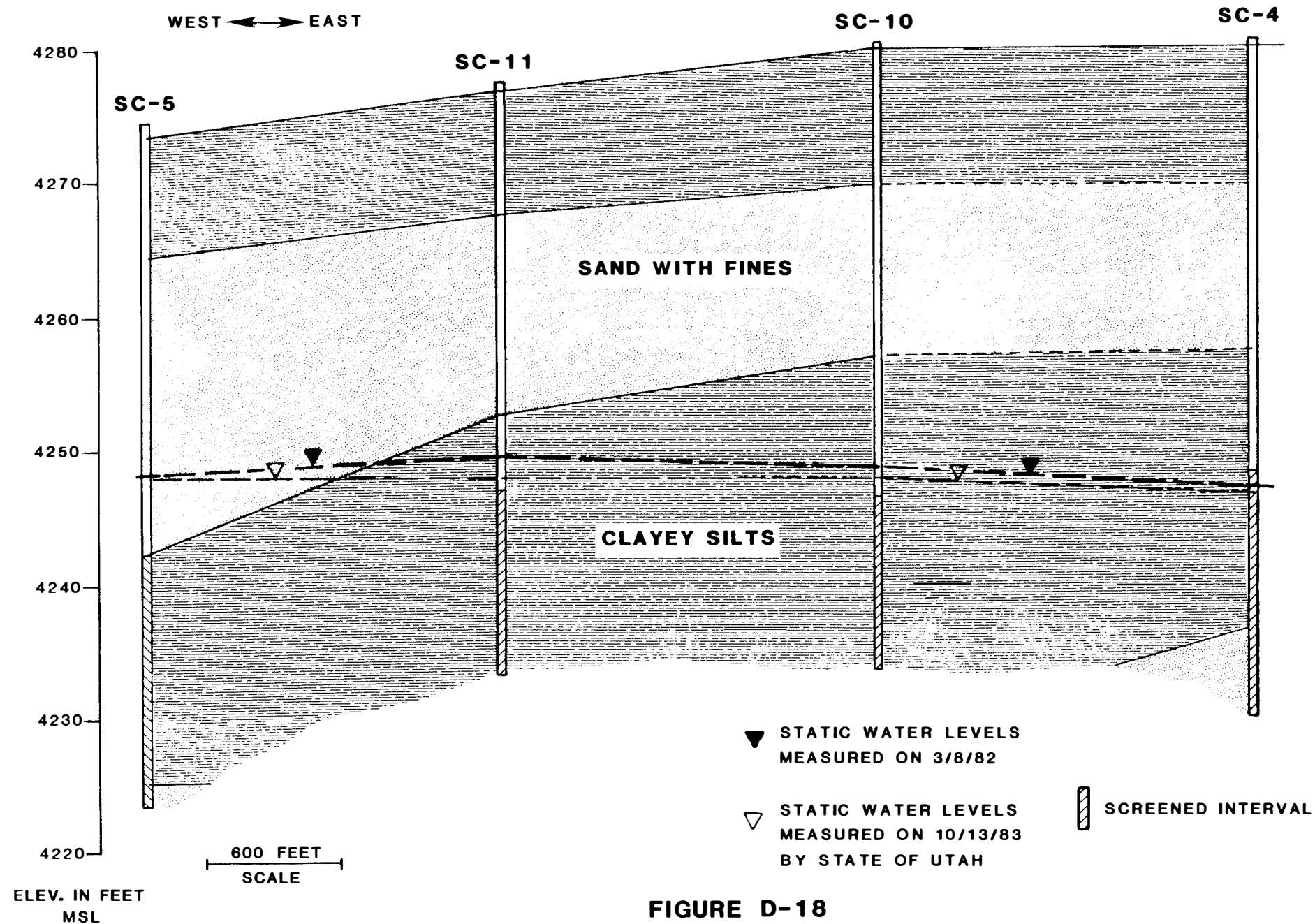


FIGURE D-18
EAST-WEST SOIL PROFILE NORTH OF SOUTH CLIVE DISPOSAL SITE

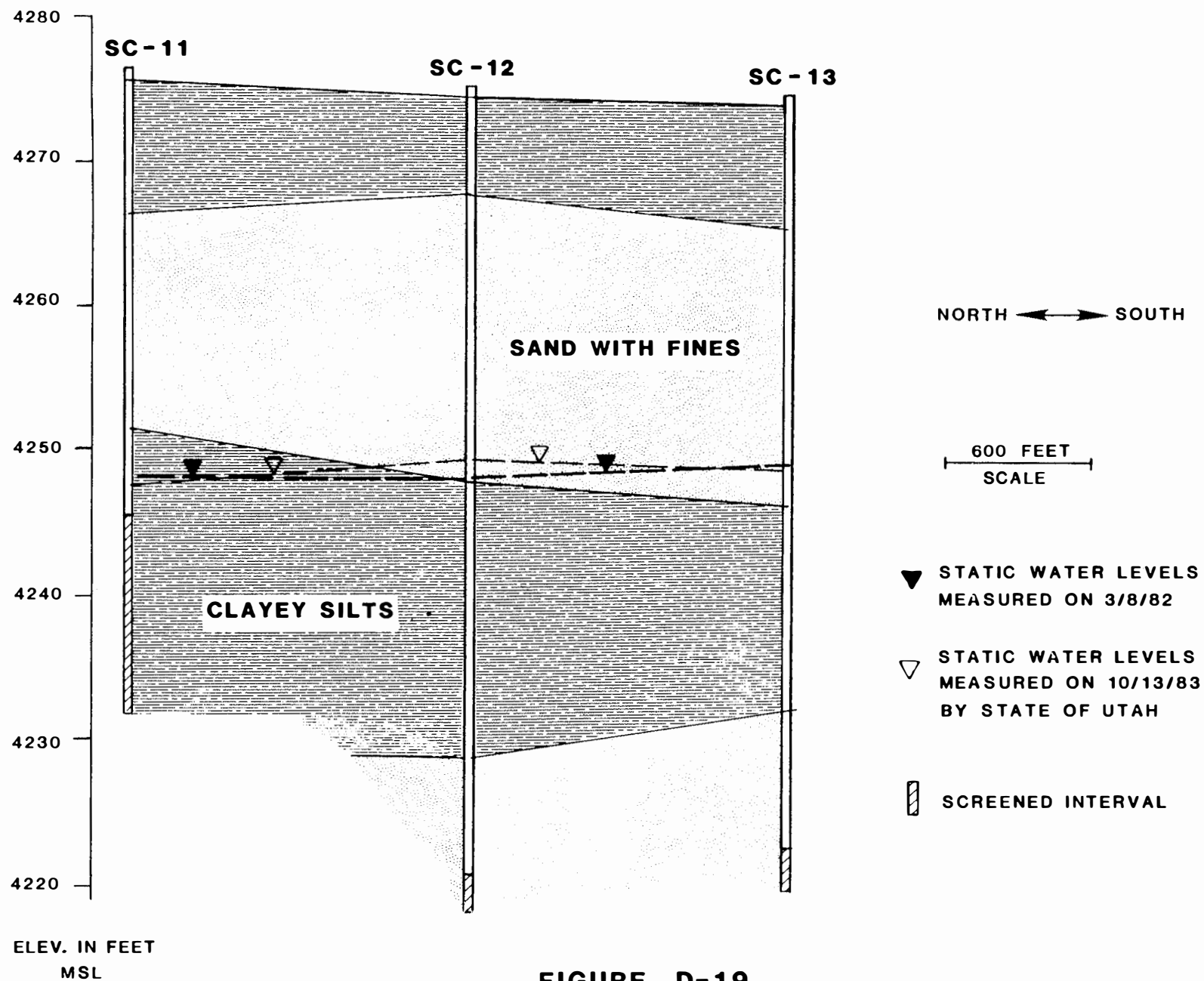


FIGURE D-19
NORTH-SOUTH SOIL PROFILE CENTER OF CLIVE DISPOSAL SITE

Pump tests were done at two wells, no. 7 and no. 8. For each of the tests, water levels were measured in both the pumping well and two nearby observation wells (Table D-34). Water levels were measured in all wells during both the drawdown and the recovery phases of the test. Initial analyses of the test data, using the Theis method, Jacob's method, and Theis' Recovery Method, indicate transmissivities ranging between 0.8 to 166 ft²/day, with a mean value of approximately 40 ft²/day.

D.5.3 Existing water quality

Ground-water samples from five monitoring wells at the South Clive site were obtained and analyzed for major cations and anions, metals, and radionuclides. The wells were sampled four times over the course of a year in order to define temporal variation in water quality. Results of the analyses are presented in Table D-35.

The ground water at the South Clive site is characterized by high levels of sodium, chloride, magnesium, sulfate, bicarbonate, and total dissolved solids. There is no indication of significant seasonal variation in water quality. Concentrations of total dissolved solids ranged between about 20,000 mg/l to about 50,000 mg/l. The water can be classified as unfit for all but limited industrial uses without extensive treatment, but could be used for dust control during disposal of tailings.

Significant concentrations of radionuclides are reported for analyses of water samples at the South Clive site. Dissolved uranium ranged from 2.7 to 35.9 pCi/l (0.004 to 0.053 mg/l). Reported concentrations of radon daughters were mostly reported on a "total" basis rather than a "dissolved" basis, but one analysis reported 6.8 ± 1.6 pCi/l of Pb-210 on a dissolved basis. Ra-226 was not reported on a dissolved basis.

D.5.4 Water uses

Other than the 17 monitoring wells installed for the UMTRA project, there are no existing ground-water wells on or near the South Clive site. The closest known wells are approximately 3 miles northwest and 3.4 miles east of the site. Locations of these and other nearby wells are listed in Table D-36 and shown on Figure D-20. The well west of the site has been destroyed; one of the two wells east of the site is in current use to water livestock--the second well was destroyed. In the Bonneville Salt Flats to the west, high salinity ground water is used for mineral extraction.

Without extensive treatment, use of the ground water in the South Clive area would appear to be confined to very limited industrial uses. In general, the use of ground water and surface water in the Great Salt Lake Desert is concentrated along mountain fronts where the majority of fresh ground water and spring discharge occurs.

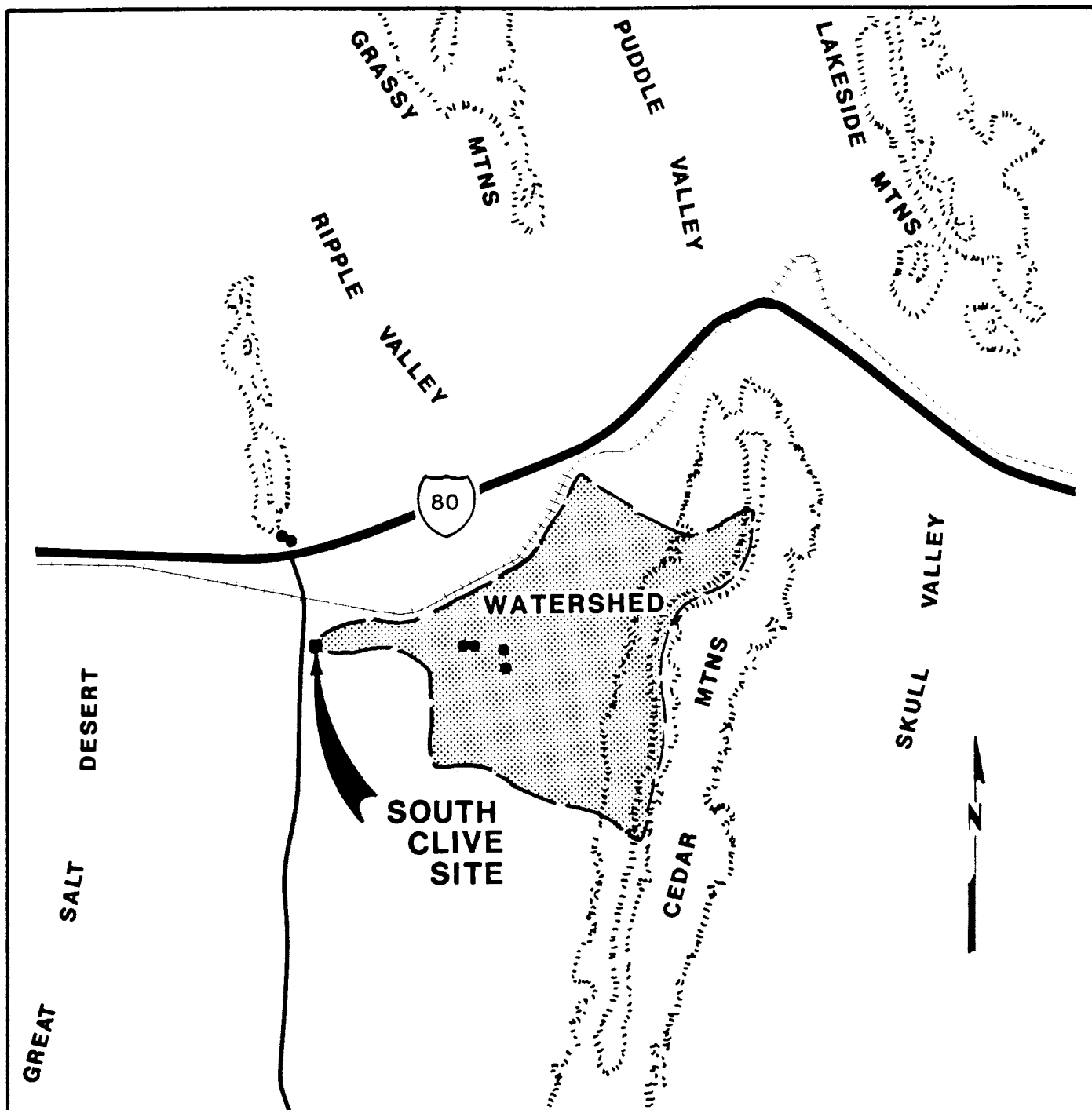
Table D-34. Pump tests - South Clive site

Test No. 1

<u>Well ID</u>	<u>Use of well</u>	<u>Distance to pumped well (ft)</u>
7	pumping	0
7A	observation	8.9
7B	observation	15.7

Test No. 2

<u>Well ID</u>	<u>Use of well</u>	<u>Distance to pumped well (ft)</u>
8	pumping	0
8A	observation	9.4
8B	observation	21.5



2 0 2 4
SCALE IN MILES

LEGEND

- SELECTED WELL IN THE SOUTH CLIVE AREA

FIGURE D-20
SOUTH CLIVE WATERSHED

Table D-35 . Chemical ground-water quality - South Clive site

Parameter (metals)	Well number ^a				
	SC-1	SC-2	SC-3	SC-4	SC-5
Date sampled	9/30/81	9/22/81	9/24/81	9/29/81	9/23/81
Aluminum - (Al)	<0.1 ^b	<0.1	<0.1	<0.1	<0.1
Arsenic (As)	- ^c	-	-	-	-
Arsenic - total (As)	0.01	0.01	0.04	0.07	0.01
Barium (Ba)	-	-	-	-	-
Barium - total (Ba)	<0.1	0.1	2.9	4.2	2.7
Boron - total (B)	0.24	0.98	2.99	0.28	0.56
Cadmium (Cd)	-	-	-	-	-
Cadmium - total (Cd)	0.11	0.12	0.17	0.15	0.18
Chromium (Cr)	-	-	-	-	-
Chromium - total (Cr)	0.03	0.07	0.27	0.37	0.26
Cobalt (Co)	-	-	-	-	-
Copper (Cu)	-	-	-	-	-
Copper - total (Cu)	0.07	0.10	0.26	0.36	0.34
Iron (Fe)	0.14	0.25	0.16	0.14	0.11
Iron - total (Fe)	2.50	24.70	146	229	167
Lead (Pb)	-	-	-	-	-
Lead - total (Pb)	0.6	<0.05	<0.1	0.8	<0.1
Magnesium (Mg)	460	920	400	420	310
Manganese (Mn)	0.63	0.11	0.08	0.22	0.11
Manganese - total (Mn)	-	-	-	-	-
Mercury - total (Hg)	2.7	1.0	0.8	2.0	1.9
(in micrograms per liter)					
Molybdenum (Mo)	<0.1	0.8	<0.1	<0.1	<0.1
Nickel - (Ni)	-	-	-	-	-
Potassium (K)	310	530	430	320	390
Selenium (Se)	<0.01	<0.01	<0.01	<0.01	<0.01
Selenium - total (Se)	-	-	-	-	-
Silver (Ag)	0.07	0.09	0.05	0.07	0.04
Silver - total (Ag)	-	-	-	-	-
Sodium (Na)	11,500	160,000	11,000	12,000	9,140
Sodium - total (Na)	-	-	-	-	-
Strontium (Sr)	9.50	15.20	10.70	12.50	14.60
Vanadium (V)	<0.5	<0.5	<0.5	<0.5	<0.5
Zinc (Zn)	0.07	0.05	0.08	0.05	0.06
Zinc - total (Zn)	-	-	-	-	-

^a For well locations, see Figure D-15.^b All values in milligrams per liter on a dissolved basis, unless otherwise noted.^c - indicates concentration not determined.

Table D-35. (continued)

Parameter (metals)	Well number				
	SC-1	SC-2	SC-3	SC-4	SC-5
Date sampled	2/8/82	2/8/82	2/8/82	2/8/82	2/8/82
Aluminum (Al)	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic (As)	0.02	0.06	0.01	0.01	0.02
Arsenic - total (As)	0.02	0.06	0.02	0.01	0.03
Barium (Ba)	0.4	<0.1	<0.1	<0.1	<0.1
Barium - total (Ba)	0.4	0.5	5.4	1.2	2.7
Boron (B)	0.93	1.90	1.80	1.50	1.30
Cadmium (Cd)	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium - total (Cd)	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium (Cr)	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium - total (Cr)	0.01	0.04	0.23	0.10	0.14
Cobalt (Co)	<0.1	<0.1	<0.1	<0.1	<0.1
Copper (Cu)	<0.01	<0.01	<0.01	<0.01	<0.01
Copper - total (Cu)	0.01	0.04	0.27	0.07	0.18
Iron (Fe)	0.07	0.17	0.14	0.12	0.13
Iron - total (Fe)	0.84	27.00	240	59.00	150
Lead (Pb)	<0.05	<0.05	<0.05	<0.05	<0.05
Lead - total (Pb)	<0.05	<0.05	0.14	0.05	0.12
Magnesium (Mg)	310	790	400	400	270
Manganese (Mn)	0.24	0.09	0.09	0.13	0.11
Manganese - total (Mn)	0.28	0.83	6.40	1.21	3.84
Mercury - total (Hg)	<0.3	0.3	<0.3	<0.3	0.3
(in micrograms per liter)					
Molybdenum (Mo)	<0.1	0.5	<0.1	<0.1	<0.1
Nickel (Ni)	<0.05	<0.05	<0.05	<0.05	<0.05
Potassium (K)	220	400	360	310	300
Selenium (Se)	<0.01	<0.01	<0.01	<0.01	<0.01
Selenium - total (Se)	<0.01	0.02	0.01	0.01	<0.01
Silver (Ag)	<0.01	<0.01	<0.01	<0.01	<0.01
Silver - total (Ag)	<0.01	<0.01	<0.01	<0.01	<0.01
Sodium (Na)	6,200	17,000	12,000	12,000	8,700
Sodium - total (Na)	6,200	17,000	12,000	12,000	8,700
Strontium (Sr)	9.90	20.60	14.60	15.40	18.70
Vanadium (V)	<0.5	<0.5	<0.5	<0.5	<0.5
Zinc (Zn)	0.04	0.05	0.08	0.16	0.09
Zinc - total (Zn)	0.05	0.15	3.10	0.28	0.58

Table D-35. (continued)

Parameter (metals)	Well number				
	SC-1	SC-2	SC-3	SC-4	SC-5
Date sampled	6/2/82	6/2/82	6/2/82	6/2/82	6/2/82
Aluminum (Al)	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic (As)	0.01	0.05	0.01	0.01	0.02
Arsenic - total (As)	0.01	0.05	0.02	0.01	0.02
Barium (Ba)	<0.1	<0.1	<0.1	<0.1	<0.1
Barium - total (Ba)	0.2	1.4	2.5	1.2	0.4
Boron (B)	2.63	3.08	2.63	2.53	2.43
Cadmium (Cd)	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium - total (Cd)	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium (Cr)	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium - total (Cr)	<0.01	0.10	0.16	0.14	0.02
Cobalt (Co)	<0.1	<0.1	<0.1	<0.1	<0.1
Copper (Cu)	<0.01	<0.01	<0.01	<0.01	<0.01
Copper - total (Cu)	0.02	0.11	0.14	0.11	0.10
Iron (Fe)	0.20	0.18	0.11	0.12	0.06
Iron - total (Fe)	1.11	38.00	65.00	47.00	6.00
Lead (Pb)	<0.05	<0.05	<0.05	<0.05	<0.05
Lead - total (Pb)	<0.05	<0.05	<0.05	<0.05	<0.05
Magnesium (Mg)	560	850	470	450	280
Manganese (Mn)	0.92	0.06	0.04	0.11	0.09
Manganese - total (Mn)	0.95	0.06	0.04	0.13	0.10
Mercury - total (Hg) (in micrograms per liter)	<0.3	<0.3	<0.3	<0.3	<0.3
Molybdenum (Mo)	<0.1	0.5	<0.1	<0.1	<0.1
Nickel (Ni)	<0.05	<0.05	<0.05	<0.05	<0.05
Potassium (K)	310	380	350	300	280
Selenium (Se)	<0.01	<0.01	<0.01	<0.01	<0.01
Selenium - total (Se)	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (Ag)	<0.01	<0.01	<0.01	<0.01	<0.01
Silver - total (Ag)	<0.01	<0.01	<0.01	<0.01	<0.01
Sodium (Na)	12,000	14,000	11,500	11,500	8,150
Sodium - total (Na)	12,000	14,000	11,500	12,000	8,700
Strontium (Sr)	10.90	16.20	12.00	12.20	14.00
Vanadium (V)	<0.5	<0.5	<0.5	<0.5	<0.5
Zinc (Zn)	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc - total (Zn)	0.30	2.20	1.50	2.10	1.30

Table D-35. (continued)

Parameter (metals)	Well number				
	SC-1	SC-2	SC-3	SC-4	SC-5
Date sampled	8/25/82	8/25/82	8/25/82	8/25/82	8/25/82
Aluminum (Al)	<0.1	0.5	0.1	<0.1	<0.1
Arsenic (As)	<0.01	0.02	<0.01	<0.01	0.02
Arsenic - total (As)	<0.01	0.02	0.01	<0.01	0.02
Barium (Ba)	<0.1	<0.1	<0.1	<0.1	<0.1
Barium - total (Ba)	0.2	0.4	3.3	0.2	0.2
Boron (B)	1.95	2.68	2.79	2.10	1.96
Cadmium (Cd)	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium - total (Cd)	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium (Cr)	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium - total (Cr)	<0.01	0.03	0.13	0.02	0.01
Cobalt (Co)	<0.1	<0.1	<0.1	<0.1	<0.1
Copper (Cu)	0.01	0.02	<0.01	<0.01	0.10
Copper - total (Cu)	0.01	0.02	0.22	0.04	0.10
Iron (Fe)	<0.05	0.34	0.09	<0.05	<0.05
Iron - total (Fe)	1.39	17.00	110	12.00	9.00
Lead (Pb)	<0.01	<0.01	<0.01	<0.01	<0.01
Lead - total (Pb)	0.01	0.01	0.05	0.01	0.01
Magnesium (Mg)	520	870	430	410	270
Manganese (Mn)	1.07	0.09	0.08	0.08	0.07
Manganese - total (Mn)	1.08	0.60	3.50	0.31	0.37
Mercury - total (Hg)	<0.3	<0.3	<0.3	<0.3	<0.3
(in micrograms per liter)					
Molybdenum (Mo)	<0.1	0.5	<0.11	<0.1	<0.1
Nickel (Ni)	<0.05	<0.05	<0.055	<0.05	<0.0
Potassium (K)	390	470	430	370	340
Selenium (Se)	<0.01	<0.01	<0.01	<0.01	<0.01
Selenium - total (Se)	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (Ag)	<0.01	<0.01	<0.01	<0.01	<0.01
Silver - total (Ag)	<0.01	<0.01	<0.01	<0.01	<0.01
Sodium (Na)	12,600	15,000	12,000	11,500	8,500
Sodium - total (Na)	12,600	15,000	12,000	11,500	8,500
Strontium (Sr)	13.00	20.00	15.00	15.00	18.00
Vanadium (V)	<0.5	<0.5	<0.5	<0.5	<0.5
Zinc (Zn)	<0.01	0.07	0.03	0.01	0.10
Zinc - total (Zn)	0.04	0.15	0.72	0.07	0.10

Table D-35. (continued)

General parameters	Well number				
	SC-1	SC-2	SC-3	SC-4	SC-5
Date sampled	9/30/81	9/22/81	9/24/81	9/29/81	9/23/81
Ammonia (NH ₃ -N)	0.09	0.19	<0.05	0.05	0.10
Bicarbonate (HCO ₃)	271	151	329	383	183
Carbonate (CO ₃)	<1	<1	<1	<1	<1
Calcium (Ca)	360	600	280	360	240
Chloride (Cl)	18,417	25,347	18,309	19,936	14,934
Chloride - total (Cl)	-	-	-	-	-
Conductivity - field (in micromhos per centimeter)	61,500	66,500	52,500	57,000	51,500
Cyanide - total (CN)	-	-	-	-	-
Fluoride (F)	0.49	0.82	1.35	0.42	0.53
Fluoride - total (F)	-	-	-	-	-
Hydroxide (OH)	<0.5	<0.5	<0.5	<0.5	<0.5
Nitrate (NO ₃ -N)	<0.1	0.9	<0.1	<.01	0.5
Nitrate - total (NO ₃ -N)	-	-	-	-	-
pH - field	7.9	8.7	7.8	7.8	8.2
pH -lab @ 25°C	7.79	7.80	7.81	8.25	7.50
Phenol	-	-	-	-	-
Phosphate - total (PO ₄ -P) .	0.13	0.04	0.02	0.13	0.06
Redox potential (EH) (in millivolts)	55	91	105	54	104
Salinity - field (0/00)	-	-	-	-	-
Sulfate (SO ₄)	1,761	5,144	1,564	2,041	1,778
Sulfate - total (SO ₄)	-	-	-	-	-
Sulfide (H ₂ S)	-	-	-	-	-
Temperature - field (°C)	14.6	14.6	14.9	13.4	19.3
Total alkalinity (as CaCO ₃)	235	139	289	331	169
Total dissolved solids (as calcium)	33,699	50,130	34,830	36,150	27,050
Total hardness (as CaCO ₃)	2,792	5,284	2,345	2,627	1,875
Total organic carbon	-	-	-	-	-

Table D-35. (continued)

General parameters	Well number				
	SC-1	SC-2	SC-3	SC-4	SC-5
Date sampled	2/8/82	2/8/82	2/8/82	2/8/82	2/8/82
Ammonia (NH ₃ -N)	<0.02	<0.02	<0.02	<0.02	<0.02
(un-ionized)					
Bicarbonate (HCO ₃)	168	171	342	366	201
Carbonate (CO ₃)	<1	<1	-	<1	<1
Calcium (Ca)	310	560	300	330	240
Chloride (Cl)	10,720	27,169	19,362	19,228	14,690
Chloride - total (Cl)	10,890	27,169	19,362	19,682	14,861
Conductivity - field	45,000	70,000	64,000	60,000	53,000
(in microhms per centimeter)					
Cyanide - total (CN)	<0.05	<0.05	<0.05	<0.05	<0.05
Fluoride (F)	0.87	1.46	1.40	1.04	1.10
Fluoride - total (F)	0.90	1.50	1.40	1.04	1.10
Hydroxide (OH)	<0.5	<0.5	<0.5	<0.5	<0.5
Nitrate (NO ₃ -N)	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrate - total (NO ₃)	<0.1	<0.1	<0.1	<0.1	<0.1
pH - field	8.3	7.8	7.7	7.8	8.2
pH - lab @25°C	7.81	7.58	8.00	8.02	8.10
Phenol	<0.005	<0.005	<0.005	<0.005	<0.005
Phosphate - total (PO ₄ -P)	0.05	0.08	0.14	0.27	0.09
Redox potential (EH)	71	50	60	60	67
(in millivolts)					
Salinity - field (0/00)	-	-	-	-	-
Sulfate (SO ₄)	545	4,447	1,475	1,534	1,036
Sulfate - total (SO ₄)	639	4,499	1,524	1,857	1,116
Sulfide (H ₂ S)	<0.05	<0.05	<0.05	<0.05	<0.05
Temperature - field (°C)	8.9	8.7	8.9	9.7	10.6
Total alkalinity (as CaCO ₃)	157	159	299	319	182
Total dissolved solids	19,717	49,935	34,747	34,879	25,277
(as calcium)					
Total hardness (as CaCO ₃)	2,050	4,649	2,395	2,470	1,710
Total organic carbon	2	4	3	6	4

Table D-35. (continued)

General parameters	Well number				
	SC-1	SC-2	SC-3	SC-4	SC-5
Date sampled	6/2/82	6/2/82	6/2/82	6/2/82	6/2/82
Ammonia (NH ₃ -N) (un-ionized)	<0.05	<0.05	<0.05	<0.05	<0.05
Bicarbonate (HCO ₃)	268	164	338	359	203
Carbonate (CO ₃)	<1	<1	<1	<1	<1
Calcium (Ca)	400	610	310	350	260
Chloride (Cl)	20,725	24,832	19,149	19,047	13,511
Chloride - total (Cl)	20,725	24,832	19,149	19,047	13,545
Conductivity - field (in micromhos per centimeter)	83,000	96,000	79,000	79,000	60,000
Cyanide - total (CN)	<0.005	<0.005	<0.005	<0.005	<0.005
Fluoride (F)	0.53	1.00	0.94	0.48	0.65
Fluoride - total (F)	0.56	1.20	2.21	0.55	0.70
Hydroxide (OH)	<0.5	<0.5	<0.5	<0.5	<0.5
Nitrate (NO ₃ -N)	<0.05	<0.05	<0.05	<0.05	<0.05
Nitrate - total (NO ₃)	0.36	0.57	2.22	0.36	0.17
pH - field	7.7	7.5	7.5	7.5	7.7
pH - lab @25°C	7.49	7.77	7.88	7.84	7.83
Phenol	<0.005	<0.005	<0.005	<0.005	<0.005
Phosphate - total (PO ₄ -P)	0.13	0.14	0.18	0.13	0.14
Redox potential (EH) (in millivolts)	52	48	53	55	62
Salinity - field (0/00)	-	-	-	-	-
Sulfate (SO ₄)	13.6	18.1	14.4	15.2	10.3
Sulfate - total (SO ₄)	13.6	33.7	43.6	37.0	10.3
Sulfide (H ₂ S)	<0.05	<0.05	<0.05	<0.05	<0.05
Temperature - field (°C)	13.0	12.0	12.0	13.0	13.0
Total alkalinity (as CaCO ₃)	239	153	294	312	183
Total dissolved solids (as calcium)	37,512	44,120	34,418	34,520	24,618
Total hardness (as CaCO ₃)					
Total organic carbon	10	17	25	23	12

Table D-35. (continued)

General parameters	Well number				
	SC-1	SC-2	SC-3	SC-4	SC-5
Date sampled	8/25/82	8/25/82	8/25/82	8/25/82	8/25/82
Ammonia (NH ₃ -N) (un-ionized)	0.22	0.14	<0.01	0.31	0.41
Bicarbonate (HCO ₃)	249	160	338	340	196
Carbonate (CO ₃)	<1	<1	<1	<1	<1
Calcium (Ca)	350	570	300	320	230
Chloride (Cl)	20,774	24,585	19,270	18,863	13,502
Chloride - total (Cl)	20,830	24,879	19,485	18,817	13,785
Conductivity - field (in micromhos per centimeter)	57,000	96,000	70,000	79,000	60,000
Cyanide - total (CN)	<0.05	<0.05	<0.05	<0.05	<0.05
Fluoride (F)	0.62	1.13	1.03	0.52	0.76
Fluoride - total (F)	0.65	1.25	1.36	0.57	0.88
Hydroxide (OH)	<0.5	<0.5	<0.5	<0.5	<0.5
Nitrate (NO ₃ -N)	0.2	2.1	<0.1	0.3	<0.1
Nitrate - total (NO ₃)	0.26	3.83	0.18	0.35	0.19
pH - field	7.4	7.6	7.5	7.5	7.8
pH - lab @25°C	7.70	7.59	7.72	7.80	8.00
Phenol	<0.005	<0.005	<0.005	<0.005	<0.005
Phosphate - total (PO ₄ -P)	0.16	0.05	0.08	0.07	0.14
Redox potential (EH) (in millivolts)	50	45	50	52	57
Salinity - field (0/00)	-	-	-	-	-
Sulfate (SO ₄)	1,773	4,152	1,437	1,477	951
Sulfate - total (SO ₄)	1,793	4,271	1,473	1,475	990
Sulfide (H ₂ S)	<0.1	<0.1	<0.1	<0.1	<0.1
Temperature - field (°C)	17.6	15.0	14.0	13.0	14.0
Total alkalinity (as CaCO ₃)	223	147	291	291	171
Total dissolved solids (as calcium)	37,238	46,842	34,474	33,860	24,270
Total hardness (as CaCO ₃)	3,014	5,004	2,518	2,486	1,685
Total organic carbon	4	12	4	7	23

Table D-35. (continued)

Radiochemistry ^d	Well number ^a				
	SC-1	SC-2	SC-3	SC-4	SC-5
Date sampled	9/30/81	9/22/81	9/24/81	9/29/81	9/23/81
Gross alpha, dissolved	0±110 ^b	155±188	0±170	0±200	0±196
Gross beta, dissolved	710±140	588±358	481±166	411±188	564±193
Radium - 226, dissolved	0.8±0.2	0.3±0.2	0.4±0.2	0.5±0.2	0.6±0.2
Radium - 228, dissolved	- ^c	-	-	-	-
Thorium - 230, dissolved	3.4±0.8	2.2±1.1	2.7±0.5	3.8±0.8	14.0±4.0
Lead - 210, dissolved	6.8±1.6	0.6±0.6	0.5±0.7	1.0±0.9	0.2±0.7
Polonium - 210, dissolved	0.0±0.3	0.1±0.2	0.0±0.2	0.0±0.4	0.0±0.2
Uranium (U ₃ O ₈), dissolved	8.1	27.1	6.8	8.8	3.4
Uranium (U ₃ O ₈), total	8.1	29.8	14.2	16.2	14.2

Table D-35. (continued)

Radiochemistry	Well number				
	SC-1	SC-2	SC-3	SC-4	SC-5
Date sampled	2/8/82	2/8/82	2/8/82	2/8/82	2/8/82
Gross alpha, total	0.0±72.7	76.3±183	35.4±155	0.0±131	0.0±92.9
Gross beta, total	192±188	299±206	282±203	346±205	320±198
Radium-226, total	0.7±0.2	0.8±0.2	0.9±0.2	1.5±0.3	0.8±0.2
Radium-228, total	3.4±3.7	2.2±3.9	2.9±3.4	1.4±3.5	0.3±3.7
Thorium-230, total	0.0±2.1	2.6±1.4	1.0±1.1	0.0±2.3	1.8±2.7
Lead-210, total	0.3±1.3	0.4±1.3	0.0±1.3	0.3±1.4	0.0±1.4
Polonium-210, total	0.2±0.4	0.2±0.4	0.0±0.0	0.1±0.2	0.2±0.2
Uranium (U ₃ O ₈), dissolved	2.7	35.2	11.5	11.5	2.7
Uranium (U ₃ O ₈), total	2.7	39.3	49.4	19.6	24.4

Table D-35. (continued)

Radiochemistry	Well number				
	SC-1	SC-2	SC-3	SC-4	SC-5
Date sampled	6/2/82	6/2/82	6/2/82	6/2/82	6/2/82
Gross alpha, total	0.0±235	345±435	374±414	90.2±343	25.3±271
Gross beta, total	0.0±720	412±765	478±764	198±748	309±405
Radium-226, total	1.2±0.2	0.8±0.2	0.5±0.1	2.0±0.2	1.0±0.2
Radium-228, total	4.1±1.5	1.6±1.5	0.8±1.2	2.7±1.4	1.2±1.3
Thorium-230, total	2.5±1.2	2.7±1.1	9.3±2.0	0.8±1.0	6.4±1.6
Lead-210, total	0.1±1.0	0.8±1.2	0.5±1.1	0.6±1.4	0.9±1.1
Polonium-210, total	0.3±0.2	0.0±0.2	0.2±0.2	0.2±0.2	0.0±0.1
Uranium (U ₃ O ₈), dissolved	7.4	35.9	11.5	13.5	6.1
Uranium (U ₃ O ₈), total	8.8	35.9	14.9	13.5	6.1

Table D-35. (continued)

Radiochemistry	Well number				
	SC-1	SC-2	SC-3	SC-4	SC-5
Date sampled	8/25/82	8/25/82	8/25/82	8/25/82	8/25/82
Gross alpha, total	0.0±132	0.0±252	13.9±196	0.0±131	0.0±90.6
Gross beta, total	393±237	481±255	477±313	323±232	231±218
Radium-226, total	1.2±0.3	3.0±0.4	0.2±0.1	1.1±0.2	2.0±0.3
Radium-228, total	4.9±3.2	3.1±3.4	0.0±2.8	5.1±3.2	2.8±3.2
Thorium-230, total	0.6±2.4	3.7±2.1	5.8±2.4	14.2±4.3	8.1±2.7
Lead-210, total	3.6±2.1	5.4±2.4	7.4±2.2	1.6±2.0	1.9±2.0
Polonium-210, total	0.5±0.4	3.6±0.9	8.1±1.7	0.8±0.5	1.7±0.6
Uranium (U ₃ O ₈), dissolved	5.4	22.1	6.0	10.1	2.7
Uranium (U ₃ O ₈), total	5.4	32.8	11.4	10.7	4.7

^dAll values in picocuries per liter.

Table D-36. Records of selected wells in the South Clive area

Location ^c	Owner/User name	Year drilled	Depth of well (ft)	Casing diameter	Depth to top of perforated section (ft)	Altitude (ft)	Water level below land surface datum (ft)
^a T1S, R11W Sec. 18	U.S. Bureau of Land Management (Clive well)	-	90	-	-	-	-
^a T1S, R11W Sec. 18 bcd	Cox Construction Company	1969	350	8	185	4,350	53
^a T1S, R11W Sec. 36 bba	Desert Livestock Company	1940	276	6	-	4,550	264
^b T1S, R11W Sec. 36 bba	Desert Livestock Company	1946	293	6	265	4,550	263
^b T1S, R10W Sec. 31 cab	U.S. Bureau of Reclamation	1976	300	-	-	-	-
^b T1S, R10W Sec. 31 bdb	U.S. Bureau of Reclamation	1976	180	6-5/8	80	-	8

^aStephens, J.C., 1974. Hydrologic Reconnaissance of the Northern Great Salt Lake Desert and Summary Hydrologic Reconnaissance of Northwestern Utah, U.S. Geol. Survey in Cooperation with the Utah Department of Natural Resources, Technical Publication 42, Salt Lake City, Utah.

^bData obtained from the State of Utah Office of State Engineer, May 1981.

^cThe proposed tailings embankment at the South Clive site would be in the North half of T1S, R11W, Sec. 32.

Table D-36. (continued)

Location	Owner/User name	Rate of Discharge (gpm)	Drawdown (ft)	Date of measurement	Method of lift	Use of water or well	Remarks or data available
T1S, R11W Sec. 18	U.S. Bureau of Land Management (Clive well)	-	-	-	none	unused	Well never used; water reported to have contained 35,700 ppm of NaCl.
T1S, R11W Sec. 18 bcd	Cox Construction Company	600	120	12-29-69	none	unused	Specific capacity = 5 gpm/ft drawdown; supplied water for road construction; later destroyed.
T1S, R11W Sec. 36 bba	Desert Livestock Company	18	-	5-04-40	none	unused	Well has been destroyed.
T1S, R11W Sec. 36 bba	Desert Livestock Company	-	-	11-10-46	piston pump	livestock	Log available.
T1S, R10W Sec. 31 cab	U.S. Bureau of Reclamation	-	-	-	none	none	Abandoned and destroyed; dry hole; log available.
T1S, R10W Sec. 31 beb	U.S. Bureau of Reclamation	40	90	9-14-76	-	-	Log available.

D.6. CONCLUSIONS AND SUMMARY--SOUTH CLIVE SITE

- Two ground-water systems can be found in the vicinity of the South Clive site: valley fill and alluvial fan.
- The South Clive site overlies briny ground water downgradient of the recharge to any usable ground water in the alluvial fan aquifer.
- The potential for infiltration at the site is minimal.
- Shallow ground water at the site is characterized by high TDS and certain radionuclides with little seasonal variation in quality.
- Water uses in the area are limited to a few stock wells, due to the poor quality of the ground water.

D.7 SURFACE-WATER QUALITY, TRANSPORTATION ROUTE

Additional water-quality data are available for surface-water sampling sites along the transportation route between the Vitro and South Clive sites. Sampling locations are shown in Figure D-21 and described in Table D-37. The data are presented in Table D-38. At least 27 other water-quality monitoring stations of the State of Utah and the US Geological Survey have been identified as being on or near the transportation route.

Table D-37. Surface-water sampling locations

<u>Location ID</u>	<u>Location description</u>
5-1	Jordan River west of White's ballpark, south side of West N. Temple St.
5-2	Jordan River southeast of Salt Lake Airport, west bank of river.
5-3	Great Salt Lake at Salt Air Marina and boat launch ramp, at rock embankment northeast of marina.
5-4	Ephemeral drainage course 1/2 mile from Timpie, Utah, south side of eastbound highway I-80.
5-5	Ephemeral drainage course 3 miles east of Delle, Utah south side of eastbound highway I-80.

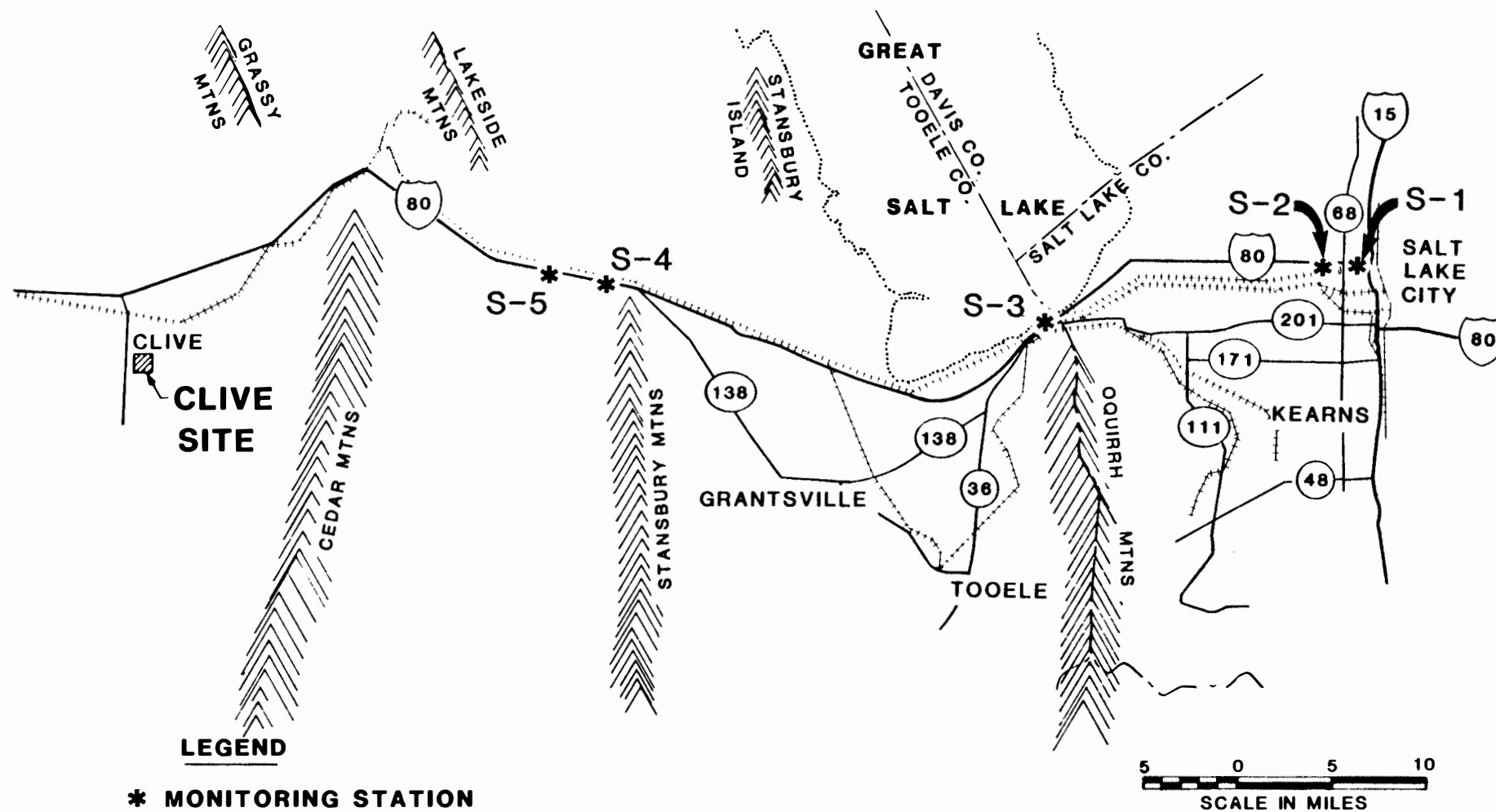


FIGURE D-21
LOCATIONS OF SURFACE WATER QUALITY SAMPLING STATIONS.

Table D-38. Surface-water quality - Vitro to South Clive transportation route

Parameter (metals)	Location number ^a				
	S-1	S-2	S-3	S-4	S-5
Date sampled	9/10/81	9/10/81	9/8/81	9/9/81	9/9/81
Aluminum - (Al)	<0.1 ^b	<0.1	<0.1	<0.1	<0.1
Arsenic (As)	- ^c	-	-	-	-
Arsenic - total (As)	<0.01	<0.01	0.03	<0.01	<0.01
Barium (Ba)	-	-	-	-	-
Barium - total (Ba)	<0.1	<0.1	<0.1	<0.1	<0.1
Boron - total (B)	0.30	0.26	2.76	0.34	0.61
Cadmium (Cd)	-	-	-	-	-
Cadmium - total (Cd)	<0.01	<0.01	0.22	0.01	0.04
Chromium (Cr)	-	-	-	-	-
Chromium - total (Cr)	<0.01	<0.01	0.10	<0.01	<0.01
Cobalt (Co)	-	-	-	-	-
Copper (Cu)	-	-	-	-	-
Copper - total (Cu)	-	-	-	-	-
Iron (Fe)	<0.05	<0.05	0.73	<0.05	<0.05
Iron - total (Fe)	0.88	0.72	0.75	<0.05	0.74
Lead (Pb)	-	-	-	-	-
Lead - total (Pb)	<0.1	<0.1	1.7	<0.1	<0.1
Magnesium (Mg)	54.0	56.0	4,500	73.0	120
Manganese (Mn)	0.04	0.05	0.23	0.01	0.05
Manganese - total (Mn)	-	-	-	-	-
Mercury - total (Hg)	<0.3	<0.3	1.2	0.4	<0.3
(in micrograms per liter)					
Molybdenum (Mo)	<0.1	<0.1	0.4	<0.1	<0.1
Nickel - (Ni)	-	-	-	-	-
Potassium (K)	13.0	14.0	2,700	92.0	160
Selenium (Se)	<0.01	<0.01	<0.01	<0.01	<0.01
Selenium - total (Se)	-	-	-	-	-
Silver (Ag)	<0.01	<0.01	0.17	<0.01	0.01
Silver - total (Ag)	-	-	-	-	-
Sodium (Na)	180	190	44,500	2,600	4,600
Sodium - total (Na)	-	-	-	-	-
Strontium (Sr)	0.74	0.74	2.55	0.97	6.40
Vanadium (V)	<0.5	<0.5	<0.5	<0.5	<0.5
Zinc (Zn)	<0.01	0.03	0.13	0.01	0.02
Zinc - total (Zn)	-	-	-	-	-

^aFor sampling locations, see Figure D-12.^bAll values in milligrams per liter on a dissolved basis, unless otherwise noted.^c-indicates concentration not determined.

Table D-38. (continued)

Parameters (metals)	Location number				
	S-1	S-2	S-3	S-4	S-5
Date sampled	1/27/82	1/27/82	1/27/82	1/27/82	1/27/82
Aluminum (Al)	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic (As)	0.01	<0.01	0.03	0.02	<0.01
Arsenic - total (As)	0.01	0.01	0.15	0.02	0.01
Barium (Ba)	<0.1	<0.1	<0.1	<0.1	<0.1
Barium - total (Ba)	<0.1	<0.1	<0.1	<0.1	<0.1
Boron (B)	0.12	0.20	13.52	0.75	0.85
Cadmium (Cd)	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium - total (Cd)	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium (Cr)	<0.01	<0.01	0.08	<0.01	<0.01
Chromium - total (Cr)	0.02	0.01	0.08	<0.01	<0.01
Cobalt (Co)	<0.1	<0.1	1.1	0.1	0.1
Copper (Cu)	<0.01	<0.01	0.22	0.01	0.03
Copper - total (Cu)	0.04	0.07	0.22	0.02	0.04
Iron (Fe)	<0.05	<0.05	0.51	<0.05	<0.05
Iron - total (Fe)	4.11	5.80	0.53	0.07	0.45
Lead (Pb)	<0.05	<0.05	<0.05	<0.05	<0.05
Lead - total (Pb)	0.11	<0.05	<0.05	<0.05	<0.05
Magnesium (Mg)	42.0	55.0	5,000	76.0	190
Manganese (Mn)	0.04	0.05	0.23	<0.01	0.02
Manganese - total (Mn)	0.11	0.14	0.23	<0.01	0.03
Mercury - total (Hg)	<0.3	<0.3	<0.3	<0.3	<0.3
(in micrograms per liter)					
Molybdenum (Mo)	<0.1	<0.1	<0.1	<0.1	<0.1
Nickel (Ni)	<0.05	<0.05	1.10	0.10	0.18
Potassium (K)	11.0	16.0	3,000	100	200
Selenium (Se)	<0.01	<0.01	<0.01	<0.01	<0.01
Selenium - total (Se)	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (Ag)	<0.01	<0.01	<0.01	<0.01	<0.01
Silver - total (Ag)	<0.01	<0.01	<0.01	<0.01	<0.01
Sodium - (Na)	290	170	43,800	2,770	6,300
Sodium - total (Na)	290	170	44,000	2,800	6,300
Strontium (Sr)	0.70	0.75	2.68	1.05	3.33
Vanadium (V)	<0.5	<0.5	<0.5	<0.5	<0.5
Zinc (Zn)	0.03	0.02	0.12	0.02	0.04
Zinc - total (Zn)	0.29	0.21	0.21	0.08	0.09

Table D-38. (continued)

Parameter (metals)	Location number				
	S-1	S-2	S-3	S-4	S-5
Date sampled	4/26/82	4/26/82	4/26/82	4/26/82	4/26/82
Aluminum (Al)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Arsenic (As)	< 0.01	< 0.01	0.07	0.02	0.02
Arsenic - total (As)	< 0.01	< 0.01	0.07	0.02	0.02
Barium (Ba)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Barium - total (Ba)	0.3	< 0.1	< 0.1	< 0.1	< 0.1
Boron (B)	0.25	0.51	18.13	0.99	3.75
Cadmium (Cd)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Cadmium - total (Cd)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Chromium (Cr)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Chromium - total (Cr)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Cobalt (Co)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Copper (Cu)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Copper - total (Cu)	0.02	0.02	< 0.01	< 0.01	< 0.01
Iron (Fe)	< 0.05	< 0.05	0.51	< 0.05	0.16
Iron - total (Fe)	2.94	2.72	0.54	< 0.05	0.18
Lead (Pb)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Lead - total (Pb)	< 0.05	0.06	< 0.05	< 0.05	< 0.05
Magnesium (Mg)	36.0	48.0	4,400	76.0	490
Manganese (Mn)	0.02	0.01	0.15	< 0.01	0.06
Manganese - total (Mn)	0.12	0.08	0.15	< 0.01	0.06
Mercury - total (Hg)	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
(in micrograms per liter)					
Molybdenum (Mo)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Nickel (Ni)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Potassium (K)	6.40	11.0	1,700	100	440
Selenium (Se)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Selenium - total (Se)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Silver (Ag)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Silver - total (Ag)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Sodium (Na)	80.0	130	40,000	2,800	15,000
Sodium - total (Na)	80.0	130	40,000	2,800	15,000
Strontium (Sr)	0.60	0.77	3.02	1.20	9.50
Vanadium (V)	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Zinc (Zn)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Zinc - total (Zn)	0.08	0.08	0.03	0.03	0.03

Table D-38. (continued)

Parameter (metals)	Location number				
	S-1	S-2	S-3	S-4	S-5
Date sampled	6/16/82	6/16/82	6/16/82	6/16/82	6/16/82
Aluminum (Al)	<0.1	<0.1	<0.1	<0.1	NS ^d
Arsenic (As)	<0.01	<0.01	0.04	0.01	NS
Arsenic - total (As)	<0.01	<0.01	0.04	<0.01	NS
Barium (Ba)	<0.1	<0.1	<0.1	<0.1	NS
Barium - total (Ba)	<0.1	<0.1	<0.1	<0.1	NS
Boron (B)	0.25	0.38	9.78	1.00	NS
Cadmium (Cd)	<0.01	<0.01	<0.01	<0.01	NS
Cadmium - total (Cd)	<0.01	<0.01	<0.01	<0.01	NS
Chromium (Cr)	<0.01	<0.01	<0.01	<0.01	NS
Chromium - total (Cr)	<0.01	<0.01	<0.01	<0.01	NS
Cobalt (Co)	<0.1	<0.1	<0.1	<0.1	NS
Copper (Cu)	<0.01	<0.01	0.03	<0.01	NS
Copper - total (Cu)	0.06	0.05	0.03	<0.01	NS
Iron (Fe)	<0.05	<0.05	<0.05	<0.05	NS
Iron - total (Fe)	1.03	0.96	0.50	0.05	NS
Lead (Pb)	<0.05	<0.05	<0.05	<0.05	NS
Lead - total (Pb)	0.06	0.05	<0.05	<0.05	NS
Magnesium (Mg)	28.0	30.0	2,500	75.0	NS
Manganese (Mn)	0.01	<0.01	0.05	<0.01	NS
Manganese - total (Mn)	0.06	0.05	0.05	0.08	NS
Mercury - total (Hg)	<0.3	<0.3	<0.3	<0.3	NS
(in micrograms per liter)					
Molybdenum (Mo)	<0.1	<0.1	0.3	<0.1	NS
Nickel (Ni)	<0.05	<0.05	<0.05	<0.05	NS
Potassium (K)	6.00	7.50	1,600	95.0	NS
Selenium (Se)	<0.01	<0.01	<0.01	<0.01	NS
Selenium - total (Se)	<0.01	<0.01	<0.01	<0.01	NS
Silver (Ag)	<0.01	<0.01	<0.01	<0.01	NS
Silver - total (Ag)	<0.01	<0.01	<0.01	<0.01	NS
Sodium (Na)	67.0	80.0	24,000	2,700	NS
Sodium - total (Na)	67.0	80.0	24,000	2,700	NS
Strontium (Sr)	0.42	0.42	2.21	1.14	NS
Vanadium (V)	<0.5	<0.5	<0.5	<0.5	NS
Zinc (Zn)	0.20	0.65	<0.01	<0.01	NS
Zinc - total (Zn)	1.10	2.00	0.87	0.12	NS

^dNS-Not sampled because of insufficient flow.

Table D-38. (continued)

Parameter (metals)	Location number				
	S-1	S-2	S-3	S-4	S-5
Date sampled	8/18/82	8/18/82	8/18/82	8/18/82	8/18/82
Aluminum (Al)	< 0.1	< 0.1	< 0.1	< 0.1	
Arsenic (As)	< 0.01	< 0.01	0.05	< 0.01	NS
Arsenic - total (As)	0.01	0.01	0.08	0.01	NS
Barium (Ba)	< 0.1	< 0.1	< 0.1	< 0.1	NS
Barium - total (Ba)	< 0.1	< 0.1	< 0.1	< 0.1	NS
Boron (B)	0.45	0.49	17.10	0.89	NS
Cadmium (Cd)	< 0.01	< 0.01	< 0.01	< 0.01	NS
Cadmium - total (Cd)	< 0.01	< 0.01	< 0.01	< 0.01	NS
Chromium (Cr)	< 0.01	< 0.01	< 0.01	< 0.01	NS
Chromium - total (Cr)	< 0.01	< 0.01	< 0.01	< 0.01	NS
Cobalt (Co)	< 0.1	< 0.1	0.9	< 0.1	NS
Copper (Cu)	< 0.01	< 0.01	0.04	< 0.01	NS
Copper - total (Cu)	< 0.01	< 0.01	0.04	< 0.01	NS
Iron (Fe)	< 0.05	< 0.05	0.41	< 0.05	NS
Iron - total (Fe)	0.73	0.72	0.43	< 0.05	NS
Lead (Pb)	< 0.05	< 0.05	< 0.05	< 0.05	NS
Lead - total (Pb)	< 0.05	< 0.05	< 0.05	< 0.05	NS
Magnesium (Mg)	51.0	55.0	4,500	75.0	NS
Manganese (Mn)	0.03	0.03	0.15	< 0.01	NS
Manganese - total (Mn)	0.05	0.05	0.15	< 0.01	NS
Mercury - total (Hg)	< 0.3	< 0.3	< 0.3	< 0.3	NS
(in micrograms per liter)					
Molybdenum (Mo)	< 0.1	< 0.1	< 0.1	< 0.1	NS
Nickel (Ni)	< 0.05	< 0.05	1.03	< 0.05	NS
Potassium (K)	16.0	16.0	1,700	106	NS
Selenium (Se)	< 0.01	< 0.01	< 0.01	< 0.01	NS
Selenium - total (Se)	< 0.01	< 0.01	< 0.01	< 0.01	NS
Silver (Ag)	< 0.01	< 0.01	< 0.01	< 0.01	NS
Silver - total (Ag)	< 0.01	< 0.01	< 0.01	< 0.01	NS
Sodium (Na)	160	180	38,000	2,800	NS
Sodium - total (Na)	160	180	38,000	2,800	NS
Strontium (Sr)	1.05	1.06	3.35	1.23	NS
Vanadium (V)	< 0.5	< 0.5	< 0.5	< 0.5	NS
Zinc (Zn)	0.02	0.02	0.09	< 0.01	NS
Zinc - total (Zn)	0.23	0.11	0.34	0.07	NS

Table D-38. (continued)

Parameter (metals)	Location number				
	S-1	S-2	S-3	S-4	S-5
Date sampled	10/14/82	10/14/82	10/14/82	10/14/82	10/14/82
Aluminum (Al)	< 0.1	< 0.1	< 0.1	< 0.1	0.1
Aluminum - total (Al)	1.3	1.9	< 0.1	< 0.1	< 0.1
Arsenic (As)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Arsenic - total (As)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Barium (Ba)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Barium - total (Ba)	< 0.1	< 0.1	0.1	< 0.1	0.2
Boron (B)	0.34	0.37	10.9	0.92	2.53
Cadmium (Cd)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Cadmium - total (Cd)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Chromium (Cr)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Chromium - total (Cr)	0.01	0.01	< 0.01	< 0.01	0.01
Cobalt (Co)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Copper (Cu)	0.03	0.04	< 0.01	< 0.01	< 0.01
Copper - total (Cu)	0.07	0.11	0.03	0.03	0.08
Iron (Fe)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Iron - total (Fe)	1.23	2.54	0.07	0.08	0.11
Lead (Pb)	< 0.01	0.01	< 0.01	< 0.01	< 0.01
Lead - total (Pb)	0.02	0.03	< 0.01	< 0.01	< 0.01
Magnesium (Mg)	50	50	4,200	80	240
Manganese (Mn)	0.01	0.01	0.01	< 0.01	0.01
Manganese - total (Mn)	0.04	0.09	0.05	< 0.01	0.01
Mercury - total (Hg)	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
(in micrograms per liter)					
Molybdenum (Mo)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Nickel (Ni)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Potassium (K)	7.5	8.6	2,500	89	260
Selenium (Se)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Selenium - total (Se)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Silver (Ag)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Silver - total (Ag)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Sodium (Na)	130	140	37,000	2,500	8,000
Sodium - total (Na)	130	140	27,000	2,500	8,000
Strontium (Sr)	0.82	0.77	3.00	1.17	6.8
Vanadium (V)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Zinc (Zn)	0.06	0.10	0.18	0.07	0.06
Zinc - total (Zn)	0.02	0.02	0.03	< 0.01	< 0.01

Table D-38. (continued)

General parameters	Location number				
	S-1	S-2	S-3	S-4	S-5
Date sampled	9/10/81	9/10/81	9/8/81	9/9/81	9/9/81
Ammonia (NH ₃ -N)	0.95	1.27	6.50	0.05	0.34
Bicarbonate (HCO ₃)	297	299	600	178	56.1
Carbonate (CO ₃)	< 1	< 1	3.61	< 1	< 1
Calcium (Ca)	98.0	100	270	150	500
Chloride (Cl)	238	251	80,689	4,360	7,689
Chloride - total (Cl)	-	-	-	-	-
Conductivity - field (in micromhos per centimeter)	2,190	2,000	80,000	19,500	61,000
Conductivity - lab (in micromhos)	1,715	1,757	-	13,829	27,446
Fluoride (F)	0.64	0.67	0.29	0.31	0.19
Fluoride - total (F)	-	-	-	-	-
Hydroxide (OH)	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Nitrate (NO ₃ -N)	1.8	1.9	0.1	0.6	0.3
Nitrate - total (NO ₃ -N)	-	-	-	-	-
pH - field	8.1	8.3	8.7	9.1	8.7
pH -lab @ 25°C	7.89	7.98	8.40	8.42	7.61
Phenol	-	-	-	-	-
Phosphate - total (PO ₄ -P)	0.97	0.97	0.50	0.01	0.01
Redox potential (EH) (in millivolts)	157	156	26	90	76
Salinity - field (0/00)	-	-	-	-	-
Sulfate (SO ₄)	298	313	10,711	314	1,217
Sulfate - total (SO ₄)	-	-	-	-	-
Sulfide (H ₂ S)	-	-	-	-	-
Temperature - field (°C)	18.7	18.5	22.5	22.0	14.3
Total alkalinity (as CaCO ₃)	257	261	579	184	64
Total dissolved solids (as calcium)	1,140	1,153	154,740	8,160	15,252
Total hardness (as CaCO ₃)	466	480	19,196	675	1,742
Total organic carbon	-	-	-	-	-

Table D-38. (continued)

General parameters	Location number				
	S-1	S-2	S-3	S-4	S-5
Date sampled	1/27/82	1/27/82	1/27/82	1/27/82	1/27/82
Ammonia (NH ₃ -N) (un-ionized)	0.03	<0.02	<0.02	<0.02	<0.02
Bicarbonate (HCO ₃)	235	297	638	211	174
Carbonate (CO ₃)	< 1	< 1	< 1	< 1	< 1
Calcium (Ca)	72.0	79.0	290	110	250
Chloride (Cl)	458	253	79,238	4,481	10,425
Chloride - total (Cl)	458	253	79,465	4,492	10,425
Conductivity - field (in micromhos)	2,200	1,600	77,000	22,000	42,000
Cyanide - total (CN)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Fluoride (F)	0.68	0.82	0.66	0.50	0.58
Fluoride - total (F)	0.68	0.82	1.2	0.53	0.82
Hydroxide (OH)	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Nitrate (NO ₃ -N)	1.2	1.2	0.1	0.7	0.3
Nitrate - total (NO ₃)	2.9	3.6	0.1	0.7	0.3
pH - field	8.1	8.1	8.9	8.8	8.5
pH - lab @25°C	7.60	8.50	8.20	8.50	8.05
Phenol	0.009	< 0.005	< 0.005	< 0.005	< 0.005
Phosphate - total (PO ₄ -P)	0.91	0.94	0.23	0.03	0.02
Redox potential (EH) (in millivolts)	150	152	-90	-20	-50
Salinity - field (0/00)	-	-	-	-	-
Sulfate (SO ₄)	184	229	9,984	327	876
Sulfate - total (SO ₄)	222	299	9,984	331	904
Sulfide (H ₂ S)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Temperature - field (°C)	5.0	7.3	3.8	12.2	4.0
Total alkalinity (as CaCO ₃)	210	261	557	190	160
Total dissolved solids (as calcium)	1,273	981	144,512	8,092	18,472
Total hardness (as CaCO ₃)	352	423	21,304	587	1,406
Total organic carbon	28	25	64	12	20

Table D-38. (continued)

General parameters	Location number				
	S-1	S-2	S-3	S-4	S-5
Date sampled	4/26/82	4/26/82	4/26/82	4/26/82	4/26/82
Ammonia (NH ₃ -N) (un-ionized)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Bicarbonate (HCO ₃)	268	262	617	194	117
Carbonate (CO ₃)	< 1	< 1	< 1	< 1	< 1
Calcium (Ca)	79.0	75.0	270	140	540
Chloride (Cl)	109	171	70,843	4,436	24,923
Chloride - total (Cl)	109	172	70,843	4,492	24,979
Conductivity - field (in micromhos per centimeter)	760	1,400	77,000	20,500	63,000
Cyanide - total (CN)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Fluoride (F)	0.33	0.54	0.59	0.37	0.59
Fluoride - total (F)	0.35	0.56	0.59	0.37	0.59
Hydroxide (OH)	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Nitrate (NO ₃ -N)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Nitrate - total (NO ₃)	0.1	0.2	< 0.1	< 0.1	< 0.1
pH - field	8.2	8.1	8.8	8.7	8.9
pH - lab @25°C	8.00	7.90	8.20	8.40	8.20
Phenol	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Phosphate - total (PO ₄ -P)	0.55	0.58	0.65	0.02	0.06
Redox potential (EH) (in millivolts)	178	164	21	89	49
Salinity - field (0/00)	-	-	-	-	-
Sulfate (SO ₄)	140	212	9,444	331	2,066
Sulfate - total (SO ₄)	145	219	9,658	332	2,090
Sulfide (H ₂ S)	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Temperature - field (°C)	12.6	14.5	12.8	16.3	14.4
Total alkalinity (as CaCO ₃)	234	227	533	187	116
Total dissolved solids (as calcium)	620	830	135,175	8,360	45,106
Total hardness (as CaCO ₃)	345	384	18,784	662	3,365
Total organic carbon	11	8	37	3	18

Table D-38. (continued)

General parameters	Location number				
	S-1	S-2	S-3	S-4	S-5
Date sampled	6/16/82	6/16/82	6/16/82	6/16/82	6/16/82
Ammonia (NH ₃ -N)	< 0.05	< 0.05	< 0.05	0.05	NS
(un-ionized)					
Bicarbonate (HCO ₃)	207	186	431	196	NS
Carbonate (CO ₃)	< 1	< 1	< 1	< 1	NS
Calcium (Ca)	66.0	58.0	250	130	NS
Chloride (Cl)	94.6	107	39,603	4,388	NS
Chloride - total (Cl)	92.6	105.2	38,845.0	4,456.5	NS
Conductivity - field	730	730	89,000	21,000	NS
(in micromhos per centimeter)					
Cyanide - total (CN)	<0.05	<0.05	<0.05	<0.05	NS
Fluoride (F)	0.34	0.38	0.67	0.35	NS
Fluoride - total (F)	0.31	0.37	0.66	0.34	NS
Hydroxide (OH)	<0.5	<0.05	<0.5	<0.5	NS
Nitrate (NO ₃ -N)	1.0	1.0	<0.1	0.2	NS
Nitrate - total (NO ₃)	0.9	0.9	<0.1	0.2	NS
pH - field	8.1	8.0	8.3	8.4	NS
pH - lab @25°C	7.88	7.78	8.32	8.43	NS
Phenol	<0.005	<0.005	<0.005	<0.005	NS
Phosphate - total (PO ₄ -P)	0.28	0.35	0.80	0.02	NS
Redox potential (EH)	184	178	32	83	NS
(in millivolts)					
Salinity - field (0/00)	-	-	-	-	NS
Sulfate (SO ₄)	117	138	5,162	319	NS
Sulfate - total (SO ₄)	119	142	5,033	334	NS
Sulfide (H ₂ S)	<0.05	<0.05	<0.05	<0.05	NS
Temperature - field (°C)	17.0	16.0	26.0	23.0	NS
Total alkalinity (as CaCO ₃)	183	164	375	183	NS
Total dissolved solids	482	516	76,602	8,122	NS
(as calcium)					
Total hardness (as CaCO ₃)	280	268	10,914	633	NS
Total organic carbon	12	10	29	6	NS

Table D-38. (continued)

General parameters	Location number				
	S-1	S-2	S-3	S-4	S-5
Date sampled	8/18/82	8/18/82	8/18/82	8/18/82	8/18/82
Ammonia (NH ₃ -N) (un-ionized)	<0.05	0.07	<0.05	<0.05	NS
Bicarbonate (HCO ₃)	309	327	617	206	NS
Carbonate (CO ₃)	<1	<1	<1	<1	NS
Calcium (Ca)	100	105	250	120	NS
Chloride (Cl)	214	250	70,673	4,416	NS
Chloride - total (Cl)	213	238	74,178	4,423	NS
Conductivity - field (in micromhos)	2,000	2,200	97,000	20,000	NS
Cyanide - total (CN)	<0.05	<0.05	<0.05	<0.05	NS
Fluoride (F)	0.62	0.70	0.62	0.46	NS
Fluoride - total (F)	0.68	0.73	0.65	0.37	NS
Hydroxide (OH)	<0.5	<0.5	<0.5	<0.5	NS
Nitrate (NO ₃ -N)	2.3	1.8	<0.1	0.4	NS
Nitrate - total (NO ₃)	2.2	1.7	<0.1	0.4	NS
pH - field	7.88	8.00	8.42	8.40	NS
pH - lab @25°C	7.90	8.00	8.07	8.30	NS
Phenol	<0.005	<0.005	<0.005	<0.005	NS
Phosphate - total (PO ₄ -P)	1.29	1.32	0.22	<0.01	NS
Redox potential (EH) (in millivolts)	160	160	22	83	NS
Salinity - field (0/00)	-	-	-	-	NS
Sulfate (SO ₄)	289	334	9,497	322	NS
Sulfate - total (SO ₄)	279	318	9,275	316	NS
Sulfide (H ₂ S)	0.05	0.04	0.03	0.04	NS
Temperature - field (°C)	22.0	22.0	28.0	22.0	NS
Total alkalinity (as CaCO ₃)	268	281	532	182	NS
Total dissolved solids (as calcium)	1,096	1,178	130,628	7,844	NS
Total hardness (as CaCO ₃)	459	488	19,146	608	NS
Total organic carbon	10	9	35	3	NS

Table D-38. (continued)

General parameters	Location number				
	S-1	S-2	S-3	S-4	S-5
Date sampled	10/14/82	10/14/82	10/14/82	10/14/82	10/14/82
Ammonia (NH ₃ -N)	<0.05	<0.05	<0.05	<0.05	<0.05
(un-ionized)					
Bicarbonate (HCO ₃)	270.0	264.0	442.0	209.0	172.0
Carbonate (CO ₃)	<1	<1	<1	<1	<1
Calcium (Ca)	77	71	280	150	420
Chloride (Cl)	180.0	194.8	49,072	4,438.5	13,009
Chloride - total (Cl)	180.0	194.8	47,544	4,438.5	13,123
Conductivity - field	2,500	2,800	72,000	26,000	62,000
(in micromhos per centimeter)					
Cyanide - total (CN)	<0.05	<0.05	<0.05	<0.05	<0.05
Fluoride (F)	0.6	0.6	0.9	0.4	0.5
Fluoride - total (F)	0.6	0.6	1.0	0.4	0.6
Hydroxide (OH)	<0.5	<0.5	<0.5	<0.5	<0.5
Nitrate (NO ₃ -N)	1.5	1.4	0.2	0.8	0.1
Nitrate - total (NO ₃)	1.7	1.4	0.7	0.8	0.1
pH - field	7.96	8.09	8.50	8.40	8.27
pH - lab @ 25°C	8.18	8.20	8.21	8.15	8.10
Phenol	<0.005	<0.005	<0.005	<0.005	<0.005
Phosphate - total (PO ₄ -P)	0.40	0.46	0.25	<0.01	0.03
Redox potential (EH)	160	158	35	73	62
(in millivolts)					
Salinity - field (0/00)	-	-	-	-	-
Sulfate (SO ₄)	213	248	5,889	328	1,304
Sulfate - total (SO ₄)	238	248	5,893	321	1,335
Sulfide (H ₂ S)	0.05	0.06	0.07	0.06	0.07
Temperature - field (°C)	13	12	15	11.5	7.5
Total alkalinity (as CaCO ₃)	236	229	379	182	151
Total dissolved solids	858	890	93,014	8,018	23,830
(as calcium)					
Total hardness (as CaCO ₃)	398	383	17,995	704	2,037
Total organic carbon	9	7	25	8	18

Table D-38. (continued)

Radiochemistry ^d	Location number				
	S-1	S-2	S-3	S-4	S-5
Date sampled	9/10/81	9/10/81	9/8/81	9/9/81	9/9/81
Gross alpha, dissolved	10+6	2+6	207+187	0+37	0+48
Gross beta, dissolved	6+4	20+5	1075+222	0+40	10+45
Radium - 226, dissolved	0.0+0.02	1.4+0.3	0.7+0.2	0.4+0.2	1.8+0.3
Radium - 228, dissolved	-	-	-	-	-
Thorium - 230, dissolved	0.5+0.5	0.6+0.6	0.7+0.6	0.3+0.4	1.1+0.7
Lead - 210, dissolved	0.9+0.6	0.5+0.7	5.2+1.6	0.6+0.7	0.3+0.8
Polonium - 210, dissolved	0.1+0.2	0.3+0.3	0.0+0.2	0.0+0.2	0.0+0.2
Uranium (U ₃ O ₈), dissolved	<0.7	<0.7	8.1	<0.7	<0.7

^dAll values in picocuries per liter.

Table D-38. (continued)

Radiochemistry	Location number				
	S-1	S-2	S-3	S-4	S-5
Date sampled	1/27/82	1/27/82	1/27/82	1/27/82	1/27/82
Gross alpha, total	6.6 $\pm$ 9.2	11.2 $\pm$ 10.4	290 $\pm$ 400	2.5 $\pm$ 10.9	12.0 $\pm$ 28.0
Gross beta, total	0.0 $\pm$ 23.0	34.5 $\pm$ 25.0	460 $\pm$ 405	31.0 $\pm$ 20.0	85.0 $\pm$ 41.0
Radium - 226, total	0.4 $\pm$ 0.2	0.6 $\pm$ 0.2	0.9 $\pm$ 0.4	0.5 $\pm$ 0.2	0.5 $\pm$ 0.1
Radium - 228, total	0.9 $\pm$ 3.5	1.0 $\pm$ 3.8	0.0 $\pm$ 3.1	1.3 $\pm$ 3.5	0.0 $\pm$ 1.4
Thorium - 230, total	0.6 $\pm$ 1.1	2.4 $\pm$ 4.0	0.0 $\pm$ 11.3	1.0 $\pm$ 0.9	2.4 $\pm$ 1.4
Lead - 210, total	0.5 $\pm$ 1.7	0.7 $\pm$ 1.3	0.3 $\pm$ 1.3	0.0 $\pm$ 1.3	0.0 $\pm$ 1.3
Polonium - 210, total	0.4 $\pm$ 0.7	0.0 $\pm$ 0.6	0.0 $\pm$ 0.4	0.0 $\pm$ 0.5	0.0 $\pm$ 0.5
Uranium (U ₃ O ₈), dissolved	3.4	6.1	7.4	2.0	5.4
Uranium (U ₃ O ₈), total	3.4	13.5	13.5	3.4	6.8

Table D-38. (continued)

Radiochemistry	Location number				
	S-1	S-2	S-3	S-4	S-5
Date sampled	4/26/82	4/26/82	4/26/82	4/26/82	4/26/82
Gross alpha, total	6.0+6.0	100+22.0	1.6+8.3	0.0+50.0	0.0+147
Gross beta, total	11.5+3.3	0.0+8.0	650+120	203+121	453+145
Radium-226, total	0.0+0.1	0.5+0.2	0.7+0.2	1.8+0.2	0.5+0.2
Radium-228, total	0.0+0.0	0.0+1.8	0.0+2.0	1.8+1.6	3.7+2.0
Thorium-230, total	0.0+0.5	1.6+1.0	0.0+0.6	0.0+0.4	0.2+0.6
Lead-210, total	0.1+0.8	0.5+0.8	0.5+0.8	0.0+0.9	0.0+0.9
Polonium-210, total	0.5+0.3	0.7+0.4	1.3+0.7	0.4+0.2	0.5+0.4
Uranium (U ₃ O ₈) dissolved	2.0	4.7	6.1	<0.7	3.4
Uranium (U ₃ O ₈), total	2.0	6.1	8.1	2.0	5.4

Table D-38. (continued)

Radiochemistry	Location number				
	S-1	S-2	S-3	S-4	S-5
Date sampled	6/16/82	6/16/82	6/16/82	6/16/82	6/16/82
Gross alpha, total	7.3+4.6	6.3+4.3	0.0+194	0.0+27.2	NS ^e
Gross beta, total	10.0+12.0	6.4+11.8	1836+593	15.8+87.7	NS
Radium-226, total	0.5+0.1	0.4+0.1	1.1+0.3	1.4+0.2	NS
Radium-228, total	2.9+1.9	0.8+1.8	1.5+2.6	1.3+2.1	NS
Thorium-230, total	8.6+2.0	1.9+1.4	1.5+1.1	0.9+1.6	NS
Lead-210, total	1.5+1.0	1.8+1.6	0.3+1.0	2.1+1.1	NS
Polonium-210, total	0.2+0.2	1.4+1.0	0.2+0.3	0.2+0.3	NS
Uranium (U ₃ O ₈) dissolved	0.7	2.0	5.4	<0.7	NS
Uranium (U ₃ O ₈), total	0.7	4.1	5.4	<0.7	NS

^eNS-not sampled because of insufficient flow.

Table D-38. (continued)

Radiochemistry	Location number				
	S-1	S-2	S-3	S-4	S-5
Date sampled	8/18/82	8/18/82	8/18/82	8/18/82	8/18/82
Gross alpha, total	0.0±9.2	0.0±24.7	0.0±630	0.0±40.9	NS
Gross beta, total	42.0±44.3	0.0±133	744±998	117±216	NS
Radium-226, total	0.4±0.2	0.3±0.2	1.2±0.3	1.8±0.3	NS
Radium-228, total	2.0±4.4	0.0±4.9	0.0±5.0	8.6±5.0	NS
Thorium-230, total	3.0±2.1	2.1±1.5	0.9±1.4	1.3±1.4	NS
Lead-210, total	1.0±1.3	0.4±1.2	0.2±1.2	0.7±1.2	NS
Polonium-210, total	0.6±0.5	0.2±0.3	0.3±0.3	1.1±0.6	NS
Uranium (U ₃ O ₈) dissolved	<1.4	<1.4	<1.4	<1.4	NS
Uranium (U ₃ O ₈), total	<1.4	<1.4	<1.4	<1.4	NS

Table D-38. (continued)

Radiochemistry	Location number				
	S-1	S-2	S-3	S-4	S-5
Date sampled	10/14/82	10/14/82	10/14/82	10/14/82	10/14/82
Gross alpha, total	4.0+4.9	11.6+6.7	0.0+134.1	18.5+26.2	0.0+76.3
Gross beta, total	26.6+19.8	6.3+19.1	1062.4+502.2	67.8+81.4	372.3+129.3
Radium-226, total	0.6+0.2	0.6+0.2	1.6+0.3	1.6+0.3	0.4+0.2
Radium-228, total	1.0+1.0	0.1+1.0	1.6+1.1	0.5+1.2	1.5+1.1
Thorium-230, total	3.2+1.1	8.7+2.2	0.3+1.1	2.3+1.2	31.2+4.3
Lead-210, total	0.0+1.2	0.4+1.2	0.1+1.2	0.0+1.2	0.5+1.3
Polonium-210, total	1.0+0.6	1.0+0.6	1.2+0.4	0.7+0.4	0.9+0.5
Uranium (U ₃ O ₈) dissolved	6.7	8.0	8.0	1.3	6.7
Uranium (U ₃ O ₈), total	7.4	8.0	8.0	1.3	6.7

REFERENCES

- Bear, J. (1979) Hydraulics of Ground Water, McGraw-Hill Book Company, New York, New York.
- Bohn, H. L., 1975. Soil Chemistry, John Wiley & Sons, New York, New York.
- Cooper, H. H. Jr, J. D. Bredehoeft, and I. S. Papadopoulos, 1967. "Response of a Finite-Diameter Well to an Instantaneous Charge of Water," Water Resources Research, V. 3, no. 1, p. 263-269.
- Dames & Moore, 1982, "Field Hydrologic Data," unpublished report, prepared by Dames & Moore, Los Angeles, California, for the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.
- Davis, S. N., and R. J. M. DeWiest, (1965) Hydrogeology, John Wiley & Sons, Inc., New York, New York.
- DOE (U.S. Department of Energy), 1983. Draft Environmental Impact Statement, Remedial Action at the Former Vitro Chemical Company Site, South Salt Lake, Salt Lake County, Utah, DOE/EIS-0099-D, prepared by Dames & Moore, Los Angeles, California, for the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.
- Douglas, R. L. and J. M. Hans, Jr. 1975. "Gamma Radiation Surveys at Inactive Uranium Mill Sites," E A Technical Note ORP/LV-75-5.
- EPA, "Water Quality Criteria," 1973, WPA-R3-73-033, Washington, D.C.
- EPA (United States Environmental Protection Agency), 1979, Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020, Washington, D.C.
- EPA, "Handbook - Remedial Action at Waste Disposal Sites, 1982," EPA-625/6-82-006, Washington, D.C.
- FBDU (Ford, Bacon and Davis, Utah, Inc.), 1981. Engineering Assessment of Inactive Uranium Mill Tailings, Vitro Site, Salt Lake City, Utah, DOE/UMT-0120, prepared by FBDU, Inc., Salt Lake City, Utah, for the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.
- Ferris, J. G., and D. B. Knowles, 1963. "Methods of Determining Permeability, Transmissibility and Drawdown," U.S.G.S. Water Supply Paper 1536-I. U. S. Government Printing Office, Washington, D.C.
- Garrels, R. M., and L. L. Christ, 1965. Solutions, Minerals, and Equilibria, Harper and Row, New York, New York.
- Gilbert, F., P. C. Chee, M. J. Knight, J. M. Peterson, C. J. Roberts, J. E. Robinson, S. Y. H. Tsai, and Y. Yuan, 1983. Pathways, Analysis and Radiation Dose Estimates for Radioactive Residues at Formerly Utilized MED/AEC Sites, ORO-832, prepared by Argonne National Laboratory, Chicago, Illinois, for the U.S. Department of Energy, Washington, D.C.

- Hely, A. G., R. W. Mower, and C. A. Harr, 1971. "Water Resources of Salt Lake County, Utah," State of Utah Department of Natural Resources, Technical Publication No. 31, Salt Lake City, Utah.
- Hintze, L. F., and A. W. Miller, 1975. "Hydrologic Study of Vitro Site," unpublished report prepared by Ford, Bacon and Davis, Utah, Salt Lake City, Utah, for the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.
- Hood, J. W. and K. M. Waddell, 1968. "Hydrologic Reconnaissance of Skull Valley, Tooele County, Utah," State of Utah Department of Natural Resources Technical Publication No. 18, Salt Lake City, Utah.
- Hvorslev, M. J., 1951. "Time Lag and Soil Permeability in Ground Water Observations." U.S. Army Corps of Engineers, Waterways Experiment Station Bulletin 36, Vicksburg, Mississippi
- LeGrendre, G. R., and D. D. Runnells, 1975. "Removal of Dissolved Molybdenum From Waste Waters by Precipitates of Ferric Iron," Environmental Science and Technology, Vol. 9, No. 8.
- Lohman, S. W., 1972. "Ground-Water Hydraulics," U.S. Geological Survey Professional Paper No. 708, Washington, D. C.
- Markos, G., and K. J. Bush, 1982. Geochemical Investigation of UMTRAP Designated Site at Salt Lake City, Utah. GECR #R-826. Contract No. DE-AC04-82AL18797, DOE/UMT/0235, prepared by GEGR, Inc., Rapid City, South Dakota, for the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.
- Neuman, S. D., and P. A. Witherspoon, 1972. "Field Determination of the Hydraulic Properties of Leaky Multiple Aquifer Systems," Water Resources Research, Vol. 8, No. 5, pages 1284-1298.
- Parkhurst, D.L., Thorstenson, D.C. and Plummer, D. N. (1980) "PHREEQE-A Computer Program for Geochemical Calculations," U.S. Geological Survey Water Resources Investigation 80-96, Washington, D.C.
- PNL (Pacific Northwest Laboratory), Peterson, S. R., A. R. Felmy, R. J. Serne, and G. W. Gee, 1983. Predictive Geochemical Modeling of Interactions Between Uranium Mill Tailings Solutions and Sediments in a Flow-Through System, NUREG/CR 3404 (PNL-4782), prepared by Pacific Northwest Laboratory, Richland, Washington, for U.S. NRC, Washington, D.C.
- Prakash, A., 1982. "Ground-Water Contamination Due to Vanishing and Finite-Size Continuous Sources," Journal of the Hydraulics Division, Proceedings of the American Society of Civil Engineers, Vol. 108, No. HY4.
- Price, D. and E. L. Bolke, 1970. "Hydrologic reconnaissance of the Sink Valley Area, Tooele and Box Elder Counties, Utah," State of Utah Department of Natural Resources Technical Publication No. 26, Salt Lake City, Utah.

Prickett, T., and G. Lonnquist, 1971. "Selected Digital Computer Techniques for Ground-Water Resource Evaluation," Illinois State Water Survey Bulletin 55, Champaign, Illinois.

Sherwood, D. R., and R. J. Serne, Tailings Treatment Techniques for Uranium Mill Waste: A Review of Existing Information." 1983 NUREG/CR 2983, PNL-4453.

State of Utah, Department of Health, Division of Environmental Health, "Estimate of Value of Vitro Site Aquifer," Memo, Gaybe J. Smith, September 1983, Salt Lake City, Utah.

State of Utah, "Report of Well and Tunnel Driller," Report no.'s 2901, 3122, 3187, 3188, 3223, 12251, 12466, Application no. 1732328, Salt Lake City, Utah.

State of Utah, Reports of the Utah Lake and Jordan River Water Commissioner," 1943-1968, Salt Lake City, Utah.

State of Utah, "Wastewater Disposal Regulations, Part II Standards of Quality for Waters of the State", 1978, Salt Lake City, Utah.

State of Utah, 1983. "Results of 32 Splits on Vitro Site Ground-Water Samples," unpublished data.

Stephens, J. C., 1974. "Hydrologic Reconnaissance of the Northern Great Salt Lake Desert and Summary Hydrologic Reconnaissance of Northwestern Utah," State of Utah Department of Natural Resources Technical Publication No. 42, Salt Lake City, Utah.

TAC (Technical Assistance Contractor), 1983. "Laboratory and Field Data, Vitro Site, South Salt Lake, Utah," unpublished report prepared by Sergeant, Hauskins, & Beckwith, Phoenix, Arizona, for the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.

Todd, D. K., 1980. Ground-Water Hydrology, John Wiley & Sons, Inc. New York, New York.

USGS (United States Geological Survey) 1983, unpublished well data, Water Resources Division, Salt Lake City, Utah.

Weber, M. F., 1983. Trip report to Nuclear Regulatory Commission Waste Management Group, 3100/MFW/09/30, Washington, D.C.

Weston, "Feasibility Study Report - Mathews Electroplating Site, Salem, Virginia" 1983, prepared by Ray F. Weston, Inc., West Chester, Pennsylvania.

Wigley, T. M. L., 1977. "WATSPEC! A Computer Program for Determining the Equilibrium Speciation of Aqueous Solutions," British Geomorphological Research Group Technical Bulletin, Vol. 20, 48 p.

Appendix E

SOCIOECONOMIC INFORMATION

TABLE OF CONTENTS

	<u>Page</u>
E.1 LAND USE	E-1
E.1.1 Vitro site	E-4
E.1.1.1 Historic land use	E-4
E.1.1.2 Present land use	E-4
E.1.1.3 Potential future land use and development . . .	E-6
E.1.2 South Clive site	E-6
E.2 SCENIC, HISTORIC, AND CULTURAL RESOURCES	E-7
E.2.1 Regional history	E-7
E.2.2 History of South Salt Lake	E-9
E.2.3 Scenic quality rating of South Clive site	E-9
E.2.4 Archaeologic, historic, and cultural significance of South Clive site	E-10
E.3 SOCIOECONOMICS	E-11
E.3.1 Regional Population.	E-11
E.3.1.1 Local population and demography	E-11
E.3.1.2 Population projections	E-13
E.3.2 Economic structure	E-13
E.3.2.1 Regional economic conditions	E-13
E.3.2.2 Local economic conditions	E-15
E.3.3 Governmental structures	E-16
E.3.4 Housing	E-17
E.3.5 Community services	E-17
E.3.5.1 Schools	E-17
E.3.5.2 Tooele County social services	E-18
E.3.5.3 Tooele City social services	E-18
E.3.5.4 Grantsville social services	E-19
E.3.5.5 City of South Salt Lake social services	E-20
E.3.6 Transportation networks	E-21
E.3.6.1 Highways	E-21
E.3.6.2 Railroads	E-22
E.3.7 Recreation	E-22
References for Appendix E	E-25

LIST OF FIGURES

	<u>Page</u>
E-1 Regional land ownership	E-3
E-2 Land use within 0.5-mile radius of Vitro site	E-5
E-3 Routes of Utah's early explorers	E-8
E-4 Transportation routes and traffic volumes	E-22

LIST OF TABLES

	<u>Page</u>
E-1 Land use (by use or ownership) for Tooele County, in acres 1970 . .	E-2
E-2 Historic population data	E-11

E.1 LAND USE

Regional land-use patterns are distinctly different in heavily urbanized Salt Lake County and the more rural Tooele County. The Salt Lake County population is almost entirely urban (99.1 percent of its population lived in urban areas according to the 1980 census). Of a total county land area of 488,960 acres, 307,978 (63.0 percent) are privately owned and 66,118 acres (13.5 percent) are considered urban or are occupied by roads and railroads. The Federal government owns and controls 110,335 acres (22.6 percent), while the State owns 4,286 acres (0.9 percent). There are 243 acres of small water areas (2 to 40 acres) and streams that are less than 0.13 mile in width (Utah State Department of Agriculture, 1981).

Salt Lake County's 1980 land use included 38,096 acres (16.8 percent) of residential, 52,995 acres (23.4 percent) of agricultural and 78,032 acres (34.5 percent) of vacant land. By 1995, residential land use is projected to increase 36.1 percent to 51,848 acres. While agricultural land use and vacant land are projected to decrease by 30.3 percent and 24.5 percent, respectively (Wasatch Front Regional Council, 1980). In 1980, transportation used 24,815 acres (11.0 percent), industry 15,801 acres (7.0 percent), and commercial 5,073 acres (2.2 percent).

In Tooele County the Federal government owns and controls 82.6 percent of the county land area of 4.43 million acres (Table E-1). The greatest portion (1,948,417 acres) of the Federal land is public domain administered by the U.S. Bureau of Land Management (BLM). The U.S. Department of Defense (DOD) controls the next greatest portion of 1,558,862 acres, and national forests occupy 152,223 acres (Utah State Department of Agriculture, 1981). Regional land ownership is shown in Figure E-1.

Tooele County land, excluding Federal and urban land and small bodies of water, totals 755,288 acres. Land use for this acreage is as follows:

Cropland	39,776
Pasture	2,326
Range	418,469
Forest	214,332
Other	<u>80,385</u>
Subtotal	755,288

Population figures from the 1970 census show that 28.2 percent of Tooele County's population was rural. This is somewhat higher than the 19.6 percent rural population of the state.

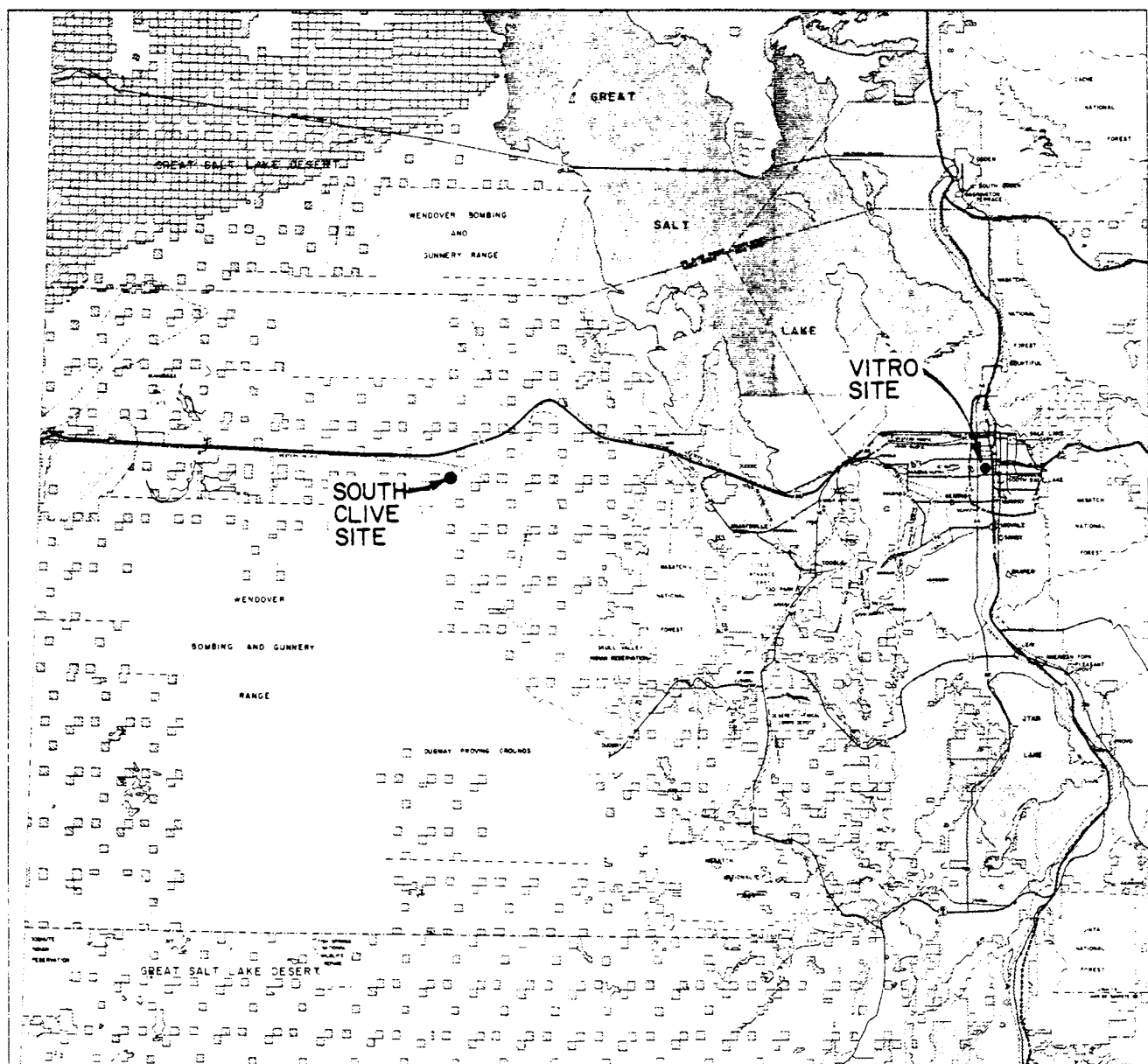
Much of the state-owned land in Tooele County is leased to private citizens for grazing cattle. The estimated total number of cattle in Tooele County (18,300) is 2.1 percent of the state total (Utah State Department of Agriculture, 1981).

Table E-1. Land use (by use or ownership) for
Tooele County, in acres, 1970

Use or ownership	Acres	Percent of total county
Federal land	3,659,502	82.60
Residential and accessory use	1,546	0.03
Commercial	240	0.01
Industrial (plant sites, 885; salt ponds and other 50,000)	50,885	1.15
Agriculture (crops 39,776: irrigated 18,859 non-irrig. 20,917)	39,776	0.90
Other private lands	425,107	9.60
State lands (no highways)	218,640	4.94
Highways, roads & streets	13,651	0.30
Railroads	3,000	0.06
Indian land	17,763	0.40
Public & quasi-public, in municipalities	588	0.01
Small waters (excluding all of more than 40 acres) ^a	22	0.00
Totals	4,430,720	100.00

^aWater areas of 2 to 40 acres and streams less than 0.125 mile
in width.

Source: Mountain Area Planners, 1972.



LEGEND

-  Public Land - BLM, Indian Reservations, and Military
-  State Land
-  Private Land

BASE MAP REFERENCE:
UTAH TRAVEL COUNCIL, NO DATE.

0 5 10 15 25 MILES
SCALE

**FIGURE E-1
REGIONAL LAND OWNERSHIP**

E.1.1 Vitro site

The entire 128-acre Vitro site is owned by the Central Valley Water Reclamation Facility Board, operator of the sewage treatment plant to the north of the site.

Land ownership in the vicinity is predominantly private.

E.1.1.1 Historic land use

The Vitro site was used for an alumina plant during World War II. That plant was converted to produce uranium beginning in May 1951; the output was sold to the U.S. Atomic Energy Commission (AEC) under procurement contracts until February 1964. The plant was then converted to produce commercial vanadium, operating until July 1968. Plant demolition was completed during 1970.

The site is part of a 1979 annexation by the City of South Salt Lake of a portion of unincorporated Salt Lake County. Land use within a 0.5-mile radius of the site began to change from predominantly agricultural and vacant to other uses in 1979. In 1974, a construction moratorium imposed by the Salt Lake City-County Board of Health banned construction within a 0.5-mile radius of the site. This ban was lifted in 1979.

E.1.1.2 Present land use

Land use within a 0.5-mile radius of the site is shown on Figure E-2 and is as follows:

Land Use	Percentage of total within 0.5-mile radius (1370 acres)
Residential	6
Commercial	5
Industrial	18
Transportation/Utility	28
Agriculture	16
Vacant (excluding Vitro site)	27

Source: FBDU, 1981

The Salt Lake City Suburban Sanitary District No. 1 sewage treatment plant is located immediately to the north of the Vitro site (Figure E-1). This facility has been in operation since its initial construction in 1954. The Central Valley Water Reclamation Facility (CVWRF) Board, owner and operator of the treatment facility, is currently building a new facility on the Vitro site. The new plant is planned to be operating by 1987 at sufficient capacity to provide treatment through the year 2000.

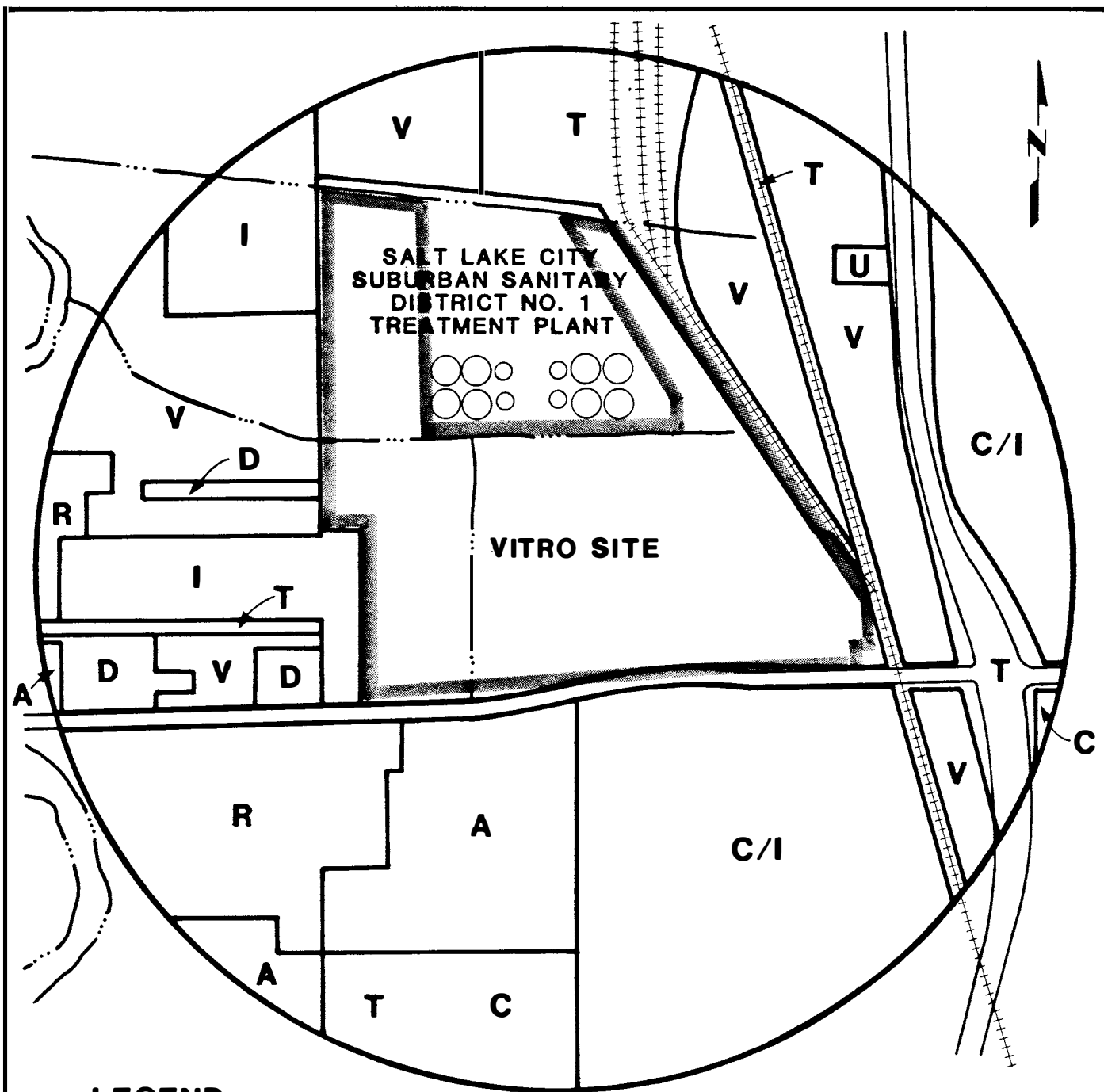


**FIGURE E-2
LAND USE WITHIN 0.5-MILE RADIUS OF VITRO SITE**

E.1.1.3 Potential future land use and development

The potential for development of the vacant portions of the 128-acre Vitro site is essentially nil in the absence of some remedial plan to eliminate hazards caused by the presence of the tailings. Plans for CVWRF's expansion of its wastewater treatment facility to 100 million gallons per day, and construction of a temporary industrial park and a municipal solid waste-to-energy facility cannot be implemented without some remedial action.

In the general vicinity of the site, the level topography, soils suited for foundations, and good accessibility render lands suitable for a wide range of urban uses. It is generally agreed by the CVWRF Board, South Salt Lake officials, and Salt Lake County officials that the "highest and best" use for the area is primarily in wholesaling and warehousing functions. However, the 3300 South Street frontage portion of the Vitro site is currently zoned Business (A) which permits a wide variety of business and retail activities.

The City's Master Plan contains estimates of the absorption of vacant land zoned for industrial use in South Salt Lake. The "high estimate" projects that between 82 and 84 percent of the City's development scenario assumes the following "major economic stimuli": (1) deployment of the MX missile system in western Utah; (2) increased extraction of coal reserves in Utah's Overthrust Belt; and (3) continued development of statewide water and power projects. The "low estimate" assumes a moderate national and/or regional recession. Under this scenario, 58 percent of the available industrial land will be absorbed by 1990. Because of the low average income of the city's population, as well as its proximity to the Salt Lake City business district, retail and commercial development in the area is expected to be minimal. South Salt Lake's forecasted growth will be predominantly in wholesaling, distribution, and office/warehouse (70 percent) and industrial uses (16 percent), with the remaining 14 percent being a combination of retailing, office, and service businesses (Vanwagoner and Associates, 1980).

E.1.2 South Clive site

The South Clive site is owned by the State of Utah. Most lands within a 10-mile radius are public domain administered by the BLM, with scattered lands owned by the State of Utah or privately.

Most lands within a 10-mile radius of the site are used very rarely because of their remoteness from urbanized areas and the poor soil, occasional muddy conditions, and sparse vegetation characteristic of the region. Sheep grazing and recreational-vehicle driving are the primary uses made of the area, but such uses are apparently light. The productivity (in terms of animal units supported) of the South Clive site and vicinity for grazing, although relatively good for the area (e.g., the Mud Flats), is low relative to other lands in the region. The Skull Valley Company holds a State grazing lease for the site. Although no reports on land uses in the vicinity could be found, numerous trails in the area indicate that it has been used on occasion for recreational vehicle purposes, and much of the vicinity may be used on occasion for jackrabbit hunting. The only other use of lands within a 10-mile radius is for transportation. Interstate 80 and the Union Pacific System railway pass 2.5 miles and 1 mile north, respectively, of the site.

E.2 SCENIC, HISTORIC, AND CULTURAL RESOURCES

E.2.1 Regional history

During the 1820s, the area around the Great Salt Lake was explored by trappers and scouts of the Ashley party, Jim Bridger, Jedediah S. Smith, Colonel J.G. Fremont, and Kit Carson. Use of the explorers' trails (Figure E-3) soon expanded to cattle drives and settlers, most of whom were headed to California or Oregon. One such group of settlers was the Donner party that opened the route through the Wasatch Range and across the Great Salt Lake Desert north of Clive.

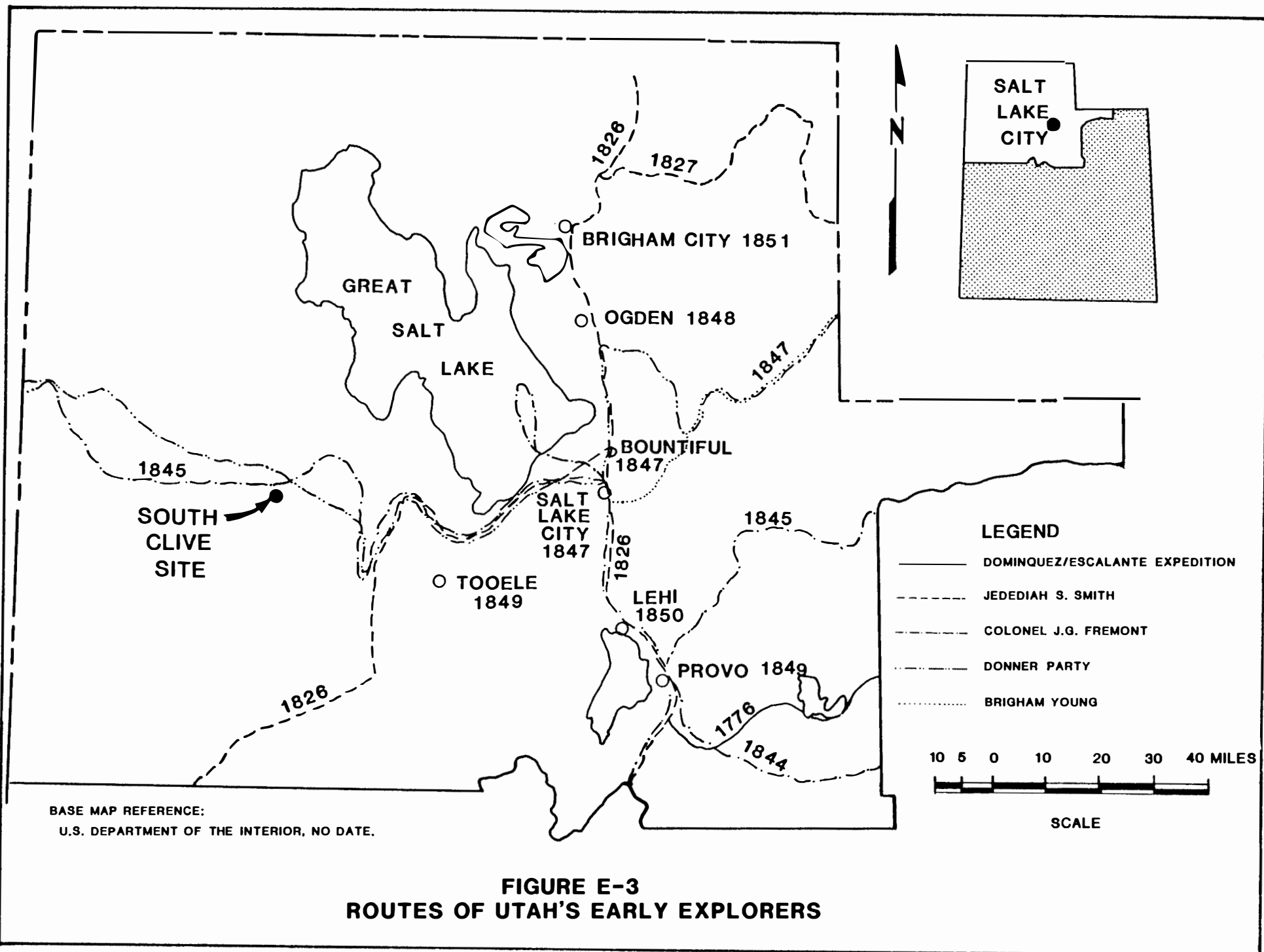
On July 24, 1847, the pioneer party of Mormons led by Brigham Young pulled out of Emigration Canyon, following the Donner route into the Valley of the Great Salt Lake, and settled the site near present Temple Square in Salt Lake City where they built cabins on Settlement Creek and Twin Springs (present Stansbury Park). Within two years another townsite was established at Grantsville. Religious refugees seeking an isolated location to practice their faith in comparative freedom, the Mormons colonized over 300 settlements in and near the Great Basin under the leadership of Brigham Young.

The theodemocratic state of Deseret was proposed in 1849, when a Mormon committee sent a petition to Washington, D.C. asking for a territorial government of their own. The "state" encompassed the vast area of present day Utah, Nevada, Arizona and portions of Oregon, Wyoming, Colorado, New Mexico, Idaho, and California. Tooele County was established by the State of Deseret in January of 1850.

Utah's applications for statehood were denied, however, for over forty years because of theocratic domination of the civil government and the practice of polygamy. After the Manifesto of 1890, the U.S. Congress passed an enabling act inviting Utah to submit a constitution for statehood. The constitution was ratified in November of 1895. On January 4, 1896, President Cleveland signed the statehood act and Utah joined the Union.

During the years since statehood, a split-party system of "middle-of-the-road" conservative politics has maintained the pre-statehood theme of community. The Mormon vote has traditionally been a key factor in political issues. The separation of church and state became more evident with the emergence of a substantial business sector, the commercialization of agriculture, and the development of corporate mining and manufacturing.

With World War I came the sophistication of industrialization. Shortly after the war ended, the cancellation of government contracts, the termination of wartime business controls, and the change of marketing and business patterns that had developed during the war brought to an end the "warborn" economic boom in Utah. Like the rest of the country, Utah was severely affected by the 1929 stock market crash. All aspects of Utah's economy plummeted, and did not recover until the outbreak of World War II. During the course of the war, Utah became the site of ten major military bases and an army hospital, employing approximately 100,000 people. Fort Douglas, established in 1862, became the nerve center for states west of the Rockies, and Kearns Army Air Base was rapidly constructed and trained over 90,000 airmen between August 1942 and October 1943. The nation's largest military reserve, covering three and a half million acres, is the Wendover Air Force Base in Tooele County where the 509th Composite that dropped the atomic



bombs on Hiroshima and Nagasaki trained. Also constructed were the Tooele Army Depot, the Deseret Chemical Depot, and the Dugway Proving Ground. The building of military installations during the war and the continuation of their use has resulted in Utah being the state with the largest number of government employees. In 1974, more than 11 percent of the population was employed by the government (Peterson, 1977).

Agriculture and mining industries have taken a less substantial place in the economy than government employment. However, energy prices have created a stimulus for production of fossil fuels and coal mining has made a recent comeback in Utah. Other mining industries continue to flourish. In recent years tourism has provided a great boost to Utah's economy.

E.2.2 History of South Salt Lake

On September 29, 1938, South Salt Lake was incorporated in time to make the September 30 deadline for application for a Public Works Administration grant for federal financial aid to build a sewer system. By the fall of 1940, the main sewer system had been installed. The city would not grow until it could provide a potable water system; a water revenue bond election was held and the issue was passed in 1947. The town also established its own bank and obtained a charter for Valley State Bank in 1947. In 1950, the town's first post office was built and it became a third-class city. The population at the time of incorporation was 4000; by 1950 it had grown to 5000. The city expanded its boundaries in 1955 by annexing to Eighth West Street. During the 1950s, the city grew and became a major industrial center.

By 1970 the city's residential population was declining. In 1979, the city annexed approximately 900 acres, extending its boundaries from Mill Creek to 3300 South Street and from the Jordan River to Seventh East Street, thereby increasing its population to 10,500. The daytime population increases to about 40,000 due to the large commercial-industrial sector of the city.

E.2.3 Scenic quality rating of South Clive site

The BLM Visual Resource Inventory and Evaluation System (BLM, 1978) was used to rate the scenic quality of the site relative to the physiographic province. This rating system employs a scale of 0 to 33, with higher ratings (19 or above) indicating that special management attention is required. The numerical rating system is shown below, with the ratings for the South Clive site underlined.

Scenic Quality Rating

<u>Category</u>	<u>Score</u>		
	<u>High</u>	<u>Medium</u>	<u>Low</u>
Landform	5	<u>3</u>	1
Vegetation	5	<u>3</u>	<u>1</u>
Water	5	<u>3</u>	0
Color	5	<u>3</u>	<u>1</u>
Influence	5	<u>3</u>	0
Scarcity	6	<u>2</u>	<u>1</u>
Cultural Modification	2	<u>0</u>	4

The total score of 12 assigned to the South Clive Site is a low-to-medium rating for scenic quality, indicating that no special management attention is necessary.

E.2.4 Archaeologic, historic, and cultural significance of South Clive site

On August 24-26, 1981, an intensive cultural resource inventory of the South Clive site and vicinity was conducted by the Archaeological-Environmental Research Corporation. No cultural resource sites were identified during the inventory but one isolated artifact (designated 615A/X1) was found. This artifact is four pieces of broken purple glass from some unknown historic glass object. It does not appear that such a find indicates the existence on the site of significant archaeologic artifacts.

The Ground to Air Pilotless Aircraft Launch Site and Blockhouse listed in the National Register of Historical Places is approximately 10 miles west of Clive at Knolls. To the southeast of Clive (approximately 23 air miles) is the site of the Iosepa Settlement Cemetery. These are the historic sites closest to the transportation corridors between the Vitro site and the South Clive site.

E.3 SOCIOECONOMICS

E.3.1 Regional Population

According to the 1980 census (U.S. Department of Commerce, 1981), the state of Utah had a total population of 1,461,037 (Table E-2). This was an increase of 37.9 percent since 1970, the largest since the 1940-1950 decade when the population grew by 25.2 percent. Most of the state's population (80.4 percent) lived in urban areas (places of 2500 or more), predominantly in the Wasatch Front. The median age of Utah residents in 1980 was 24.2 years, lowest in the nation. The state's population growth between 1950 and 1960 was 95 percent from natural increase (births minus deaths), with only a small amount of immigration (10,000 people). During the next decade, natural increase offset the outmigration of approximately 11,000, to increase the total population by 18.9 percent. "Baseline" population projections indicate that by the year 2000 the state could increase its total population to 2.3 million persons, 60 percent over that of 1980 (Utah State Planning Coordinator, 1981).

Table E-2. Historic population data

	Population (percent change from previous Census)				
	1940	1950	1960	1970	1980
State	550,310 (8.4)	688,862 (25.2)	890,627 (29.3)	1,059,273 (18.9)	1,461,037 (37.9)
Tooele County	9,133 (-2.97)	14,636 (60.3)	17,868 (22.1)	21,545 (20.6)	26,033 (20.8)
Salt Lake County	211,623 (9.0)	274,895 (29.8)	383,035 (39.3)	458,607 (19.7)	619,066 (35.0)

Source: U.S. Department of Commerce, 1952, 1963, 1973, and 1981.

E.3.1.1 Local population and demography

Historic and current populations and trends are described in the following sections for the City of South Salt Lake, the area within 0.5 mile of the Vitro site, Tooele City, and Grantsville. The sources of demographic information are the decennial census counts, unless otherwise indicated.

City of South Salt Lake

The population of South Salt Lake decreased at an average annual rate of 2.0 percent during the 1960-1970 period, from 9520 in 1960 to 7810 in 1970. It then grew by an average annual rate of 3.1 percent during the 1970s, reaching 10,561 in 1980. In 1980, 92.6 percent of its population was classified as white,

compared to 94.3 percent for Salt Lake County and 94.6 percent for the state as a whole. South Salt Lake can be characterized as an area with small families, in life cycle stages either before or after the child-rearing stage. The proportion of families with incomes below poverty level in 1970 was 10.3 percent, higher than the statewide average of 9.2 percent.

Vitro site vicinity

Population counts were conducted for the area within 0.5 mile of the Vitro site by FBDU (1981). These counts indicated that 497 persons resided in the area, with average residential densities generally increasing with distance from the site. Average population density within 0.5 mile of the Vitro site was about one person per acre. Beyond 0.5 mile, density increased rapidly to 4.3 persons per acre within 2 miles.

Tooele City

Tooele City's population grew from 9133 in 1960 to 12,539 in 1970, an average annual increase of 3.2 percent. In the following decade the growth rate decreased to 1.3 percent per year, to a 1980 city population of 14,335. Nonwhite persons made up 8 percent of the city's population in 1980.

Tooele City's population was, on the average, older than the state's in 1970 (24.7 versus 23.1 years of age), and had a lower percent of persons over 64 years old (6.2 percent versus 7.3 percent for the state). A relatively high proportion of its population was married (69 percent of males versus 56.6 percent for the state) and its birth rate* (435) was about equal to the state average (436).

The average household size in Tooele City was 3.38 persons in 1970, slightly less than the statewide average. Thus, much of the city's population appears to be in the early child-rearing life cycle stage. Its population was slightly less educated (an average of 12.2 years of education) than the statewide average but far more educated than the national average. Only 4.8 percent of its families had incomes less than the poverty level. The County mortality rate decreased more rapidly than the birth rate during the 1970s, causing an increase in the net natural population. However, net outmigration during the 1970s (including annexation of land) caused a loss of 682 residents.

Grantsville

Grantsville's population grew by an average annual rate of 3.1 percent between 1960 and 1970, from 2166 to 2931 persons, and increased by 4.2 percent per year during the 1970s to a 1980 population of 4419. Only 4.2 percent of its population was nonwhite in 1980.

Grantsville's population had a high birth rate in 1970 (517 versus 436 for the state), a large average household size (3.71), a low proportion of population over 65, and a high proportion under 18. Thus, many Grantsville residents appear to be members of families in the early child-rearing life cycle stage.

*Live births per 100,000 population.

E.3.1.2 Population projections

A growth rate averaging 3.1 percent is assumed most probable for Salt Lake County through the year 2005 because it corresponds to the growth rate of the County from 1970 to 1978. The development of synthetic fuels within the state, however, could create a short-lived rapid growth which should taper off. Assuming that rapid developments in the energy field occur, the growth rate could go up to "7.0 percent declining," meaning in 25 years the growth rate will taper off to zero (FBDU, 1981). A growth rate of 0.8 percent would be consistent with that of the entire United States.

It is projected that Tooele County will increase its population at an annual rate of 3.8 percent until 1985; thereafter, its growth rate will decline. This projection is based on expected energy development and subsequent employment opportunity that should also taper off. It is expected that the largest percentages of growth will occur in Tooele City, Grantsville, and Wendover (Mountain Area Planners, 1972).

E.3.2 Economic structure

The distribution of Utah's employment and income among industrial sectors indicates a well-balanced and healthy economy similar in structure to that of the United States as a whole. The state's most prominent employment sectors in 1979 were services with a 16.4 percent share of total wage and salary employment, government with a 24.0 percent share, retail trade at 17.0 percent, and manufacturing with 15.4 percent (U.S. Department of Commerce, 1981). Per capita income in 1979 was \$7182, which placed Utah below both the Rocky Mountain state and national averages. During the 1970s, the economy grew and matured sufficiently to begin providing a nearly full range of goods and services to its residents without extensive dependence, as had been previously the case, on other regions in obtaining those goods and services (Utah State Planning Coordinator, 1981).

E.3.2.1 Regional economic conditions

The economies of Salt Lake and Tooele Counties, the two counties in the immediate project region, differ in structure although the two are classified as being in the same (Salt Lake City) Standard Metropolitan Statistical Area. Thus, the following discussion distinguishes the two counties.

Salt Lake County, which is the State of Utah's central economic area, exhibits the same general economic health as the state as a whole. Its unemployment rate in 1980 averaged 5.1 percent, compared to a 5.4 percent statewide average (Utah Department of Employment Security, 1980). As is true for the state as a whole, the County unemployment rate has been increasing since 1979. It was 6.0 percent in February 1981, 7.4 percent during 1982 and 7.5 percent as of May 1983. Based on an analysis of 1979 employment patterns by industrial sector, the County's export base consisted primarily of durable goods manufacturing, transportation and public utilities, wholesale and retail trade,

finance, insurance, and real estate, and services; the importance of these sectors underscores the County's role as the state's economic services center. Government employment is less prominent in Salt Lake County than in the state as a whole. Based on the 2.5 employment multiplier used by the Utah State Planning Coordinator's Office for the Wasatch Front planning area, the basic/nonbasic employment multiplier for Salt Lake County is estimated at approximately 2.5 jobs for every job created in the basic, or export, sector of the economy.

Tooele County's economy is based primarily on Federal employment. Employment at the Deseret Test Center and Army Depot were primarily responsible for the Federal government employment share of 49.7 percent of the total 1979 wage and salary jobs in the County. Mining is the second most important sector of the export base of the County, providing 7.3 percent of the wage and salary jobs. The major nonmanufacturing employers in Tooele County are the Tooele Army Depot (3800 employees), the Deseret Test Center (680 employees), the Tooele County School District (710 employees), and Anaconda Copper (665 employees). Major employers in the manufacturing, mining, and processing sectors are N.L. Industries (735 employees), Catalina Sportswear (75 employees), American Salt (70 employees), and Kaiser Aluminum and Chemical (65 employees). The mining and processing sector primarily produces magnesium, potash, salt, tin, lead, silver, zinc, and copper (Utah Industrial Development Information System, no date).

The remaining sectors of the Tooele County economy have far lower shares of total County employment than the state average, indicating that much of the income earned by workers in the basic sectors of the County is spent in other counties, particularly Salt Lake County. The basic to nonbasic employment multiplier for Tooele County, assuming that all Federal and mining employment, 75 percent of all employment in the manufacturing sector, and 10 percent of all state and local government employment can be classified as basic, is estimated at a total of 1.5 jobs for every job created in the basic sectors. This estimate of the county's multiplier is consistent with multipliers often estimated for rural areas with underdeveloped service economies.

Tooele County's unemployment rate remained close to 5.8 percent through 1980 and early 1981, having increased from 5.0 percent in 1979 (Utah Department of Employment Security, 1980). By contrast, the statewide unemployment rate for 1980 was 5.4 percent. Unemployment in Tooele County during 1982 was 9.9 percent. This compares to a figure of 7.8 percent for the entire state during 1982. Current (May 1983) unemployment rates for the State of Utah and Tooele County are 8.8 percent and 9.9 percent, respectively. Future unemployment rates in the county, which depend to a large extent upon employment at Dugway, are expected to moderate as Federal defense expenditures rise and the nationwide economy stabilizes.

Per capita income in Tooele County in 1979 was \$6782, 94.4 percent of the statewide average (U.S. Department of Commerce, 1981). In 1974, per capita income in Tooele County exceeded the state average by 2.5 percent, and in 1969 the County had 6.0 percent more income per capita than the state. Thus, while per capita income in Tooele County has grown in real terms since 1969, its rate of growth has been significantly less than that for the state as a whole. Transfer payments represented 15.2 percent of Tooele County personal income in 1979, compared to an 11.7 percent statewide average. This is a reflection both of the

higher proportion of elderly persons (and, therefore, social security income) in Tooele County than in the state, and the lower per capita income and hence higher per capita rate of welfare payments. In general, the economic data reveal that the Tooele County economy is stable due to Federal military employment but, like most rural areas in the state, it has a relatively high unemployment rate and underdeveloped secondary economy.

E.3.2.2 Local economic conditions

This section contains brief descriptions of the economies of towns and cities near the Vitro site and the South Clive site--the City of South Salt Lake, in which the Vitro site is located, and Tooele, Grantsville, and Wendover in Tooele County.

City of South Salt Lake

The economy of the City of South Salt Lake is based primarily in manufacturing, transportation, and wholesale and retail trade (Utah Department of Employment Security, 1980). Much of the manufacturing and warehousing in the Salt Lake City urban area is located in South Salt Lake. Major employers (Utah Industrial Development Division, no date) include the ZCMI Central Warehouse (695 employees) and EDO Western Corporation (270 employees). The city's proximity to major highways makes it an ideal location for warehousing and transportation oriented industry. The existence of significant amounts of vacant land in the city, primarily near the Vitro site, will permit further industrial/warehouse development uses for which the area is planned and zoned.

The large industrial tax base in South Salt Lake permits the city to levy a relatively low city property tax (the 1982 mil levy was 6.25). The city also has a sales tax of 0.75 percent which, in combination with a large taxable sales base (\$254,513,460 in 1979), yields large revenues for the city (Utah Industrial Development Division, no date). Sales taxes are anticipated to yield about \$2.2 million in revenue in the 1981-82 fiscal year, 64.7 percent of total city general fund revenues of \$3,406,916. Property tax receipts are projected to total \$465,000, 13.6 percent of all general fund revenues (City of South Salt Lake, 1981). The city will also receive about \$399,000 in Federal revenue sharing monies.

City of Tooele

The economy of the city of Tooele, the economic and population center of Tooele County, closely resembles that of Tooele County. Principal employers in the city in 1979 were the U.S. Army Depot (3800 employees), Anaconda Copper (850 employees), Federal, state, and local offices (500 employees), the Tooele School District (400 employees), Tooele Valley Hospital (85), Catalina Sportswear (75 employees), and the Lake Point Salt Company (45 employees) (Utah Industrial Development Division, no date). Military, other governmental, and mining-related employment form the city's economic base. However, to the extent that the city functions as an economic center for the county, retail and wholesale trade and financial service employment also contribute to the city's economic base. Thus,

a portion of the income earned by residents of Tooele County is spent in Tooele City, adding to the city's employment. The city's total employment in May 1981 was estimated at 7412 or about 70 percent of the total county employment.

Several new industrial developments are planned for the city, chief among which is EMKO's industrial park, which includes 1783 acres and will be developed over the next 8 years. In addition, Getty Oil is planning a gold processing facility, to employ 250-300 persons, in Mercus, 15 miles south of Tooele. The Army Depot will also be increasing employment by 500 persons.

The city's 1981 property tax rate was 25.16 mils. With a citywide assessed valuation of \$31,474,748, property tax billings for the tax year will be approximately \$757,300. The city also has a sales tax of 0.75 percent, which is anticipated to bring in \$470,000 in sales tax revenue (Tooele City Corporation, 1981).

Grantsville

Grantsville, located approximately 34 miles from the South Clive site, had a 1980 population of 4419 (U.S. Department of Commerce, 1981). Grantsville's economy is based primarily on chemical manufacture and mineral mining and processing. The largest employer is NL Industries' Mineral Division, manufacturers of organic chemicals, with 725 employees (Utah Industrial Development Division, no date). Other major employers are Teddy Bear/Skyline, Inc., a food service company (80 employees), the American Salt Company (70 employees), the Tooele School District (65 employees), and U.S. Lime (45 employees).

Most of these firms, however, are not actually located within the city boundaries, as evidenced by the fact the State Employment Security Division estimated Grantsville employment at only 248 in May 1981. The city's property tax base is small, being approximately \$7 million; hence, a relatively high tax rate of 23.77 mils is levied by the city, which is expected to yield about \$167,000 in the coming year. No major industrial developments are foreseen to improve the property tax base.

In addition to the property tax base, the city receives sales tax revenues at a rate of 0.75 percent, which are expected to total about \$45,000 in the 1981 fiscal year. With a planned city budget of \$403,459 for 1982, miscellaneous intergovernmental transfers (such as returns from the state gas and liquor tax) and operating revenues (such as for water and sewer service and garbage collection) are, in sum, important revenue sources that help support city services. Services include police and fire protection, garbage collection, and water and sewer service.

E.3.3 Governmental structures

South Salt Lake, Tooele City, and Grantsville all have similar governmental structures, being governed by a mayor and five councilpersons. Likewise, both Tooele and Salt Lake Counties are governed by three elected county commissioners who make certain decisions, such as those concerning zoning, and oversee the provision of services in their respective counties. For instance, Salt Lake

County provides flood protection and health services to the City of South Salt Lake but delegates to the city the responsibility for maintenance of county roads within the city. Special districts, though not governmental entities, are important in both counties, providing services such as sewage treatment and public education.

E.3.4 Housing

The total number of housing units in Tooele County increased from 6455 to 8566, an increase of 32.7 percent, between 1970 and 1980 (U.S. Department of Commerce, 1981). Housing unit supplies increased more rapidly than population, indicating a decreased average household size. Housing unit growth was greatest, percentage-wise, in the Grantsville area, at 64.8 percent but Grantsville's 1980 housing stock was still small at only 1348 units. The 1980 Census preliminary count indicated that 5 percent of all units in Grantsville were vacant. Wendover also experienced a housing stock growth from 278 to 409 units in the 1970-80 period, a 47.1 percent increase; this rate of growth was, however, still less than the statewide 55.2 percent average. Tooele City's housing stock grew by 26.5 percent to 4877 units. Actual 1980 vacancy rate data are not yet available from the Bureau of Census, but the preliminary count indicated approximately 5.3 percent of the units are vacant. The County averaged 3.23 persons per dwelling unit in 1980.

In all jurisdictions, residential building activity virtually stopped with the high interest rates of 1980-82.

E.3.5 Community services

This section focuses upon the demand for and supply of social services in the areas of concern (Tooele City, Grantsville, South Salt Lake, and Tooele County). The services described below include schools, police and fire protection, public water and sewer systems, health services, and general government.

E.3.5.1 Schools

Schools are provided at the county or district level.

Tooele County

Total enrollment in the Tooele County School District was 7011 students during the 1981-82 school year, 0.3 percent higher than the previous year (1980-81) and 2.5 percent higher than the second previous year (1979-80) (Tooele County Schools, 1981). It appears that enrollment will increase in the short-term future at about the same rate (1.2 percent per year) as in the recent past. In the short term, this rate of enrollment growth is not expected to cause physical capacity or fiscal problems since the system is not experiencing significant overcrowding and has some excess bonding capacity. A new elementary

school is being built in Grantsville to alleviate overcrowding and will be completed by the 1982-83 school year. If Wendover's casino sector grows as is rumored some crowding may ultimately result. District-wide per student operating costs were \$1712 in 1981, and total per student costs were \$2535.

City of South Salt Lake

Education in the City of South Salt Lake and other nearby areas is provided by the Granite School District, one of four districts in Salt Lake County. Total district enrollment was 61,485 in September 1981, only about 2360 of whom were residents of South Salt Lake. Overall district enrollment declined during the 1970s, but has recently begun to rise again. This gradual enrollment rise is expected to continue. The four schools that service the bulk of South Salt Lake, however, are expected to continue to have stable enrollments. No crowding problems exist or are expected in these schools. District-wide per student operating costs were \$1769 in 1981, and total per student costs were \$2241.

E.3.5.2 Tooele County social services

Tooele County is governed by three County Commissioners. Economic planning and development agencies are the Tooele County Planning Office, Tooele County Chamber of Commerce, and the Wasatch Front Range Council of Governments.

Police protection is provided to the unincorporated areas in the county by a sheriff and 14 deputies (an average of 2.0 officers per 1000 population), and by 20-member Jeep Patrol (Tooele County Chamber of Commerce, 1980). The county sheriff also directs the county volunteer fire department which has 18 fire trucks at 9 fire substations located in Vernon, Clover, Terra, Ophir, Stockton, Pine Canyon, Lake Point, Stansbury Park, and Grantsville.

The county's single hospital, with 36 beds, is located in Tooele City and has a low average occupancy rate of 35 to 38 percent. Other medical services include two health clinics, one mental health clinic serving out-patients on a 24-hour basis, a vision center and optometrists, a foot clinic, and a veterinary clinic. Ambulance service is provided for the county by one privately-owned company in Tooele with one ambulance and by three vehicles managed by Advanced Health Systems located in Grantsville. The Tooele Valley Rest Home is also located in Tooele City. It has 46 beds, a 100 percent occupancy rate, and a waiting list (Tooele County Chamber of Commerce, 1980).

The county operates one public library housing 48,786 volumes, two book-mobiles and a storage facility in Grantsville that is open to the public. The library has a 1981-82 appropriations budget of \$73,350. Because this library services the entire county and has a high circulation rate per capita, some improvements are recommended (University of Utah Planning Program, 1981).

E.3.5.3 Tooele City social services

Tooele City is governed by a mayor and five city councilmen. It has one full-time licensed city engineer. Tooele City employs 22 full-time police

officers (1.53 officers per 1000 population), 2 animal control officers, 4 dispatchers, and 1 records officer, and maintains 10 pieces of motorized equipment. A minimum of three patrolmen and cars plus at least one detective are on duty at any given time within a 24-hour period within the city limits. The city budget for police protection was \$663,393 for the 1980-81 fiscal year and \$723,438 for the 1981-82 year. Protection is considered adequate.

Tooele City has an all-volunteer fire department consisting of about 50 volunteers. Firefighting equipment includes one equipment truck, two 1500-gallon pumper trucks, one 1000-gallon pumper truck, and two 1500-gallon brush and grass fire trucks. Fire hydrants throughout the city limits are located every 800 feet. The 1980-81 fiscal year budget for fire protection was \$90,238; for 1981-82 it increased to \$123,172. Fire protection is considered to be adequate; the fire insurance rate classification within the city limits is 5 and outside the city limits the classification is 10. These classifications are determined by the American Insurance Association on a scale of 1 to 10, with 10 being lowest rating (Tooele County Chamber of Commerce, 1980).

Tooele's water system is city-owned and is supplied by wells and springs. The system has an above ground storage capacity of 7 million gallons (mg) utilizing two 2 mg tanks, one 2.5 mg tank, and one 0.5 mg tank. The city's well system consists of 5 wells with a total rated pumping capacity of 4250 gallons per minute (gpm), or 6.12 million gallons per day (mgd). Average daily use is approximately 2 mgd, but during the summer it ranges as high as 8 mgd which is above the rated capacity of the system. The city is currently investigating the purchase of water from outside sources. Tooele also has two irrigation companies. One is a pressure system that is dual to the culinary system. The other is a gravity flow system. To the north of Tooele are two small unincorporated communities, Erda and Stansbury Park. Water for both agricultural and domestic use is provided by flowing artesian wells. Five irrigation companies within the area (Tooele, Grantsville, and Stockton) provide water for agricultural use and domestic gardening within each city's limits.

Tooele's sewage treatment plant is a combination primary settling tank, trickling filter, and digester. A recent addition to the system, within the past three years, has brought its life expectancy to 20 years. Average peak use is 25 percent below capacity of 2 mgd.

E.3.5.4 Grantsville social services

Grantsville is governed by a mayor and five city councilmen. It employs one part-time licensed city engineer. Grantsville currently employs three full-time police officers and expects to hire a fourth in the near future for 0.9 officers per 1000 population. The department maintains four pieces of motorized equipment. The city budget for police protection is \$122,000 for fiscal year 1981-82. According to the Grantsville Mayor, police protection is adequate.

Grantsville's fire department is manned by 30 volunteers. Firefighting equipment consists of 5 trucks, 4 pumpers, and 1 brush and grass fire truck. The American Insurance Association rate classification is 10. The fiscal year 1981-82 city budget for fire protection is \$15,000.

Grantsville's water source is local wells and the water is untreated. Storage capacity is 0.725 mg and deliverable capacity is 1.96 mgd (Bureau of Economic and Business Research, 1980). The system is projected to be sufficient until 1990 or until a population of 5200 is reached (using 1320 connections). At that time the demand requirement will reach just over 2 mgd.

Based on 20 average water users and 9 high users, an engineering study indicated that a population of 3500 would require an average daily demand of 102,192 gallons per day (Engineering Associates, 1975).

Line improvements are currently being made to improve the water pressure. To decrease wasteful consumption, North Willow Irrigation Company is currently building a reservoir and will soon be piping irrigation water to customers in Grantsville.

The sewage-treatment plant utilizes an aerated lagoon system, with a design rate capacity of 0.6 million gallons per day (mgd). The average daily flow is 0.4 mgd. The system is currently deemed to be adequate until 1990; when built in 1970, the design capacity was for an expected ten years or adequate for a population of 3850. When needed, expansion of the evaporation ponds will be relatively easy as the city owns the adjoining land.

E.3.5.5 City of South Salt Lake social services

South Salt Lake is governed by a mayor and five councilmen. The city employs a part-time licensed engineer (Utah Industrial Development Division, no date).

The South Salt Lake Police Department employs 22 officers (2.0 officers per 1000 population) as well as a public relations specialist, lieutenant, and chief. It operates 17 vehicles and has 3 to 4 patrolmen on-duty at any hour, providing an average response time of 2-3 minutes. Its budget for fiscal year 1981-82 was \$897,816, of which \$727,326 (81 percent) is personnel-related expenses (salaries, benefits, training, uniforms, etc.).

The South Salt Lake Fire Department employs 16 men on a full-time basis and has 25 volunteers. Firefighting equipment includes two ladder trucks, two squad trucks, three pumper trucks and one utility/service truck. Response time is two to three minutes. The American Insurance Association rating for South Salt Lake is 5. The department's budget for 1981-82 fiscal year is \$581,159.

South Salt Lake utilizes a gravity water system from six wells. Three wells flow directly into the system while the remaining require pressure pumps to circulate their water. The pressure required for this circulation is 64 to 84 pounds per square inch. The system's storage capacity and peak pumping capacity is 9 million gallons per day (mgd). The average pumping capacity is 5.5 mgd.

The sewage-treatment facility for South Salt Lake is a combination primary clarifier, trickling filter, and anaerobic digester. The design average flow capacity is 3 mgd. Current average flow is 2.4 mgd.

Located immediately to the north of the Vitro site is the Salt Lake City Suburban Sanitary District No. 1 treatment plant. This system is biofilter primary sedimentation type with a design average flow capacity of 17.25 mgd. The Central Valley Water Reclamation Facility is currently building a new facility on the site utilizing a portion of the existing plant. Operation is planned for 1987. This plant will have a design average flow of 50 mgd and is expected to last until the year 2000. Once completed, this system will replace the South Salt Lake and the Salt Lake City Suburban District No. 1 plants as well as the 7.5-mgd Granger-Hunter District plant, the 8-mgd Cottonwood District plant, and the 4-mgd Murray City plant.

E.3.6 Transportation networks

The major transportation routes from the Vitro site to the South Clive site are defined in the following two sections. Annual average daily traffic counts for potential haul routes (borrow and tailings) were provided by the Utah Department of Transportation (1980, 1984).

E.3.6.1 Highways

The Vitro site is bounded on the south by 3300 South Street, which is Utah State Highway 171 and on the west by 900 West Street. State Highway 171 extends west through Granger and Hunter and ends at the intersection with State Highway 111 just south of Magna. 900 West Street runs north-south and intersects State Highway 201 (U.S. Alternate) approximately 1.75 miles to the north of Highway 171. State Highway 201 also runs east-west, passes Magna on the north and, 8 miles to the west, joins Interstate 80 that extends west past Clive (Figure E-4).

An automatic traffic recorder station located very near the Vitro site on State Highway 171 indicated an annual average daily traffic count of 24,850 in 1979. Near the new Interstate 215, the volume increased to about 32,000 and then to 34,385 near Granger. From just west of Granger, the volume decreased from 18,575 near Hunter to 13,790 near Magna at the intersection with State Highway 111. North of this intersection, the traffic volume on State Highway 111 between State Highways 171 and 201 averaged 8380. Just before joining Interstate 80, the volume on State Highway 201 was over 10,000.

To utilize the four-lane highway system from the Vitro site to Clive, the most logical route would be north on Interstate 15 to State Highway 201. However, traffic volumes are much higher using this route. At the intersection of I-15 and 3300 South Street, the average daily traffic count was about 24,850 vehicles in 1980. On I-15 the count was 102,230 just before the interchange with I-80 and then 123,015 just north of the interchange. Just west of I-15 on State Highway 201 the count was 67,670 and reduced to 41,700 about a mile west of I-215. By about half way to Magna from I-15 the count decreased further to 17,680, dropping again to 10,810 just before the intersection with State Highway 111. West of this intersection the volume was only 9720 and continued to become less (6060) before joining Interstate 80. On I-80, vehicle counts were 15,515 between the junction with State Highway 201 and the turnoff to Tooele (State

REFERENCE:
UTAH DEPARTMENT OF TRANSPORTATION, 1980.

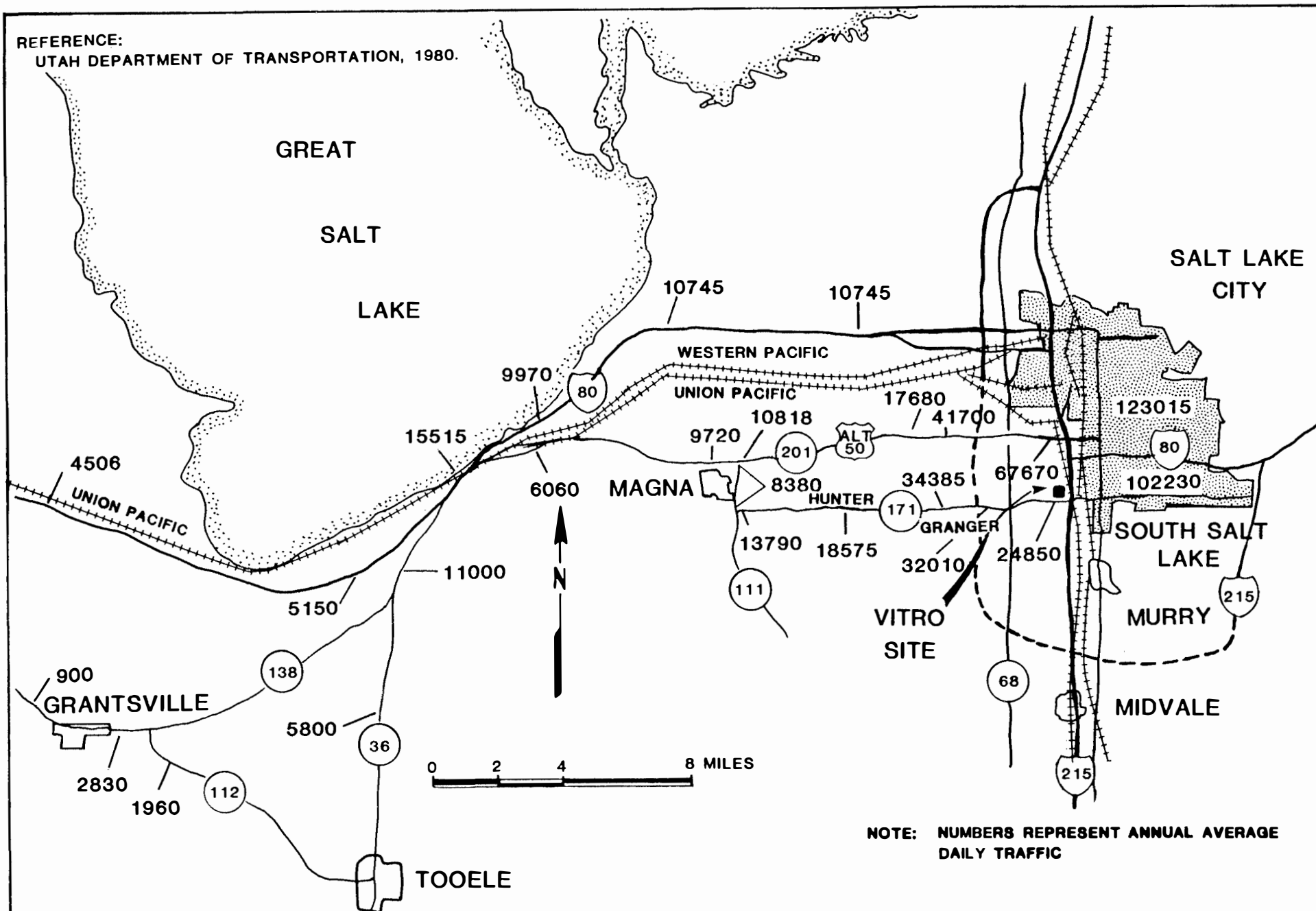


FIGURE E-4. TRANSPORTATION ROUTES AND TRAFFIC VOLUMES

Highway 36). Progressing westward, the traffic volumes continue to decrease; first, from 5150 to 4560 (to the north of Grantsville) and then to 3465 at Rowley Junction, another 10 miles distant. From here, and proceeding past Clive, the average volume remains constant at 3465 to Wendover.

E.3.6.2 Railroads

The Denver and Rio Grande Western Railroad forms the east boundary of the Vitro site. The tailings would be transported into Salt Lake City and then along the Union Pacific line to Clive.

E.3.7 Recreation

In 1975, the Institute for the Study of Outdoor Recreation and Tourism at Utah State University inventoried facilities for most types of outdoor recreation within the state of Utah.

In Tooele County, the greatest number of facilities were available for four-wheeling with open space, playgrounds, tennis courts, and softball fields next. Facilities available for picnicking and camping were also abundant, the Wasatch National Forests providing a total of 936 sites for outdoor activities such as fishing, hiking, camping and picnicking, and hunting (Utah Travel Council, 1979). State Parks within Tooele County include the Great Salt Lake State Park Saltair Beach, located 15 miles west of Salt Lake City, the Bonneville Salt Flats, and Danger Cave located near Wendover. The salt flats are listed in the National Register of Historical Places, being approximately 44,000 acres of the remains of ancient Lake Bonneville that at one time covered nearly one-third of the state. The salt flats' fame derives primarily from land speed record attempts at the Bonneville Race Track.

Recreational use of land within a 5-mile radius of Clive is limited to occasional recreational vehicle use and jackrabbit hunting. Jackrabbit hunting throughout the county is allowed any time without a permit or license. Hunting other game is allowed only seasonally and requires a permit or license. Off-road vehicle use near the site is rare because of the number of mud flats in the vicinity.

In Salt Lake County, facilities for softball, playgrounds, open space, soccer, tennis, and swimming are the most numerous with football, golf, and picnicking next. South Salt Lake has three parks for general picnic and recreation purposes and one ballfield, and borders a public golf course.

REFERENCES FOR APPENDIX E

- Bureau of Economic and Business Research, 1980. "Utah Community Economic facts," prepared for Utah Industrial Development Division, Salt Lake City, Utah.
- BLM (Bureau of Land Management, U.S. Department of Interior), 1978. Upland Visual Resource Inventory and Evaluation, BLM Manual Section 8411, Salt Lake City, Utah.
- City of South Salt Lake, 1981. Official Budgets for Fiscal Year Ending June 30, 1982, South Salt Lake, Utah.
- Engineering Associates, 1975. "Culinary Water Study for Grantsville," Salt Lake City, Utah.
- FBDU (Ford, Bacon and Davis Utah Inc.), 1981. Engineering Assessment of Inactive Uranium Mill Tailings for Vitro Site, Salt Lake City, Utah, DOE/UMT-0102, prepared for U.S. Department of Energy, Albuquerque Operations Office, Albuquerque, New Mexico.
- Mountain Area Planners, 1972. "A Master Plan for Tooele County and Municipalities, 1990," Salt Lake City, Utah.
- Peterson, Charles S., 1977. Utah - A History. W.W. Norton and Company, Inc., New York, New York.
- Tooele City Corporation, 1981. "Combined General, Road "C" and Collector Road Funds, 1981-1982 Revenues," Tooele City, Utah.
- Tooele County Chamber of Commerce, 1980. "General Information on Tooele County," Tooele City, Utah.
- Tooele County Schools, 1981. "Enrollment by Schools, (August 31, 1981, October 1, 1980, September 6, 1979)," Tooele City, Utah.
- U.S. Department of Commerce, 1952. Census of Population: 1950, Characteristics of the Population, Bureau of the Census, Volume 2, Part 44 - Utah, U.S. Government Printing Office, Washington, D.C.
- U.S. Department of Commerce, 1963. Census of Population: 1960, Characteristics of the Population, Bureau of the Census, Volume 1, Part 46 - Utah, U.S. Government Printing Office, Washington, D.C.
- U.S. Department of Commerce, 1973. Census of Population: 1970, Characteristics of the Population, Bureau of the Census, Volume 1, Part 46 - Utah, U.S. Government Printing Office, Washington, D.C.
- U.S. Department of Commerce, 1981. 1980 Census of Population and Housing, Utah, Bureau of the Census, U.S. Government Printing Office, Washington, D.C.
- U.S. Department of Interior, no date. Desert Crossroads, Bureau of Land Management, Salt Lake District Office, 2370 South 2300 West, Salt Lake City, Utah 84119.

- University of Utah Planning Program, 1981. "Tooele, Utah, 1981, A Comprehensive Plan," Department of Geography, 1981 Practicum, Salt Lake City, Utah .
- Utah Department of Employment Security, 1980. Employment by Work Site in David, Salt Lake, Utah, and Weber County Work Site Districts in the State of Utah, 1971-1979, Salt Lake City, Utah.
- Utah Department of Transportation, 1980. Traffic on Utah Highways - 1979, Salt Lake City, Utah.
- Utah Department of Transportation, 1984. Personal communication with Ron Phyllips, January 20, 1984.
- Utah Industrial Development Division, no date. "Community Economic Facts," editions for Tooele County, Tooele, Grantsville, Wendover, and South Salt Lake.
- Utah State Department of Agriculture, 1981. Utah Agricultural Statistics, 1982, Salt Lake City, Utah.
- Utah State Planning Coordinator, 1981. Utah 2000: A High Development Scenario, Salt Lake City, Utah.
- Utah Travel Council, 1979. Utah! Recreational Guide, published brochure, Salt Lake City, Utah.
- Vanwagoner, W.T. and Associates, Inc., 1980. "South Salt Lake City Master Plan, Phase II," Salt Lake City, Utah.
- Wasatch Front Regional Council, 1980. "Surveillance of Land Use and Socioeconomic Characteristics, 1970, 1978, 1979, and 1995," Surveillance Report, Volume 2, No. 6, December 1980.

Appendix F

Radiological Information

Table of Contents

	<u>Page</u>
F-1 Basic facts about radiation and its measurement.....	F-3
F-2 Method of analysis.....	F-7
F.2.1 Health effects of exposure to radon daughters.....	F-7
F.2.2 Health effects of exposure to gamma radiation.....	F-9
F.3 Site radiological characteristics.....	F-11
F.3.1 Existing pile characteristics.....	F-11
F.3.2 Environmental radiation measurements.....	F-13
F.3.2.1 Vitro site environmental radioactivity.....	F-13
F.3.2.2 South Clive site environmental radioactivity....	F-18
F.3.2.3 Transportation corridor environmental radioactivity.....	F-24
F.4 Radioactive source term.....	F-27
F.4.1 Radon release source term.....	F-27
F.4.2 Particulate release source term during remedial action...	F-29
F.4.3 Gamma radiation source term.....	F-34
F.4.4 Atmospheric dispersion of Rn-222.....	F-36
F.4.5 Accident analysis.....	F-38
F.4.5.1 Accidental spill of material on land.....	F-38
F.4.5.2 Surface-water transport accident.....	F-41
F.5 Health effects.....	F-43
F.5.1 Alternative 1 - no action.....	F-43
F.5.2 Alternative 2 - stabilization at Vitro.....	F-45
F.5.3 Alternative 3 - disposal at South Clive.....	F-47
F.5.4 Maximally exposed resident.....	F-53
F.5.5 Health effects perspective.....	F-53
References for Appendix F.....	F-55

List of Figures

	<u>Page</u>
F-1 Uranium 238 decay series.....	F-5
F-2 Location and measurement results, PERMS.....	F-15
F-3 External gamma radiation levels as a function of distance from the tailings pile.....	F-17
F-4 Locations of environmental radiation sampling programs for South Clive site.....	F-19
F-5 Background radon concentration (week) - South Clive.....	F-22
F-6 Idealized material removal schematic.....	F-28
F-7 Source term geometry.....	F-37

List of Tables

	<u>Page</u>
F-1 Radioactive airborne particulate concentrations at the Central Valley Water Reclamation Facility.....	F-14
F-2 Summary of radiological sampling program.....	F-18
F-3 Radionuclide airborne particulate concentrations in the South Clive site vicinity.....	F-21
F-4 Ambient-air radon-222 concentrations in the vicinity of South Clive site (track etch method).....	F-23
F-5 Radionuclide concentrations in soil samples from South Clive site vicinity.....	F-23
F-6 Average radionuclide concentrations in vegetation and wildlife in the vicinity of the South Clive site.....	F-25
F-7 Radionuclide airborne--particulate concentrations along the transportation corridor between Vitro and South Clive sites.	F-25
F-8 Ambient-air radon-222 concentrations along the transportation corridor between Vitro and South Clive sites (track-etch method)	F-26
F-9 Radionuclide concentrations in surface soil along the transportation corridor between Vitro and South Clive sites.....	F-26
F-10 Occupational dose parameters.....	F-33
F-11 Occupational Radiation Dose Summary for Comparing Significance of Radiation Sources.....	F-35
F-12 Doses due to a hypothetical accident.....	F-40
F-13 Summary of MILDOS results for no action alternative (person-rem)	F-44
F-14 Worker exposure categories by remedial action phase.....	F-46
F-15 Summary of MILDOS predicted doses around the Vitro site, scaled for the disposal at Vitro alternative (person-rem).....	F-47
F-16 Worker exposure categories by remedial action phase - truck transport.....	F-49
F-17 Worker exposure categories by remedial action phase - train transport.....	F-50
F-18 Summary of MILDOS predicted doses around the Vitro site, scaled for the disposal at South Clive alternative (person-rem).	F-51
F-19 Dose to an "onlooker" along tailings transportation route.....	F-52

RADIOLOGICAL INFORMATION

This appendix contains: (1) basic facts about radiation and its measurement useful for understanding the methods and calculations which follow, (2) a description of the methods used to calculate health effects of the various alternatives, (3) the data and calculations for the radioactive release source term represented by the various alternatives, and (4) estimates of the health effects of the occupational and population radiation exposures from the alternative remedial actions.

The radiation doses and health impacts for the general population and remedial action workers are addressed for each of the Vitro tailings site remedial action alternatives. The slightly increased doses received by these individuals can, in a statistical sense, increase the potential for individual and population health effects (excess fatal cancers) above those expected from normal causes. Assumptions made during the calculations of health effects for the general population and for remedial action workers are realistically conservative, in order to give a realistic upper limit for the excess cancers that might occur.

F.1 BASIC FACTS ABOUT RADIATION AND ITS MEASUREMENT

Atoms that spontaneously transform, or "decay," into new atoms are termed "radioactive." The decaying atom is called the "parent," and the atom produced by the transformation is called the "daughter." The rate at which atoms decay is the "activity" measured by the unit "curie." A more convenient unit for measuring the activity of radioactive atoms in tailings piles is the picocurie (pCi), which is one-millionth of one-millionth (1×10^{-12}) of a curie. The half-life of a radioactive substance is the time required for the radioactive substance to lose 50 percent of its activity by decay. Each "radionuclide" has a unique half-life.

When atoms undergo radioactive decay, they emit "radiation." The most common types of radiation are alpha particles, beta particles, and gamma rays. "Alpha" and "beta" radiation are tiny particles with excess energy, and "gamma" radiation is pure energy without mass. Radiation transfers energy to matter as it travels through matter. Alpha radiation penetrates only a few millimeters into matter and beta radiation penetrates a few centimeters, unlike gamma radiation which can travel deeper into matter in the same way as x-rays. Alpha radiation will not penetrate through a layer of skin, whereas gamma radiation has some probability of travelling through the whole body without transferring energy.

The amount of radiation to which an individual is exposed may be expressed in terms of the amount of energy imparted to cells and tissue by the radiation and the degree of biological damage associated with the energy as it is absorbed. This absorbed energy is termed the absorbed dose and is given in units of rads, where one rad equals 100 ergs of energy absorbed per gram of material irradiated. When the irradiated material is living tissue, the damage per rad varies depending on the type of radiation. By applying a "quality factor" to each specific type of radiation, the degree of biological damage can be expressed independently of the type of radiation causing it. The biologically relevant absorbed energy is termed the dose equivalent and the unit is the rem. One rad is equal to one rem for less damaging radiations where the quality factor is one (e.g., gamma rays). For comparison, one rad of internal alpha-deposited energy is equal to 20 rem because alpha particles are more damaging to tissue and the quality factor for alpha radiation is 20. The millirem equals one-thousandth (1×10^{-3}) of a rem and is in more common usage when expressing doses from environmental levels of radiation.

When a succession of radioactive parent atoms decay to radioactive daughter atoms, a "radioactive decay series" is formed. U-238 is such a radioactive parent atom and the U-238 decay series is shown in Figure F-1 (Lederer et al., 1967; BRH, 1970). The U-238 decay series includes Th-230, Ra-226, Rn-222 (radon), short-lived radon daughters, and other long-lived radioactive atoms. The U-238 decay series ends with Pb-206, an atom that is stable and not radioactive. When the daughters in a radioactive decay chain have shorter half-lives than the parent, the daughter activities will increase (termed "ingrowth"), until they equal the activity of the parent.

Radon is the radionuclide of primary importance to the UMTRA Project because it represents the largest radiation exposure pathway to the general

population. The half-life of radon (3.8 days) is short relative to the half-life of Ra-226 (1620 years). As Ra-226 decays, the newly produced radon will begin to decay, and the radon activity will become equal to the Ra-226 activity within 30 days. Similarly, the short-lived radon daughter activities will ingrow within 4 hours to equal the activity of radon. When the activities of the parent and its daughters are equal, the daughters are said to be in "100-percent equilibrium" or simply in "equilibrium." If the daughters are diluted or carried away as they are formed, they will not reach 100-percent equilibrium.

The only member of the U-238 decay series that is not a solid is radon. Radon is an inert gas and does not react chemically with other elements; it therefore can diffuse out of matter and into the atmosphere. Atmospheric radon concentration is measured in units of picocurie per liter (pCi/l). In the uranium milling process, Ra-226, the parent of radon, is left in the tailings, which then become a source from which radon diffuses into the atmosphere. Once in the atmosphere, radon is transported downwind and, according to its 3.8-day half-life, decays into the short-lived radon daughters which can attach to particulates in the air. Since radon is an inert gas, it is inhaled and exhaled, contributing very little radiation exposure to the lung. The radon daughters are solids, however, and once inhaled can deposit in or attach to the lung and then decay, transmitting alpha energy in the lung. Because of the short half-life, these daughters will decay before being removed from the lung.

Trace amounts of U-238 and its daughters are found everywhere on the earth; therefore, radon and its short-lived daughters contribute significantly to the background radiation exposure of the general population. Human exposure to radiation originates from both natural and man-made sources. The major natural radiations originate from cosmic and terrestrial external sources, and from naturally occurring radionuclides which are deposited inside the body via the ingestion and inhalation pathways. Exposure to man-made sources results primarily from medical exposures (e.g., diagnostic x-rays), with minor contributions from sources such as airline travel, atmospheric weapons tests, the nuclear power industry, consumer products, and technologically enhanced natural radiation (TENR).

Medical usage of radiation is responsible for the highest contribution to man's radiation exposure, accounting for approximately 50 percent of man's total radiation exposure. Other man-made contributors, including airline travel, atmospheric weapons tests, the nuclear industry, and consumer and industrial products together account for approximately 5 percent. The remaining 45 percent of man's total radiation exposure results from exposure to natural radiation sources.

The health effects attributed to a radiation dose are categorized into two general types: somatic and genetic. Somatic effects are manifested in the exposed individual (e.g., cancer) and genetic effects are manifested in the descendants of the exposed individual. The International Commission on Radiation Protection (ICRP, 1977) estimated the genetic effect to be less than the somatic effects; therefore, only risk of somatic effects are considered.

Nuclide	Historical name	Half-life	Major radiation energies (MeV) and intensities†		
			α	β	γ
$^{238}_{92}\text{U}$	Uranium I	$4.51 \times 10^9 \text{ y}$	4.15 (25%) 4.20 (75%)	---	---
$^{234}_{90}\text{Th}$	Uranium X_1	24.1d	---	0.103 (21%) 0.193 (79%)	0.063c± (3.5%) 0.093c (4%)
$^{234}_{91}\text{Pa}^m$	Uranium X_2	1.17m	---	2.29 (98%)	0.765 (0.30%) 1.001 (0.60%)
99.87% $^{234}_{91}\text{Pa}$ 0.13%	Uranium Z	6.75h	---	0.53 (66%) 1.13 (13%)	0.100 (50%) 0.70 (24%) 0.90 (70%)
$^{234}_{92}\text{U}$	Uranium II	$2.47 \times 10^5 \text{ y}$	4.72 (28%) 4.77 (72%)	---	0.053 (0.2%)
$^{230}_{90}\text{Th}$	Ionium	$8.0 \times 10^4 \text{ y}$	4.62 (24%) 4.68 (76%)	---	0.068 (0.6%) 0.142 (0.07%)
$^{226}_{88}\text{Ra}$	Radium	1602y	4.60 (6%) 4.78 (95%)	---	0.186 (4%)
$^{222}_{86}\text{Rn}$	Emanation Radon (Rn)	3.823d	5.49 (100%)	---	0.510 (0.07%)
$^{218}_{84}\text{Po}$	Radium A	3.05m	6.00 (~100%)	0.33 (~0.019%)	---
99.98% $^{214}_{82}\text{Pb}$ 0.02%	Radium B	26.8m	---	0.65 (50%) 0.71 (40%) 0.98 (6%)	0.295 (19%) 0.352 (36%)
$^{218}_{85}\text{At}$	Astatine	~2s	6.65 (6%) 6.70 (94%)	? (~0.1%)	---
$^{214}_{83}\text{Bi}$	Radium C	19.7m	5.45 (0.012%) 5.51 (0.008%)	1.0 (23%) 1.51 (40%) 3.26 (19%)	0.609 (47%) 1.120 (17%) 1.764 (17%)
99.98% $^{214}_{84}\text{Po}$ 0.02%	Radium C'	164μs	7.69 (100%)	---	0.799 (0.014%)
$^{214}_{81}\text{Tl}$	Radium C''	1.3m	---	1.3 (25%) 1.9 (56%) 2.3 (19%)	0.296 (80%) 0.795 (100%) 1.31 (21%)
$^{214}_{82}\text{Pb}$	Radium D	21y	3.72 (.000002%)	0.016 (85%) 0.061 (15%)	0.047 (4%)
$^{214}_{83}\text{Bi}$	Radium E	5.01d	4.65 (.00007%) 4.69 (.00005%)	1.161 (~100%)	---
~100% $^{214}_{84}\text{Po}$.00013%	Radium F	138.4d	5.305 (100%)	---	0.803 (0.0011%)
$^{214}_{81}\text{Tl}$	Radium E''	4.19m	---	1.571 (100%)	---
$^{206}_{82}\text{Pb}$	Radium G	Stable	---	---	---

**FIGURE F-1
URANIUM 238 DECAY SERIES**

F.2 METHOD OF ANALYSIS

Radiation and its associated health effects have been studied more thoroughly than health effects from other carcinogenic agents. The evaluation of health effects caused by low-level radiation is, however, a difficult task, and many uncertainties are associated with the estimation of risks from radiation. The traditional approach for estimating risks from low-level radiation exposures is to extrapolate from effects observed at high radiation exposures using the linear dose-response and no threshold assumptions. Synergistic effects of other health effect agents (e.g., chemicals), are not considered in this analysis.

There are five principal pathways which could potentially result in exposure of man to radiation from the tailings pile. These are (1) inhalation of radon daughters; (2) direct exposure to gamma radiation emitted from the contaminated area; (3) inhalation and ingestion of airborne radioactive particulates; (4) ingestion of ground and surface water contaminated with radioactive materials; and (5) ingestion of contaminated foodstuff produced in areas contaminated by tailings. For calculations of health effects in this appendix, only the most significant radiation exposure pathways are considered; they are inhalation of radon daughters and direct exposure to gamma radiation. Analyses for the latter three radiation exposure pathways lead to doses that are much smaller (several orders of magnitude) than doses from radon daughter inhalation and direct gamma radiation. The latter three radiation exposure pathways are not considered in this analysis.

The health effect estimations made in this appendix are primarily based on data and models presented in the BEIR-III report (NAS, 1980). Quantitative risk estimation of somatic effects for various organs of the body can be obtained using available human radiation exposure data. The manifestation of a cancer caused by radiation exposure would occur after a latent period of up to 25 years, depending on the type of cancer and the age of the person exposed. The risks from radiation will vary with adult age and sex, but are presented as average values where variation due to adult age and sex is small. No data are available that indicate whether risk estimates for adults are appropriate for radiation exposure during childhood. Because the BEIR-III report does not always make firm recommendations for application of the data, health risk estimates in this appendix also make use of recommendations published in scientific journals.

F.2.1 Health effects of exposure to radon daughters

The health effects of radon diffusion from tailings arise from inhalation of the short-lived radon daughters which then deposit energy from alpha particles in the lung. For radiation protection purposes, the ICRP (1977) proposed an individual lung-cancer risk factor of 20×10^{-6} per rem, or 20 excess cancer deaths where one million individuals each receive a one-rem lung dose equivalent from radon daughters.

Other standards-setting organizations express the excess risk of lung cancer based on the lung collective dose equivalent in person-working-level months (person-WLM). The unit of working level (WL) is defined as any

combination of short-lived radon daughters in one liter of air which, on complete decay, gives a total emission of 1.3×10^5 million electron volts of alpha radiation. One WL is equivalent to 100 pCi of radon per liter of air with the short-lived radon daughters in 100-percent equilibrium. At equilibrium levels less than 100 percent, the WL corresponding to a given radon concentration is reduced. The working-level month (WLM) is a unit defined as the exposure resulting from the inhalation of air with a concentration of 1 WL of radon daughters for 170 working hours. The total dose of one or more persons is the product of the number of persons and the average dose they receive; the unit for the measurement of such a population dose is the person-WLM.

Some of the estimates of excess fatal lung cancers given in terms of person-WLM follow. The United Nations Scientific Committee on the Effects of Atomic Radiation quoted a range of 200 to 450×10^{-6} deaths per person-WLM (UNSCEAR, 1977), while the NRC in its environmental impact statement on uranium milling quoted 360×10^{-6} deaths per person-WLM (NRC, 1980b). The BEIR-III report formulated an age-dependent model for predicting the risk of lung cancer based on several studies of uranium and fluorspar miners. Evans et al., (1981), reviewed the BEIR-III study, lung-cancer risk estimates published by other authors, and epidemiological evidence. They concluded that the most defensible upper-bound to the lifetime lung-cancer risk for the general population is 100×10^{-6} deaths per person-WLM.

The BEIR-III committee reported the conversion factor that one WLM is approximately equal to a 5-rem dose equivalent commitment to the lung. The risk estimate of 100×10^{-6} deaths per person-WLM is therefore equivalent to the ICRP risk estimate, 20×10^{-6} deaths per person-rem, which is used in this appendix.

To estimate the radon daughter concentrations breathed by the general population and remedial action workers, two methods are used: (1) atmospheric dispersion calculations for radon released from the tailings pile (the MILDOS computer code was used, see Section F.3), and (2) long-term measurements of atmospheric radon concentrations around the Vitro tailings site (see Section F.3).

In order to convert measured or modeled radon and radon daughter concentrations in air to rem of dose equivalent commitment, the following conversion factor was developed assuming a conservative 25 percent equilibrium of radon daughters both on the pile and within 1 km of the pile:

$$7.4 \times 10^{-5} \text{ (rem/(hr} \times \text{pCi/l))}.$$

This is derived from the calculation

$$\begin{aligned} \frac{5 \text{ rem}}{\text{WLM}} &= \frac{5 \text{ rem}}{\text{WLM (170 hr/M) (100 (pCi/l)/WL)}} = \frac{2.94 \times 10^{-4} \text{ rem}}{\text{hr} \times (\text{pCi/l})} \text{ (at 100\% eq.)} \\ \text{or,} &= \frac{7.4 \times 10^{-5} \text{ rem}}{\text{hr} \times (\text{pCi/l})} \text{ (at 25\% eq.)} \end{aligned}$$

F.2.2 Health effects of exposure to gamma radiation

Tailings piles emit gamma radiation that delivers an external exposure to the whole body of people near the pile. The BEIR-III report contains several models for estimating cancer risk resulting from exposure to gamma radiation. Health effect estimates in this appendix for excess cancer deaths due to gamma radiation use a risk factor of 120×10^{-6} deaths per person-rem (NAS, 1980; Cohen, 1981). This is equivalent to 120 excess cancer deaths in an exposed population for each 1,000,000 person-rem of collective dose equivalent. A person-rem is the product of the radiation dose equivalent multiplied by the number of people receiving that dose equivalent.

Health effect estimates for gamma radiation exposure were performed for remedial action workers and for the general population within 1 km from the tailings site. The contribution from the tailings pile to gamma radiation levels becomes negligible beyond approximately 1 km from the tailings pile perimeter. A health effect analysis was done for the general population and remedial action workers to determine gamma radiation impacts during transportation of tailings material in the relocation alternative actions.

For gamma radiation, 1 rem is approximately equal to one roentgen (R) which is the unit for measuring gamma-radiation intensity in air. A microroentgen (microR) is 1×10^{-6} R, and typical environmental gamma radiation levels are expressed in microR/hr.

The ICRP (1977) reported that the average risk estimated for genetic effects, as expressed in the first two generations and considered genetically significant, is 40×10^{-6} per rem. For all subsequent generations, the risk is estimated to be equal to that expressed in the first two generations. The total genetic risk (all generations) is, therefore, 80×10^{-6} per rem. This is sufficiently similar to the somatic risk estimate so that protection of the individual against somatic effects will ensure adequate protection against genetic effects.

The gamma radiation exposures on and around the Vitro tailings pile are estimated from direct measurements and from the radium-226 content of the tailings. The exposures to workers takes account of substantial shielding offered by the working environment.

F.3 SITE RADIOLOGICAL CHARACTERISTICS

In this section the data concerning the environmental radiation conditions of the Vitro pile, the areas around the Vitro site, the South Clive site, and the transportation corridor are described.

F.3.1 Existing pile characteristics

The Vitro site is a 128-acre tract located about 4 miles southwest of downtown Salt Lake City, Utah. As described in Appendix A, there are approximately 2.3 million cubic yards of uranium mill tailings, rubble, sewage sludge, and other mill wastes on the site. An additional 0.15 million cubic yards of windblown and other off-site contaminated materials will be included in the final stabilization (Table A-1, Appendix A).

The tailings materials are located in three roughly rectangular areas, designated as the northwest (NW), southwest (SW), and southeast (SE) tailings. The original mill location is a triangular area to the east of the SE tailings, which is also contaminated and included in the volume estimates above. The Central Valley Water Reclamation Facility (CVWRF) sewage treatment plant No. 1 is situated to the north of the SE tailings and east of the NW tailings. A descriptive map of the Vitro site showing the approximate locations of the three tailings areas, the original mill site, and the CVWRF plant is presented in Figure 1-2 of the main text.

The cross sections of the three main piles (NW, SW, and SE tailings) are variable and their overall dimensions (average areas and thicknesses) are not uniformly reported (FBDU, 1981; ORNL, 1977; Martin et al., 1980; Schiager, 1974). Martin et al. reported 90 acres of tailings, Schiager 93 acres, and ORNL 117 acres. FBDU (1981) did not give an area for the tailings, but stated that the site is 128 acres. For the source term calculations, 128 acres was chosen as the area to be remediated.

Depths of the tailings on the bulk of the site were reported to vary from 6 to 17 feet (Martin et al., 1980) but the more recent data of Mountain States Research and Development, Inc. (MSRD, 1982) indicate the range may go as much as 40 feet deep on the SE pile. The bulk of the material is in the SE pile, which appears to be the thickest. Based on the MSRD sampling program, it appears that a reasonable average for the depth of contaminated material beneath the site is 2 feet (MSRD, 1982; Brewer et al., 1982).

Physical characteristics

Physical characteristics of the tailings are described by Martin et al., (1980) and by MSRD (1982). The NW tailings consist mainly of medium to fine sands. The SW and SE piles contain mostly fine sands with varying proportions of slimes. The site average tailings moisture content is 20 percent, with the contaminated material beneath the site averaging 23 percent (MSRD, 1982).

An average tailings moisture content of 20 percent was assumed for the in-situ condition. If the tailings materials are moved to the South Clive disposal site, it is reasonable to expect that the moisture content will be lower. The NRC (1980a) reports data indicating that nonclayey soils would be

expected to retain 6 to 10 percent moisture, and that clayey soils would retain 9 to 12 percent moisture or more. Soil tests indicate that Vitro tailings could retain more moisture than this. Nevertheless, lacking site-specific data, a value of 10 percent was assumed as a reasonable generic value for long-term tailings moisture retention at the South Clive site.

In-situ densities are on the order of 1.4 g/cm^3 . Results of standard Proctor tests indicate that maximum densities of 1.6 to 1.8 g/cm^3 would be obtained for the sandier materials at 10 to 16 percent moisture content. The maximum densities for the finer materials would be about 1.5 g/cm^3 at 20 to 30 percent moisture. Most field samples were at 75 to 85 percent of the maximum Proctor density (FBDU 1981). A tailings density of 1.6 g/cm^3 was used in this appendix for stabilized tailings.

The radon emanation coefficient is the fraction of radon produced within the soil or tailings grains that is released to the interstitial pore spaces. Vitro tailings samples analyzed at LASL (1981) ranged from 0.12 to 0.20. The NRC (1979) reported a measured value of 0.2 for Vitro tailings and considered this to be a good generic value for tailings. An emanation coefficient of 0.20 was used in this appendix.

Radionuclide content

The principal isotopes of concern in assessing the radiological impacts of the proposed alternatives are U-238, Th-230, and Ra-226. Concentrations of other isotopes may be estimated based on these three radionuclides and the assumption of secular equilibrium. Although many estimates of the radionuclide contents of the Vitro tailings have been made (FBDU, 1981; ORNL, 1977; LASL, 1981; Schiager, 1974), the values used in this appendix are based on the statistically designed drilling and sampling program of MSRD (1982). Additional work using MSRD samples has been done by Sandia (1982a) and Bendix (1983).

MSRD (1982) found a site average of 0.014 percent uranium (U_3O_8) in the tailings. This corresponds to about 40 pCi/g of U-238, based on 104 boreholes sampled every 2.5 feet. This concentration is at the low end of the ranges of previously reported values, 20 to 107 pCi/g, (FBDU, 1981; ORNL, 1977; LASL, 1981) but is based on the most complete data available.

The Ra-226 concentration in the material on the site averages 560 pCi/g based on 181 samples from 66 of the 104 boreholes drilled by MSRD. The Ra-226 analyses were done by Bendix Field Engineering (Bendix, 1983) on all samples of sufficient volume that remained from the sampling program. This is in the range of previously reported values, 100 to 2000 pCi/g (FBDU, 1981; ORNL, 1977; Schiager, 1974; LASL, 1981), and is based on the most complete data available.

A Th-230 concentration of 560 pCi/g may be estimated assuming the Ra-226 is in secular equilibrium. Other information indicates the Th-230 concentration is perhaps 30 percent lower than this (LASL, 1981), probably due to extraction during the acid leach process. The value 560 pCi/g is used in this report as a conservative estimate.

In summary, the radionuclide concentrations used in this appendix are 560 pCi/g for Ra-226, 560 pCi/g for Th-230, and 40 pCi/g for U-238.

Radon flux

Radon flux at the Vitro site has been measured or calculated by various groups. Short-term flux measurements by ORNL (1977) averaged 320 pCi/m²s, although ORNL also calculated a flux of 550 pCi/m²s based on Ra-226 content of the material. Schiager (1974) reported values that, when weighted by the area of the source, yield an average of 400 pCi/m²s; although he assumed a value of 350 pCi/m²s. FBDU (1981) reported a measured range of 19 to 440 pCi/m²s and an area-weighted average of 250 pCi/m²s, but used a calculated value of 600 pCi/m²s in estimating the health effects. The NRC (1979) reported radon flux-to-radium concentration ratios of 0.35 for wet tailings, and 1.2 for dry tailings in units of pCi/m²s radon flux per pCi/g of Ra-226; however, the NRC prefers a generic value of 1.0 for this ratio. Based on the above estimated average radium concentration of 560 pCi/g, an assumed radon flux-to-radium concentration ratio of 1 gram per square meter-second would yield a radon flux of 560 pCi/m²s. This value will be used in this appendix.

Radon in air

On-site, ambient air radon concentrations are needed to estimate exposures of workers during remedial action. Long-term radon concentration measurements made around the Vitro pile (see Section F.3.2.1) show high values at the edge of the pile of 4 or 5 pCi/l. Assuming isotropic winds, it could be argued that a reasonable value for the interior of the pile would be about 10 pCi/l on the long-term average.

Schiager (1974) estimated, for very conservative conditions, that the radon concentration might average 6.8 pCi/l. However, his estimate was based on a flux of 350 pCi/m²s Rn-222 rather than the 560 pCi/m²s indicated above. The comparable estimate is thus 11 pCi/l.

Based on the available information, it is believed that 30 pCi/l is a conservative upper bound for the long-term average radon concentration in air on the Vitro pile.

F.3.2 Environmental radiation measurements

The environmental radiation levels for the area surrounding the Vitro site and the South Clive site have been studied (EPA, 1975; FBDU, 1981; ORNL, 1977; ANL, 1983a), and are summarized here.

F.3.2.1 Vitro site environmental radioactivity

Airborne particulates

Radioactive airborne particulate concentrations were measured in the vicinity of the tailings pile at the Vitro site by the EPA (1975). The average airborne radionuclide concentrations were determined at the CVWRF sewage-treatment plant for a one-year sampling program during which 26

consecutive two-week samples were collected and analyzed (ORNL, 1977). Average concentrations of the nine radionuclides reported at this location ranged from 6.5×10^{-5} pCi/l (Po-210) to 2.5×10^{-8} pCi/l (U-235) and are presented in Table F-1.

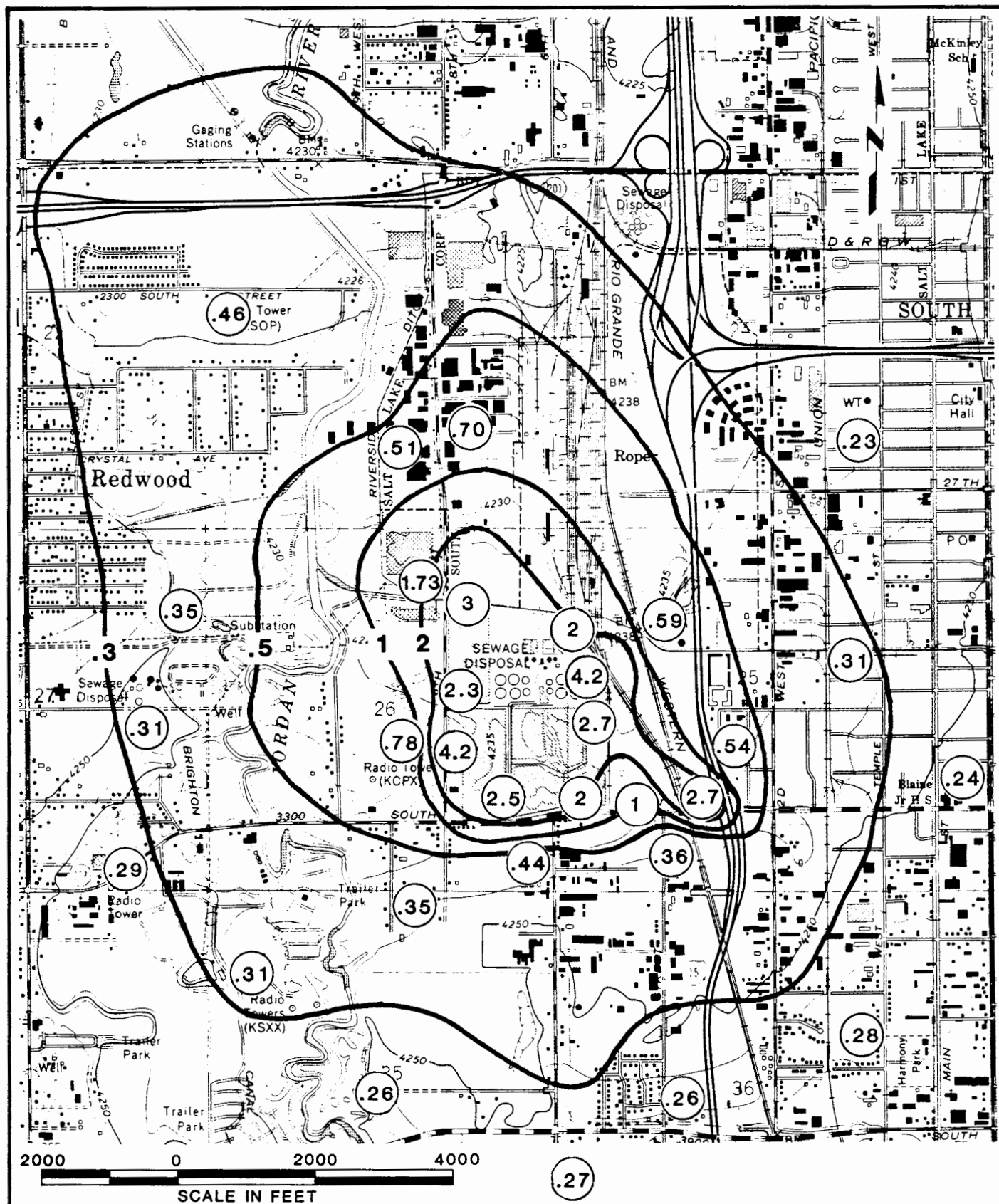
Table F-1. Radioactive airborne particulate concentrations at the Central Valley Water Reclamation Facility

Radionuclide	Concentration (pCi/l)	Reference concentration ^a (pCi/l)
Uranium-238	2.0×10^{-7}	3×10^{-3}
Uranium-235	2.5×10^{-8}	4×10^{-3}
Uranium-234	2.2×10^{-7}	4×10^{-3}
Thorium-232	6.4×10^{-8}	1×10^{-3}
Thorium-230	8.8×10^{-7}	8×10^{-5}
Radium-228	1.7×10^{-6}	1×10^{-3}
Radium-226	1.8×10^{-6}	2×10^{-3}
Polonium-210	6.5×10^{-5}	7×10^{-3}
Lead-210	1.0×10^{-5}	4×10^{-3}

^aThe smaller of the two concentrations for soluble and insoluble particulates in air given in 10 CFR Part 20, Appendix B, Table II, Column 1. Source: ORNL, 1977.

Radon in air

Ambient-air Rn-222 concentrations have been measured and calculated for the area surrounding the Vitro pile (FBDU, 1981; ORNL, 1977; Shearer and Sills, 1969). Previous estimates indicated 7 pCi/l Rn-222 at about 0.1 mile from the edge of the pile, decreasing to 0.38 pCi/l at about 1 mile from the pile edge. These were short-term measurements, and have been improved on by more recent long-term measurements by Monsanto (1983). Beginning in January 1982, an ambient radon monitoring program in the Vitro site vicinity began which ran for 18 months at 40 locations. Weekly average radon concentrations were measured with Passive Environmental Radon Monitors (PERMs). The locations of the monitors and results of the measurements are shown in Figure F-2. The contour lines indicate isopleths of the 18-month average radon concentration. The concentration field is a result of the radon released from the site and its subsequent atmospheric dispersion, on an average basis. The background radon concentration of about 0.25 pCi/l is approached at an excess of a mile from the site. The maximum concentrations are the 4 to 5 pCi/l at the pile edges.



Gamma radiation

Gamma radiation exposure rates have been measured around the Vitro tailings piles by FBDU (1981). They presented data reproduced here as Figure F-3, but the location of the edge of the tailings and the direction in which the data were taken were not given. In a study of Salt Lake City, the background gamma radiation exposure rate was found to be 12 microR/hr, with a range from 9 to 17 microR/hr. The contribution of the tailings piles becomes negligible at about 1 km (0.6 mile) from the perimeter of the pile, based on Figure F-3. This is much closer to the pile than the distance over which the radon releases influence atmospheric radon concentrations.

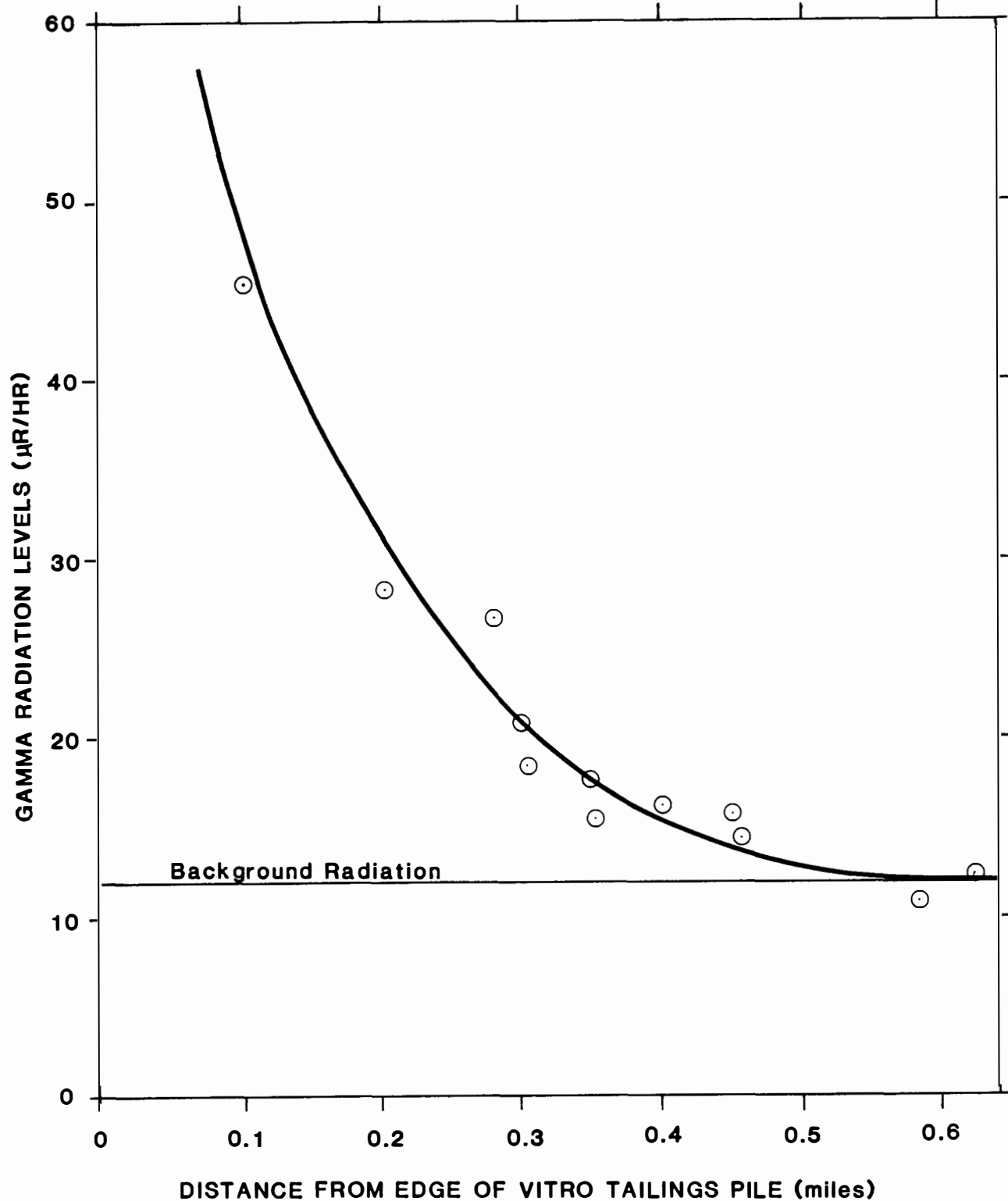
Soil and sediment radioactivity

Background concentrations of radionuclides in soils have been measured in and around Salt Lake City by a number of investigators (ORNL, 1977). Results are generally comparable and are typified by the ORNL results, which indicate the following values (geometric mean plus or minus geometric standard deviation): Ra-226, 1.5 ± 1.2 picocuries per gram, and U-238, 2.0 ± 3.6 picocuries per gram. In addition, soil samples were collected by ORNL (1977) from 58 locations within about 400 to 1000 meters of the (south) tailings pile. Samples were collected at the surface and at one-foot depth and were analyzed for Ra-226. Concentrations in surface samples ranged from background levels (about 1 pCi/g) away from the pile to 560 pCi/g of Ra-226 near the pile. Samples obtained from the one-foot depth ranged from background to 460 pCi/g of Ra-226.

Sediment samples from the Jordan River, Mill Creek, and the Vitro drainage ditch were collected and analyzed for U-238, Th-230, Ra-226, and Pb-210 (ORNL, 1977). Results showed no contamination in Jordan River sediments, and slightly elevated levels (roughly twice estimated background) in Mill Creek sediments. The drainage ditch sediments, however, were shown to contain relatively elevated concentrations of all three radionuclides. Ra-226 concentrations range from 60 to 120 pCi/g, while Th-230 concentrations ranged up to 284 pCi/g, which was higher than any other reported radionuclide.

Radionuclides in biota

The concentration and uptake of radioactive elements by plants and animals was qualitatively investigated by FBDU (1981). Based upon this preliminary study, the contribution of biota to human exposures as a result of uptake of radionuclides originating in the tailings was found to be negligible compared to the major pathways of inhalation and direct radiation exposure. The uptake of radioactive elements by plants and their subsequent concentration in the food chain is not an important pathway because there is little actively-cultivated land near the Vitro site; the 220 acres of agricultural property within 0.5 mile of the site are mainly located upwind from the site and, therefore, receive no windblown material; the small amount of agricultural land within 1500 feet of the site that may receive some windblown contamination would be cleaned up during the vicinity property remedial actions if the levels of radioactivity in surface soils exceeded EPA standards. Consequently, the food-chain pathway was not considered in this assessment.



Reference: FBDU, 1981

FIGURE F-3
EXTERNAL GAMMA RADIATION LEVELS AS A FUNCTION
OF DISTANCE FROM THE TAILINGS PILE

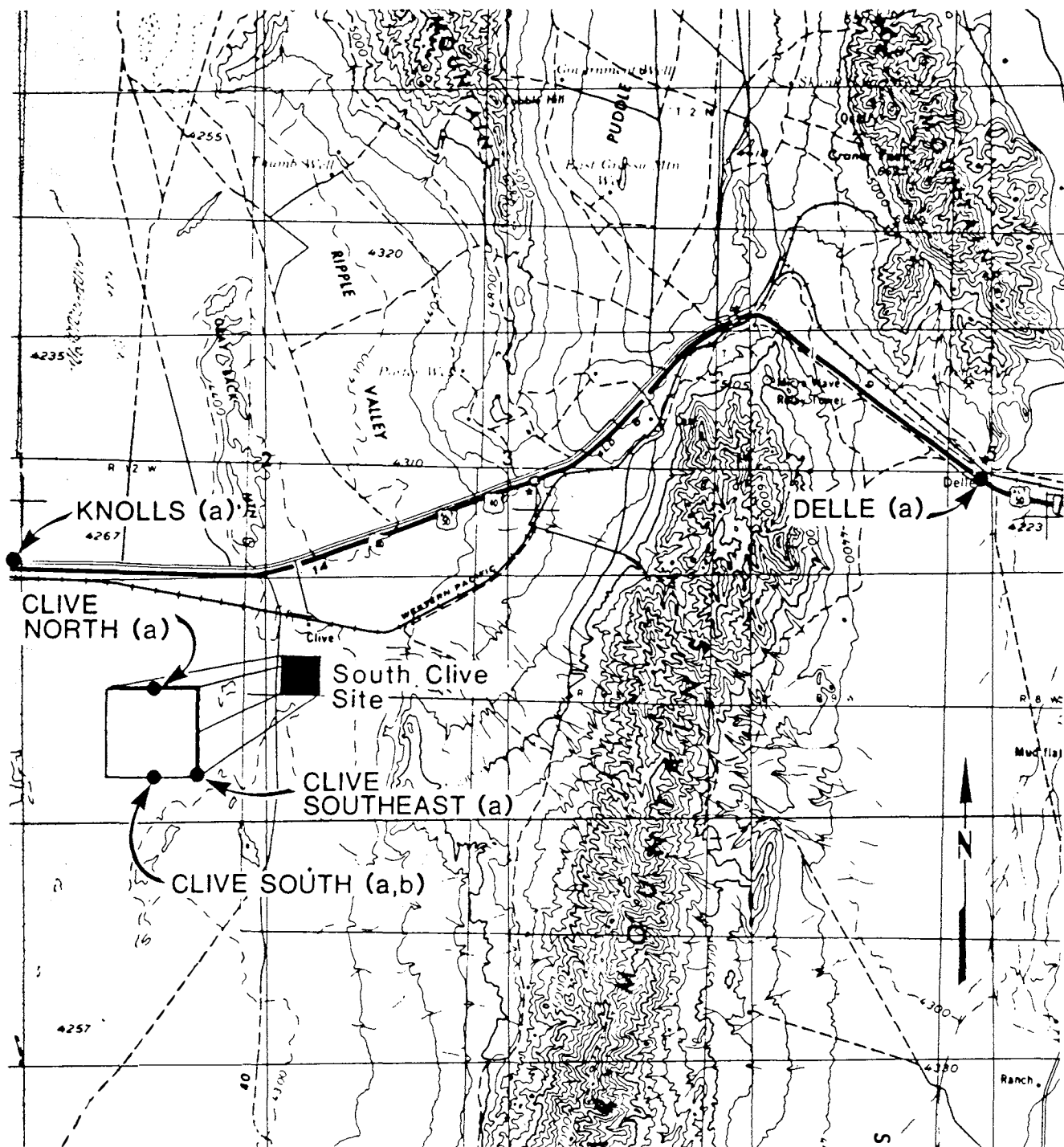
F.3.2.2 South Clive site environmental radioactivity

Radiation levels currently existing at the South Clive site have been determined from monitoring programs conducted by Dames & Moore and Argonne National Laboratory (ANL). The data presented below are the result of three months of monitoring (December 1981 to February 1982). The environmental characterization program included measurement of the radionuclide content of airborne particulates, ambient radon concentrations in air, gamma radiation exposure rates, and radionuclide concentrations in surface soils, vegetation, and animals.

The radiological environmental sampling program formulated for South Clive is summarized in Table F-2, and the sampling locations are identified in Figure F-4. Surface and ground waters were sampled (when present) and analyzed as part of the water quality program (Appendix D). The lower limits of detection for the environmental radiological monitoring program were sufficiently sensitive to meet the specifications of the US NRC (NRC, 1980a).

Table F-2. Summary of radiological sampling program

Sampling	Method	Number of sampling points	Frequency
Air particulate	Eberline Model RAS-1 regulated air samplers	5	continuous
Ambient air radon-222	Eberline Model RGM-2 radon Gas monitors Track-etch	5 5	continuous 7-day periods (quarterly) continuous
Radon flux	Charcoal cannister	9	24-hr periods 3 times/year (spring, summer, fall)
External gamma radiation	Eberline Model PRM-7 scintillation survey meters Thermoluminescent dosimeters (TLDS)	80 5	once quarterly
Soil	Surface - ring method Subsurface - trench method	46 15	once once
Biota vegetation	---	3	3 times/yr (spring, summer, fall)
wildlife	---	3	once



BASE MAP REFERENCE:
USGS TOOLE 1° X 2° QUADRANGLE,
UTAH, 1953 (REVISED 1970).

SCALE 1:250,000
(1 INCH EQUALS APPROXIMATELY 4 MILES)

LEGEND

- a Air particulates, ambient air radon (RGM-2 and Track-Etch), and external gamma (TLD).
- b Soil, biota, radon flux, and external gamma (survey meter).

FIGURE F-4
LOCATIONS OF ENVIRONMENTAL RADIATION SAMPLING PROGRAMS
FOR SOUTH CLIVE SITE

Airborne particulates

Continuous sampling for airborne particulates with low-volume air samplers was done for four quarters, with weekly filter changes. The filters were composited for each location on a quarterly basis and analyzed for uranium, Ra-226, Th-230 and Pb-210. The results of the quarterly composites are given in Table F-3.

Radon-222 in air

Radon concentrations were measured by Argonne National Laboratory at the locations of the airborne particulate samplers using the following instrumentation and schedule:

<u>Instrument</u>	<u>Frequency</u>	<u>Type</u>
Eberline RGM-2 radon gas monitor	Quarterly	1 week, continuous
Track-etch detectors	Monthly	Integrated
Track-etch detectors	Quarterly	Integrated
Track-etch detectors	Annual	Integrated

One of the quarterly seven-day continuous records for the RGM-2 is shown in Figure F-5. It indicates the typical diurnal variation characteristic of remote locations with no elevated radon source present. In comparison, the monthly values of radon concentration using track-etch detectors are presented in Table F-4. The RGM-2 measurement averaged 0.8 pCi/l for the week shown; the track-etch detector gives a monthly average of 0.31 pCi/l.

Gamma radiation

A general area survey of gamma radiation exposure rates was conducted by Argonne National Laboratory at the South Clive site. The measurements averaged 14 microR/hr and ranged from 11.0 to 16 micro R/hr. (ANL, 1982a).

Soil radioactivity

Soil sampling of surface soils (top 5 cm of soil) and subsurface soils (1 m below surface) was done at some locations. The samples were collected using the methods described by US AEC Regulatory Guide 4.5 (AEC, 1974). The results of soil analyses are presented in Table F-5.

Radionuclides in biota

Biota sampling included collection of vegetation and rabbits in the vicinity of the South Clive site. Vegetation samples consisted of a minimum of 2 kg of the crown of the plant. Three rabbits were taken in the vicinity, and their flesh was analyzed for radionuclide content. The average

Table F-3. Radionuclide airborne particulate concentrations
in the South Clive site vicinity

Radionuclide	Quarter	Concentration (pCi/l $\pm$ 2 σ)		
		South Clive	North Clive	Southeast Clive
U-nat	1	0 $\pm$ 3.5E-08 ^a	0 $\pm$ 3.5E-08	0 $\pm$ 3.5E-08
	2	7.5E-08 $\pm$ 5.0E-08	8.7E-08 $\pm$ 4.3E-08	6.4E-08 $\pm$ 4.3E-08
	3	0 $\pm$ 1.9E-08	0 $\pm$ 3.8E-08	3.6E-08 $\pm$ 1.8E-08
	4	0 $\pm$ 1.9E-08	0 $\pm$ 2.0E-08	0 $\pm$ 1.8E-08
	Average	1.9E-08 $\pm$ 1.7E-08	2.2E-08 $\pm$ 1.8E-08	2.5E-08 $\pm$ 1.5E-08
Th-230	1	1.5E-07 $\pm$ 1.8E-08	8.9E-08 $\pm$ 3.5E-08	2.1E-07 $\pm$ 3.5E-08
	2	1.0E-07 $\pm$ 2.5E-08	2.2E-07 $\pm$ 4.3E-08	6.0E-06 $\pm$ 2.1E-08
	3	0 $\pm$ 1.9E-08	7.5E-08 $\pm$ 1.9E-08	3.6E-08 $\pm$ 1.8E-08
	4	5.7E-08 $\pm$ 2.5E-08	8.0E-08 $\pm$ 2.0E-08	7.3E-08 $\pm$ 1.8E-08
	Average	7.7E-08 $\pm$ 1.0E-08	1.2E-07 $\pm$ 1.5E-08	1.6E-06 $\pm$ 1.2E-08
Ra-226	1	0 $\pm$ 1.4E-08	0 $\pm$ 1.4E-08	3.0E-08 $\pm$ 1.3E-08
	2	0 $\pm$ 7.7E-09	0 $\pm$ 6.2E-09	6.2E-09 $\pm$ 6.2E-09
	3	2.4E-08 $\pm$ 1.5E-08	3.2E-08 $\pm$ 1.5E-08	2.9E-08 $\pm$ 1.5E-08
	4	1.9E-08 $\pm$ 6.6E-09	1.2E-08 $\pm$ 1.6E-08	2.9E-08 $\pm$ 1.5E-08
	Average	1.1E-08 $\pm$ 6.6E-08	1.2E-08 $\pm$ 6.7E-08	2.4E-06 $\pm$ 6.4E-09
Pb-210	1	3.2E-05 $\pm$ 1.6E-06	6.2E-05 $\pm$ 3.6E-06	1.2E-05 $\pm$ 7.0E-07
	2	1.3E-05 $\pm$ 7.5E-07	1.3E-05 $\pm$ 6.5E-07	2.5E-05 $\pm$ 1.3E-06
	3	1.7E-05 $\pm$ 7.4E-07	1.7E-05 $\pm$ 7.5E-07	1.5E-05 $\pm$ 7.2E-07
	4	2.0E-05 $\pm$ 9.5E-07	2.1E-05 $\pm$ 9.9E-07	2.3E-05 $\pm$ 1.1E-06
	Average	2.1E-05 $\pm$ 5.3E-07	2.8E-05 $\pm$ 9.7E-07	1.9E-06 $\pm$ 4.9E-07

^aE-x is equivalent to 10^{-x}

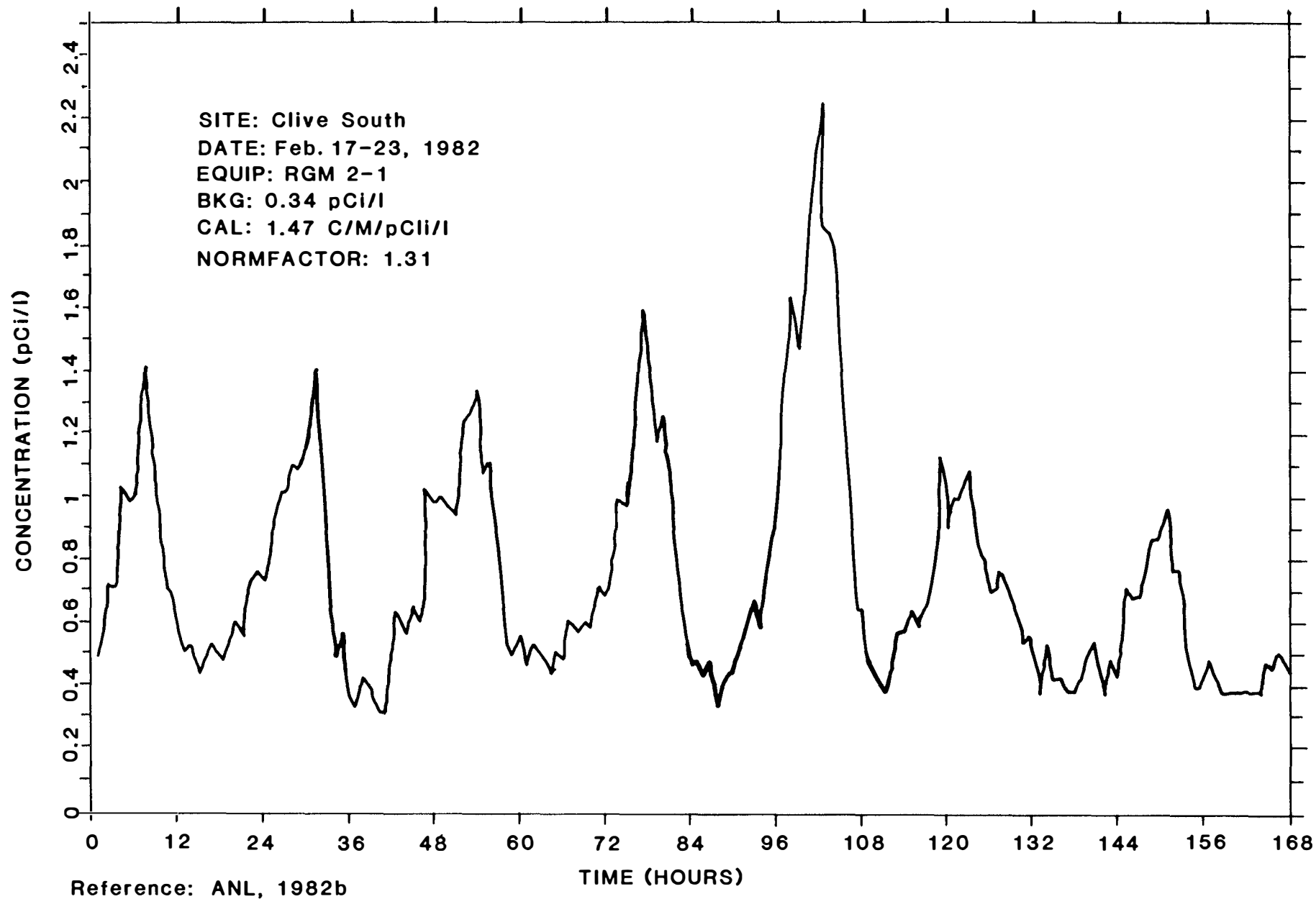


FIGURE F-5
BACKGROUND RADON CONCENTRATION (WEEK) - SOUTH CLIVE

Table F-4. Ambient-air radon-222 concentrations in the vicinity of South Clive site (track-etch method)

Collection date	Radon-222 concentration in air (pCi/l)		
	North Clive	South Clive	Southeast Clive
Monthly			
December (11/17-12/15) 1981	0.23 $\pm$ 43.1% 0.71 $\pm$ 14.5%	0.23 $\pm$ 43.1% 0.19 $\pm$ 47.7%	0.26 $\pm$ 39.6% 0.12 $\pm$ 63.8%
January (12/15-1/19) 1982	0.13 $\pm$ 48.7% 0.26 $\pm$ 33.1%	0.26 $\pm$ 33.1% 0.16 $\pm$ 43.9%	0.29 $\pm$ 31.4% 0.19 $\pm$ 40.2%
February (1/19-2/23) 1982	0.21 $\pm$ 37.4% 0.58 $\pm$ 21.8%	0.32 $\pm$ 30.8% 0.34 $\pm$ 28.7%	0.61 $\pm$ 21.3% 0.19 $\pm$ 40.2%
Average	0.35 $\pm$ 0.23	0.25 $\pm$ 0.07	0.28 $\pm$ 0.17
Quarterly			
12/81-2/82	0.25 $\pm$ 19.6% 0.38 $\pm$ 16.0%	0.30 $\pm$ 17.9% 0.31 $\pm$ 17.7%	0.28 $\pm$ 18.5% 0.23 $\pm$ 20.8%
Average	0.32	0.31	0.26

Source: ANL, 1982a.

Table F-5. Radionuclide concentrations in soil samples from South Clive site vicinity

Location	Radionuclide	Concentration (pCi/g dry wt $\pm$ 2)
Clive-North (surface)	U-238	1.1 $\pm$ 0.1
	Th-230	1.1 $\pm$ 0.2
	Ra-226	1.1 $\pm$ 0.1
	Pb-210	1.1 $\pm$ 0.2
Clive-South (surface)	U-238	0.7 $\pm$ 0.1
	Th-230	1.1 $\pm$ 0.2
	Ra-226	0.9 $\pm$ 0.1
	Pb-210	1.4 $\pm$ 0.2
Clive-Southeast (surface)	U-238	0.7 $\pm$ 0.1
	Th-230	1.1 $\pm$ 0.2
	Ra-226	1.0 $\pm$ 0.1
	Pb-210	1.4 $\pm$ 0.2
Clive-South (subsurface)	U-238	1.3 $\pm$ 0.1
	Th-230	1.1 $\pm$ 0.2
	Ra-226	0.7 $\pm$ 0.1
	Pb-210	0.9 $\pm$ 0.2

Source: Dames & Moore, 1984, unpublished

concentrations of uranium, Ra-226, Th-230, Po-210, and Pb-210 are presented in Table F-6. Note the significantly greater concentrations of the radon daughters in these samples as compared to the concentrations of the radon precursors, and as compared to the concentrations in local soils. This is assumed to be due to the large surface area to mass ratio of plants as opposed to soils, resulting in enhanced deposition and retention of airborne radon daughters by plants. The elevated radon daughter concentrations in rabbits is presumably the result of consuming the vegetation.

F.3.2.3 Transportation corridor environmental radioactivity

The radiation environment existing along the transportation route from the Vitro site to the South Clive site has been monitored by Dames & Moore and Argonne National Laboratory. The Delle and Knolls monitoring sites are located along the corridor, Figure F-4.

Airborne particulates

The radionuclide content of airborne particulates was measured at Delle and Knolls for two quarters (Table F-7). The data presented in Table F-7 indicate no significant differences from the values measured at South Clive.

Radon-222 in air

Three-month average ambient Rn-222 concentrations in air were measured at Delle and Knolls using track-etch detection (ANL, 1982a). The data of Table F-8 average 0.35 pCi/l and 0.23 pCi/l at the two sites.

Gamma radiation

Gamma radiation exposure rates were measured at four locations along the transportation corridor. The average exposure rates were 13 microR/hr at Lake Point Junction, 15 microR/hr at Timpie, 10 microR/hr at Delle, and 10 microR/hr at Knolls (ANL, 1982a).

Soil radioactivity

Radionuclide concentrations in soil along the transportation route were evaluated from soil samples taken at Delle and Knolls. The samples were analyzed for U-238, Ra-226, Th-230, and Pb-210 (Table F-9). The soil concentrations of these radionuclides were not significantly different from those measured for the South Clive site.

Table F-6. Average radionuclide concentrations in vegetation and wildlife in the vicinity of the South Clive site.
(pCi/kg wet weight $\pm$ 2)

Radionuclide	Vegetation samples	Wildlife samples
U (Nat)	5.4 $\pm$ 0.4	0.5 $\pm$ 0.2
Th-230	6.0 $\pm$ 0.6	0.5 $\pm$ 0.2
Ra-226	3.1 $\pm$ 0.3	0.6 $\pm$ 0.05
Pb-210	198 $\pm$ 9	4.0 $\pm$ 1.0
Po-210	48 $\pm$ 3	8.0 $\pm$ 1.0

Source: Dames & Moore, 1984, unpublished

Table F-7. Radionuclide airborne-particulate concentrations along the transportation corridor between Vitro and South Clive sites

Radionuclide	Quarter	Concentration (pCi/l $\pm$ 2)	
		Knolls	Delle
U-Nat	1	3.5E-08 ^a $\pm$ 1.7E-08	3.5E-08 $\pm$ 1.8E-08
	2	1.1E-07 $\pm$ 4.5E-08	0 $\pm$ 4.0E-08
	3	0 $\pm$ 2.3E-08	0 $\pm$ 1.9E-08
	4	3.8E-08 $\pm$ 1.9E-08	3.5E-08 $\pm$ 1.8E-08
	Average	4.6E-08 $\pm$ 1.4E-08	1.8E-08 $\pm$ 1.3E-08
Th-230	1	1.8E-07 $\pm$ 3.5E-08	2.7E-06 $\pm$ 1.4E-07
	2	1.3E-07 $\pm$ 2.2E-08	8.0E-08 $\pm$ 4.0E-08
	3	4.6E-08 $\pm$ 2.3E-08	2.4E-07 $\pm$ 3.7E-08
	4	7.7E-08 $\pm$ 1.9E-08	1.1E-07 $\pm$ 1.8E-08
	Average	1.1E-07 $\pm$ 1.3E-08	7.8E-07 $\pm$ 3.8E-08
Ra-226	1	2.3E-08 $\pm$ 1.4E-08	5.1E-08 $\pm$ 1.4E-08
	2	3.3E-08 $\pm$ 1.8E-08	2.0E-08 $\pm$ 1.6E-08
	3	4.2E-08 $\pm$ 1.9E-08	4.5E-08 $\pm$ 1.5E-08
	4	3.5E-08 $\pm$ 1.5E-08	0 $\pm$ 1.4E-08
	Average	3.3E-08 $\pm$ 8.3E-09	2.9E-08 $\pm$ 7.4E-09
Pb-210	1	3.0E-05 $\pm$ 1.4E-06	3.3E-05 $\pm$ 1.8E-06
	2	1.2E-05 $\pm$ 6.7E-07	1.2E-05 $\pm$ 6.0E-07
	3	1.6E-05 $\pm$ 7.0E-07	1.7E-05 $\pm$ 7.4E-07
	4	2.7E-05 $\pm$ 5.4E-06	2.2E-05 $\pm$ 1.1E-06
	Average	2.1E-05 $\pm$ 5.4E-07	1.1E-05 $\pm$ 5.8E-07

^aE-x is equivalent to 10^{-x}

Source: Dames & Moore, 1984, published

Table F-8. Ambient-air radon-222 concentrations along the transportation corridor between Vitro and South Clive sites (track-etch method)

Collection date	Radon-222 concentration in air (pCi/l)	
	Delle	Knolls
Monthly		
December (11/17-12/15) 1981	$0.67 \pm 14.5\%$ $0.23 \pm 43.1\%$	$0.19 \pm 47.7\%$ $0.12 \pm 63.8\%$
January (12/15-1/19) 1982	$0.42 \pm 25.7\%$ $0.11 \pm 55.5\%$	$0.16 \pm 43.9\%$ $0.08 \pm 66.0\%$
February (1/19-2/23) 1982	$0.24 \pm 35.0\%$ $0.26 \pm 33.1\%$	$0.32 \pm 30.0\%$ $0.19 \pm 40.2\%$
Average	0.32 ± 0.20	0.18 ± 0.08
Quarterly		
11/81-2/82 --	$0.25 \pm 20.0\%$ $0.44 \pm 14.7\%$	$0.25 \pm 19.6\%$ $0.21 \pm 21.8\%$
Average	0.35	0.23

Source: ANL, 1982a.

Table F-9. Radionuclide concentrations in surface soil along the transportation corridor between Vitro and South Clive sites

Location	Radionuclide	Concentration (pCi/g dry wt ± 2)
Knolls	U-238	1.0 ± 0.1
	Th-230	0.9 ± 0.2
	Ra-226	0.7 ± 0.1
	Pb-210	1.6 ± 0.2
Delle	U-238	1.5 ± 0.1
	Th-230	0.9 ± 0.2
	Ra-226	0.7 ± 0.1
	Pb-210	1.1 ± 0.2

Source: Dames & Moore, 1984, published

F.4 RADIOACTIVE SOURCE TERM

In this section the calculations necessary to estimate the radiological effect of the proposed alternative remedial actions are presented. Most of the important radioactive releases occur at the Vitro site; however, calculations for the South Clive site and the transportation corridor are also considered necessary.

F.4.1 Radon release source term

Radon may be released from the tailings during four phases of the remedial action process: (1) prior to remedial action, (2) during the material moving operations, (3) after the relocation of the material but prior to installation of the cover, and (4) after the material has been covered. In Alternative 1 (no action) only phase (1) applies; in Alternatives 2 and 3 all four phases apply.

Alternative 1- no action

For this alternative a radon flux of $560 \text{ pCi/m}^2\text{s}$ exists on the approximately 128 acres of the site ($518,000 \text{ m}^2$). The total estimated radon release is $(560 \text{ pCi/m}^2\text{s}) (518,000 \text{ m}^2) (3.15 \times 10^7 \text{ s/yr}) = 9.1 \times 10^3 \text{ Ci/yr}$.

Alternative 3 - relocation and stabilization at South Clive

During the material moving operations it is reasonable to assume all interstitial radon would be released. The total quantity of Rn-222 in equilibrium with Ra-226 is estimated to be 1500 Ci. Based on an average emanation coefficient of 0.2, the total radon that could be released from the interstitial spaces is 300 Ci.

The contaminated material at the Vitro site would be excavated and transported to the South Clive site during a three year period. If the excavation rate is uniform, approximately 100 Ci would be released from excavated material each year for the three years. These 100 Ci must be added to the contribution from the tailings areas not yet excavated. The situation is portrayed in the material-removal diagram of Figure F-6, where two thirds of the pile are undisturbed (parts B & C) during removal of the first third of the pile (part A); and, on the average, half of Part A also contributes a yearly flux at a rate of $560 \text{ pCi/m}^2\text{s}$. Applying this logic to the three years of pile removal, the radon releases at the Vitro site are:

First year: $6100 \text{ Ci} + 1/2 (3050) \text{ Ci} + 100 \text{ Ci} = 7725 \text{ Ci}$.

Second year: $3050 \text{ Ci} + 1/2 (3050) \text{ Ci} + 100 \text{ Ci} = 4675 \text{ Ci}$.

Third year: $1/2 (3050 \text{ Ci}) + 100 \text{ Ci} = 1625 \text{ Ci}$.

In the fourth year and thereafter, the radon flux from the decontaminated Vitro site would be the normal background flux, $1\text{--}2 \text{ pCi/m}^2\text{s}$. This would result in annual releases of 16 to 30 Ci.

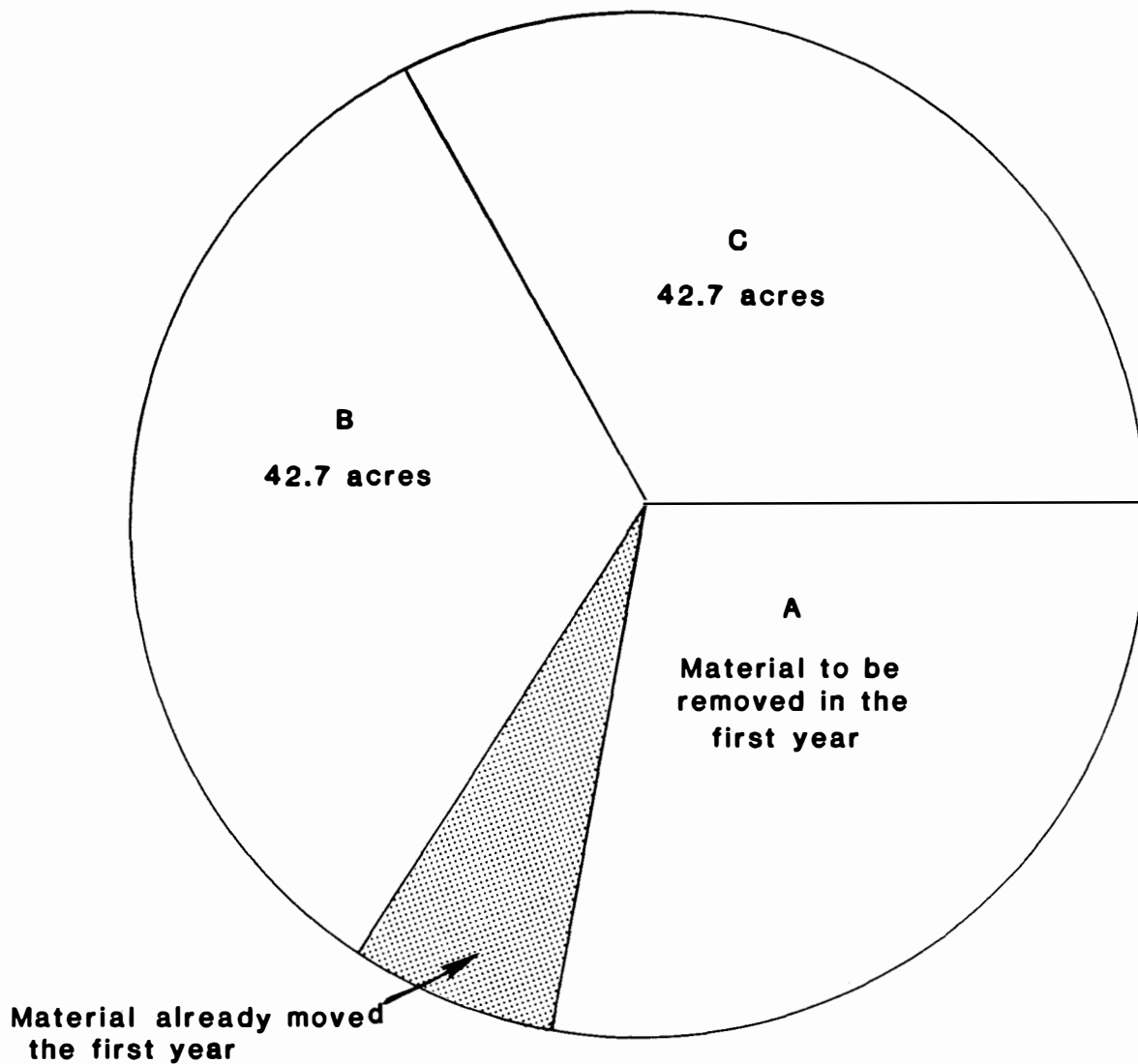


FIGURE F-6
IDEALIZED MATERIAL REMOVAL SCHEMATIC

A radon source term for tailings disposal operations at South Clive during Alternative 3 is not needed as there are no residents within 15 miles of the site. For occupational exposures it is assumed that the radon concentration on the pile will be the same as at the Vitro site, 30 pCi/l.

Alternative 2 - stabilization at Vitro

For disposal at the Vitro site the entire tailings volume will be disturbed, just as in Alternative 3. Although the time scale for the remedial action is slightly shorter, it is convenient to assume the same tailings movement scenario for stabilization at Vitro as for transport to South Clive. Thus the radon source term will be identical, on a yearly basis, to that for Alternative 3.

In the years following completion of on-site stabilization, the radon flux from the 55-acre tailings embankment would be less than or equal to the EPA standard of 20 pCi/m²s plus 1 to 2 pCi/m²s background soil flux, or about 160 to 170 Ci/yr.

F.4.2 Particulate release source term during remedial action

This section determines the magnitude of particulate releases from the Vitro site during the various remedial action alternatives. It was found that the radioactive source term due to particulate releases is orders of magnitude below that due to radon. Thus the particulate source term is not of importance in estimating the health effects to surrounding populations.

Alternative 1 - no action

Dust suspension due to wind erosion of the tailings piles is a mechanism for mobilization of tailings material during the no action alternative. As evidenced by the windblown contamination near the tailings pile, this process has operated, to some degree, during the period of existence of the Vitro site (ORNL, 1977).

The mechanism of soil erosion by wind depends on factors such as wind speed, soil properties such as particle size and moisture content, and the nature of the surface. Wind action results in three basic modes of particle motion: surface creep (particles above 500 μ m in size), saltation (particles between 100 μ m and 500 μ m in size), and airborne suspension (particles less than 100 μ m in size) (NRC, 1980a). The last mode of particle motion i.e., airborne suspension, which in general is a consequence of the saltation process, is considered herein.

An equation presented in Appendix G-1 of NUREG-0706 was utilized (NRC, 1980b). The model below is identical to the referenced formula except that the algebraic form is made explicit and all units have been cast in the MKS system. The resuspension rate for particulates less than 20 μ m in aerodynamic diameter is given by

$$E = 2 \times 10^{-6} (U/U_0)^2 (U/U_0 - 1) [(U/U_0)^{P/3} - 1]$$

where

- E = suspension rate, in grams per square meter per second ($\text{g}/\text{m}^2\text{s}$).
- U = shear velocity, meters per second (m/s).
- U_0 = threshold velocity for saltation (m/s).
- p = mass percent of particles less than $20\ \mu\text{m}$ in aerodynamic diameter.

The shear velocity, U, is given by the equation (NRC, 1980b)

$$U = \text{wind speed at height } (z) / [2.5 \ln(z/z_0)]$$

where z_0 is the height at which the windspeed is equal to zero. Assuming a particle density of $2.4\ \text{g}/\text{cm}^3$, and an average particle diameter of $300\ \mu\text{m}$, typical of fine grained soils, the threshold velocity for saltation U_0 can be calculated to yield (NRC, 1980b)

$$U_0 = 0.29\ \text{m}/\text{s}$$

An average wind speed of $4.5\ \text{m}/\text{sec}$ (the long-term annual average wind speed in the 48 conterminous states) measured 1 meter above the ground surface yields

$$U = 0.39\ \text{m}/\text{s}$$

and the equation for E reduces to

$$E = 1.22 \times 10^{-6} [(1.34)^p - 1]\ \text{g}/\text{m}^2\text{s}$$

In general, (p) is a coefficient around a few percent. Assuming a value of 3 percent yields a suspension rate due to wind action of

$$E = 4.1 \times 10^{-7}\ \text{g}/\text{m}^2\text{s}$$

Wind suspension is the source term for the resuspension flux of particles for the no action alternative. The resuspension rate of $4.1 \times 10^{-7}\ \text{g}/\text{m}^2\text{sec}$, along with the concentrations from Section F.3.1 were used to calculate the source terms for the particulates. For the no-action alternative the source terms are listed below.

$$\text{Ra-226} = 3.8 \times 10^{-3}\ \text{curies}/\text{yr}$$

$$\text{U-238} = 2.7 \times 10^{-4}\ \text{curies}/\text{yr}$$

$$\text{Th-230} = 3.8 \times 10^{-3}\ \text{curies}/\text{yr}$$

In comparison to the $9100\ \text{Ci}/\text{yr}$ of radon released from the Vitro site, these quantities are insignificant over the term of remedial action. It is believed they need not be considered further for population exposures.

Alternatives 2 and 3

For the alternatives involving tailings disturbance by heavy equipment, the particulate-release radioactive source term may be estimated from the air quality data of Appendix G. For the operations involving tailings movement, the resulting dust releases are estimated at $4 \times 10^5\ \text{kg}/\text{yr}$. Assuming all of

this dust contains the average Ra-226, Th-230, and U-238 concentrations estimated for the tailings, the radionuclide releases would be:

$$\begin{aligned}\text{Ra-226: } & (560 \times 10^{-12} \text{ Ci/g}) (4 \times 10^8 \text{ g/yr}) = 0.22 \text{ Ci/yr} \\ \text{Th-230: } & (560 \times 10^{-12} \text{ Ci/g}) (4 \times 10^8 \text{ g/yr}) = 0.22 \text{ Ci/yr} \\ \text{U-238: } & (40 \times 10^{-12} \text{ Ci/g}) (4 \times 10^8 \text{ g/yr}) = 0.016 \text{ Ci/yr}\end{aligned}$$

By comparison to the roughly 9000 Ci/yr of radon released from the Vitro site these quantities are insignificant. It is believed they need not be considered further for population exposures due to remedial action. No particulate release estimates are needed for the South Clive site since there is no population at risk. It is assumed that there are no routine particulate releases in the transportation corridor because covered vehicles will be used.

After completion of remedial action, the particulate-release radionuclide source term will be due to the natural radioactivity of the cover soils and the effects of wind erosion. It will not differ from that of surrounding natural lands.

Occupational and population exposures to particulates

Occupational exposures for remedial action workers breathing dust in the vicinity of earth moving equipment may be estimated for comparison to the gamma radiation exposure and to the radon daughter exposure. A method proposed by NRC (1981b) was used to estimate doses from inhalation of particulates. These doses would be to the worker's lung from inhalation of respirable particulates ($<10 \mu\text{m}$ in size) that contain trace amounts of U-238, Th-230, and Ra-226. The equation used is:

$$H = (f_o f_d f_w f_s)_{\text{air}} \times C_w \times \text{PDCF}_{\text{air}} \quad (\text{NRC, 1981b})$$

where

H = the 50-year dose commitment to the lung in mrem.

PDCF_{air} = pathway dose conversion factor for air pathways only, i.e., inhalation and direct radiation.

C_w = the radionuclide concentration in the material in picocuries per cubic meter.

f_o = the time-delay factor which is equal to 1 for this appendix.

f_d = site design factor which is equal to 1 for this appendix.

f_w = waste form and package factor which is equal to 1 for this appendix.

f_s = for the air uptake pathways, f_s , is the product of the soil-to-air transfer factor, T_{sa} , and the exposure duration factor (the fraction of a year that the worker is exposed).

The soil to air transfer factor, T_{sa} , may be expressed in terms of the geometry of the problem, the suspension flux (E), and the empirical equation

$$T_{sa} = \frac{ExGxfr}{uxd}, \text{ in m}^3 \text{ of soil per m}^3 \text{ of air} \quad (\text{NRC, 1981b})$$

where

E = suspension rate of transportation ($<30 \mu\text{m}$) particulates in units of $\text{g/m}^2\text{s}$.

fr = fraction of suspended transportable particulates that are respirable ($<10 \mu\text{m}$).

G = Geometry factor = (area subject to dusting)/(width of area x mixing height).

d = density of the soil (g/cm^3); assume 1.6.

u = wind speed (m/sec); assume 1.6.

The following calculates the transfer factor for particulates from excavation at the Vitro site for the action alternative. The total emission term for the Vitro site from construction would be $4 \times 10^5 \text{ kg/yr}$. The tailings piles encompass approximately 128 acres of contaminated material or equivalently $518,000 \text{ m}^2$. One third of the pile is removed per year, i.e., 43 acres or equivalently $173,000 \text{ m}^2$.

The total particulate release rate is about $4 \times 10^5 \text{ kg/yr}$ as indicated above. Of this, about 65 percent by weight would be in particles larger than $30 \mu\text{m}$, based on particle size distributions given by MSRD (1982). This assumes that the particle size distribution of initially suspended dust is proportional to the particle size distribution in the tailings, and assumes that only a small fraction of the tailings mass is in particles too large to be disturbed by earth-moving equipment. The factor E is thus $(0.35) (4 \times 10^5 \text{ kg/yr}) (1000 \text{ g/kg}) (1 \text{ yr}/3.15 \times 10^7 \text{ s}) (1/1.73 \times 10^5 \text{ m}^2) = 2.6 \times 10^{-5} \text{ g/m}^2\text{s}$.

Roughly 30 percent of the release rate for $30 \mu\text{m}$ and smaller particles will represent particles smaller than $10 \mu\text{m}$. Thus the factor fr in this calculation is 0.3.

The geometry factor was calculated by assuming that the area of construction would be 43 acres or $173,000 \text{ m}^2$ and that the mixing height would be 3 meters. The width of the area is best represented by the diameter of a circle whose area is $173,000 \text{ m}^2$. The width of the area is then equal to 470 meters. These assumptions yield $G = 123$.

Therefore,

$$T_{sa} = \frac{(2.6 \times 10^{-5} \text{ g/m}^2 \text{ sec}) (123) (.3)}{(1.6 \text{ m/s}) (1.6 \times 10^6 \text{ g/m}^3)} = 3.7 \times 10^{-10}$$

Table F-10 lists the pathway dose conversion factors for the air pathways and also soil concentrations (pCi/m³) for Ra-226, Th-230, and U-238 at the Vitro site. The dose from Pb-210 has been shown to be small when compared to the three principal radionuclides. Assuming that 20 percent of the radon is released from the soil, the concentration of the Pb-210 and its decay product Po-210 would be approximately 80 percent of the Ra-226 concentration. Calculations presented in ANL, 1983b (Table 4.3) show that the lung dose would increase by only 6 percent if Pb-210 and Po-210 were considered.

Table F-10. Occupational dose parameters

Nuclide	PDCF-air (mrem-m ³ /Ci)	Concentration in soil ^a (pCi/m ³)
Ra-226	1.936x10 ¹⁴	8.9x10 ⁸
Th-230	8.518x10 ¹³	8.9x10 ⁸
U-238	7.55 x10 ¹⁴	6.3x10 ⁷

^aAssuming a density of 1.6 g/cm³ and concentrations of 560 pCi/g for Th-230, Ra-226, and 40 pCi/g for U-238.

Source: NRC, 1981b.

The calculated 50-year dose commitments to the lungs from Ra-226, Th-230, and U-238 from excavation at the Vitro site are shown below. An assumption was made that a person would work 8 hours a day, 250 days a year. The fraction of a year that a person would work is, therefore, 0.228.

a) 50-year dose-commitment from Ra-226 to the lung

$$H = (1 \times 1 \times 1 \times 0.228 \times 3.7 \times 10^{-10}) \times 8.9 \times 10^8 \text{ pCi/m}^3 \times 1.936 \times 10^{14} \text{ mrem-m}^3/\text{Ci} \times 1 \text{ Ci/} 1 \times 10^{12} \text{ pCi}$$

$$H = 14.5 \text{ mrem}$$

b) 50-year dose-commitment from Th-230 to the lung

$$H = (0.228 \times 3.7 \times 10^{-10}) \times 8.9 \times 10^8 \text{ pCi/m}^3 \times 8.518 \times 10^{13} \text{ mrem-m}^3/\text{Ci} \times 1 \text{ Ci/} 1 \times 10^{12} \text{ pCi}$$

$$H = 6.4 \text{ mrem}$$

c) 50-year dose-commitment from U-238 to the lung

$$H = (0.228 \times 3.7 \times 10^{-10}) \times 6.3 \times 10^7 \text{ pCi/m}^3 \times 7.55 \times 10^{14} \text{ mrem-m}^3/\text{Ci} \times 1 \text{ Ci/} 1 \times 10^{12} \text{ pCi}$$

$$H = 4.0 \text{ mrem}$$

The doses to remedial action workers resulting from particulate inhalation are very small compared to the doses from radon and radon daughter exposures and gamma radiation exposures. This point is illustrated by the information summarized in Table F-11, where the doses from particulates are compared to the other radiation doses. The other doses are calculated and summarized in different units (person-rem) in Section F.5 and are recalculated and presented here only for comparison. The information presented in the Alternative 2 portion of Table F-11 is specific to that Alternative, but the conclusions regarding the significance of particulate doses would be the same for explicit calculations for Alternative 3.

Also summarized in Table F-11, are doses that might accrue to a remedial action worker on the Vitro tailings pile under the conditions existing if no action were taken (Alternative 1). Of course, no remedial action workers are present for the no action alternative, so these calculations are only for comparison purposes.

It is clear from Table F-11 that particulate doses are a small component of the total radiation doses that a remedial action worker might receive. The particulate doses are less than 10 percent of the gamma radiation dose above, and when the radon and radon daughter doses are considered, the particulate doses are certainly negligible (less than one percent of the dose to the workers).

For populations off the pile, the particulate component of total dose becomes even smaller. The airborne particulate concentrations will decrease more rapidly than airborne radon concentrations due to the more effective removal of the particulates from the lower atmosphere as compared to the gaseous radon.

The particles to which radon daughters attach will, in general, be submicron atmospheric dust particles. Only a small fraction of the particulate releases used in the above calculations ($<10\ \mu\text{m}$ was used) will be in a comparable size range and subject to the same prolonged and extensive atmospheric transport.

Based on this, it may be concluded that since particulate doses are negligible for remedial action workers, then particulate doses to off-site populations that result from remedial actions are negligible as well. The major radiation doses to off-site populations are from radon and radon daughter exposures; particulate releases have no important effect.

F.4.3 Gamma radiation source term

The gamma radiation emissions from the Vitro site are described by Figure F-3. For persons further than 1 km (0.5 miles) from the site, gamma radiation exposure is negligible. For persons living or working within 1 km of the Vitro site, a reasonable average value of 11 microR/hr gamma exposure due to the site may be applied.

For occupational workers on the site gamma radiation exposure is higher. Using the 560 pCi/g concentration of Ra-226 assumed for the tailings, the

Table F-11. Occupational radiation dose summary for
comparing significance of radiation sources

<u>No Action^a (2000 hr/yr exposure)</u>							
	<u>Radon</u>			<u>Gamma</u>		<u>Particulates^b</u>	
	<u>Ci/yr</u>	<u>pCi/l</u>	<u>mrem</u>	<u>μr/hr</u>	<u>mrem</u>	<u>Ci/yr</u>	<u>mrem</u>
yr 1	9,100	30	4,400	140	280	0.008	0.43
yr 2	9,100	30	4,400	140	280	0.008	0.43
yr 3	<u>9,100</u>	<u>30</u>	<u>4,400</u>	<u>140</u>	<u>280</u>	<u>0.008</u>	<u>0.43</u>
Total			13,200		840		1.3 = 14,000

<u>Alternative 2 (2000 hr exposure)</u>							
	<u>Radon</u>			<u>Gamma</u>		<u>Particulates^c</u>	
	<u>Ci/yr</u>	<u>pCi/l</u>	<u>mrem</u>	<u>μr/hr</u>	<u>mrem</u>	<u>Ci/yr</u>	<u>mrem</u>
yr 1	7,725	30	4,400	140	280	0.46	2.49
yr 2	4,675	15	2,200	140	280	0.46	2.49
yr 3	<u>1,625</u>	<u>10</u>	<u>1,500</u>	<u>140</u>	<u>280</u>	<u>0.46</u>	<u>2.49</u>
Total			8,100		840		74.7 = 9,000

^aNo remedial action workers are present for the no action alternative; these calculated exposures are merely for comparison.

^bParticulate releases due to wind erosion of the tailings pile.

^cParticulate releases due to earthmoving equipment during remedial action.

average gamma radiation exposure rate can be estimated by the method of Schiager (1974): the gamma exposure rate (microR/hr) is 2.5 times the radium concentration (pCi/g). In this case, $(2.5 \text{ (microR/hr)/(pCi/g)}) (560 \text{ pCi/g}) = 1400 \text{ microR/hr}$. This would be the hourly exposure to an unshielded worker on the pile. The majority of workers will be enclosed in the cabs of trucks or other earth moving equipment. As an inch of iron reduces the gamma radiation by a factor of 10, a more likely exposure is 140 microR/hr. Also, the placing of cover on the pile will reduce the gamma exposure rate by a factor of 10 per foot of soil; this again leads to the gamma exposure rate of 140 microR/hr as an appropriate upper estimate.

Following remedial action, gamma exposure rates will be at background levels (about 13 microR/hr) since sufficient cover will be applied to block the gamma radiation.

F.4.4 Atmospheric dispersion of Rn-222

Atmospheric-dispersion calculations are used as the basis for estimating the environmental radiation dose (for individuals and populations) resulting from radon and radon daughters from uranium mill tailings piles. In this report, the computer code MILDOS was utilized to calculate the atmospheric dispersion of radon, and the doses received by individuals and the population during the various phases of the proposed alternatives. The results of the MILDOS runs are used in Section F.5.

The computer code MILDOS was developed by the NRC to estimate the impacts from radioactive emission from uranium milling facilities, based on the calculational procedures outlined in Appendix G of NUREG-0706 (NRC, 1980b) and in Chapter 2 of the MILDOS user's manual (NRC, 1981a).

In MILDOS, emissions of radioactive materials from fixed-point sources or area sources are modeled using a sector-averaged Gaussian plume dispersion model. Exposure rates are presented for various source and receptor point locations. In order to run the code, four categories of inputs are required: source parameters, meteorological and population parameters, translocation parameters, and receptor parameters.

The first source parameter required is the number of sources of discrete effluents. This may be an actual number if there are fixed point sources or an assumed number for area sources. The number of sources of discrete effluents used for area sources is dependent upon the area of the source. Each source considered may be no larger than 0.1 square kilometers (km^2) when input for MILDOS. Therefore, the number of sources should be chosen or assumed such that each one has an area no greater than 0.1 km^2 . As mentioned above, approximately 128 acres of the Vitro site contain contaminated materials. The 128 acres were divided into six square areas each of approximately 21.3 acres or 0.086 km^2 (see Figure F-7). Figure F-7 was drawn so that the areas and their locations were representative of the northwest, southwest, and southeast tailings. The coordinates (x, length; y, width; and z, height) of the midpoints of the six source areas were input into MILDOS in units of kilometers.

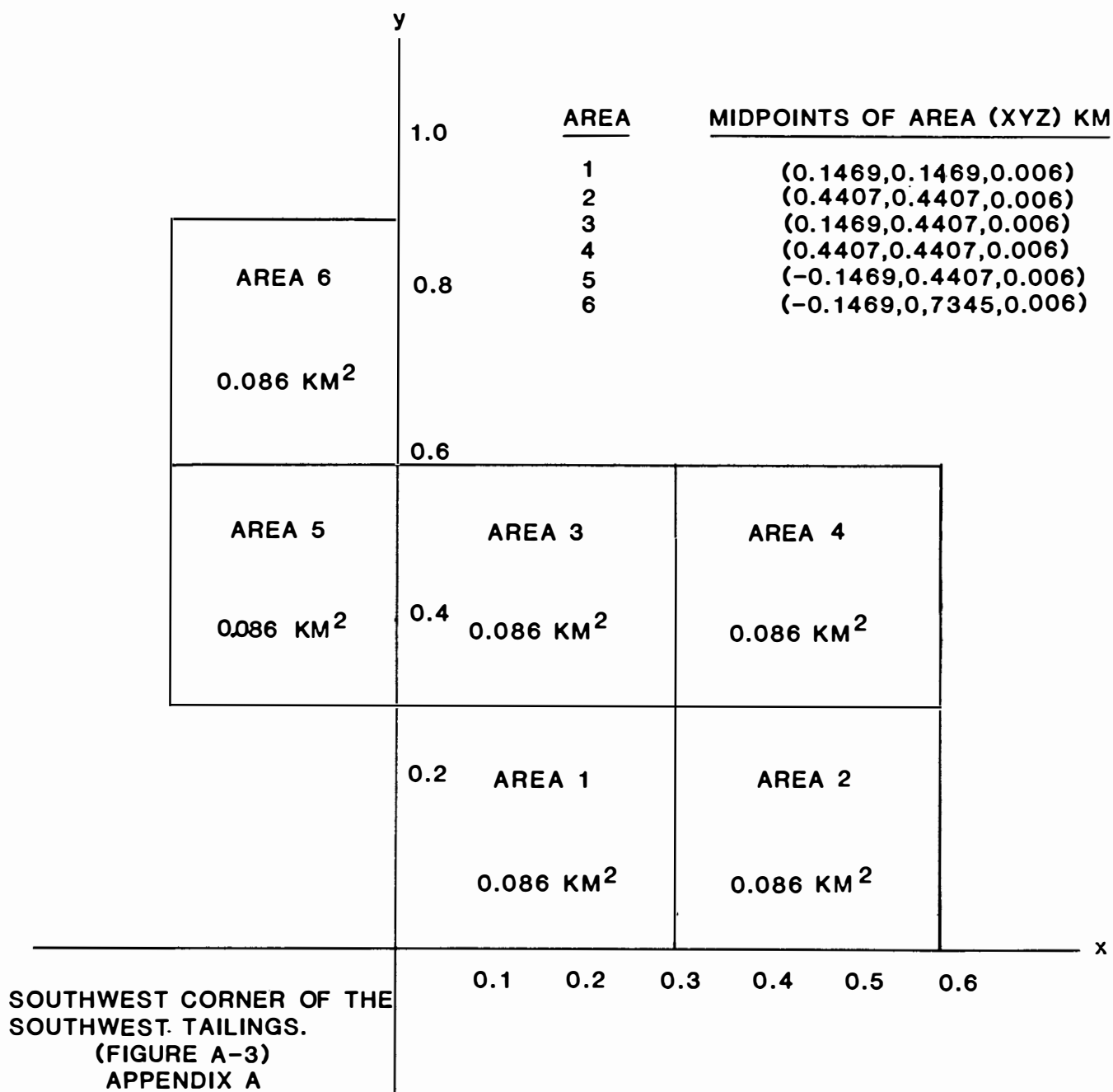


FIGURE F-7
SOURCE TERM GEOMETRY

The source terms from the preceding sections were recalculated and entered for a two-year interval as MILDOS calculates concentrations and doses on a two-year minimum time step. For example, a source term for each nuclide was calculated by taking the mean of the first and second years, and dividing by the number of source terms, six.

The particle-size distribution for each source was matched with the appropriate set-number provided in the code and included in the source input. For example, particle-size distribution set-number 3, which represents tailings characteristics, was entered.

The second group of parameters requires population and meteorological data for the site. The meteorological data required included the joint fractional frequency distribution of wind in a certain wind direction and in specific wind speeds and atmospheric stability classes. These data were entered for the Vitro site along with the population distribution, for 16 wind sectors, out to a radius of 10 km from the site. The wind data are presented in Appendix G.

The third group of parameters required are the translocation parameters. These parameters, along with the meteorological data, determine the actual movement of the radionuclides once they leave the source. Usually, food production in the region for vegetables, milk, and meat must be input in areal units of kilograms per year per square kilometers. For the analyses of the Vitro site, areal food production and forage uptake by animals was assumed to be zero.

The receptor parameters represent the final set of data required for the MILDOS code. Ten individual receptors were located at a radius of 1 km and compass directions of N, ENE, E, SE, SSE, S, SSW, SW, WSW and NNW.

F.4.5 Accident analyses

This section considers accidents that might occur during the transport of tailings to South Clive in Alternative 3. No accidents will occur in the no action alternative, and it is difficult to think of an accident occurring on the Vitro site which will have radiological consequences of any significance in relation to the radiological effect of the site itself. Accidents are considered explicitly for the train-transport option for moving the tailings to South Clive; the impact of a truck transport accident is scaled according to the volume of material carried. Two kinds of accidents are considered: (1) the spill occurs on land and the tailings are dispersed by wind, (2) the spill will fall into the Great Salt Lake.

F.4.5.1 Accidental spill of material on land

The potential impacts from a spill of material on land were calculated using a computer model "AIRREL" (a certified computer model developed by Dames & Moore). AIRREL calculates the theoretical radiological impacts to an individual or to populations resulting from an accidental release of uranium mill tailings to the atmosphere. The particulates released in this fashion would be subject to transportation by prevailing winds to distances where they

might become accessible to the surrounding population. The impacts incurred through this airborne transport mechanism are expressed in terms of the radiological dose that would be received by all individuals (cumulative dose) near the accidental release. The population dose is expressed in units of man-rem.

In the AIRREL code, the population dose is determined by multiplying the radionuclide concentration at a particular downwind distance by the dose conversion factor applicable to the radionuclide and body organ of interest and by the number of persons affected. In this program three radionuclides (U-238, Th-230, and Ra-226) and five body organs (whole body, bone, lung, liver, and kidney) are considered. Dose conversion factors obtained from the program MILDOS are used in the calculations. Up to 10 downwind locations and their respective populations can be considered in a single execution of the program.

The radionuclide concentration at a particular location downwind from a ground-level point source is found using the basic atmospheric diffusion equation (AEC, 1967).

$$X = \frac{Q}{\pi u \sigma_y \sigma_z}$$

where

X = average centerline ground level concentration (Ci/m³).
 Q = radionuclide source term (Ci/sec).
 u = wind speed (m/sec) (u = 1 m/sec in the code).
 σ_y = horizontal standard deviation of plume (m).
 σ_z = vertical standard deviation of plume (m).
 π = 3.1416.

The standard deviations σ_y and σ_z are measures of the spatial spread of the particulates plume as a function of downwind distance and meteorological stability class. In this program a Pasquill Type F stability class is assumed based on the recommendations of U.S. NRC Regulatory Guides 1.3 and 1.4. These standard deviations can be computed using the following empirical relations (NRC, 1980a)

$$\sigma_y = 0.04r (1 + 0.0001r)^{-1/2}$$

and

$$\sigma_z = 0.016r (1 + 0.0003r)^{-1}$$

where r is the downwind distance in meters.

AIRREL expresses the population dose as follows:

$$\text{Dose } (r, n, \theta) = c(r, n) \times \text{DCF}(n, \theta) \times (T/8760) \times \text{POP } (r)$$

where

Dose = radiological impact (man-rem).
 c = radionuclide concentration (pCi/m³).

DCF = dose conversion factor (mrem/yr per pCi/m³).
 T = duration time (hours).
 POP = population count (number of individuals).
 r = downwind distance.
 n = radionuclide "n".
 θ = body organ "θ".

For a land spill, a worst case accident would be a derailment of the unit train with a subsequent spill of material. As the train would contain 5000 tons of material (or a volume of 2840 m³), a full derailment was assumed to dump material over an area twice the ground area of the train. Assuming that the cars are 2 meters deep by 3 meters wide, a suspension rate 4.1×10^{-7} g/m²s (F.2.1.1) leads to estimated source terms for U-238, Th-230, and Ra-226 of

378 pCi/hr, 3220 pCi/hr, and 3200 pCi/hr, respectively.

The 1-hour doses to individuals at 0.1, 1.0, 2.0, and 10 km from this accident, as computed by AIRREL, are listed in Table F-12. An additional but smaller dose of less than 11 percent would be incurred if Pb-210 and Po-210 were considered (ANL, 1983b; Table 4-3).

Table F-12. Doses due to a hypothetical accident

	Distance (m)	Dose (mrem)				
		Whole body	Bone	Lung	Liver	Kidney
U-238	100	4.245E-05 ^a	7.176E-04	4.626E-03	0.000E+00	1.634E-04
	500	1.933E-06	3.268E-05	2.106E-04	0.000E+00	7.441E-06
	1000	5.592E-07	9.452E-05	6.093E-05	0.000E+00	2.152E-06
	1500	2.834E-07	4.791E-06	3.088E-05	0.000E+00	1.091E-06
	2000	1.797E-07	3.038E-06	1.958E-05	0.000E+00	6.917E-07
Th-230	100	5.028E-03 ^a	1.798E-01	8.698E-02	1.035E-02	5.028E-02
	500	2.289E-04	8.189E-03	3.961E-03	4.713E-04	2.289E-03
	1000	6.622E-05	2.369E-03	1.146E-03	1.363E-04	6.622E-04
	1500	3.335E-05	1.201E-03	5.807E-04	6.909E-05	3.357E-04
	2000	2.128E-05	7.612E-04	3.682E-04	4.381E-05	2.128E-04
Ra-226	100	1.314E-03	1.314E-02	1.791E-01	1.640E-06	4.624E-05
	500	5.983E-05	5.983E-04	8.155E-03	7.470E-08	2.106E-06
	1000	1.731E-05	1.731E-04	2.359E-03	2.161E-08	6.091E-07
	1500	8.772E-06	8.772E-05	1.196E-03	1.095E-08	3.087E-07
	2000	5.562E-06	5.562E-05	7.581E-04	6.994E-09	1.957E-07

^aE-x is equivalent to 10^{-x}.

These doses are insignificant compared to the doses received by workers on the site and by the population immediately surrounding the Vitro site, as

could be guessed from the small quantity of tailings carried by each train and the limited time of exposure.

Scaling for a truck accident would be according to the ratio of (35 tons per truck/5000 tons per train) or 7×10^{-3} . This implies that the doses due to a truck spill will be more than 100 times smaller than the doses due to a train spill.

The probability of either accident is roughly 9×10^{-7} per mile traveled (SNL 1982b), or about 0.05 spills by rail transport, or 7.0 spills by truck transport over the three years of the relocation to South Clive. Since these estimates are based on the frequency of injury and death accidents (SNL 1982b), it is clear that the major impact will not be radiological, but the actual injuries or deaths involved.

F.4.5.2 Surface-water transport accident

The transport of tailings by rail to the South Clive site during Alternative 3 could also result in a potential spill of material into the Great Salt Lake since the train route is adjacent to the lake for approximately 14 miles or 16 percent of the trip. This results in a total accident probability of 0.008 spills during the three years of relocation to the South Clive site, which is a negligible chance.

In addition to the negligible probability, the consequences of such an accident would also be negligible. The tailings material is largely insoluble and water transport of suspensions would be the major mechanism of dispersion. As the water body considered is not a quick moving stream, the majority of material would settle to the bottom; it would not enter into a drinking water or irrigation pathway. Water from the Great Salt Lake is not used for drinking or farming.

F.5 HEALTH EFFECTS

For each of the proposed alternatives for the Vitro tailings site, the information and calculations presented above are applied to give an estimate of the impact of the remedial action in terms of health effects in the general population and the remedial action workers.

F.5.1 Alternative 1 - no action

Remedial action worker health effects.

No remedial action workers are exposed to radon daughters or gamma radiation under this alternative.

General population and nearby worker health effects from radon daughter exposure.

Two methods are used to estimate these exposures. For the major portion of the population, the computer code MILDOS is used to provide estimates of radon daughter exposure of the population. This code does not provide estimates within 1 km of the source, however. For the small population within 1 km of the Vitro site, radon daughter concentrations are estimated from long-term radon concentration measurements.

Population within 1 km of the Vitro site

For persons living or working within 1 km of the Vitro site, long-term radon concentration measurements are available for estimating radon daughter exposures (Section F.3.2.1). Based on Figure F-2, a suitable average Rn-222 concentration within 1 km of the site is 0.5 pCi/l. Assuming 25 percent equilibrium of the radon daughters at this close distance from the pile (Borak 1983), the conversion factor 7.4×10^{-5} rem/(hr-pCi/l) (Section F.2.1) may be applied.

Five hundred people live to the west and southwest of the site, within 1 km (FBDU, 1981). Using a three-year period of exposure for comparison to the other alternatives, the population dose equivalent commitment is (500 persons) (0.5 pCi/l) (8760 hr/yr) (3 yr) (7.4×10^{-5} rem/(hr-pCi/l)) = 486 person-rem. Applying the lung cancer risk estimator (20×10^{-6} cancer/person-rem, Section F.2.1) gives an estimated excess of 0.0097 lung cancers in this group.

There are approximately 50 full-time workers employed near the Vitro site at the CVWRF. These persons are close enough to the tailings that the 30 pCi/l radon concentration estimated to exist on the pile will be used (Section F.3.1). Assuming 25 percent equilibrium of the radon daughters, and a 40-hour work week per person, the dose equivalent commitment to these nearby workers is (50 persons) (30 pCi/l) (2000 hr/yr) (3 yr) (7.4×10^{-5} rem/(hr-pCi/l)) = 666 person-rem. This results in an estimated excess 0.013 lung cancer deaths in the nearby worker group.

Population beyond 1 km of the Vitro site

The computer code MILDOS was used to estimate population doses beyond 1 km from the Vitro site. The input data required for MILDOS have been described above (Section F.4.4). The output is summarized in Table F-13 for a three-year exposure (comparable to the time for remedial action).

Table F-13. Summary of MILDOS results for no action alternative (person-rem).

Organ	Distance, km	
	1-2	1-10
Whole body	9.0	220
Bone	9.1	240
Lung	9.0	220
Bronchial epithelium	3600	27000

General population and nearby worker health effects from gamma radiation exposure.

Approximately 500 persons live within 1 km of the Vitro site (FBDU, 1981). Some of these reside in a trailer park to the west at about 0.5 mile, while some reside in an area 0.05 to 0.5 mile extending from the southwestern corner of the site. From Figure F-3 it is seen that gamma exposure is insignificant at 0.5 mile or more. The elevated gamma exposure rate within 0.5 mile averages about 11 microR/hr. Assuming 250 persons live within 0.5 mile, the population dose equivalent is (250 persons)(11 microR/hr)(8760 hr/yr)(3 yr)(1×10^{-6} rem/microR) = 72 person-rem. The estimate of excess health effects is 0.0086 cancer deaths.

About 50 persons work full time near the Vitro site at the CVWRF. Using the same gamma exposure rate for these persons as for remedial action workers on the pile for other alternative remedial actions (see following section), an upper estimate of 140 microR/hr may be applied to the nearby workers. The resulting population dose equivalent is (50 persons)(140 microR/hr)(2000 hr/yr)(3 yr)(1×10^{-6} rem/microR) = 42 person-rem. The estimate of excess fatal cancers due to gamma exposure of nearby workers is 0.0050 cancer deaths.

F.5.2 Alternative 2 - stabilization at Vitro

Remedial action worker health effects from radon daughter exposure.

Worker exposure to radon daughters will occur at the Vitro site during excavation and stabilization of the tailings. A conservative assumption is that a radon concentration of 30 pCi/l will exist on the pile (Section F.3.1). Radon daughter equilibrium is assumed to be 25 percent (Section F.2.1). As given in Table A-4 (Appendix A), the worker exposure hours required for this alternative total 2.3×10^5 person-hr. This worker exposure results in a dose equivalent commitment of $(2.3 \times 10^5 \text{ person-hr})(30 \text{ pCi/l})(7.4 \times 10^{-5} \text{ rem/(hr-pCi/l)}) = 480 \text{ person-rem}$. This corresponds to an estimated excess of 0.0096 lung cancer deaths among the workers.

Remedial action worker health effects from gamma radiation exposures.

Remedial action workers on the pile will be exposed to gamma radiation from tailings, as well as radon daughters. The estimated gamma exposure rate on the pile in microR/hr is 2.5 times the average Ra-226 concentration in pCi/g (Schiager, 1974), or 1400 microR/hr based on the measured average Ra-226 concentration of 560 pCi/g (Section F.3.1). This is a highly conservative estimate and represents an upper limit which, in practice, is not expected to be received. On a partially reclaimed portion of the tailings pile, the exposure rate would be reduced by a factor of 10 for each foot of cover material. The majority of workers will be enclosed in the cabs of earth moving equipment. This will provide shielding, reducing the exposure rate by a factor of 10 per inch of iron. A more realistic upper bound for the gamma exposure would therefore be 140 microR/hr.

Based on Table A-4 (Appendix A) it is possible to estimate the number of workers exposed during each phase of remedial action for two categories: 1) workers exposed on foot on bare tailings (1400 microR/yr), and 2) workers shielded by heavy equipment or tailings cover (140 microR/hr). It was assumed that the worker classifications of equipment operators and truck drivers will be afforded shielding equivalent to 1 inch of steel. The worker classifications maintenance personnel, miscellaneous personnel, and supervisor/foremen will not be afforded shielding due to heavy equipment. Further, full exposure to tailings is assumed to be possible for the remedial action phases of site preparation, tailings relocation, liner system placement, and tailings consolidation. For the phases of cover installation, site restoration, and general supervision all workers will be afforded a factor of ten reduction in exposure rate. For simplicity only two exposure rates are considered: 1400 microR/hr for exposure on foot on bare tailings, and 140 microR/hr for workers shielded by equipment or cover. Table F-14 summarizes the worker-hours in each remedial action phase and exposure category.

Table F-14. Worker exposure categories by remedial action phase

Phase	Worker hours (000s)	
	No shielding (1400 microR/hr)	Some shielding (140 microR/hr)
Site preparation	1	1
Tailings relocation	3	7
Liner system placement	12	16
Tailings consolidation	10	43
Cover installation		17
Site restoration		25
General supervision		96
	<u>26</u>	<u>205</u>

The worker exposures are $(26 \times 10^3 \text{ person-hr})(1400 \text{ microR/hr})(1 \times 10^{-6} \text{ rem/microR}) = 36 \text{ person-rem}$ for unshielded workers, and $(205 \times 10^3 \text{ person-hr})(140 \text{ microR/hr})(1 \times 10^{-6} \text{ rem/microR}) = 29 \text{ person-rem}$ for workers afforded some shielding. These total 65 person-rem which corresponds to an estimated excess 0.003 cancer death among the workers.

General population and nearby worker health effects from exposure to radon daughters.

During the remedial action at the Vitro site the tailings area available as a radon source term will decrease from 128 to 0 acres. The amount of radon released to the atmosphere will be less than for the no action alternative due to a reduced exposed pile surface. Based on the radon source term calculations given in Section F.4.1, the total radon emission for Alternative 2 is about 0.5 times that for the no action alternative. This scaling factor may be used directly to modify the MILDOS estimates for the no action alternative to give proper values for the stabilization at Vitro alternative. In a general fashion, it is also an appropriate scaling factor to be applied to the radon concentrations that would be measured on the pile or near the pile on an average basis for the period of remedial action.

For the 500 people living within 1 km to the west and southwest of the Vitro site the radon daughter exposure will be to an average concentration of 0.25 pCi/l for roughly 3 years, giving a population dose equivalent commitment of 240 person-rem. This is estimated to result in an excess 0.0048 lung cancer deaths.

For the 50 workers at the CVWRF, an average concentration of 15 pCi/l for 36 months is assumed. This exposure leads to a population dose equivalent commitment of 330 person-rem, and an estimated excess 0.0066 lung cancer deaths.

For the population beyond 1 km of the Vitro site, the estimated population dose equivalent commitments from MILDOS may be scaled by 0.5 as discussed above. The results are summarized in Table F-15.

Table F-15. Summary of MILDOS predicted doses around the Vitro site, scaled for the disposal at Vitro alternative (person-rem).

Organ	Distance, km	
	1-2	1-10
Whole body	4.5	110
Bone	4.6	120
Lung	4.5	110
Bronchial epithelium	1800	14000

The excess health effects (lung cancer deaths) due to population and nearby population exposure to radon daughters total 0.29 excess death for the population surrounding the Vitro site out to 10 km (438,000 persons).

General population and nearby worker health effects from gamma radiation exposure.

As discussed for the no action alternative, direct gamma exposure due to the Vitro tailings is insignificant beyond 0.5 mile. Over the course of a 36-month stabilization of the tailings at the Vitro site, the excess gamma exposure rate will decrease roughly linearly to zero with time at any given point. Thus the average gamma exposure rate at any point will be about half of that used for the no action alternative. The population dose equivalent is: 36 person-rem to the population of 250 persons living to the southwest within 0.5 mile of the site. The estimate of excess lung cancer deaths is 0.00072 deaths. The dose equivalent to the 50-person work force at the CVWRF may likewise be scaled by one-half, giving 21 person-rem.

The excess health effects to the general population and nearby workers due to direct gamma radiation is estimated at 0.0011 excess death.

F.5.3 Alternative 3--disposal at South Clive

Remedial action worker health effects from radon daughter exposure.

Worker exposure to radon daughters will occur at South Clive during disposal and at Vitro during excavation. A conservative assumption is that a radon concentration of 30 pCi/l will exist on the piles at both locations (Section F.3.1). Radon daughter equilibrium is assumed to be 25 percent (Section F.2.1). Two options are available for this alternative--truck or train transport of the tailings to South Clive. Since the hours of worker exposure differ for the two options, the calculation of dose equivalent commitments is done separately for each option.

Truck haulage option

As given in Table A-8, the worker exposure hours required for this option total 1.73×10^5 person-hr at the Vitro site, and 0.97×10^5 person-hr at South Clive. Radon daughter exposure during truck haulage of tailings is negligible due to the effective dilution and dispersion caused by the moving vehicle. The worker exposures result in dose equivalent commitments of $(1.73 \times 10^5 \text{ person-hr})(30 \text{ pCi/l})(7.4 \times 10^{-5} \text{ rem/(hr-pCi/l)}) = 380$ person-rem at Vitro, and $(0.97 \times 10^5 \text{ person-hr})(30 \text{ pCi/l})(7.4 \times 10^{-5} \text{ rem/(hr} \cdot \text{pCi/l)}) = 220$ person-rem at South Clive.

The total remedial action worker dose equivalent commitment from radon daughter exposure under the truck haulage option is 600 person-rem. This corresponds to an estimated excess of 0.012 lung cancer deaths among the workers.

Train haulage option

As given in Table A-7, the worker exposure hours required for the option total 1.91×10^5 person-hr at the Vitro site, and 1.43×10^5 person-hr at South Clive. Radon daughter exposure during train haulage of tailings is negligible due to the effective dilution and dispersion caused by the moving vehicle. The worker exposures result in dose equivalent commitments of $(1.91 \times 10^5 \text{ person-hr})(30 \text{ pCi/l})(7.4 \times 10^{-5} \text{ rem/(hr-pCi/l)}) = 420$ person-rem at Vitro, and $(1.43 \times 10^5 \text{ person-hr})(30 \text{ pCi/l})(7.4 \times 10^{-5} \text{ rem/(hr-pCi/l)}) = 320$ person-rem at South Clive.

The total remedial action worker dose equivalent commitment from radon daughter exposure under the train haulage option is 740 person-rem. This corresponds to an estimated excess of 0.015 lung cancer deaths among the workers.

Remedial action worker health effects from gamma radiation exposure.

Remedial action workers on foot on bare tailings will be exposed to 1400 microR/hr and those afforded shielding by heavy equipment or cover will be exposed to 140 microR/hr as discussed above for Alternative 2.

For tailings transport by truck or train, workers on the vehicles will be exposed to elevated gamma radiation. Exposures during transport may be conservatively estimated by using an exposure rate of 140 microR/hr in the occupied areas of a vehicle. This is based on assuming that the estimated 1400 microR/hr near a large volume of tailings applies to a train or truck, and allowing a factor of 10 reduction to account for vehicle shielding of the workers.

Truck haulage option

Table F-16 details the number of worker hours in each exposure category according to the phase of remedial action work, for the truck transport option.

Table F-16. Worker exposure categories by remedial action phase - truck transport

Phase	Worker hours (000s)		
	No shielding (1400 microR/hr)	Some shielding (140 microR/hr) on-site transport	
Site preparation - Vitro	1.5	.5	-
Site preparation - Clive	-	-	-
Tailings relocation - Vitro	106.5	30.5	489
Embankment construction - Clive	71	26	-
Site restoration - Vitro	15	20	-
Total	194	77	489

As given in Table F-16 the worker-hours of exposure on foot on bare tailings total 1.23×10^5 at Vitro and 0.71×10^5 at South Clive, and result in $(1.94 \times 10^5 \text{ person-hr})(1400 \text{ microR/hr})(1 \times 10^{-6} \text{ rem/microR}) = 270 \text{ person-rem}$. Heavy equipment operator-hours total 0.51×10^5 at Vitro and 0.26×10^5 at South Clive, and result in $(0.77 \times 10^5 \text{ person-hr})(140 \text{ microR/hr})(1 \times 10^{-6} \text{ rem/microR}) = 11 \text{ person-rem}$. The transport of tailings requires 489×10^5 worker-hours, and results in $(489 \times 10^5 \text{ person-hr})(140 \text{ microR/hr})(1 \times 10^{-6} \text{ rem/microR}) = 68 \text{ person-rem}$.

The total remedial action worker exposure for the truck transport option is 350 person-rem. This corresponds to an estimated excess of 0.042 cancer deaths among the workers.

Train haulage option

As given in Table F-17, the worker exposure hours on foot on bare tailings total 1.08×10^5 at Vitro and 0.71×10^5 at South Clive, and result in $(1.79 \times 10^5 \text{ person-hr})(1400 \text{ microR/hr})(1 \times 10^{-6} \text{ rem/microR}) = 250 \text{ person-rem}$. Heavy equipment operator-hours are 0.84×10^5 at Vitro and 0.72×10^5 at South Clive, resulting in $(1.56 \times 10^5 \text{ person-hr})(140 \text{ microR/hr})(1 \times 10^{-6} \text{ rem/microR}) = 22 \text{ person-rem}$. The transport of tailings requires 0.25×10^5 person-hr, and results in $(0.25 \times 10^5 \text{ person-hr})(140 \text{ microR/hr})(1 \times 10^{-6} \text{ rem/microR}) = 4 \text{ person-rem}$.

The total remedial action worker dose exposure for the train transport option is 280 person-rem. This corresponds to an estimated excess of 0.034 cancer death among the workers.

Table F-17. Worker exposure categories by remedial action phase -
train transport

Phase	Worker hours (000s)		
	No shielding (1400 microR/hr)	Some shielding (140 microR/hr) on-site transport	
Site preparation - Vitro	7	3	-
Site preparation - Clive	-	-	-
Tailings relocation - Vitro	86	61	25
Embankment construction - Clive	71	72	-
Site restoration - Vitro	15	20	-
Total	179	156	25

General population and nearby worker health effects from radon daughter exposure.

There are no residents within 10 km of the South Clive site, thus no population exposures accrue from the uncovered tailings at South Clive. The population exposures for this alternative will occur around the Vitro site and along the transportation corridor to South Clive.

The excavation and transport of the tailings will take approximately three years. Over the course of this period, the tailings radon source term will decrease at the Vitro site as described in Section F.4.1. The total radon released over the three-year remedial action is about 0.5 times the amount released during three years of the no action alternative. Using this as a scaling factor, the population dose equivalent commitments around the Vitro site are about 0.5 times those for the no action alternative. The estimated population dose equivalent commitments are: 240 person-rem to 500 persons living within 1 km of the site, 330 person-rem to 50 nearby workers at the Central Valley Water Facility, and doses based on MILDOS for the population beyond 1 km as summarized in Table F-18.

Table F-18. Summary of MILDOS predicted doses around the Vitro site, scaled for the disposal at South Clive alternative (person-rem).

Organ	Distance, km	
	1-2	1-10
Whole body	4.5	110
Bone	4.6	120
Lung	4.5	110
Bronchial epithelium	1800	14000

The excess health effects (lung cancer deaths) due to population and nearby population exposure to radon daughters totals 0.29 excess death for the entire population surrounding the Vitro site out to 10 km (438,000 persons).

General population and nearby worker health effects from gamma radiation exposure.

As discussed for the no action alternative, direct gamma exposure due to the Vitro tailings is insignificant beyond 0.5 mile. Over the course of the three-year removal of the tailings to South Clive, the excess gamma exposure rate at any point will decrease roughly linearly with time from the present value to zero. Thus, the average gamma exposure rate at any point for this alternative will be one-half that used for the no action alternative. In the no action alternative a population of 250 persons living to the southwest was exposed to 11 microR/hr. Scaling by half gives an exposure rate of 5.5 microR/hr, indicating a population dose equivalent of 36 person-rem for the three-year period of tailings relocation. The dose equivalent to the 50-person work force at the Central Valley Water Facility may likewise be scaled by one-half, giving 21 person-rem.

The excess health effects to the general population and nearby workers due to direct gamma radiation is estimated at 0.0011 excess deaths.

General population health effects from transportation of tailings to South Clive.

The exposure rate for people living along the shipping route during normal transport conditions can be determined according to the following equation (AEC, 1972; Dames & Moore, 1975; NRC, 1981b).

$$D(d) = \frac{2 K}{V} I(d)$$

where

D(d) = total integrated dose at distance d, in mrem.

K = dose rate factor in mrem-ft² per hour.

V = shipment speed in feet per hour.

d = perpendicular distance of an individual from the shipment path, in feet, where

$$I(d) = \int_d^{\infty} \frac{\exp(-ur) B(r) dr}{r (r^2 - d^2)^{1/2}}$$

and where u is the linear absorption coefficient for air in reciprocal feet (taken to be 0.00118 ft⁻¹ in this appendix), and B(r) is the dimensionless Berger buildup factor in air given by the formula

$$B(r) = 1 + 0.0006 r$$

where r is distance expressed in feet.

For the transportation of the uranium tailings, the dose rate (K) was assumed to be 140 mrem-ft²/hr. This rate was based on the assumed EGR dose rate of about 1400 microR/hr (or 1.4 mrem/hr) at a distance of 10 feet from the tailings; the shielding effect of the railroad-car sides was ignored.

A computer program TRANSDOS was developed to solve the integral and evaluate the individual exposures. The doses to onlookers were calculated at 10, 50, 100, and 500 meters using a speed of 10 miles/hour and the above dose rate factor of 140 mrem/ft²/hr. The resulting doses are listed in Table F-19.

Table F-19. Dose to an "onlooker" along tailings transportation route

Perpendicular distance of observer from shipment route (m)	Dose/shipment (rem)
10	2.4E-07
50	3.9E-08
100	1.5E-08
500	5.7E-10

These small doses total to such small population dose equivalents for the number of trips and low population densities along the transport corridor that they are not considered further.

F.5.4 Maximally exposed resident

The maximally exposed resident would be one who lives about 300 feet from the southwestern corner of the Vitro site (Figure 1-1). Assuming the edge of the Vitro site corresponds to the origin of the abscissa in Figure F-3, the person might be exposed to 50 microR/hr in addition to background gamma radiation. This would yield a dose equivalent of $(50 \text{ microR/hr})(8670 \text{ hr/yr})(1 \times 10^{-6} \text{ rem/microR}) = 0.4 \text{ rem/yr}$. The EPA (EPA, 1980) estimated the gamma dose equivalent as 0.5 rem/yr for that location.

The radon daughter exposure may be estimated from the data of Figure F-2. The location of interest falls close to the 1 pCi/l concentration line. For a resident living fulltime at this location the 1 pCi/l concentration would result in a dose equivalent commitment of $(1 \text{ pCi/l})(7.4 \times 10^{-5} \text{ rem/(hr-pCi/l)})(8670 \text{ hr/yr}) = 0.6 \text{ rem/yr}$.

F.5.5 Health effects perspective

The health effects calculations presented in this appendix are summarized in Section 5.1.4 of the main text. For comparison to the impacts of remedial action, estimates of the collective dose equivalents due to natural radioactivity (which would result from continuous exposure at the EPA limits for remedial action as discussed in Section 3.1.1 of the main text) are presented in Table 5-3. It is quickly seen that the incremental radiation dose equivalents due to remedial action are small by comparison to the dose equivalents resulting from natural radioactivity.

REFERENCES FOR APPENDIX F

- AEC (U.S. Atomic Energy Commission), 1967. Workbook of Atmospheric Dispersion Estimates, Public Health Service Publication 999-AP-26, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio.
- AEC (U.S. Atomic Energy Commission), 1972. Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants, WASH-1238.
- AEC (U.S. Atomic Energy Commission), 1974. Measurements of Radionuclides in the Environment Sampling and Analysis of Plutonium in Soil, Regulatory Guide 4.5.
- ANL (Argonne National Laboratory), 1980. Radon Release and Dispersion from an Open Pit Uranium Mine, NUREG/CR-1583.
- ANL (Argonne National Laboratory), 1982a. UMTRAP Radiological Support, Quarterly Report, January-March 1982.
- ANL (Argonne National Laboratory), 1982b. UMTRAP Radiological Support, Quarterly Report, April-June 1982.
- ANL (Argonne National Laboratory), 1983a, Final Report, UMTRAP Radiological Support Program - Environmental Measurements, October 1983, Environmental Research Division, Argonne National Laboratory, Argonne, Illinois.
- ANL (Argonne National Laboratory), 1983b, Pathway Analysis and Radiation Dose Estimates for Radioactive Residues at Formerly Utilized MED/AEC Sites. ORO-832 (Rev), Division of Environmental Impact Studies, Argonne National Laboratory, Argonne, Illinois.
- Baretto, P.M., 1973. Radon-222 Emanation Characteristics of Rocks and Minerals, IAEA-PL-565/1.
- Bendix, 1983. Radium-226 Analysis for Vitro Site Tailings Samples, Chemistry Laboratory Geochemical Support Department, Bendix Field Engineering Corporation, Grand Junction, Colorado.
- Borak, T. B., and W. C. Inkret, 1983. "Measurement of Radon Gas Concentrations and Potential Alpha Energy of Radon Daughters near a Uranium Mill Tailings Pile," unpublished data, Colorado State University, Fort Collins, Colorado, DOE contract 31-109-6878.
- Brewer, L., H. Rarrick, D. Minnema, 1982. Radium-226 Measurements Below Uranium Mill Tailings Piles, Sandia Report SAND82-0288A, Sandia National Laboratories, Albuquerque, New Mexico.
- BRH (Bureau of Radiological Health), 1980. Radiological Health Handbook, PHS Publication No. 2016, Department of Health, Education, and Welfare, Washington, D.C.

- Casarett, L.J. and J. Doull (ed), 1975. Toxicology: The Basic Science of Poisons, New York, New York.
- Cohen, B. L., 1981. "Proposals on Use of the BEIR-III report in Environmental Assessment," Health Physics, Vol. 41, pp. 769-774.
- Connecticut (Connecticut Public Utilities Commission), 1954. Gas Distribution Companies Rules, Regulations, and Standards, Docket No. 8950.
- Dames & Moore, 1975. Study of the Shipment of Spent Fuel from the Shoreham Nuclear Power Station to the Reprocessing Plant, prepared for Long Island Lighting Co., Inc., New York, New York.
- Dames & Moore, 1984. Unpublished environmental sampling data provided by Dames and Moore, Denver, Colorado, to US Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.
- DOE (U.S. Department of Energy), 1981. Executive Order 5480.1, Environmental Protection, Safety and Health Program for DOE Operations, Chapter 6, p. XI-3, August 13.
- EPA (U.S. Environmental Protection Agency), 1975. Gamma Radiation Surveys at Inactive Mill Sites, EPA Technical Note ORP/LU-75-5, August.
- EPA (U. S. Environment Protection Agency), 1980. Interim Cleanup Standards for Inactive Uranium Processing Sites. Federal Register 45(79): 27366-27368.
- Evans, R. D., J. H. Harley, W. Jacobi, A. S. McLean, W. A. Mills, and C. G. Stewart, 1981.. "Estimate of Risk from Environmental Exposure to Radon-222 and its Decay Products," Nature, Vol. 290, No. 5802, pp. 98-100.
- FBDU (Ford, Bacon and Davis Utah Inc.), 1976. Phase II - Title I Engineering Assessment of Inactive Uranium Mill Tailings, Vitro Site, Salt Lake City, Utah, GJT-1, prepared for U.S. Energy Research and Development Administration, Grand Junction, Colorado.
- FBDU (Ford, Bacon and Davis Utah Inc.), 1981. Engineering Assessment of Inactive Uranium Mill Tailings, Vitro Site, Salt Lake City, Utah, DOE/UMT-0102, prepared for U.S. Department of Energy, Albuquerque Operations Office, Albuquerque, New Mexico 87185.
- ICRP (International Commission on Radiological Protection), 1975. Anatomical, Physiological and Metabolic Characteristics, ICRP-23, 1975.
- ICRP (International Commission on Radiological Protection), 1977. Recommendations of the International Commission on Radiological Protection, (Adopted January 17, 1977), ICRP Publication 26, Pergamon Press, Elmsford, New York.
- LASL (Los Alamos Scientific Laboratory), 1981. Quarterly Report, UMTRA Project, April-June 1981, Los Alamos, New Mexico.
- Lederer, C.M., 1978. Table of Isotopes, 7th Edition., John Wiley and Sons, Inc., New York, New York.

- Martin, J.P., G.E. Veyera, D.M. Nasiataka, and L.F. Osorno, 1980. "Characterization of the Inactive Tailings Sites," Proceedings ofn Third Symposium on Uranium Mill Tailings Management, Colorado State University, Fort Collins, Colorado, (November 24-25).
- Monsanto (Monsanto Research Corporation), 1983 quarterly file reports on radon monitoring to DOE UMTRA Project Office, Albuquerque, New Mexico.
- MSRD (Mountain States Research and Development), 1982 Economic Evaluation of Inactive Uranium Mill Tailings, Vitro Site, Salt Lake City, Utah. UMTRA-DOE/ALO-171. Prepared for U.S. DOE Albuquerque Operations Office, Albuquerque, New Mexico.
- NAS (National Academy of Sciences), 1980. BEIR-III report, The Effects on Population of Exposure to Low Levels of Ionizing Radiation, Advisory Committee on Biological Effects of Ionizing Radiation, National Research Council, Washington, DC.
- NRC (U.S. Nuclear Regulatory Commission), 1977. Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes, NUREG-0170, Vol. 1, Washington, D.C.
- NRC (U.S. Nuclear Regulatory Commission), 1979. Draft Generic Environmental Impact Statement on Uranium Milling, NUREG-0511, Project M-25, Washington, D.C.
- NRC (U.S. Nuclear Regulatory Commission), 1980a. Radiological Effluent and Environmental Monitoring at Uranium Mills, Regulatory Guide 4.14, Revision 1, Washington, D.C.
- NRC (U.S. Nuclear Regulatory Commission), 1980b. Final Generic Environmental Impact Statement on Uranium Milling NUREG-0706, Washington, D.C.
- NRC (U.S. Nuclear Regulatory Commission), 1981a. MILDOS, A Computer Program for Calculating Environmental Radiation Doses from Uranium Recovery Operations, NUREG/CR-2011, Washington, D.C.
- NRC (U.S. Nuclear Regulatory Commission), 1981b. Data Base for Radioactive Waste Management-Impacts Analyses Methodology Report, NUREG/CR-1759, Volume 3, Washington, D.C.
- NRC (U.S. Nuclear Regulatory Commission), 1982. Calculational Models for Estimating Radiation Doses to Man from Airborne Radioactive Materials Resulting from Uranium Milling Operations, Regulatory Guide 3.51, Washington, D.C.
- ORNL (Oak Ridge National Laboratory), 1977. Assessment of Radiological Impact at the Inactive Uranium Mill Tailings Pile at Salt Lake City, Utah, ORNL/TM-5251, Oak Ridge, Tennessee.

- ORNL (Oak Ridge National Laboratory), 1981. State Background Radiation Levels: Results of Measurements Taken During 1975-1979, ORNL-TM-7343, Oak Ridge, Tennessee.
- Re, G., L. Skoski, and K.E. Robinson, 1980. "Determining Radon Attenuation of Cover Materials Using Field Experimentation," in First International Conference on Uranium Mine Waste Disposal, C.O. Brawner, (ed).
- SNL (Sandia National Laboratories), 1976. Severities of Transportation Accidents, Vol. 1-Summary, SLA-74-0001, Albuquerque, New Mexico.
- SNL (Sandia National Laboratories), 1982a. Radium-226 Measurements below Uranium Mill Tailings Piles. SAND82-0288A, Albuquerque, New Mexico.
- SNL (Sandia National Laboratories), 1982b. Non-Radiological Impacts of Transporting Radioactive Material. SAND81-1703, Albuquerque, New Mexico.
- Scheerer, S.D., Jr., and C.W. Sills, 1969. "Evaluation of atmospheric radon in the vicinity of uranium mill tailings," Health Physics, Vol. 17, pp. 77-88, Pergamon Press.
- Schiager, K.J., 1974. "Analysis of Radiation Exposures on or Near Uranium Mill Tailings Piles," Radiation Data and Reports, 14:411.
- UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation), 1977. Sources and Effects of Ionizing Radiation, United Nations Publication No. E.77.IX.I, Report to the General Assembly, Washington, DC.

Appendix G

MISCELLANEOUS INFORMATION AND CALCULATIONS

TABLE OF CONTENTS

	<u>Page</u>
G.1 EMISSION RATES FOR CONSTRUCTION ACTIVITIES DURING ALTERNATIVES 2 AND 3	G-3
G.2 POPULATION AND WIND DISTRIBUTIONS NEAR THE VITRO SITE	G-5

LIST OF TABLES

	<u>Page</u>
G-1 Population distribution	G-6
G-2 Vitro site joint frequency wind data	G-7

Appendix G

MISCELLANEOUS INFORMATION AND CALCULATIONS

This appendix contains miscellaneous information and calculations that are necessary for a full understanding of some of the impact assessments made in this report, but which are not presented elsewhere in the main text or the other appendices.

G.1 EMISSION RATES FOR CONSTRUCTION
ACTIVITIES DURING ALTERNATIVES 2 AND 3

The following material outlines the emission-factors proposed by a Public Health Engineer in the Utah Department of Health's Bureau of Air Quality (personal communication to Dames & Moore from Montie R. Keller, March 16, 1982). These emission factors have been used in Section 5.2 and in Appendix F to estimate the amount of particulate matter that would be raised into the air at the several sites of construction activity. Additional emission factors not covered in the March 16, 1982 memo were taken from AP-42 (EPA, 1977 and supplements). AP-42 factors were also used if they were more conservative.

Bulldozers:

Emission factor = 16 lbs per dozer-hour

Front-end loader operations:

Emission factor = 0.06 lbs per ton of material loaded

Scrapers:

Emission factor = 16 lbs per scraper-hour

Grader:

Emission factor = 32 lbs per grader-hour

Haul-road emissions:

Assumes 18-wheel, 40-ton trucks travelling at 20 mph; 15 percent silt

Emission factor = 8.91 lbs per vehicle-mile on dirt or gravel
surfaces

Exhaust (combustive) emissions from railroad engines:

Assume 135 gallons of fuel/engine-hour and 24 engine-hours/day

Emission factors = CO = 130 lb/10³ gal
HC = 94 lb/10³ gal
NO_x = 370 lb/10³ gal
SO_x = 57 lb/10³ gal
TSP = 25 lb/10³ gal

Exhaust (combustive) emissions from haul trucks:

Emission factors = CO = 28.7 g/mi
HC = 4.6 g/mi
NO_x = 20.9 g/mi
SO_x = 2.8 g/mi
TSP = 1.3 g/mi

Railroad car dump:

Emission factor = 0.02 lbs per ton of material dumped

Conveyor dump into surge bins:

Emission factor = 0.02 lbs per ton of material dumped

Conveyor belts:

Emission factor = 0.02 lbs per ton of material moved

G.2 POPULATION AND WIND DISTRIBUTIONS NEAR THE VITRO SITE

The distribution of population near the Vitro site was used in the atmospheric dispersion calculations with MILDOS (see Appendix F, Section F.4.4) to estimate population radiological doses during the alternative remedial actions. The population distribution out to 10 km from the center of the site, and in 16 directions, is shown in Table G-1.

The distribution of winds near the Vitro site was also used in the atmospheric dispersion calculations with MILDOS. The assumed wind distributions (frequency of occurrence of wind-speed intervals versus direction) for 6 classes of atmospheric stability are shown in Table G-2.

Table G-1. Population distribution

KILOMETERS	@	N 0.0	NNE 22.5	NE 45.0	ENE 67.5	E 90.0	ESE 112.5	SE 135.0	SSE 157.5	S 180.0	SSW 202.5	SW 225.0	WSW 247.5	W 270.0	WNW 292.5	NW 315.0	NNW 337.5
1.0-2.0	@	49	0	130	1373	1348	1438	500	134	196	312	841	625	641	344	456	230
2.0-3.0	@	53	383	1033	2674	2979	2779	1313	576	923	1835	2203	998	1414	511	834	333
3.0-4.0	@	820	1927	4120	3387	3923	3264	4672	1515	1751	2864	2292	2628	3139	356	346	1326
4.0-5.0	@	2857	4154	5778	3270	4908	4115	3331	1706	1798	2079	3045	4780	4160	507	3	2957
5.0-10.0	@	19685	38510	28454	24716	25771	24483	23521	25089	14676	17378	24795	25714	15097	419	259	11556
10.0-20.0	@	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20.0-30.0	@	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30.0-40.0	@	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40.0-50.0	@	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50.0-60.0	@	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60.0-70.0	@	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
70.0-80.0	@	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.0-80.0	@	23464	44974	39515	35422	38929	36079	33337	29020	19344	24468	33176	34745	24451	2137	1898	16402

TOTAL 1-80 KM POPULATION IS 437361 PERSONS

Table G-2. Vitro site joint frequency wind data

JOINT FREQUENCY IN PERCENT, DIRECTION INDICATES WHERE WIND IS FROM FREQWS=C. 0.07945, 0.31358, 0.38002, 0.17660, 0.03756, 0.01278																	
MPH	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTALS
STABILITY CLASS 1																	
1.5	0.0290	0.0246	0.0066	0.0202	0.0088	0.0044	0.0180	0.0066	0.0202	0.0000	0.0158	0.0044	0.0044	0.0044	0.0154	0.0338	0.2166
5.5	0.0799	0.0571	0.0342	0.0342	0.0457	0.0228	0.0228	0.0342	0.0342	0.0000	0.0114	0.0228	0.0228	0.0228	0.0799	0.0342	0.5590
10.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
28.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ALL	0.1089	0.0817	0.0408	0.0544	0.0545	0.0272	0.0408	0.0408	0.0544	0.0000	0.0272	0.0272	0.0272	0.0272	0.0953	0.0680	0.7756
STABILITY CLASS 2																	
1.5	0.1366	0.0541	0.0328	0.0306	0.0828	0.0431	0.0611	0.0721	0.1543	0.0361	0.1046	0.0317	0.1476	0.1119	0.1392	0.0744	1.3130
5.5	0.3767	0.1712	0.0799	0.0571	0.0799	0.0571	0.1142	0.2283	0.1712	0.1142	0.0457	0.0685	0.1027	0.2511	0.2740	0.2511	2.4429
10.0	0.4795	0.0799	0.0342	0.0342	0.0298	0.0457	0.0685	0.0913	0.1027	0.0457	0.0114	0.0685	0.0228	0.1941	0.4452	0.2397	1.9862
15.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
28.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ALL	0.9928	0.3052	0.1469	0.1219	0.1855	0.1459	0.2438	0.3917	0.4282	0.1960	0.1617	0.1687	0.2731	0.5571	0.8584	0.5652	5.7421
STABILITY CLASS 3																	
1.5	0.0664	0.0295	0.0629	0.0523	0.0042	0.0266	0.0619	0.0778	0.0394	0.0384	0.0527	0.0282	0.0079	0.0540	0.0205	0.0509	0.6736
5.5	0.5251	0.1598	0.1027	0.1370	0.1142	0.0799	0.3995	0.5137	0.4338	0.0799	0.1484	0.1256	0.2169	0.1826	0.2397	0.4224	3.8812
10.0	1.3813	0.2968	0.1370	0.0114	0.0685	0.1941	0.6050	0.9247	0.9132	0.0799	0.0571	0.0913	0.1484	0.3653	1.0616	1.2215	7.5571
15.5	0.3653	0.0114	0.0114	0.0000	0.0114	0.0114	0.0114	0.1484	0.2626	0.0114	0.0000	0.0000	0.0228	0.0342	0.1598	0.3311	1.3926
21.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0342	0.0571	0.0000	0.0000	0.0000	0.0000	0.0000	0.0228	0.1141
28.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0571	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0571
ALL	2.3381	0.4975	0.3140	0.2007	0.1983	0.3120	1.0778	1.6988	1.7632	0.2096	0.2582	0.2451	0.3960	0.6361	1.4816	2.0487	13.6757
STABILITY CLASS 4																	
1.5	0.1601	0.0697	0.0883	0.0427	0.0370	0.0526	0.0874	0.1336	0.1265	0.0463	0.0719	0.1147	0.0690	0.1738	0.1316	0.0561	1.4613
5.5	0.6279	0.3425	0.2511	0.1027	0.2055	0.2626	0.6279	0.7877	0.8676	0.1598	0.1826	0.2854	0.3311	0.4566	0.5594	0.5137	6.5641
10.0	1.9521	0.5594	0.2740	0.0457	0.2626	0.7763	4.0868	3.5731	2.7511	0.3881	0.2511	0.2740	0.4909	0.8904	0.8447	1.4155	18.8358
15.5	1.6553	0.3311	0.1027	0.0114	0.1027	0.3881	1.8265	2.8767	4.3151	0.2626	0.0913	0.1027	0.3311	0.9018	1.0502	1.9178	16.2671
21.5	0.2854	0.0114	0.0114	0.0228	0.0114	0.0457	0.0799	0.4452	1.8721	0.0685	0.0342	0.0114	0.1142	0.1941	0.1712	0.2626	3.6415
28.0	0.0571	0.0114	0.0000	0.0000	0.0000	0.0000	0.0114	0.1256	0.7763	0.0342	0.0114	0.0114	0.0342	0.0342	0.0114	0.1027	1.2213
ALL	4.7379	1.3255	0.7275	0.2253	0.6192	1.5253	6.7199	7.9419	10.7087	0.9595	0.6425	0.7996	1.3705	2.6509	2.7685	4.2684	47.9911
STABILITY CLASS 5																	
1.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5.5	0.8790	0.2626	0.2626	0.1027	0.2968	0.4224	1.0274	1.1416	1.4612	0.2968	0.3995	0.2740	0.5365	0.4224	0.2283	0.4338	8.4476
10.0	0.6621	0.2169	0.0114	0.0228	0.0228	0.4224	2.4201	3.2534	1.3927	0.1598	0.0228	0.0342	0.1826	0.1712	0.2169	0.4110	9.6231
15.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
28.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ALL	1.5411	0.4795	0.2740	0.1255	0.3156	0.8448	3.4475	4.3950	2.8539	0.4566	0.4223	0.3082	0.7191	0.5936	0.4452	0.8448	18.0707
STABILITY CLASS 6																	
1.5	0.4489	0.3119	0.2038	0.1004	0.1537	0.1860	0.4083	0.4341	0.6321	0.2334	0.2044	0.1798	0.2747	0.2155	0.1824	0.1113	4.2807
5.5	0.7877	0.4224	0.1826	0.0799	0.1941	0.4452	1.0731	1.5753	2.2146	0.5137	0.3881	0.2968	0.4338	0.2740	0.2169	0.3653	9.4635
10.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
28.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ALL	1.2366	0.7343	0.3864	0.1803	0.3478	0.6312	1.4814	2.0094	2.8467	0.7471	0.5925	0.4766	0.7085	0.4895	0.3993	0.4766	13.7442
ALL	10.9554	3.4237	1.8896	0.9081	1.7249	3.4864	13.0112	16.4776	18.6551	2.5688	2.1044	2.0254	3.4944	4.9544	6.0483	8.2717	99.9994

Appendix H

SEISMIC INFORMATION

Table of Contents

	<u>Page</u>
H.1 INTRODUCTION.....	H-1
H.2 ENGINEERING SEISMOLOGY - VITRO SITE.....	H-3
H.2.1 Regional seismotectonic setting.....	H-3
H.2.2 Local seismotectonic setting.....	H-3
H.2.2.1 Historical seismicity.....	H-3
H.2.2.2 Active faulting.....	H-6
H.2.2.3 Seismic gaps.....	H-9
H.2.3 Maximum Credible Earthquake and recurrence interval.....	H-9
H.2.4 Seismic zoning studies.....	H-11
H.2.5 Design parameters.....	H-11
H.3 GEOTECHNICAL PROFILE - VITRO SITE.....	H-13
H.4 ANALYSIS OF LIQUEFACTION POTENTIAL AND EMBANKMENT STABILITY - VITRO SITE.....	H-19
H.4.1 Seed and Idriss empirical method.....	H-19
H.4.2 Yegian and Whitman empirical approach.....	H-20
H.4.3 Embankment stability.....	H-23
H.4.4 Potential for flow slides.....	H-23
H.5 ENGINEERING SEISMOLOGY - SOUTH CLIVE SITE.....	H-27
H.5.1 Regional seismotectonic setting.....	H-27
H.5.2 Local seismotectonic setting.....	H-27
H.5.2.1 Historical seismicity.....	H-27
H.5.2.2 Active faulting.....	H-36
H.5.3 Seismic zoning.....	H-42
H.5.4 Earthquake recurrence intervals.....	H-42
H.5.5 Seismic design parameters.....	H-42
H.6 GEOTECHNICAL PROFILE - SOUTH CLIVE SITE.....	H-45
H.7 LIQUEFACTION POTENTIAL - SOUTH CLIVE SITE.....	H-47
References for Appendix H.....	H-49

List of Figures

	<u>Page</u>
H-1 Utah earthquakes, July 1962-June 1978.....	H-5
H-2 Generalized map of young faults in Utah.....	H-7
H-3 Location of east bench fault.....	H-8
H-4 Typical geotechnical profile.....	H-14
H-5 Grain size distributions.....	H-16
H-6 Blowcounts in upper sand layer.....	H-17
H-7 Results of Seed and Idriss analysis of liquefaction potential.....	H-21
H-8 Results of Yegian and Whitman analysis of liquefaction potential....	H-22
H-9 Failure surfaces considered in embankment stability analysis.....	H-24
H-10 Generalized late Mesozoic-Cenozoic tectonic map of Basin and Range..	H-28
H-11 1850 - June 1978, Mag 4.0 (Int V) or greater.....	H-29
H-12 Utah earthquakes: 1850 - 1949.....	H-30
H-13 Utah earthquakes: 1950 - 1962.....	H-31
H-14 Utah earthquakes: July 1962 - June 1978.....	H-32
H-15 Utah earthquakes: 1979.....	H-33
H-16 Utah earthquakes: 1980.....	H-34
H-17 Earthquakes epicenter map of Wasatch Front, Utah, for period June 1962 - June 1978.....	H-35
H-18 Earthquakes within 81 miles (50 km) of Clive, Utah.....	H-39
H-19 Map showing late Quaternary fault scarps, Holocene fault scarps, and source regions I, II, III, IV.....	H-40
H-20 Active Fault Zones, reported by Slemmons.....	H-41
H-21 Active Fault Zones used for determination of seismic design.....	H-43

List of Tables

	<u>Page</u>
H-1 Largest earthquakes in the Utah region 1850 through 1978.....	H-4
H-2 Summary of earthquake magnitude and recurrence interval estimates for the Utah region.....	H-10
H-3 Soil parameters.....	H-15
H-4 Stability analysis results.....	H-25
H-5 Earthquakes within 50 km of Clive, Utah, October 1974 - September 1983.....	H-37
H-6 Design criteria for potential seismic sources affecting the Clive, Utah, site.....	H-44
H-7 Selected soil parameters.....	H-45

H.1 INTRODUCTION

This appendix presents an evaluation of the potential seismic effects on the reclaimed tailings embankment at the Vitro site (Alternative 2) as described in the DEIS, and at the South Clive site (Alternative 3) as described in this FEIS. This appendix includes an assessment of the seismic hazard and earthquake design parameters, the potential for liquefaction affecting the stability of the piles, and the potential for flow slides subsequent to liquefaction (SH&B, 1983).

For stabilization in place and as a result of this assessment and in consultation with Sergeant, Hauskins, & Beckwith (SH&B), the concept presented in Section 3.2.3 and in Appendix A for the Vitro site is a refined version of the concept in the DEIS and, as such, contains measures (e.g., desaturate and compact tailings) to mitigate seismically induced liquefaction (see A.3.2.2 and 5.19.6).

Regarding relocation to the South Clive site, the sections of this appendix are based on available literature and data and do not include on-site evaluations or photogeologic studies. Preliminary calculations of a Maximum Credible Earthquake (MCE) for the site and the possible effects at the site from that event are included; however, additional studies are necessary to finalize site design parameters.

H.2 ENGINEERING SEISMOLOGY - VITRO SITE

H.2.1 Regional seismotectonic setting

The Vitro site is located along the Wasatch Front which delineates the boundaries between the Great Basin to the west and the Colorado Plateau in southeastern Utah and the Middle Rocky Mountains in northeastern Utah. The Wasatch Front has been described by Smith (1978) as a transition between major subplates of the Western Cordillera. This transition possesses a thin crust, substantial seismicity, and high heat flow. These features appear to extend eastward from the Wasatch Front for about 50 kilometers (km) under the Colorado Plateau. East-west extensional activity within the Great Basin is believed to have commenced during Oligocene time (25 to 36 million years B.P.) (Hintze, 1971). This activity has resulted in major Great Basin block faulting and possibly 3 to 5 km of normal displacement along the Wasatch Fault System (Hintze, 1971).

The Wasatch Front is part of a distinct north-trending zone of elevated seismic activity which extends from northern Arizona to northwestern Montana. This 100-km wide by 1,300-km long zone has been identified as the Intermountain Seismic Belt (ISB) by Smith and Sbar (1974). The ISB encompasses a region which has experienced more than 15 recorded earthquakes with magnitudes greater than 5.5, including the 7.1 magnitude event in 1959 at Hebgen Lake, Montana. The ISB can be classified as the most seismically active region of the Western Cordillera, excluding earthquake source areas of California and Nevada.

H.2.2 Local seismotectonic setting

H.2.2.1 Historical seismicity

The earthquake record in Utah has been the subject of intense research since the early 1960's. Historical documentation has been completed from the period of 1850 until about 1962, followed by seismographic recording by the University of Utah (Arabasz et al., 1979; Richins et al., 1981). Since 1974, telemetered seismic arrays have been operated by the University.

As presented in Table H-1, 15 moderate earthquakes have been recorded in the Utah region between 1850 and 1978. Two of these significant earthquakes may be directly related to the Wasatch Fault, the events of 1910 and 1914. As indicated by the distribution of 1962 to 1978 epicenters depicted in Figure H-1, concentrations of North Central Utah seismic events occur in the vicinity of the Hansel Valley Fault north of the Great Salt Lake and near the East Cache Fault north of Salt Lake City.

The most damaging earthquakes of the north central region of Utah occurred in Hansel Valley on March 12, 1934, and in Cache Valley on August 30, 1962. The 6.6 M_L Hansel Valley earthquake produced about 50 cm of vertical fault displacement and disruption of the land surface due to liquefaction and ground movement (Smith, 1978; Marsell, 1964). The 5.7 M_L Cache Valley event caused about one million dollars of property damage in Logan and surrounding communities (Cook, 1971).

Table H-1. Largest earthquakes in the Utah region 1850 through 1978*

Local date	Lat (°N)	Long (°W)	Intensity I_O	Magnitude M_L	Location
1884 Nov 10	42.0	111.3	VIII	(6)	Bear Lake Valley
1887 Dec 5	37.1	112.5	VII	(5-1/2)	Kanab
1900 Aug 1	40.0	112.1	VII	(5-1/2)	Eureka
1901 Nov 13	38.8	112.1	IX	(6-1/2+)	Richfield
1902 Nov 17	37.4	113.5	VIII	(6)	Pine Valley
1909 Oct 5	41.8	112.7	VIII	(6)	Hansel Valley
1910 May 22	40.8	111.9	VII	(5-1/2)	Salt Lake City
1914 May 13	41.2	112.0	VII	(5-1/2)	Ogden
1921 Sep 29	38.7	112.2	VIII	(6)	Elsinore
1921 Oct 1	38.7	112.2	VIII	(6)	Elsinore
1934 Mar 12	41.7	112.8	IX	6.6	Hansel Valley (Kosmo)
1959 Jul 21	37.0	112.5	VI	5.5+	Utah-Arizona border (Kanab)
1962 Aug 30	42.0	111.7	VII	5.7	Cache Valley (Logan)
1966 Aug 16	37.5	114.2	VI	5.6	Nevada-Utah border
1975 Mar 28	42.1	112.5	VIII	6.0	Idaho-Utah border (Pocahontas Valley)

*Table includes earthquakes of maximum Modified Mercalli intensity (I_O) of VII or greater, or of Richter magnitude 5.5 or greater. Magnitudes in parentheses are estimated from I_O . Sample area: 36°45'N - 42°30'N, 108°45'W - 114°15'W. Aftershocks are excluded.

Source: Arabasz et al., (1979).

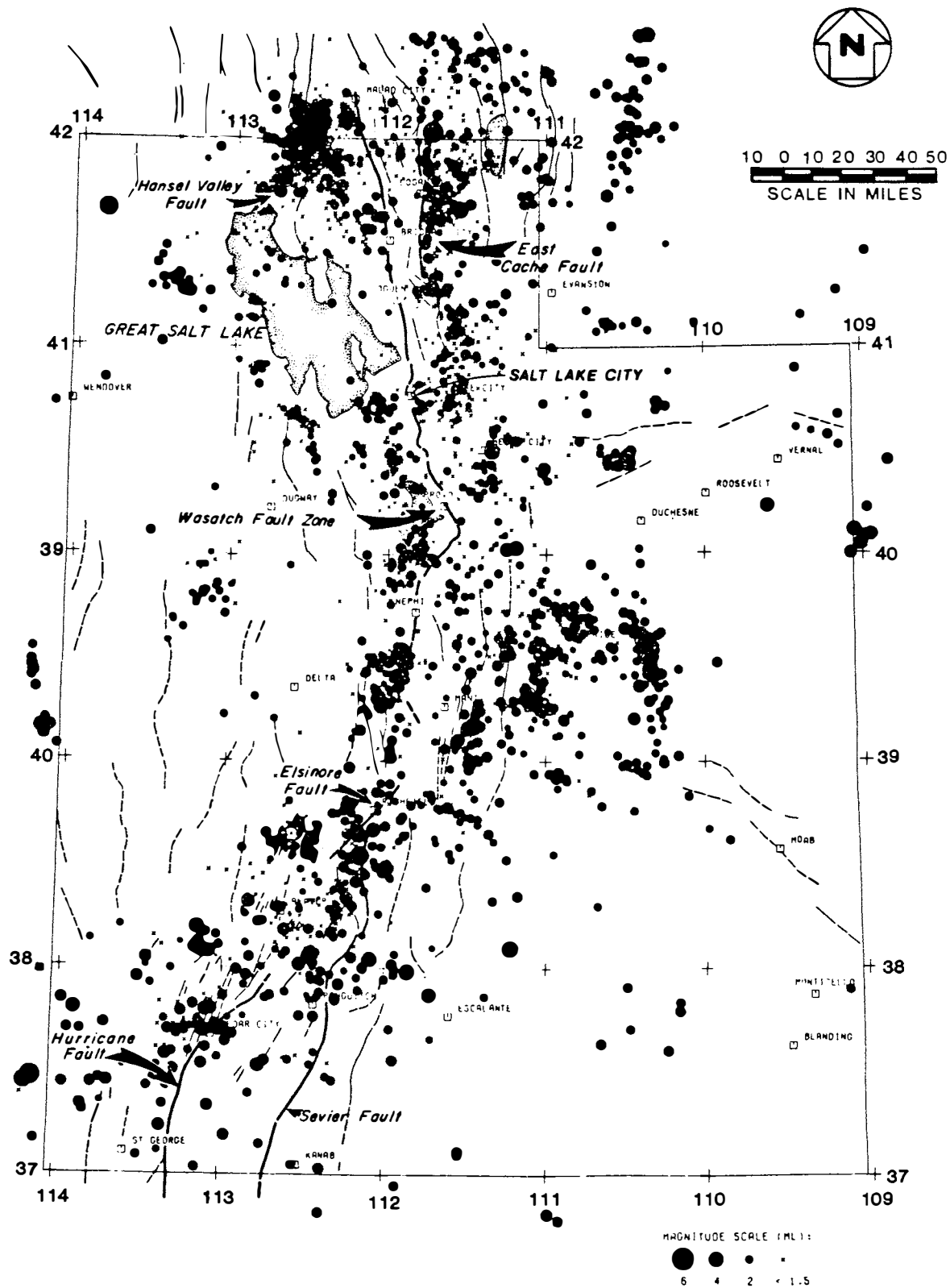


FIGURE H-1
UTAH EARTHQUAKES, JULY 1962 - JUNE 1978

REF: ARABASZ, (1979)

H.2.2.2 Active faulting

A definitive assessment of earthquake risk cannot be fully ascertained from the relatively short and incomplete 132-year record of earthquake events. Geologic evidence of past fault ruptures along the Wasatch Fault and other potential source faults has been the subject of current research in order to estimate maximum earthquake magnitude and recurrences.

Based on earthquake history and geologic evidence, the Salt Lake City region contains numerous young faults, including the Hansel Valley, East Cache, Wasatch, and unnamed faults along the west flank of the Oquirrh Mountains south of the Great Salt Lake (Figure H-2). Due to the close proximity of the Wasatch Fault to the Vitro site and its suspected activity, the earthquake risk imposed by the Wasatch Fault is greater than the risk from earthquakes generated by rupture of the other fault systems mentioned above. In terms of current criteria, an active fault is defined as a structure which has experienced displacement in the last 10 to 12 thousand years. The northern portion of the Wasatch Fault has been identified as falling within the active fault category.

The Wasatch Fault zone trends north-south through central Utah from Gunnison, Utah, to Malad City, Idaho. Swan et al., (1980) suggest that the fault system may have as many as ten, 30- to 40-km segments which are capable of separate rupture. The fault expresses Late Quaternary movement almost throughout its entire length (Swan et al., 1980). These geomorphic expressions are in the form of scarps, sagponds, springs, slickensided and sheared surfaces, and displaced beds (Van Horn, 1971). These features have been extensively documented by Cluff et al., (1970), Cluff and Slemmons (1971) and Marsell (1964).

The patterns and history of displacement along the Wasatch Fault zone appear to be highly variable. However, the predominant movement of the fault system is normal and steeply dipping to the west with valleys such as the Utah Valley near Provo lagging behind the upward movement of the Wasatch Mountain block (Hintze, 1971). A total vertical displacement of 3,000 to 4,000 meters may be present in the Utah Valley region (Hintze, 1971).

There have been no surface faulting events along the Wasatch Fault during the past 138 years (Swan et al., 1980). Geologic evidence, however, identifies multiple displacement episodes in the northern portion of the fault system. From a study of remnant facets of the Wasatch Mountain front near Provo, Hamblin (1976) estimates eight periods of fault movement separated by periods of quiescence, and three active periods in the Salt Lake City area. The most comprehensive evaluation of displacement history was performed by Swan et al., (1980). At Kaysville, 30 km north of Salt Lake City, at least three surface faulting events with displacements of 1.7 to 3.7 meters have occurred since the Middle Holocene. At Hobbie Creek, 46 km south of Salt Lake City, six to seven events with displacements of 0.8 to 2.8 meters have occurred in the past 12,000 years.

As depicted on Figure H-3, the segment of the Wasatch Fault zone closest to the Vitro site is the East Bench Fault, which is about 5 km east of the

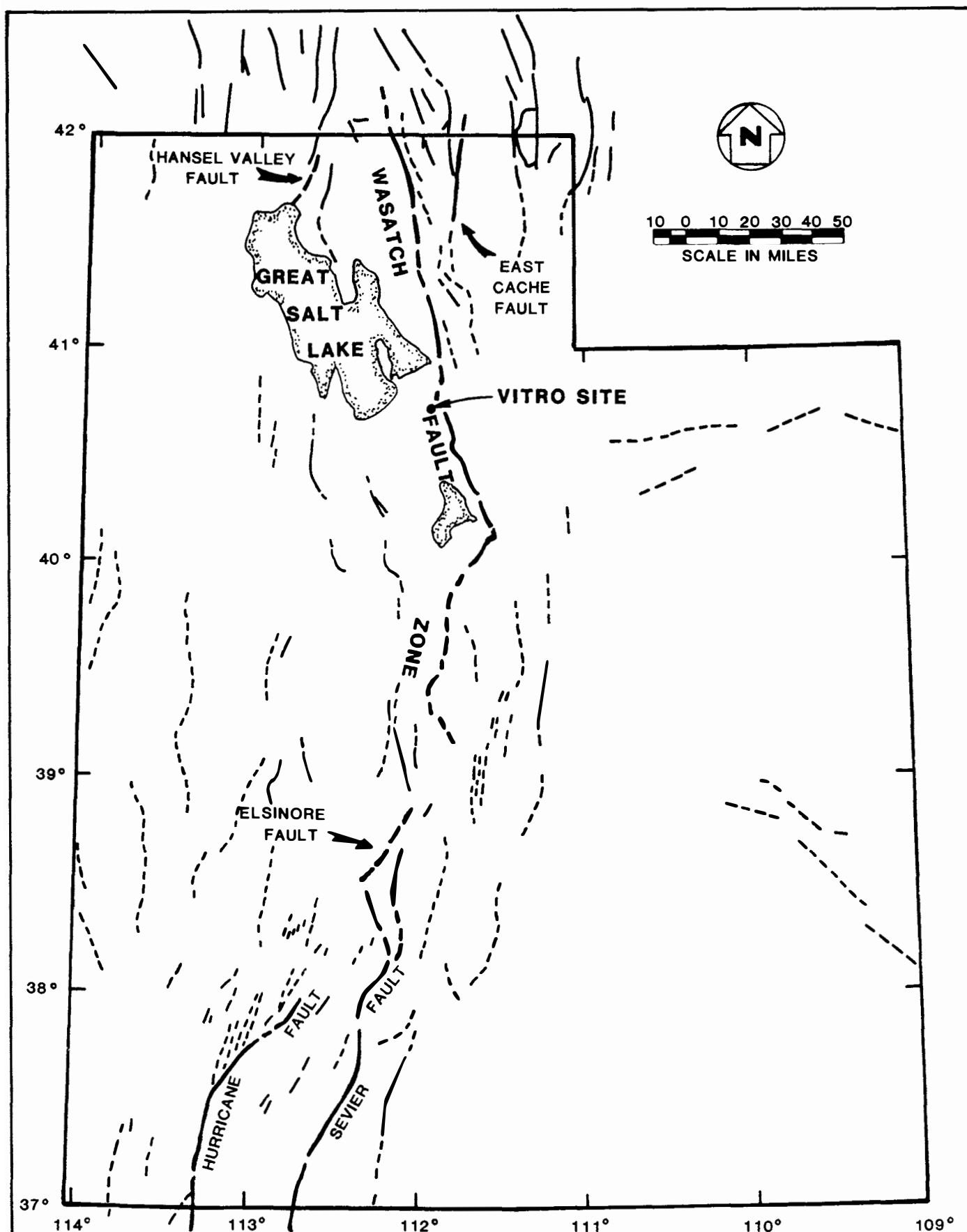


FIGURE H-2. GENERALIZED MAP OF YOUNG FAULTS IN UTAH

REF: ANDERSON & MILLER (1979)

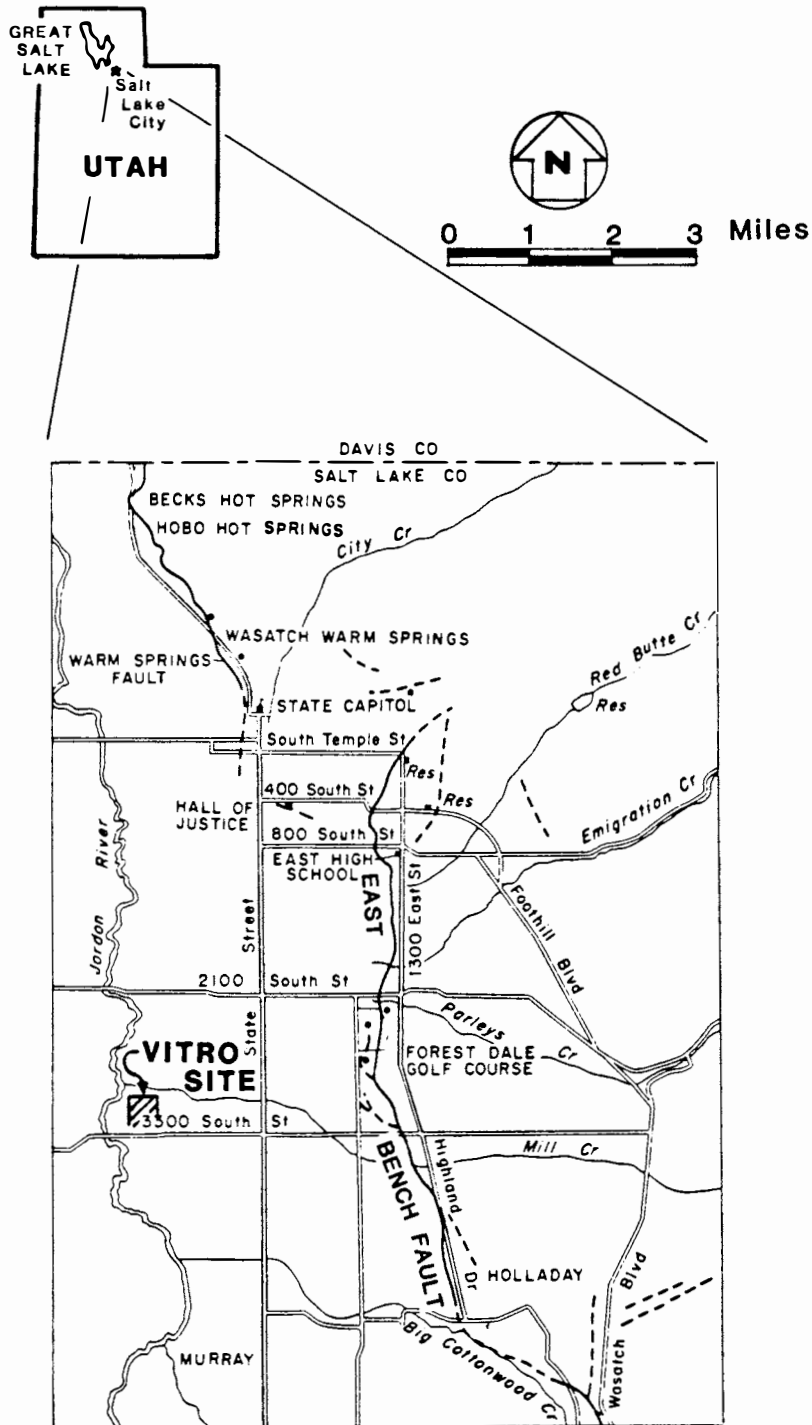


FIGURE H-3
LOCATION OF EAST BENCH FAULT

REF: VAN HORN (1971)

site. No detailed displacement history is available for this fault segment; however, its geomorphic expression definitely indicates Quaternary movement (Cluff et al., 1970).

H.2.2.3 Seismic gaps

Based upon recent microseismic data, Smith (1971) has possibly detected two major seismic gaps along the Wasatch Fault zone. One extends from Brigham City south 70 km to Salt Lake City and the other extends from Salt Lake City south 70 km to Provo. These zones of low earthquake activity are separated by an area of persistent low-to-moderate intensity earthquake events (Arabasz et al., 1980). Several hypotheses have been proposed in an attempt to explain the seismic gaps, one of which indicates that these areas could be the sites of future large earthquakes due to a long-term accumulation of tectonic stress (Smith, 1974).

H.2.3 Maximum Credible Earthquake and recurrence interval

The major objective of the investigations cited herein, and the subject of ongoing research, has been to establish the Maximum Credible Earthquake (MCE) and the recurrence interval of major earthquakes along the Wasatch Front. These studies have not presently established conclusive values for these parameters. Sufficient analysis has been completed, however, to establish reasonable seismic design criteria for the reclamation of the Vitro site. Based on various analyses of geologic data and earthquake history, several investigators have proposed values for recurrence interval and earthquake magnitude. These are summarized on Table H-2.

It is necessary to obtain specific geologic data concerning the displacement history of that particular segment to evaluate the return period of a moderate to large earthquake resulting from rupture along a Wasatch Fault segment such as the East Bench Fault. As discussed by Swan et al., (1980), there may be as many as ten fault segments which rupture separately at different return periods. As an example of the difference between the generalized return periods presented in Table H-2 and the return period of a fault segment, Swan, et al., (1980), estimate the average return periods of surface fault events of the Kaysville and Hobbie Creek segments as 500 to 1,000 and 1,500 to 2,600 years, respectively. As evident from this example, the recurrence estimates for the entire Wasatch Fault zone may substantially underestimate the return period of moderate to large earthquakes along any one fault segment.

Table H-2. Summary of earthquake magnitude & recurrence interval estimates for the Utah region

Source	Magnitude/recurrence
1. US Geological Survey (1976)	Assigned an estimated maximum credible earthquake for the entire state of Utah of magnitude 7.5.
2. Arabasz et al., (1979)	Based on historical earthquake data - following return periods presented: 22-25 years for $M_L \geq 6.0$; 111 to 115 years for $M_L \geq 7.0$; 232 to 263 years for $M_L \geq 7.5$. Estimates for the Wasatch Front area (92,810 km ²).
3. Swan et al., (1980)	For entire Wasatch Zone, moderate to large earthquake (M 6.5-7.5) return period of 50 - 430 years estimated. Values derived from recurrence intervals evidence along the Kaysville and Hobbie Creek segments of the Wasatch Zone. Evidence of recurrence along other segments not available.
4. Doser & Smith (1982)	387 - 667 year return period estimated from analysis of geologic moment rates for $6.5 \leq M_L \leq 7.5$ along entire Wasatch fault.

Source: SH&B, 1983

H.2.4 Seismic zoning studies

Various investigators have conducted seismic zoning studies to which contours of effective peak accelerations (EPA) were estimated for the area of the Vitro site. These studies are based on statistical analysis of the seismic history and a general appraisal of regional faulting and tectonics. The following is a list of these estimates:

EPA	References	Remarks
0.6g	Algermissen et al., (1982)	90 percent probability of not being exceeded in 250 years.
0.21g	Algermissen & Perkins (1976)	90 percent probability of not being exceeded in 50 years.
0.2g	Applied Technology Council (1978)	90 percent probability of not being exceeded in 50 years.
0.08g	Liu and DeCapua (1975)	100 year return.

Because of the inadequate nature of the brief historical earthquake record, these regionalized studies only provide a rough indication of seismic hazard. The analysis and conclusions presented herein concerning the seismic risk and expected ground motions have been oriented specifically toward the Vitro site and should be considered as the criteria for design rather than the above-mentioned regionalized studies.

H.2.5 Design parameters

It is understood that an Environmental Protection Agency 200-year, no-active-maintenance criterion will be applied to the reclamation design of the Vitro site. Based upon current knowledge of the recurrence interval of damaging earthquakes which would result from fault rupture along the Wasatch Front, it is concluded that there is a reasonable possibility that an M_L 7.0 or greater earthquake on the East Bench Fault will cause substantial ground shaking at the Vitro site within the next 200 years. As will be discussed in the report sections which follow, this ground motion could cause local liquefaction and ground movements of the unconsolidated deposits of Jordan Valley.

Due to its proximity to the Vitro site, rupture of the East Bench Fault segment of the Wasatch Fault system probably would cause the most intense ground shaking. The displacement history of this fault segment is not fully known; therefore, it is reasonable to apply a return period of the entire Wasatch source area to the near-site segment. This return period has been estimated to be between 50 to 667 years for earthquakes in the range of M_L 6.5 to 7.5. As with the Kaysville and Hobbie Creek Fault segments, the true return period of a

fault rupture event along the East Bench Segment may be several times longer than that of the entire Wasatch Fault zone. The risk of a damaging earthquake generated by rupture along the East Bench segment should be reassessed when more local geologic data become available.

The design earthquakes discussed above probably would be in the range of M_L 6.0 to 7.5. This near-field event would produce maximum accelerations in rock in the range of about 0.3 to 0.55g (Buckman et al., 1980). Amplification or damping effects in the unconsolidated deposits of Jordan Valley are possible, but any accelerations in this range would produce similar on-site damage.

H.3 GEOTECHNICAL PROFILE - VITRO SITE

Subsurface conditions at the Vitro site are characterized by their variability. Based on boring logs and test data presented in Dames & Moore (1982), Chen & Associates, Inc. (1980a, 1980b), Sergeant, Hauskins & Beckwith (1981), Martin et al., (1980), and Colorado State University (1982), a typical geotechnical profile for a north-south section through the middle of the southern section of the existing tailings deposit was developed. This section is shown in Figure H-4. It is necessarily simplified, because of the variability of conditions, but it does include trends important to a consideration of liquefaction potential.

As shown in Figure H-4, the top of the existing tailings pile, at this location, is at elevation 4248. Considering the complete site, variations from 4232 to 4252 are encountered. The interface between natural soils and tailings is at elevation 4231, with variations from 4225 to 4235 throughout the site.

The ground-water table at the time of the above listed investigations was at elevation 4231, or coincident with the surface of the natural soils in the model employed herein, with variations from 4226 to 4235. Tailings above the water table appear to be saturated in many places, probably because of perched water-table conditions.

The initial natural soil stratum encountered is composed of predominantly clayey soils, classifying at CL-ML to CL in the Unified Soil Classification System, grading to ML and CH in places. This layer is relatively thin, with a model thickness of 5 feet as shown in Figure H-4.

Sandy soils, classifying predominately as SP-SM to SP, underlay the clayey soils to an average depth of 11 feet. This layer is not apparent in a few borings and has a thickness of approximately 20 feet in other borings.

The sandy soils are underlain by a second layer of clayey soils, tending to be more sandy in some locations. Only six of the eight Dames & Moore (1982) borings penetrated to these depths, obviating an estimate of their thickness.

Typical properties of the different soil strata encountered are listed in Table H-3. Grain-size distributions for tailings and natural or foundation soils are plotted in Figure H-5. Gradations of the more sandy tailings are comparable to the in-situ sandy soils. Similarly, gradations of the more clayey tailings, or slimes, are comparable to the in-situ clayey soils.

Standard penetration testing (SPT) blow counts (N-values), recorded primarily in the upper sandy soil stratum, are plotted in Figure H-6, as a function of depth from the ground surface. The values are very scattered, but tend to increase with depth, though the correlation for this trend is weak. Dames & Moore values are typically higher than Chen & Associates, Inc. values. The latter values were predominantly recorded in the northeast section of the site, while the former include values from all areas of the site. Blow counts range from 5 to 25 with a mean value of 15.

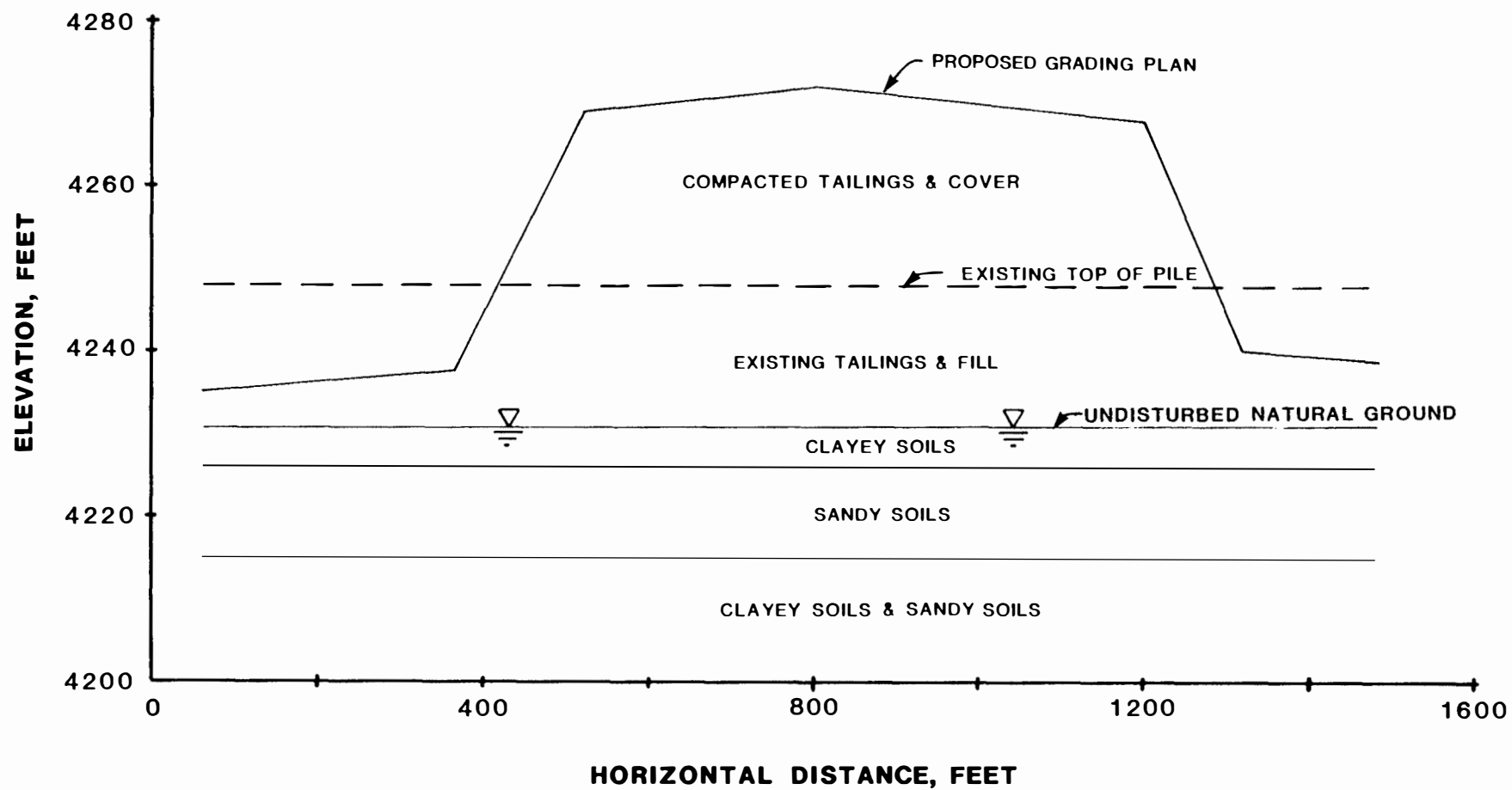
**FIGURE H-4. TYPICAL GEOTECHNICAL PROFILE**

Table H-3. Soil parameters

Soil type	Total unit weight pcf	Friction angle	Undrained cohesive strength psf
Cover & compacted tailings	125	35	200
Existing tailings & fill	115	30	0
Clayey soils	115	0	600
Sandy soils	120	35	0

Source: SH&B, 1983

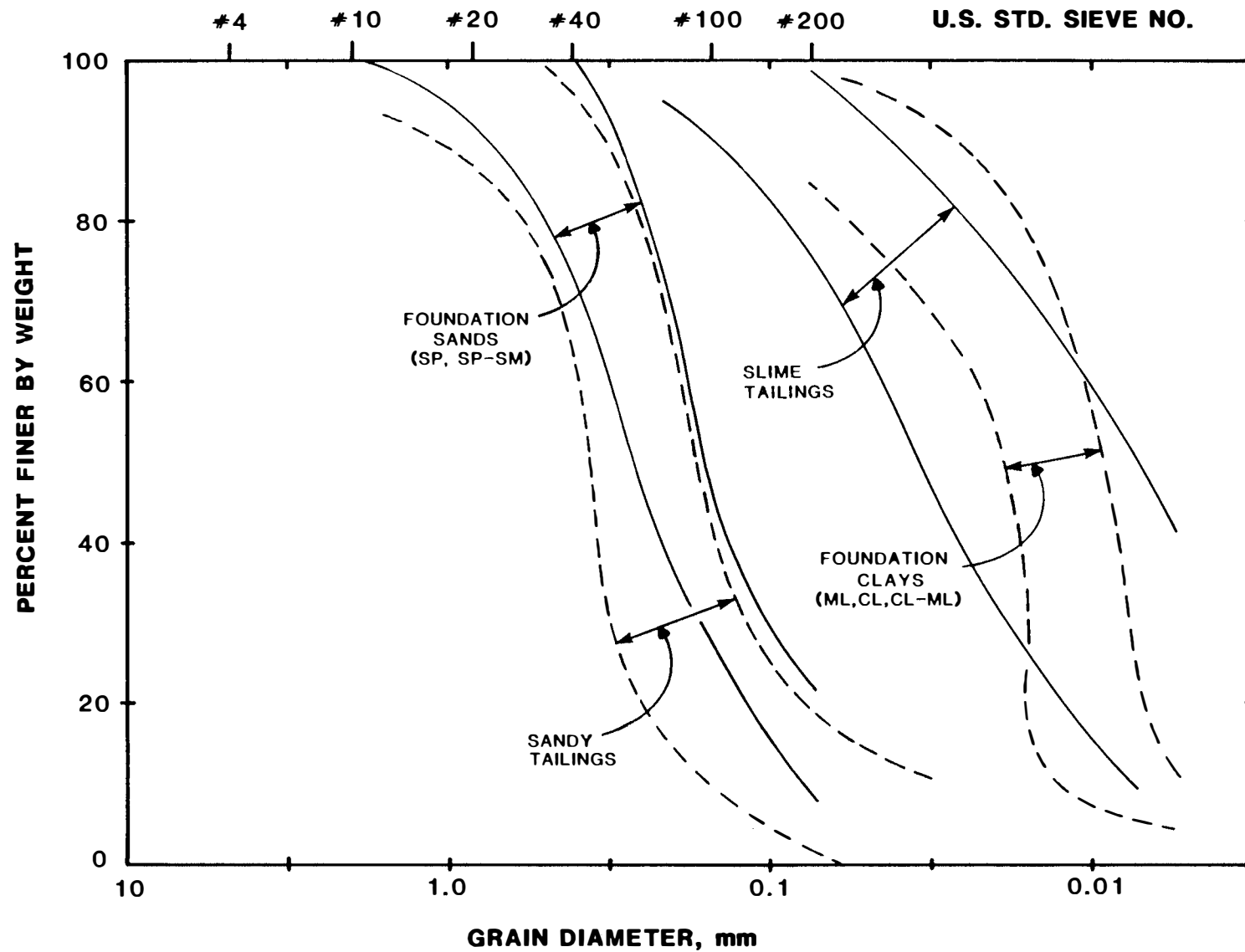


FIGURE H-5. GRAIN SIZE DISTRIBUTIONS

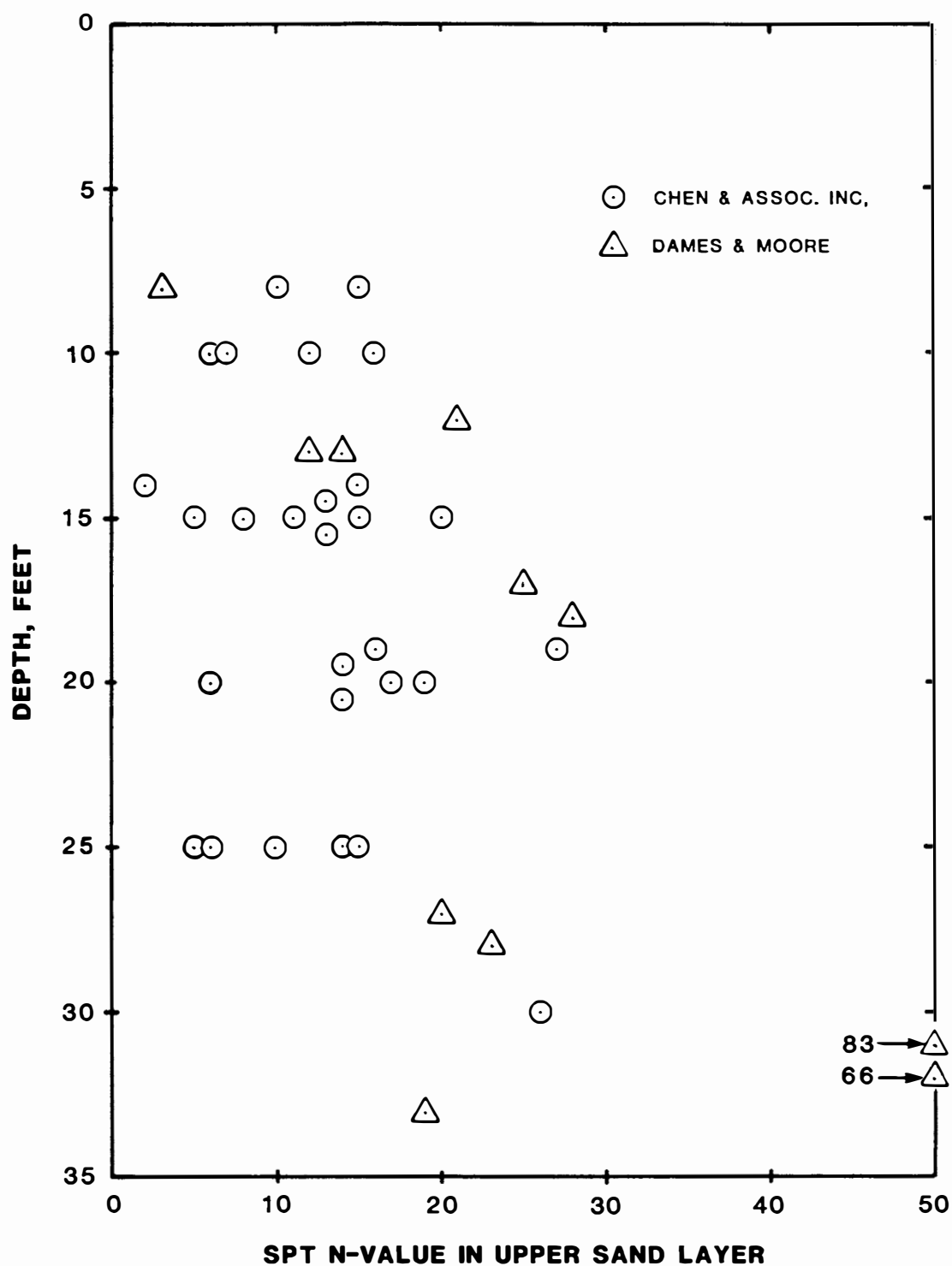


FIGURE H-6. BLOWCOUNTS IN UPPER SAND LAYER

The tailings, foundation sandy soils, and, to a lesser extent, the foundation clayey soils are susceptible to liquefaction during earthquake shaking. Particularly, the sandy soils and tailings below the water table, or those in a saturated state, have a grain-size distribution that would preclude quick dissipation of excess pore water pressures expected during a seismic event. Since the soils are lenticular, sands having a coarse gradation that otherwise would not be susceptible to liquefaction may be confined by more silty or clayey lenses. This could result in their being liquefied, or their losing a significant portion of their strength.

The more clayey soils, based on criteria reported by Seed and Idriss (1981), may also have lenses susceptible to liquefaction or significant strength loss. They suggest liquefaction can occur in clayey soils if the liquid limit is less than 35, the in-situ water content is less than 0.9 times the liquid limit, and the soil fraction finer than 0.005 mm is less than 15 percent. Based on the data presented in Table H-3, the first of these criteria is marginally met, but the last two are met, indicating at least a susceptibility of lenses of clayey soils to liquefaction. This assessment is made more critical if the potential effects of clay sensitivity are considered. Parry (1974) has indicated clays along the Wasatch Front may have sensitivities as high as 11, making them susceptible to a greater strength loss during earthquake shaking than less sensitive clays.

H.4. ANALYSIS OF LIQUEFACTION POTENTIAL & EMBANKMENT STABILITY - VITRO SITE

H.4.1 Seed & Idriss empirical method

Liquefaction of the upper sand layer of Figure H-4 was assessed using the Seed and Idriss (1981) empirical method. In this updated approach, the shear stress on horizontal planes induced by earthquake shaking is estimated in the same manner as in their earlier procedure (Seed and Idriss, 1971). The resistance to liquefaction during a seismic event, expressed in terms of a cyclic stress ratio, can be determined from laboratory testing or estimated from SPT blow count data, the mean grain-size, and effective overburden pressure. Since appropriate test data were not available, the latter approach was taken.

Three geotechnical profiles were considered, representing the range in existing and proposed conditions at the site. For these analyses, the ground surface is assumed level, which is appropriate in the center of the separate piles, but not near their edges. The first profile has a ground surface elevation of 4235, the second 4250 and the third 4270. The first is representative of the lower existing piles, the second the higher existing piles, and the third the proposed graded and covered pile.

The shear stress induced is calculated from

$$(T_h)_{ave}/\sigma_o = 0.65 (a_{max}/g) (\sigma_o/\sigma'_o) r_d,$$

where a_{max} is the maximum acceleration in g-units, σ_o and σ'_o = are the total and effective overburden stresses, and r_d is a reduction factor dependent on depth. Considering the center of the upper sand layer, and assuming $r_d = 0.9$ in all cases, an expression for induced stress as a function of a_{max}/g was developed for each case.

The shear resistance was estimated for uncorrected blow count values of 5, 15, and 25, representing the lower bound, mean, and upper bound, respectively, of data presented in Figure H-6 for the upper sand layer. Uncorrected blow counts, rather than corrected values, were used because of the scatter in data and because the range in effective overburden pressures (1 ksf $< \sigma'_o < 3$ ksf) results in correction terms varying from only 0.8 to 1.2. The larger term is associated with shallower depths. Seed and Idriss (1981) suggest that for depths of 10 feet or less, the recorded N-value should be further modified by a factor of 0.75 which offsets the 1.2 correction factor.

Seed and Idriss (1981) present two sets of curves plotting N-value versus cyclic stress ratio (for $\sigma'_o = 2$ ksf) for different earthquake magnitudes, M. The first set is for sands with D_{50} larger than 0.25 mm, and the second for low plasticity silts and sands with D_{50} less than 0.15 mm. As indicated in Figure H-5 the D_{50} size varies from 0.16 to 0.36 for the sandy foundation soils and the sandy tailings. Thus, the set of curves for sands is applicable to the major portion of tailings and in-situ soils. Using these curves, cyclic stress ratios were estimated. Finally, these ratios were equated to the induced stress ratio and a value of maximum acceleration likely to cause liquefaction calculated.

Results of the analyses are presented in Figure H-7, which plots the calculated acceleration versus blow count for two cases and two values of earthquake magnitude. For $M = 6$ and a ground surface elevation of 4235, for example, the maximum acceleration likely to induce liquefaction varies from 0.07g for $N = 5$ to 0.39g for $N = 25$. For $M = 6$ and a ground surface elevation of 4270, the proposed grading plan, the acceleration value varies from 0.1g for $N = 5$ to 0.55g for $N = 25$. This illustrates the effect that increasing confining pressure has in decreasing the susceptibility to liquefaction. Since ground surface accelerations of 0.1g to 0.5g are probable during any 200-year period, liquefaction of at least some zones of foundation soils and tailings is probable.

H.4.2 Yegian & Whitman empirical approach

Yegian and Whitman (1978) analyzed historical data on liquefaction and developed a predictive methodology that includes the effect of both earthquake magnitude and hypocentral distance. Required input to the methodology is blow count data. Recorded blow count values are corrected using the relationship $N' = 50N/(\sigma'_v + 10)$, where σ'_v is the effective overburden pressure in units of psi. For the upper sand layer under consideration, the correction term is 1.6 to 3, resulting in corrected blow counts, N' , varying from 15 to 40, with a mean value of approximately 30.

The value of N' is used to estimate a parameter S_c related to the potential for liquefaction. In the simplified approach, a boundary line representing a 50 percent probability of liquefaction occurring is computed from $M = 2 \ln ((R+16) \sigma'_v S_c / H)$, where R is the hypocentral distance in miles and H is the depth to the point of consideration in feet. Relationships between M and R for each of the three profiles were computed using $S_c = 1.7$. The point of consideration was taken as the center of the upper sand layer.

Results of the analyses are presented in Figure H-8. For a section with ground surface elevation of 4235, a seismic event with magnitude 6.1 or larger occurring 10 miles from the Vitro site would have a 50 percent or larger probability of producing liquefaction at the site. If the ground surface were at elevation 4270, a magnitude 6.8 or larger event at the same distance would result in the same likelihood of liquefaction. This comparison confirms the Seed and Idriss (1981) analysis results concerning effect of confinement. Also, since seismic events of $M = 6$ or larger occurring within 10 miles are probable during any 200-year period, the analysis confirms the conclusion that liquefaction during the design life is probable.

For comparison, two empirical relationships between M and R are included in Figure H-8. The first from Youd and Perkins (1978), defines R as the furthest distance from point of energy release to a liquefied site. Thus, it defines an upper bound envelope for R ; sites more distant than R from the point of energy release for the same M are unlikely to liquefy, but sites less distant than R could liquefy. The relationship is based on a limited number of major seismic events, and considers soil conditions generally similar to those at the Vitro site. The relationship of Kuribayashi and Tatsuoka (1977) is similar, except that it is a mean relationship for Japanese data, and R is defined as the epicentral distance. The close comparison of calculated relationships for the Vitro site to the empirical relationships lends confidence to the predictions indicated for the Vitro site.

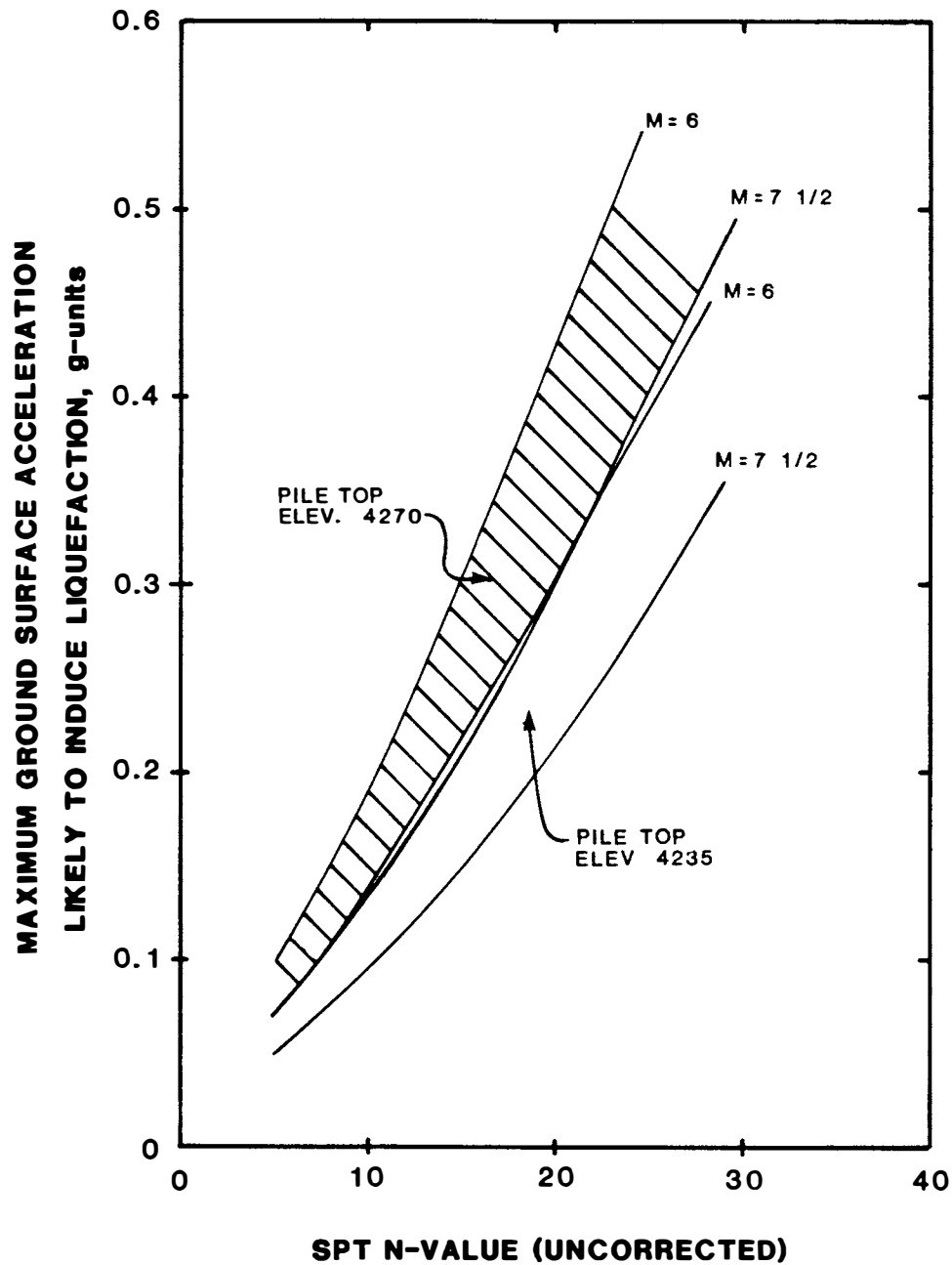


FIGURE H-7
RESULTS OF SEED & IDRISS ANALYSIS
OF LIQUEFACTION POTENTIAL

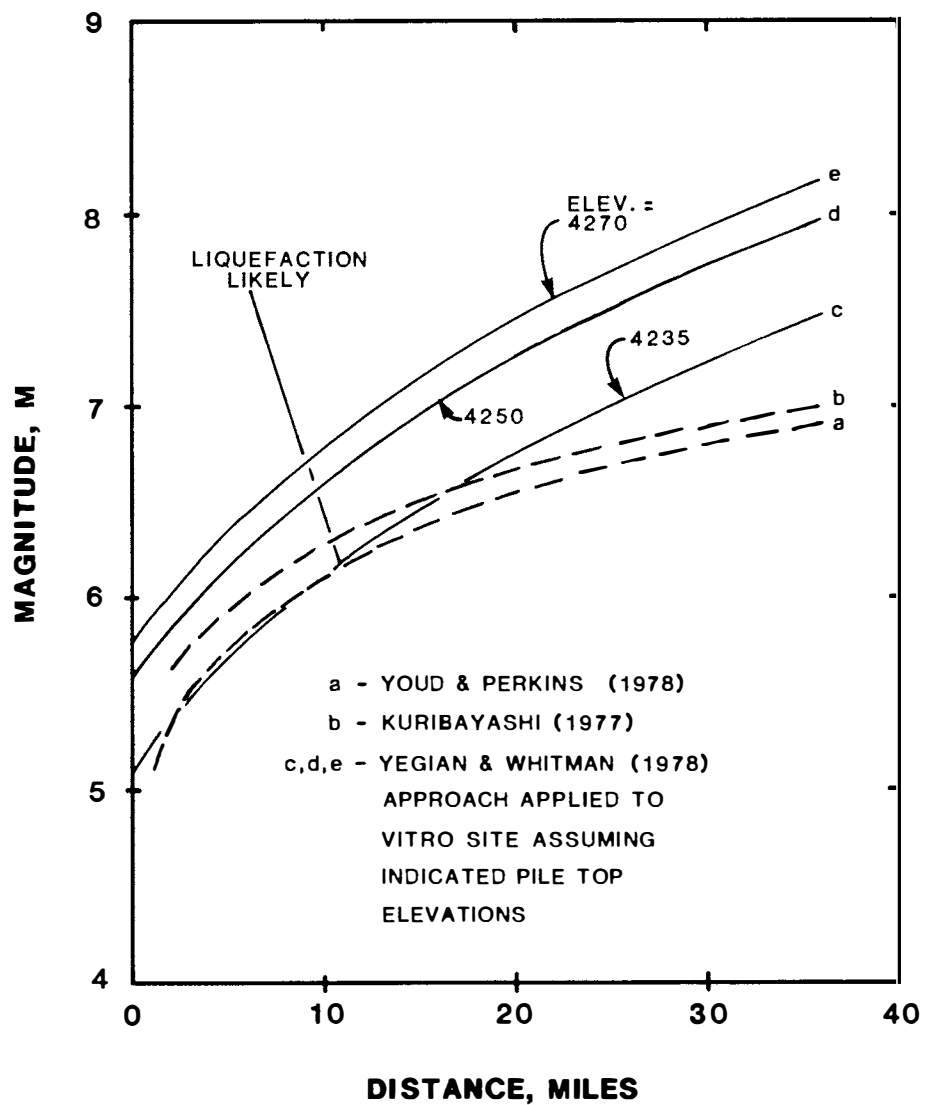


FIGURE H-8
RESULTS OF YEGIAN & WHITMAN ANALYSIS
OF LIQUEFACTION POTENTIAL

H.4.3 Embankment stability

A preliminary and somewhat simplistic assessment was made of embankment stability by performing ordinary-method-of-slices stability analysis of potential failure surfaces A and B of Figure H-9. Strengths utilized are given in Table H-3 for static loading conditions. For earthquake loading conditions, various zones of the profile were considered liquefied, or having a complete or significant strength loss. In the analyses, a horizontal seismic coefficient was not employed, since this would tend to overstate the effect of seismic shaking in the type of analysis performed.

Results of the analyses are listed in Table H-4. Because the slope angle is relatively small, static safety factors are greater than 3. If it is assumed the upper sand layer suffers a complete strength loss during a seismic event, the safety factor is reduced to a value of approximately 2. If, in addition, the existing tailings suffer a complete strength loss, the safety factor is reduced to near 1. If only the natural soils suffer a complete strength loss, the safety factor is reduced to 1.6 for surface A and 1.0 for surface B, illustrating the stability rendered by the clay layer for the shallower failure surface. If the natural soils and existing tailings all suffer complete strength loss, the safety factors are reduced to well below 1.0.

While these results are approximate and do not address deformation of the slopes or the mechanism of failure, they do indicate the potential effect of a major seismic event with a relatively long duration of shaking on embankment stability. The worst case listed in Table H-4 is likely only for a very major event. Other cases can generally be associated with events that are probable for a 200-year design life. Though complete failure is unlikely, significant deformations that would impair the functioning of the cover, and require reconstruction and repair are probable. A further assessment of movements could be made using techniques developed by Makdisi and Seed (1978; 1979), Sarma (1979) and Franklin and Chang (1977), based on more complete soil strength parameters.

H.4.4 Potential for flow slides

A potential consequence of seismically induced slope failures of tailings piles is a flow slide. Historically, earthquake-induced liquefaction of saturated tailings piles has resulted in a part of the mass of tailings flowing distances of from several hundred feet to tens of miles.

The existing tailings piles at the Vitro site are 15 to 20 feet high and contain saturated zones. The proposed single pile will be approximately 35 feet high with 5 to 1 (horizontal to vertical) slopes. The additional 15 to 20 feet will be compacted and covered with a moisture barrier of approximately 10 feet in thickness. Thus, only zones of the lower 15 to 20 feet, and the foundation soils, will be saturated. The ground slope in the area of the proposed pile varies from essentially flat to 1.5 degrees.

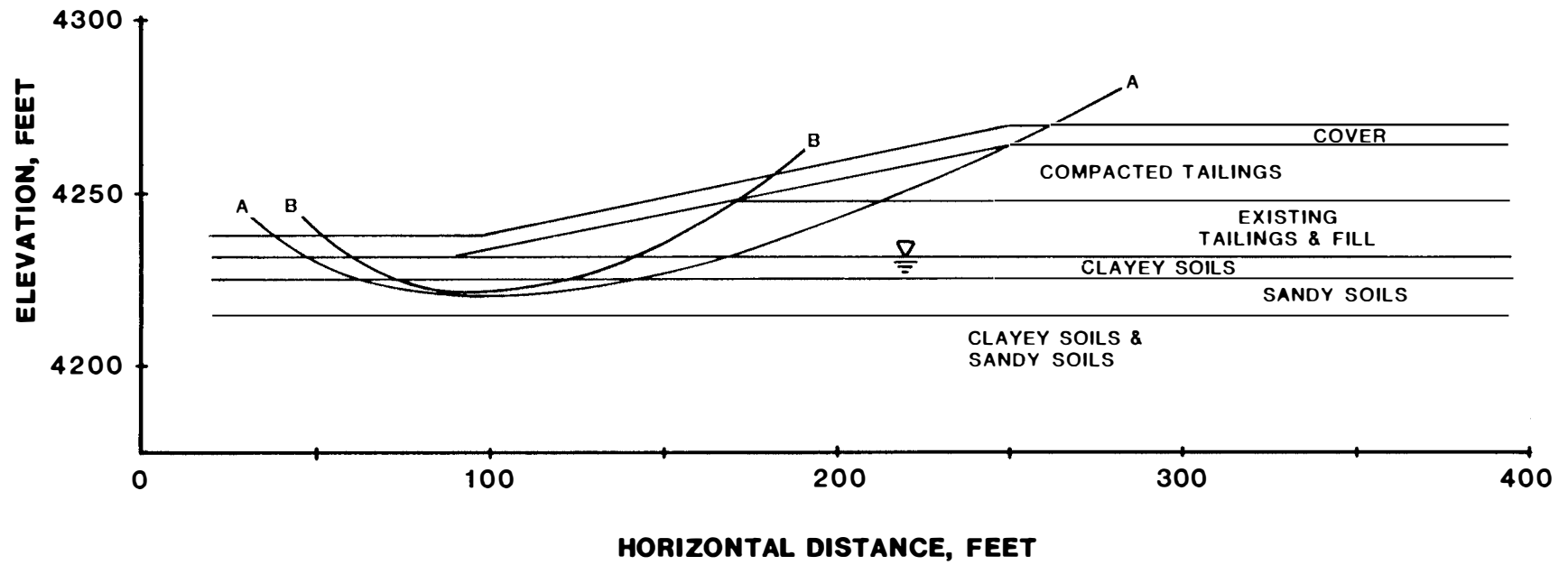


FIGURE H-9
FAILURE SURFACES CONSIDERED IN EMBANKMENT STABILITY ANALYSIS

Table H-4. Stability analysis results

Condition	Safety factor	
	Surface A	Surface B
Static	3.2	3.7
Dynamic - No strength in in-situ sands	1.9	1.9
Dynamic - No strength in in-situ sands & existing tailings	1.1	1.2
Dynamic - No strength in in-situ sands & clayey soils	1.6	1.0
Dynamic - No strength in in-situ sands, existing tailings & clayey soils	0.7	0.4

Source: SH&B, 1983

The conditions described generally preclude the occurrence of flow slides subsequent to liquefaction failure. Cases of flow slides summarized by Lucia et al., (1981) and Jeyapalan et al., (1983) indicate liquefied mine tailings will come to rest at slopes of 1 to 4 degrees after flowing over slopes of 3 to 4 degrees. In order to flow, the tailings must suffer a near total strength loss, becoming essentially a viscous fluid. The most catastrophic failures reported occurred at sites with tailings piles constructed on ground slopes of 6 degrees or greater.

Considering the predominantly partially saturated conditions of the proposed tailings at the Vitro site, and the nearly level ground surface, it is improbable that a major flow slide would occur if a liquefaction failure were to occur. The most probable effect would be slope failures and embankment cracking requiring clean-up and reconstruction.

Potential remedial measures that would mitigate the possible effects of ground shaking include vertical gravel drains near the toe of the embankment, densification of existing tailings by vibroflotation or other means, and installation of a horizontal drain at or below the bottom of the upper layer of clayey soils.

H.5 ENGINEERING SEISMOLOGY - SOUTH CLIVE SITE

H.5.1 Regional seismotectonic setting

The South Clive site is located near the eastern margin of the seismically active northern portion of the Basin and Range province (BAR) of southwestern North America (Fig. H-10). The BAR is an extensional system of horst mountain ranges and graben valleys. Systems of high-angle normal faults separate the horsts and grabens; fault-displacements in excess of 5000 feet are common across these zones (Cook et al., 1964; Stewart, 1971). Zoback and Zoback (1980) indicate that the direction of crustal extension is about N75W-S75E in the site area, as determined from stress studies, while earthquake focal mechanisms show an extensional direction of about N80E-S80W (Smith and Sbar, 1974; Arabasz et al., 1980). Stewart (1971) estimates the northern portion of the BAR (The Great Basin) has undergone about 190 km of extension since mid-Miocene time (about 15 million years before present).

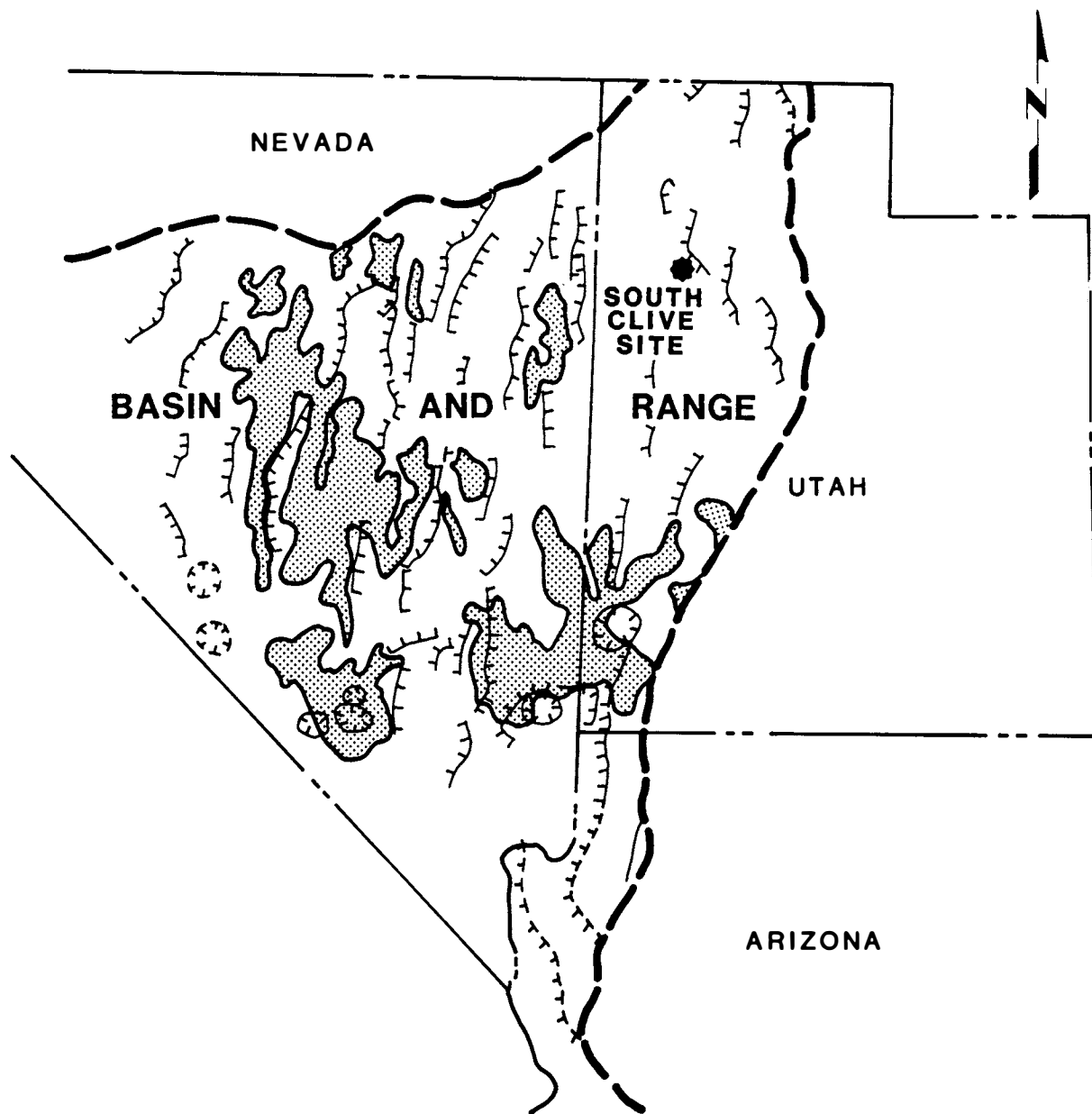
Geodetic measurements in The Great Basin indicate ongoing tectonic uplift of the region from 1 to 2 mm/year between central Nevada and the Wasatch Front (Reilinger, 1977). Additional uplift of 1.5 ± 0.5 mm/yr in western Utah occurs from isostatic crustal adjustments from unloading; the result of the desiccation of ancient Lake Bonneville about 10,000-13,000 years ago (Reilinger, 1977).

The South Clive site is on the eastern edge of the Great Salt Lake Desert in western Utah, about 105 km west of the Wasatch Front. BAR faulting to the east of the site has created several horst mountain ranges between the site and the Wasatch Front, including the seismically active Stansbury Mountains, and the Cedar Mountains. The site is on the far reaches of the alluvial apron extending from the western flank of the Cedar Mountains. Cook et al., (1964) have completed a regional gravity survey of the northern portion of the Great Salt Lake Desert, and report BAR horst and graben topography below the surface of the nearly flat desert. Extensive high-angle normal faulting bounds the buried structures and has gravity-determined displacements of several thousand feet (Cook et al., 1964). The site is in a transition zone between buried to exposed BAR topography.

H.5.2 Local seismotectonic setting

H.5.2.1 Historical seismicity

Regional seismicity maps have been compiled for Utah based on available historical data from 1850 through 1980. A selected number of these maps are presented as Figures H-11 through H-17. These data are from regional seismic nets and detect all earthquakes of about magnitude 2.5 and larger since 1962 (Arabasz et al., 1979; Richins et al., 1981). Detected events with smaller than 2.5 magnitudes are included in the data. The epicenter maps show earthquakes of about magnitude 2.5 and larger have not occurred in the site area since 1962. Maps for 1961 and earlier years depict data from the worldwide seismograph network and earlier maps from "felt" reports; thus, these maps do not have a definable lower detectability limit for earthquake size in the site area. All earthquakes above about magnitude 5.5 have probably been reported since 1850.



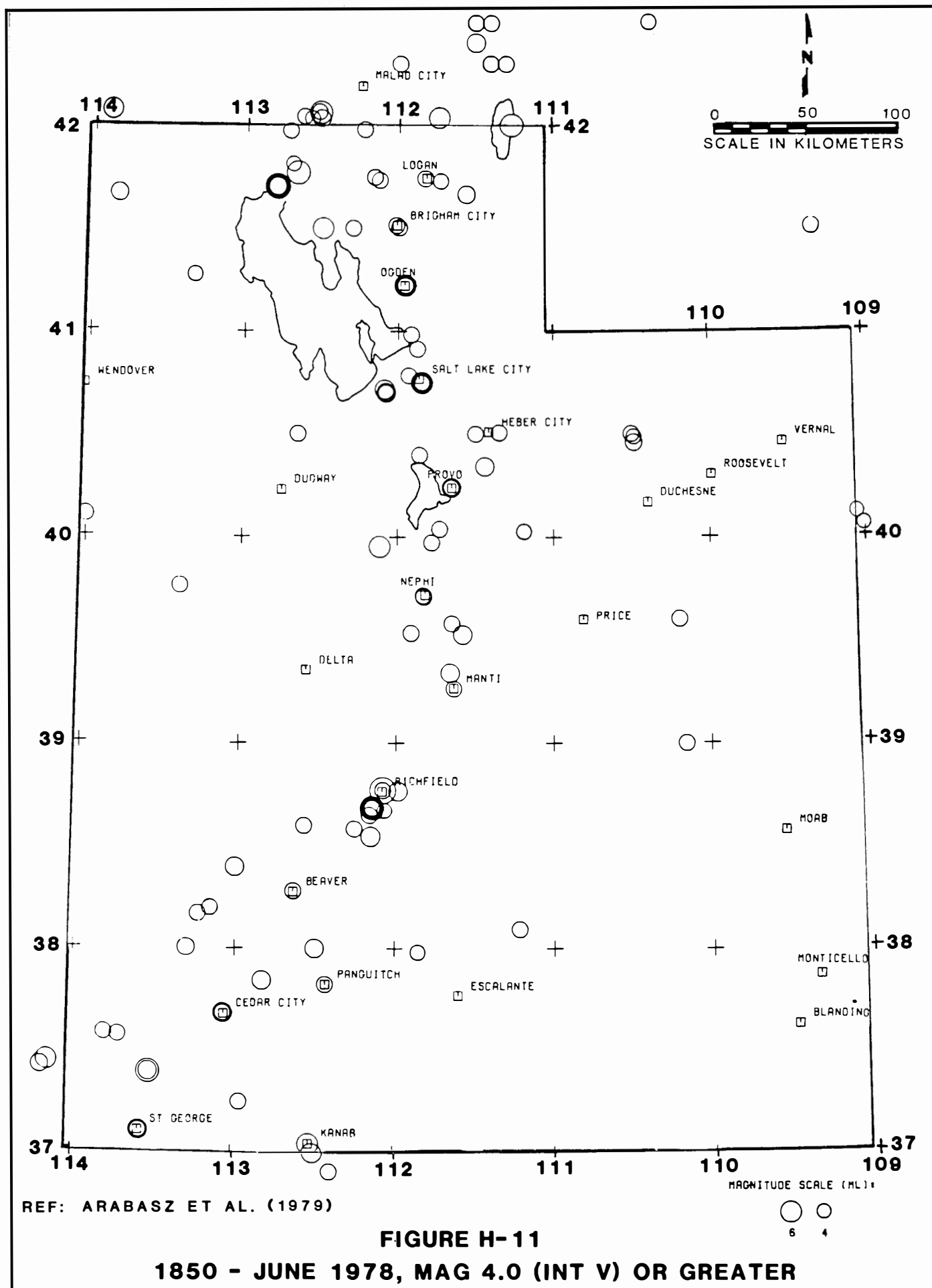
NOTE: FAULTS SHOWN DATE FROM
LATE CENOZOIC AND QUATERNARY.

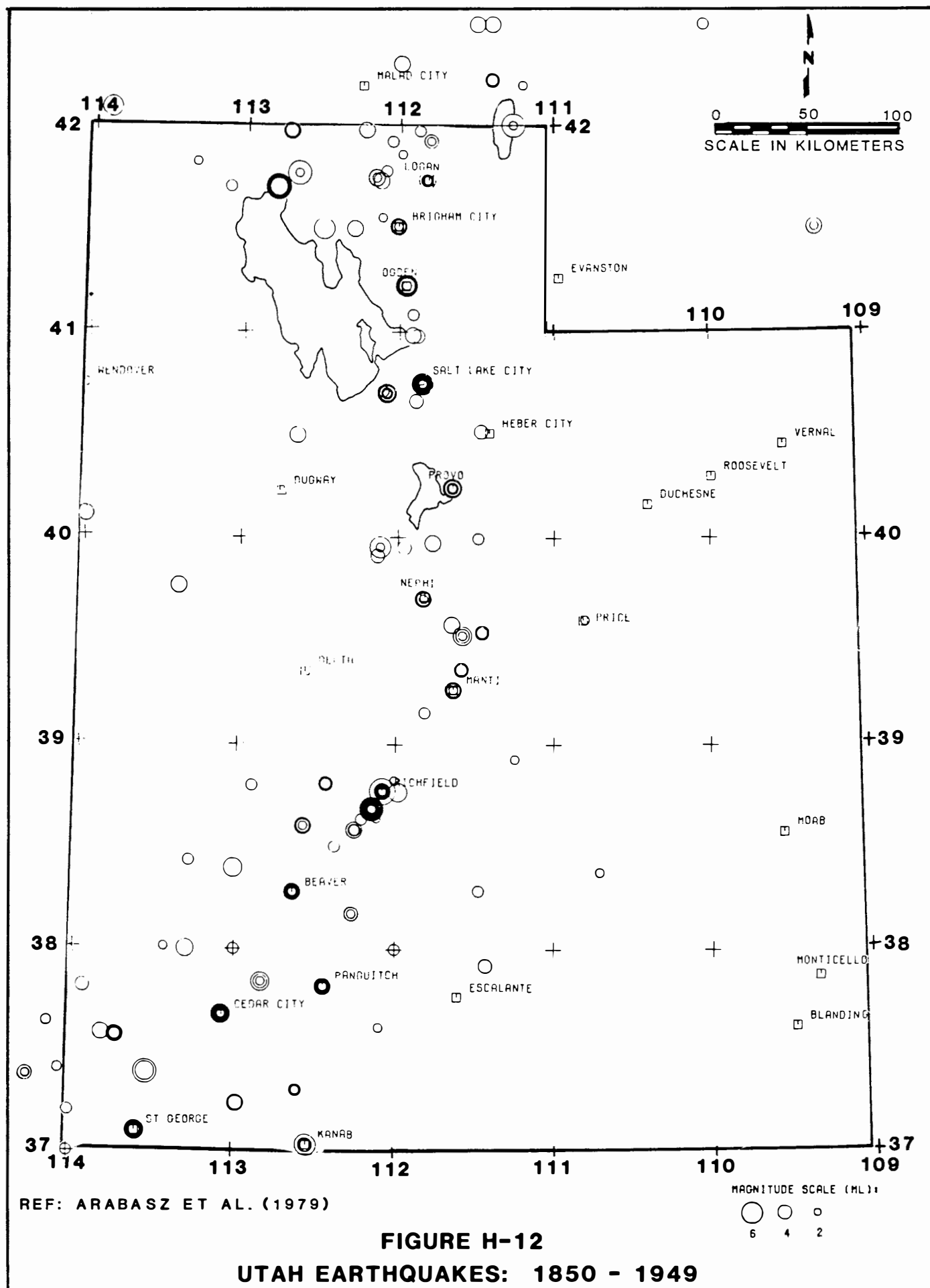
LEGEND

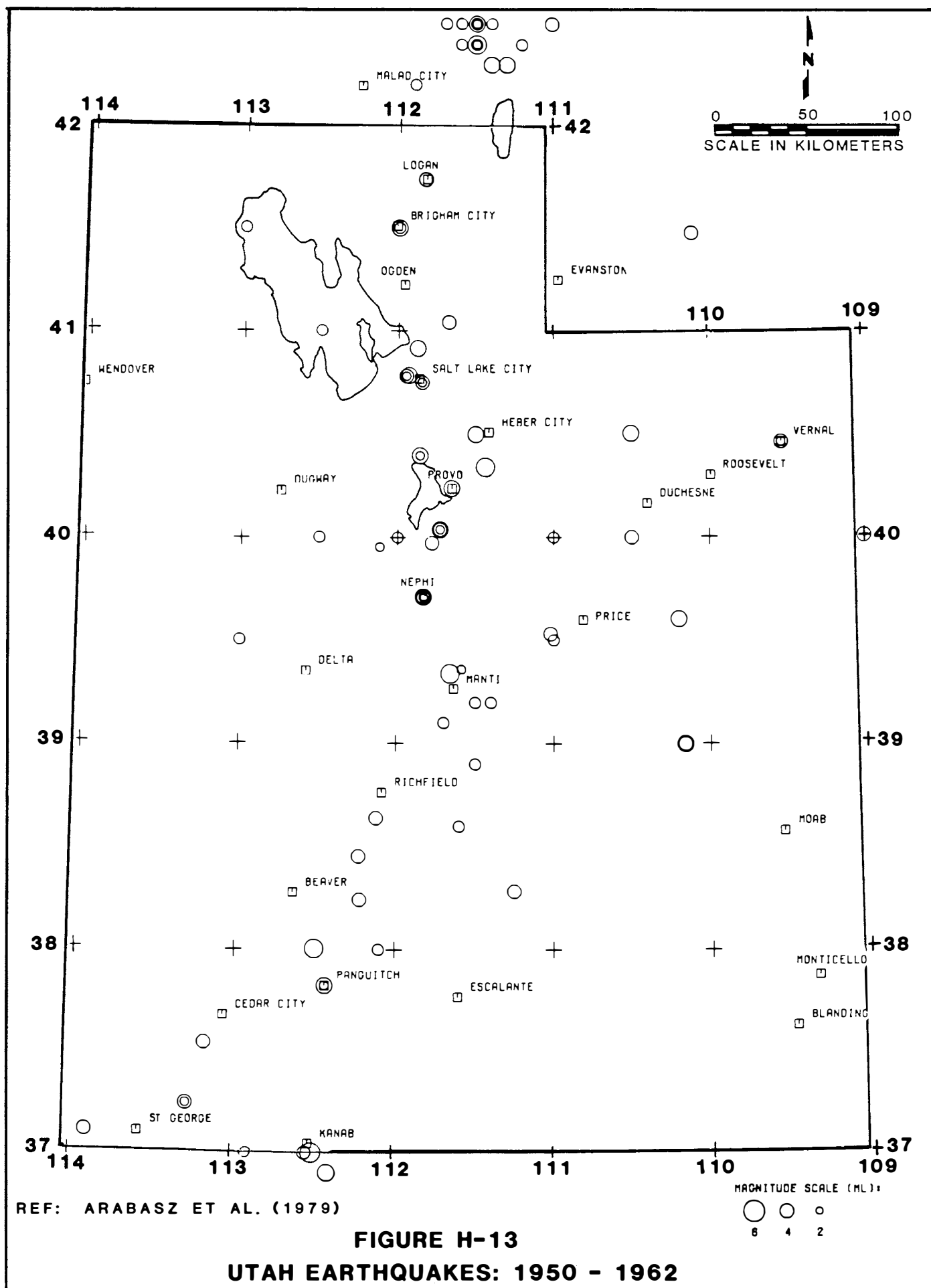
-  TERTIARY AND QUATERNARY
VOLCANIC ROCKS
-  PHYSIOGRAPHIC BOUNDARY

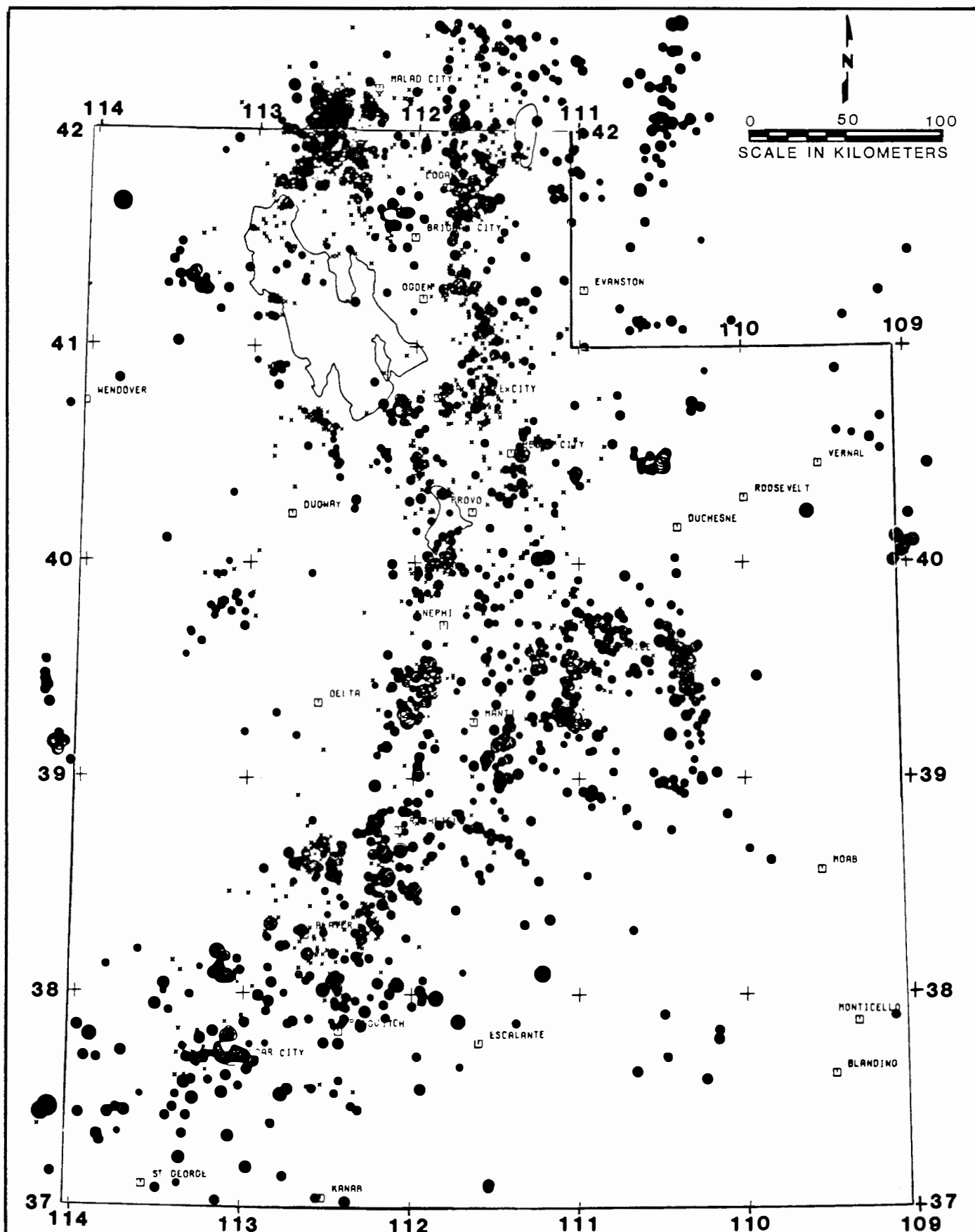
FIGURE H-10
GENERALIZED LATE MESOZOIC-CENOZOIC TECTONIC MAP
OF BASIN AND RANGE

REF: SMITH & SBAR (1974)





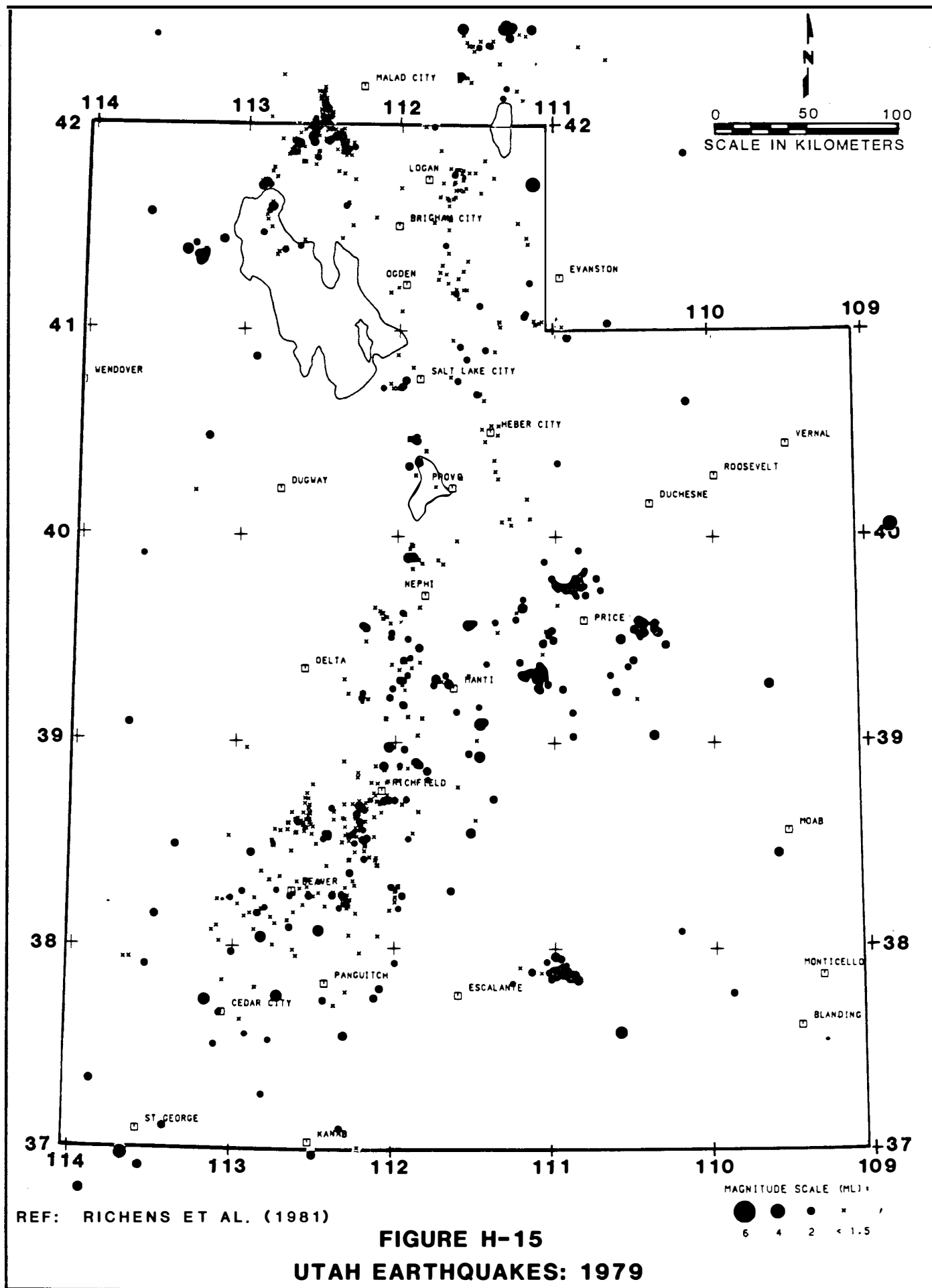


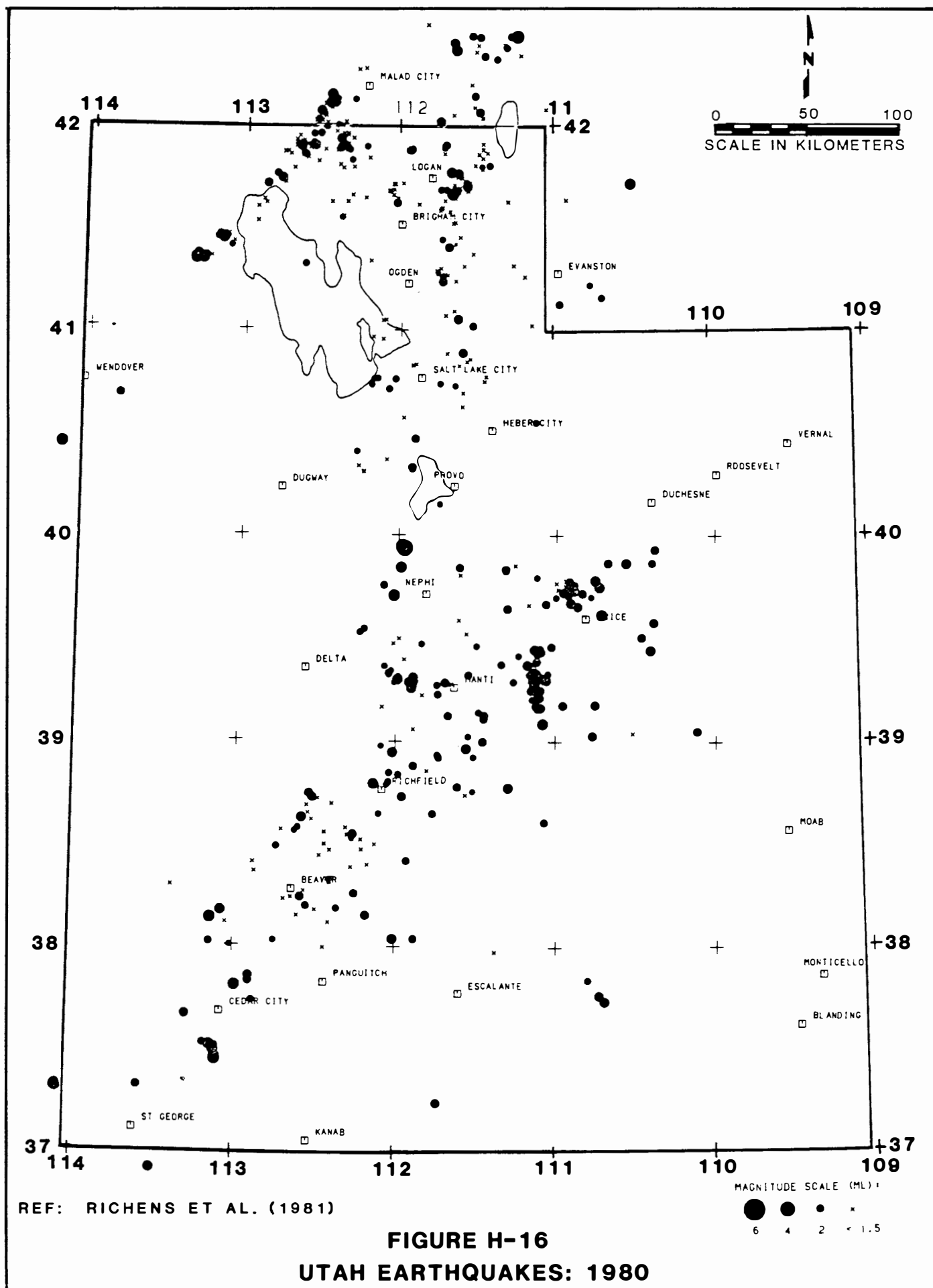


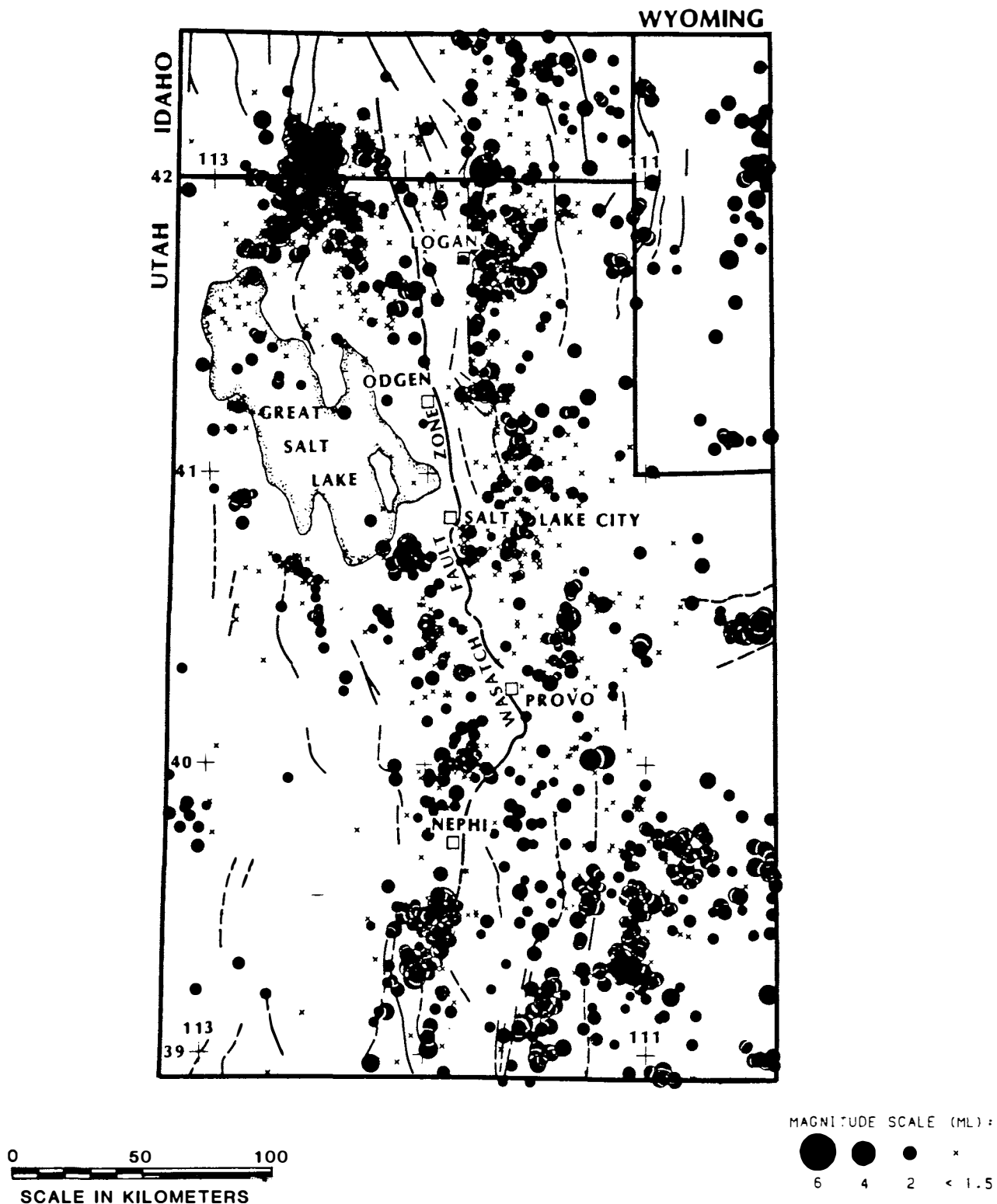
REF: ARABASZ ET AL. (1979)

MAGNITUDE SCALE (ML):
 6 4 2 < 1.5

FIGURE H-14
UTAH EARTHQUAKES: JULY 1962 - JUNE 1978







REF: ARABASZ ET AL. (1979)

FIGURE H-17
EARTHQUAKES EPICENTER MAP OF
WASATCH FRONT, UTAH FOR PERIOD 1962 - JUNE, 1978.

The only historical earthquake in Utah with surface rupturing occurred in Hansel Valley in 1934 (Bucknam et al., 1980). The site is about 100 km north of the South Clive area. The surface rupture occurred on a fault which had previous Holocene displacement. The majority of historical seismicity occurs on the Wasatch Front, but the areas of lower seismicity away from the Wasatch Front do experience small to moderate events with occasional large events, as is the case with the Hansel Valley area.

A computer search of all recorded events within a 50-km radius of Clive, Utah, from October 1974 through September 1983 is shown in Table H-5 and Figure H-18. Richins (personal communication, 1984) indicates many of these events, possibly most of them, are the result of blasts from mining operations in the vicinity of the site.

H.5.2.2 Active faulting

Bucknam and others (1980) have included the site in a region in Utah believed to contain Holocene faulting. The boundaries of their source regions encompass identified locations of Holocene faulting (Figure H-19).

Various authors have presented regional fault maps which include the South Clive site. Williams (1953) maps an unnamed fault about 25 miles in length which borders the western flank of the Cedar Mountains. This fault passes within about 5 miles of the Clive site. No age of faulting is given. Bucknam (1977) and Anderson and Miller (1979; 1980) do not include this fault in suspected Quaternary fault maps. Slemmons (personal communication, 1984) has reported several Holocene scarps of up to 6 miles in length along the west front of the Cedar Mountains, which are lower in elevation than the late Pleistocene shorelines of Lake Bonneville (Figure H-20). Both Slemmons and Buckman indicate their reported faulting is based on interpretation of small-scale (1:60,000) conventional black-and-white aerial photography and smaller scarps may be overlooked and other geomorphic features, such as fire-burns and shorelines, may be mistaken for fault scarps.

Dodge and Grose (1980) have indicated detection of young fault scarps in lake muds or lake gravels is difficult because they have considerably lower slope angles than equal height scarps in alluvial gravels. Their work in the Black Rock Desert in northwestern Nevada indicates that for 1-m-high scarp, which is less than 1,100 years old, the present scarp slope angle in alluvial gravels would be about 15 degrees, in lake gravels, about 10 degrees, and in lake muds, about 8 degrees. Thus scarps near the site in lake muds and gravels would be subtle geomorphic features and could be easily overlooked in regional studies. Their evaluation does not include scarps of between 1,100 and 10,000 years in age, but they do support the concept that early Holocene scarps may now be very subtle geomorphic features in and near the site area which are best delineated by low-sun angle techniques (Cluett and Slemmons, 1971; Slemmons, 1977).

Additional studies to clarify the delineation of fault activity in the site region were conducted. These included field reconnaissance, low-sun angle (LSA) aerial reconnaissance, and photogeologic interpretation of existing 1:24,000 scale color, infrared aerial photography. The results of these studies indicate

Table H-5 Earthquakes within 50 km of Clive, Utah,
October, 1974 - September, 1983

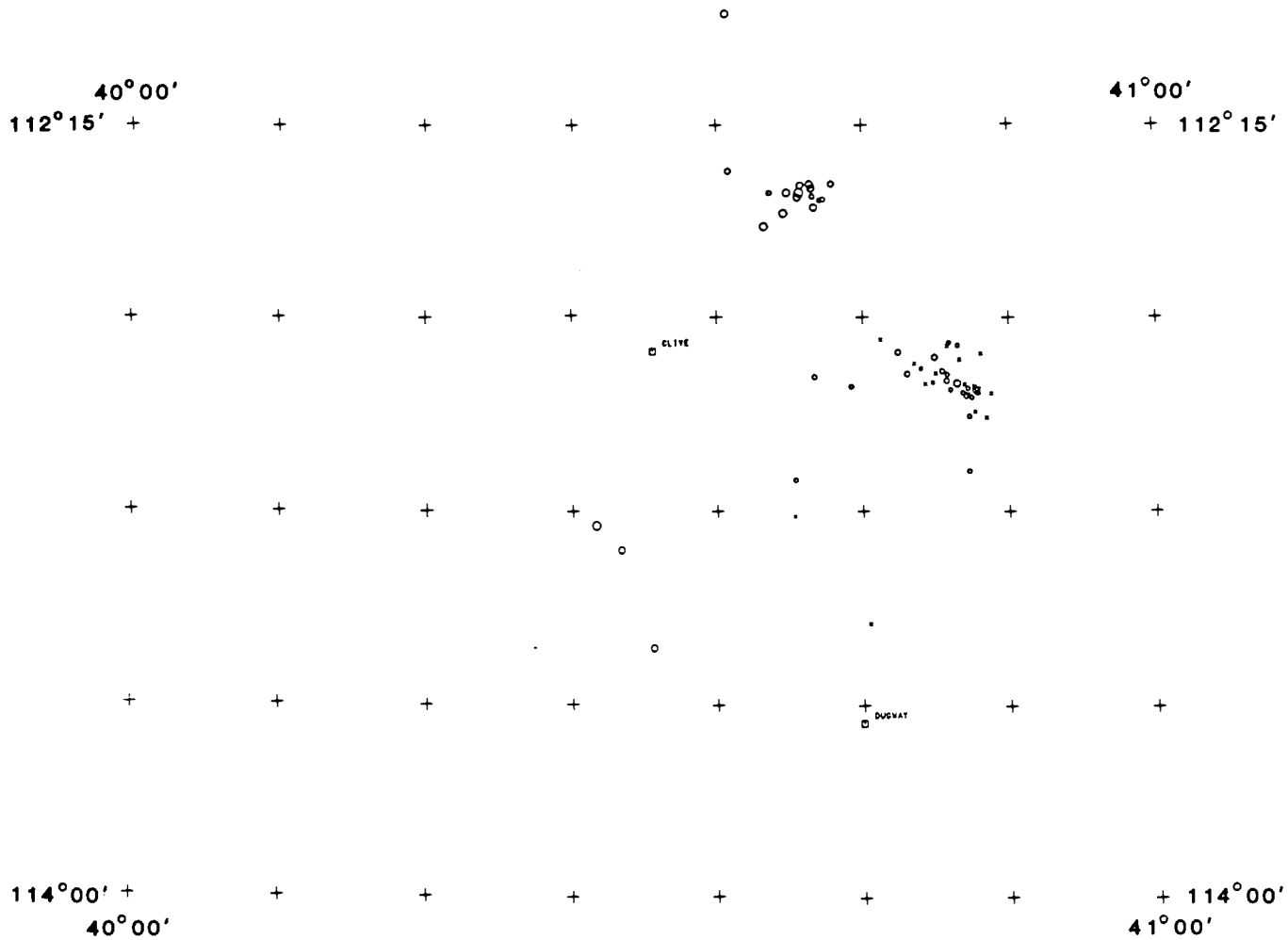
YR	DATE	ORIG	TIME	LAT-N	LONG-W	DEPTH	MAG	NO	GAP	DMN	RMS	Q	I	KM	AZ
75	0104	0850	8.30	40-39.61	112-46.14	7.0*	1.2	5	315	61	.12	D	1	29.25	99.80
75	0204	1540	29.56	40-19.42	113- 6.52	7.0*	1.7	5	321	28	.16	D	2	42.35	179.85
75	0610	0933	48.25	40-32.45	112-51.90	7.0*	1.2	11	210	38	.16	C	3	27.61	131.32
75	1103	1820	26.51	40-39.16	112-33.05	7.0*	.7	6	165	20	.35	C	4	47.61	97.01
76	0123	0054	56.48	40-40.86	112-36.86	7.0*	1.3	11	175	20	.32	C	5	41.98	93.64
76	0207	0418	29.66	40-38.81	112-33.84	7.0*	1.1	12	166	31	.21	C	6	46.60	97.97
76	0224	2249	37.81	40-40.59	112-36.34	7.0*	1.1	7	174	20	.57	D	7	42.74	94.25
76	0330	1500	2.26	40-29.61	112-51.96	7.0*	.7	10	209	33	.28	C	8	31.28	138.68
76	0423	1829	41.02	40-38.91	112-34.38	7.0*	1.3	10	167	21	.47	C	9	45.82	97.87
76	0520	2159	21.31	40-39.15	112-33.19	7.0*	1.3	6	165	20	.18	C	10	47.42	97.06
76	0528	0042	39.85	40-53.57	112-49.89	7.0*	1.8	13	192	31	.37	D	11	31.42	48.41
76	0604	2225	42.53	40-42.35	112-41.33	7.0*	1.5	7	187	22	.55	D	12	35.60	89.85
76	0628	2329	54.12	40-43.02	112-36.17	1.0	1.0	10	165	16	.68	D	13	42.88	88.22
76	0702	2045	41.26	40-54.68	112-52.68	7.0*	1.9	11	196	79	.24	C	14	30.14	40.51
76	0807	0129	36.23	40-39.89	112-35.29	7.0*	1.8	6	175	47	.50	D	15	44.33	95.78
76	0903	2136	8.95	40-39.51	112-34.20	2.1	1.1	7	173	20	.30	C	16	45.93	96.46
76	0908	2052	41.95	40-56.45	112-58.75	7.0*	1.5	12	236	84	.39	D	17	28.42	22.86
76	0910	2038	29.17	41- 8.44	112-59.13	7.0*	1.9	9	207	106	.24	C	18	49.51	12.23
76	0915	1734	41.26	40-39.36	112-33.36	7.0*	1.9	6	184	45	.40	D	19	47.14	96.63
76	1013	2048	13.60	40-54.70	112-51.38	7.0*	2.2	13	209	29	.34	D	20	31.38	43.01
76	1019	1651	33.68	40-43.29	112-43.12	7.0*	.8	7	213	27	.09	C	21	33.12	86.83
76	1023	1503	22.96	40-40.34	112-49.89	7.0*	1.3	10	206	38	.17	C	22	23.82	98.76
76	1105	2313	13.28	40-39.63	112-33.49	7.0*	1.1	14	166	27	.45	C	23	46.90	96.05
76	1123	2354	34.84	40-41.79	112-35.08	7.0*	.9	11	172	24	.30	C	24	44.41	91.22
76	1204	0345	38.60	40-40.61	112-40.41	7.0*	1.4	6	187	29	.21	D	25	37.02	94.85
76	1209	0313	45.18	40-39.11	112-31.83	7.0*	.8	5	159	28	.26	D	26	49.33	96.87
77	0115	2156	16.03	40-54.13	112-48.96	7.0*	1.3	6	190	26	.20	C	27	33.09	48.57
77	0126	1307	28.01	40-39.15	112-34.73	7.0*	1.1	12	167	29	.36	C	28	45.27	97.40
77	0204	2036	12.98	40-39.81	112-34.54	7.0*	.7	7	151	27	.43	C	29	45.39	95.83
77	0218	1443	56.27	40-40.68	112-37.50	7.0*	.8	12	158	27	.31	C	30	41.10	94.18
77	0228	2159	1.38	40-54.07	112-49.33	7.0*	1.0	9	191	26	.20	C	31	32.63	48.11
77	0302	0303	56.80	40-41.45	112-39.69	7.0*	.7	8	162	27	.37	C	32	37.94	92.38
77	0309	2325	49.60	40-37.66	112-33.33	7.0*	.5	6	163	31	.17	C	33	47.64	100.38
77	0311	2246	16.30	40-21.33	112-44.38	7.0*	.9	6	174	18	.30	C	34	49.92	141.03
77	0315	1318	13.68	40-38.79	112-33.81	7.0*	1.1	8	165	29	.25	C	35	46.64	98.01
77	0331	0359	23.12	40-39.05	112-34.17	7.0*	.8	13	150	29	.28	C	36	46.07	97.50
77	0401	1700	10.27	40-54.32	112-51.56	7.0*	1.8	7	187	29	.20	D	37	30.70	43.56
77	0405	0232	22.78	40-37.21	112-32.29	7.0*	.9	8	145	32	.17	C	38	49.24	101.03
77	0420	2053	28.01	40-42.76	112-36.36	7.0*	.8	12	156	23	.41	C	39	42.60	88.85
77	0425	1935	30.18	40-54.40	112-50.03	7.0*	1.3	9	192	27	.24	C	40	32.32	46.14

Table H-5 (Concluded)

YR	DATE	ORIG	TIME	LAT-N	LONG-W	DEPTH	MAG	NO	GAP	DMN	RMS	Q	I	KM	AZ
77	0429	0624	28.33	40-39.44	112-33.28	7.0*	1.2	11	148	28	.33	C	41	47.23	96.44
77	0504	2307	6.95	40-37.36	112-34.21	7.0*	1.2	15	149	32	.29	C	42	46.53	101.33
77	0525	2046	14.38	40-55.28	112-51.26	7.0*	1.7	9	186	29	.35	D	43	32.29	41.93
77	0622	2051	16.86	40-55.35	112-50.31	7.0*	1.9	11	193	28	.41	D	44	33.29	43.49
77	0623	2221	6.30	40-39.49	112-33.06	7.0*	.7	5	164	28	.33	D	45	47.53	96.28
77	0707	1233	47.19	40-39.95	112-37.80	7.0*	.8	6	176	28	.10	C	46	40.80	96.12
77	0713	2234	17.03	40-42.23	112-32.90	7.0*	.9	4	167	23	.12	D	47	47.47	90.16
77	0721	2020	46.36	40-33.13	112-34.11	7.0*	1.2	5	194	39	.18	D	48	48.88	110.32
77	0801	2242	51.02	40-41.98	112-37.65	7.0*	1.5	10	178	58	.44	D	49	40.78	90.83
77	0810	1328	46.35	40-40.10	112-36.40	7.0*	1.4	7	155	55	.22	C	50	42.73	95.47
77	0817	2246	46.42	40-39.39	112-36.00	7.0*	1.1	5	184	29	.10	D	51	43.44	97.12
77	0831	2052	32.93	40-53.05	112-53.02	7.0*	2.0	12	190	31	.31	D	52	27.58	43.83
77	0930	2211	22.88	40-39.96	112-37.81	7.0*	1.0	10	158	28	.36	C	53	40.78	96.10
77	1013	0232	11.12	40-41.05	112-39.01	7.0*	1.0	8	177	27	.38	C	54	38.93	93.41
78	0116	2153	57.02	40-39.85	112-38.57	7.0*	.1	7	159	29	.50	D	55	39.74	96.55
78	0124	1436	30.48	40-39.66	112-33.60	7.0*	.7	7	169	27	.28	C	56	46.74	96.00
78	0206	2257	28.94	40-54.67	112-54.46	7.0*	1.3	10	192	79	.33	D	57	28.56	36.71
78	0424	2200	15.96	40-55.03	112-50.17	7.0*	1.7	6	192	80	.05	D	58	33.00	44.44
78	0510	2308	7.34	40-42.87	112-35.25	1.1	1.1	6	210	13	.47	D	59	44.17	88.63
78	0606	2059	12.55	40-55.47	112-48.11	7.0*	1.5	8	204	24	.43	D	60	35.64	46.85
79	0329	1017	15.75	40-28.84	113-12.55	7.0*	2.2	28	264	76	.40	D	61	26.29	198.62
79	1115	1229	47.61	40-52.01	112-55.04	7.0*	2.0	20	193	34	.41	D	62	24.24	42.13
81	0711	1120	17.33	40-26.98	113- 9.93	7.0*	1.8	21	179	41	.43	C	63	28.74	189.41

NUMBER OF EVENTS = 63

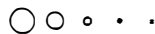
Ref. University of Utah, Department of Geology and Geophysics, 1984.



10 0 10 20 30

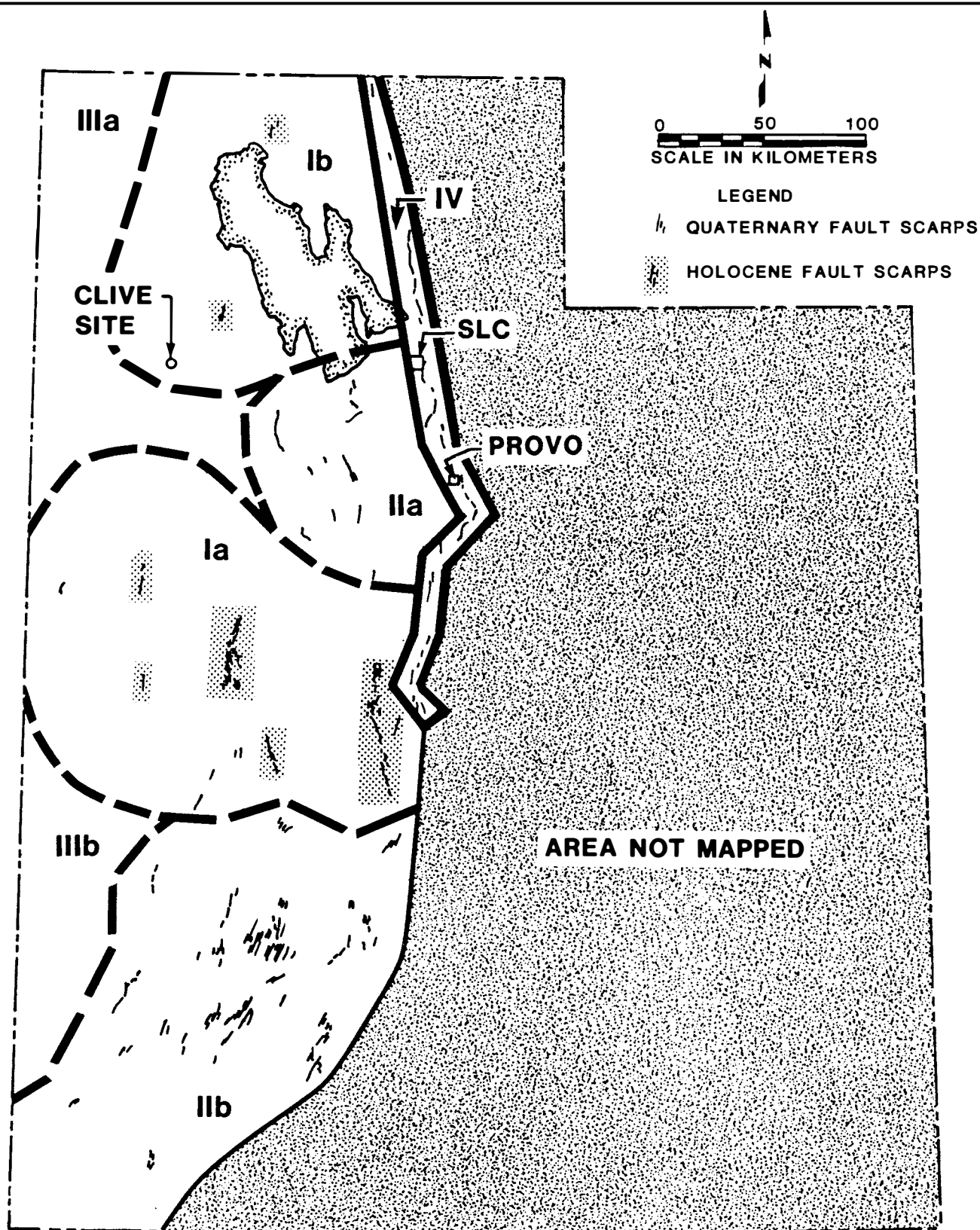
 SCALE IN KILOMETERS

MAGNITUDE SCALE (ML):


 6 4 2 1 1.0

SEISMOGRAPH STATION 

FIGURE H-18
EARTHQUAKES WITHIN 81 MILES (50 KM) OF CLIVE, UT
OCT 1974 - SEPT 1983



REF: BUCKMAN ET AL. (1980)

FIGURE H-19
LATE QUATERNARY, HOLOCENE FAULT SCARPS
AND SOURCE REGIONS I, II, III, IV

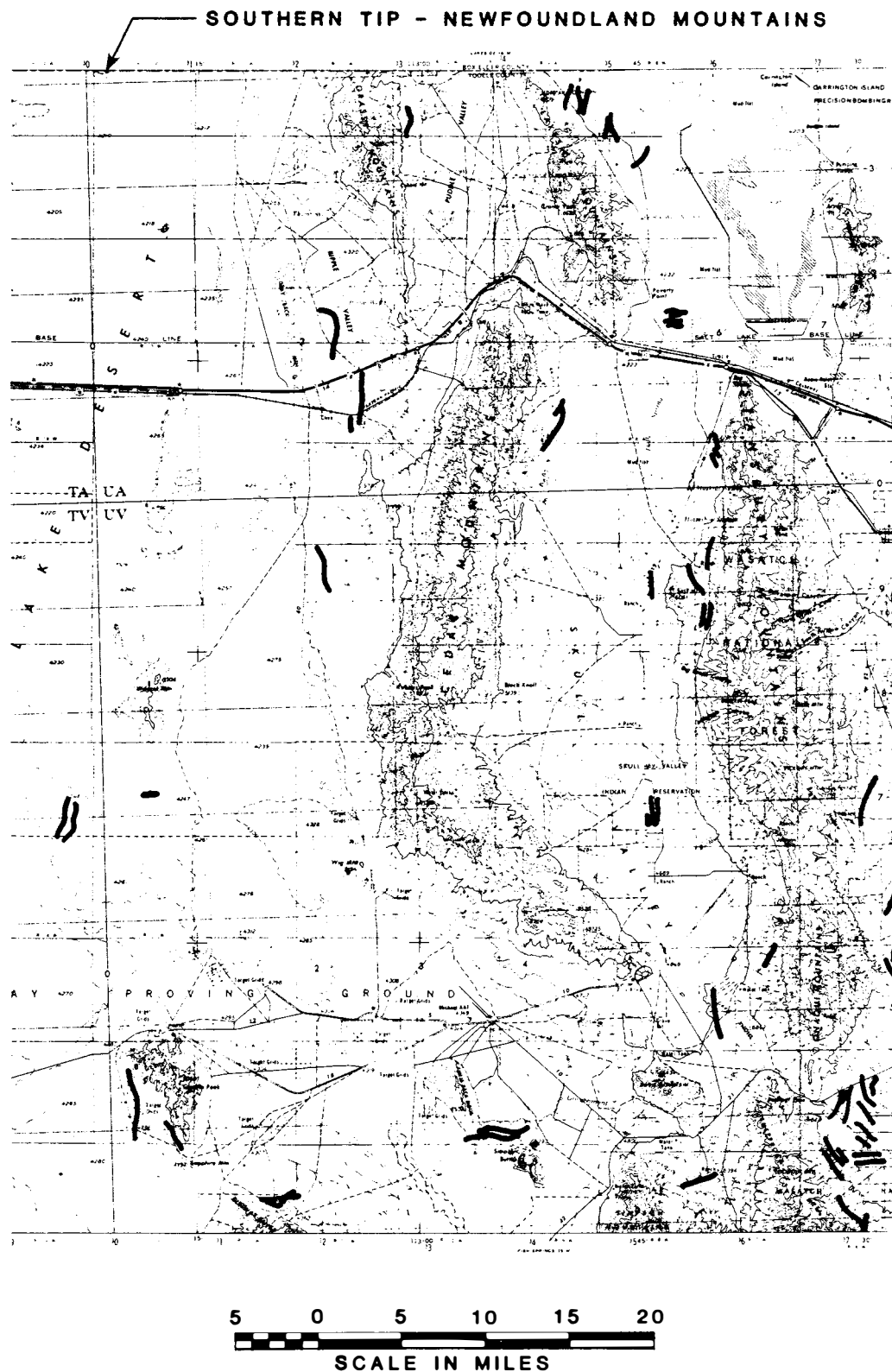


FIGURE H-20
ACTIVE FAULT ZONES
REPORTED BY SLEMMONS (1984, pers. comm.)

active faulting in the site region occurs in five zones, the southeast and northeast front of the Cedar Mountains, the west front of the Stansbury Mountains, the east front of the Newfoundland Mountains, and a zone of faulting in Puddle Valley (Figure H-21).

H.5.3 Seismic zoning

Algermissen et al., (1982) have completed seismic zoning maps for the United States based on energy release during historical earthquakes. Their zoning places the site in an area which, for a 250-year exposure, with a 90 percent probability of nonexceedence, will not have accelerations in rock in excess of about 0.2 to 0.4 g.

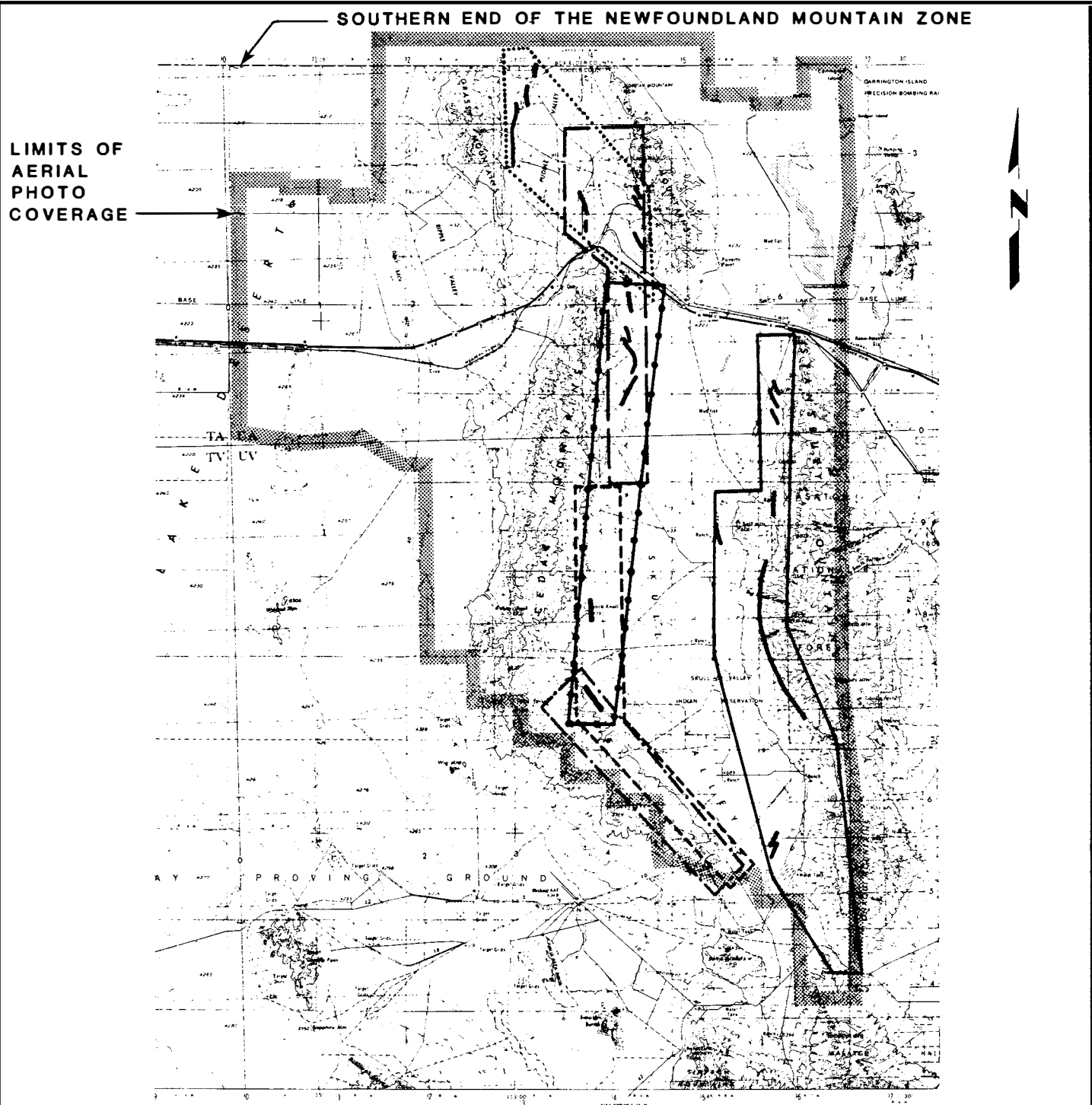
H.5.4 Earthquake recurrence intervals

Recurrence intervals vary in different areas of the BAR and range from 500 to 3000 years for active portions such as the Wasatch Front but may be over 10,000 years for the area of the site (Wallace, 1982). Further quantification of the recurrence interval requires extensive fault investigations along those zones considered capable of generating design earthquakes for the site.

H.5.5 Seismic design parameters

Earthquake sources considered in the development of the preliminary site design parameters for the South Clive site are listed in Table H-6 for the zones of active faulting in the site region. Various interpretations of segmentation of the active zones and interaction between the zones is possible. For conservatism, the northern portion of the fault system on the northeastern front of the Cedar Mountains is considered; the Puddle Valley faulting and two segments of active faulting along the southeastern front are considered together. In addition, the entire north-south trending portion of the zone along the east front of the Cedar Mountains is considered as a single fault. For all MCE magnitude calculations, it is assumed that the total fault zone lengths will rupture. The various combined segments and fault zones considered as possible source faults for design parameters at the site are depicted on Figure H-21. Table H-6 lists the MCEs and an estimated on-site maximum acceleration for each of these geometrics. Earthquakes originating along the Wasatch Front and in the Hansel Valley area are too remote to affect the seismic design parameters at the site.

Variations in maximum acceleration at a site from an MCE can be attributed to earthquake size, distance to the site, wave-path attenuation characteristics, source mechanism of the event, direction and speed of fault rupture, and local soil conditions at the site. The expected variation for acceleration values is listed in Table H-6. The maximum acceleration expected at the site is 0.31 ± 0.06 g from an MCE of $M_S = 7.1$. The source for this event could be either the east front of the Cedar Mountains or the northern segment of this zone combined with the faulting in southeastern Puddle Valley (Figure H-21). As these active zones are far removed from the site, no hazard from surface rupture exists at the site.



LEGEND

- PUDDLE VALLEY ZONE
- S.E. PUDDLE VALLEY - N.E. CEDAR MTN. ZONE
- - - - E. CEDAR MTN. ZONE
- . - . S.E. CEDAR MTN. ZONE
- - - - S. SKULL VALLEY
- W. STANSBURY MTN. ZONE



NOTE

PARAMETERS IN TABLE H-6.

FIGURE H-21
ACTIVE FAULT ZONES
USED FOR DETERMINATION OF SEISMIC DESIGN

Table H-6. Design criteria for potential seismic sources affecting the Clive, Utah, site

Source fault	Age of last movement	Maximum length	Maximum* Credible Earthquake (magnitude)	Distance to site	Estimated** maximum acceleration in rock (fraction of unit gravity)
West flank of Cedar Mountains					
Williams (1953)	Not given	35 mi (57 km)	7.3	5 mi (8 km)	0.4 g
Slemmons, (personal communication), 1984	Holocene	***4 mi (6.4 km)	6.2	3 mi (5 km)	0.5 g
	Holocene	****17 mi (27.5 km)		7.0	3 mi (5 km)
0.6 g					
West flank of Stansburg Mountains					
Bucknam (1977)	Holocene	14 mi (23 km)	6.9	24 mi (39 km)	0.2 g
Slemmons, (personal communication), 1984	Holocene	23 mi (37 km)	7.1	24 mi (39 km)	0.2 g
Northwest Puddle Valley					
Bucknam (1977)	Holocene	5 mi (8 km)	6.3	17 mi (27.5 km)	0.2 g
East flank of Newfoundland Mountains					
Cook & others (1964)	Holocene (?)	14 mi (23 km)	6.9	24 mi (39 km)	0.2 g

* Calculated from Slemmons (1977), Type A faults using total faults' length, $M = 1.845 + (1.151) \log L$ in m

Calculated from Schnabel and Seed, 1973

*** Individual Holocene Scarps

**** Zone of Holocene Scarps

H.6 GEOTECHNICAL PROFILE - SOUTH CLIVE SITE

Based on boring logs and test data presented in Dames and Moore (1982), subsurface conditions at the South Clive site consist entirely of alluvial and lacustrine sediments of varying thickness, but continuous beneath the site. Table H-7 lists selected soil parameters tested for by Dames and Moore.

Table H-7. Selected soil parameters

Boring number	Depth (ft)	Moisture content (%)	Dry density (lbs/cu ft)	Soil type (USCS)	Depth to ground water (feet)
SC-1	4.0	31.7	88	ML	27.8
SC-1	21.0	19.4	93	SM-SC	
SC-2	4.0	33.7	79	ML-CL	20.6
SC-2	18.0	34.8	85	CL-SM	
SC-3	19.0	23.2	102	ML-CL	29.3
SC-4	4.0	35.9	87	CL-ML	34.0
SC-4	8.0	33.8	78	CL-ML & SP-SM	
SC-5	9.0	4.5	113	SP-SM	26.1
SC-6	3.0	33.7	88	CL-ML	24.7
SC-6	8.0	4.1	99	SP-SM	
SC-7	6.0	33.8	85	CL-ML	21.6
SC-8	9.0	38.2	80	SM-SP	29.9
SC-8	14.0	10.5	98	SM-SP	
SC-9	3.0	21.0	89	CL-ML	31.2
SC-9	8.0	40.4	79	CL-ML	
SC-10	6.0	34.2	87	CL-ML	32.4
SC-10	11.0	43.7	78	SP-SM	
SC-11	4.0	25.1	93	CL-ML	28.4
SC-12	6.0	34.9	82	CL-ML	27.4
SC-12	11.0	4.3	103	SP-SM	
SC-13	3.0	21.8	97	CL-ML	25.9

The initial soil stratum encountered at the site is composed of predominately clayey soils, classifying as CL to ML in the Unified Soil Classification System. This layer varies in thickness from 3 to 12 feet. Standard penetration testing (SPT) blow counts (N-values) indicate this material to have a consistency ranging from medium stiff to very stiff except in boring SC-7 which is soft from 0.0 to 10.0 feet.

Sandy soils, classifying predominately as SP-SM to SC, underlay the clayey surface soils, with varying thickness ranging from 8 to 25 feet. SPT N-values indicate a density ranging from medium dense to dense.

Underlying both of these strata is another clayey soil stratum classifying predominately as a CL to ML. Four borings penetrated this stratum which has a thickness ranging from 15 to 20 feet. SPT N-values indicate a

consistency ranging from medium stiff to hard with the exception of boring SC-13, 28 to 43 feet, which is soft grading to medium dense at approximately 32 feet.

Boring SC-1 indicates that below this last clayey stratum lies a sandy soil that is in excess of 180 feet thick and has a density ranging from medium dense to hard.

Ground water was encountered in all borings and ranged from elevation 4246.7 to 4248.6 feet.

H.7 LIQUEFACTION POTENTIAL - SOUTH CLIVE SITE

A complete analytical assessment of the liquefaction potential at the South Clive site has not been completed. Two factors would indicate the potential for seismically induced liquefaction of the in-situ soil is very remote. Typically, the first layer of silty sands encountered lies above the static ground-water table. If the water table is encountered within this strata, it is only within the bottom 2 to 5 feet. The water table is located at a depth of 20 to 30 feet below the ground surface. Second, SPT blow count values for sands lying below the water table typically exceed 20, though borings SC-4 and SC-7 indicate values less than 10. Considering the depth to the water table, the relatively large overburden pressure, and the apparent medium to high densities of the sandy layers encountered, significant liquefaction due to an MCE event is improbable.

Prior to fully concluding that the South Clive site is not subject to liquefaction damage, the possibility of a long-term rise in the ground-water table should be assessed. Due to recent changes in the Great Salt Lake level and geologically recorded high-water stands of ancient Lake Bonneville, this possibility of significant changes over the site's design life appears possible.

REFERENCES

- Algermissen, S. T. and D. M. Perkins, 1976, "A Probabilistic Estimate of Maximum Acceleration in Rock in the Contiguous United States," U. S. Department of the Interior, Geological Survey, Open File Report 76-416, Washington, D.C.
- Algermissen, S. T., D. M. Perkins, P. C. Thenhaus, S. L. Hanson, and B. L. Becker, 1982, "Probabilistic Estimates of Maximum Acceleration and Velocity in Rock in the Contiguous United States," U.S. Department of the Interior, Geological Survey, Open File Report 82-1033, Washington, D.C.
- Anderson, L. W. and D. G. Miller, 1979, "Quaternary Fault Map of Utah"; Technical Report of Fugro, Inc., Long Beach, California.
- Anderson, L. W. and D. G. Miller, 1980, "Quaternary Faulting in Utah"; U.S.G.S. Open-File Report 80-801, pp. 194-226.
- Applied Technology Council Associated with the Structural Engineers Association of California, 1978, "Tentative Provisions for Development of Seismic Regulations for Buildings," National Bureau of Standards Publication 510. Washington, D.C.
- Arabasz, W. T., R. B. Smith, and W. D. Richins, (eds.), 1979, "Earthquake Studies in Utah - 1850 to 1978," University of Utah Seismograph Stations, Department of Geology and Geophysics, University of Utah, Special Publication, Salt Lake City, Utah.
- Arabasz, W. T., R. B. Smith and W. D. Richins, 1980, "Earthquake Studies Along the Wasatch Front, Utah: Network Monitoring, Seismicity, and Seismic Hazards," Bulletin of the Seismological Society of America, Volume 70, No., 5, pp. 1479-1499.
- Bucknam, R. C., 1977, Map of Suspected Fault Scarps in Unconsolidated Deposits, Tooele 1" x 2" Sheet, Utah; U.S.G.S. Open-File Report 77-495, 1 plate.
- Bucknam, R. C., S. T. Algermissen, and R. E. Anderson, 1980, "Patterns of Late Quaternary Faulting in Western Utah and an Application in Earthquake Hazard Evaluation," Proceedings of Conference X - Earthquake Hazards Along the Wasatch Sierra-Nevada Frontal Fault Zones, U. S. Geological Survey Open File Report 80-801, pp. 299-314.
- Buckman, R. C., 1984, personal communication, U.S.G.S., Denver, Colorado, January 25, 1984.
- Chen and Associates, Inc., 1980a, Geotechnical Investigation Report for Proposed North Interceptor Line, Prepared for Central Valley Water Reclamation Board, Salt Lake City, Utah.
- Chen and Associates, Inc., 1980b, Geotechnical Investigation Report for Proposed Regional Wastewater Facility, Prepared for Central Valley Water Reclamation Board, Salt Lake City, Utah.
- Cluff, L. S., G. E. Brogan, and C. E. Glass, 1970, "Wasatch Fault, Northern Region - Earthquake Fault Investigation and Evaluation," Report to the Utah Geology and Mining Survey by Woodward-Lundgren and Associates, Project G-12069.

REFERENCES

- Cluff, L. S. and D. B. Slemmons, 1971, "Wasatch Fault Zone - Features Defined by LSA Photography," Environmental Geology of the Wasatch Front, 1971, Utah Geological Association, Publication No. 1, Salt Lake City, Utah.
- Colorado State University, 1982, Preliminary Draft Report on the Salt Lake City Mill Tailings Site, (unpublished), Fort Collins, Colorado.
- Cook, K. L., M. O. Halverson, J. C. Stepp, and J. W. Berg, 1964, "Regional Gravity Survey of the Northern Great Salt Lake Desert and Adjacent Areas in Utah, Nevada and Idaho"; Geological Society of American Bulletin, Vol. 75, pp. 715-740.
- Cook, K. L., 1971, "Earthquakes Along the Wasatch Front, Utah - The Record and the Outlook," Environmental Geology of the Wasatch Front, Utah Geological Association, Publication No. 1, Salt Lake City, Utah.
- Dames and Moore, 1982, Remedial Actions of the Former Vitro Chemical Company Millsite, South Salt Lake City, Salt Lake County, Utah, PDEIS Prepared for U. S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.
- Dodge, R. L. and L. T. Grose, 1980, "Tectonic and Geomorphic Evolution of the Black Rock Fault, Northwestern Nevada"; U.S.G.S. Open-File Report 80-801, pp. 494-508.
- Doser, D. I. and R. B. Smith, 1982, "Seismic Moment Rates in the Utah Region," Bulletin of the Seismological Society of America, Volume 72, No. 2, pp. 525-551.
- Franklin, A. G. and F. K. Chang, 1977, "Earthquake Resistance of Earth and Rock-Fill Dams," Miscellaneous Paper S-71-17, U. S. Army Engineer Waterways Experiment Station.
- Hamblin, W. K., 1976, "Patterns of Displacement Along the Wasatch Fault," Geology, Volume 4, No. 10, Geological Society of America.
- Hintze, L. F., 1971, "Wasatch Fault Zone East of Provo, Utah," Environmental Geology of the Wasatch Front, 1971, Utah Geological Association, Publication No. 1.
- Jeyapalan, J. K., J. M. Duncan, and H. B. Seed, 1983, "Investigations of Flow Failures of Tailings Dams," American Society of Civil Engineers, Journal of Geotechnical Engineering, Vol. 109 No. 2, pp. 172-189.
- Kuribayashi, E. and F. Tatsuoka, 1977, "History of Earthquake Induced Soil Liquefaction in Japan," Bulletin of the Public Works Research Institute, Volume 31, Tokyo, Japan.
- Liu, S. C. and N. J. DeCapua, 1975, "Microzonation of the Rocky Mountain States," Proceedings of the U. S. National Conference on Earthquake Engineering by Earthquake Engineering Research Institute, Ann Arbor, Michigan.

REFERENCES

- Lucia, P. C., J. M. Duncan, and H. B. Seed, 1981, "Summary of Research on Case Histories of Flow Failures of Mine Tailings Impoundments," Mine Waste Disposal Technology, Bureau of Mines Information Circular 8857, pp. 46-53.
- Makdisi, F. I. and H. B. Seed, 1978, "Simplified Procedure for Estimating Dam and Embankment Earthquake-Induced Deformations," Journal of the Geotechnical Engineering Division, ASCE, Vol. 104, No. GT7.
- Makdisi, F. I. and H. B. Seed, 1979, "Simplified Procedure for Evaluating Embankment Response," Journal of the Geotechnical Engineering Division, ASCE, Volume 105, No. GT12.
- Marsell, R. E. 1964, "The Wasatch Fault Zone in North Central Utah," Guidebook to the Geology of Utah, No 18, Utah Geological Society, Salt Lake City, Utah.
- Martin, Veyera, Nasiatka and Osorno, 1980, "Characterization of the Inactive Tailings Sites," in Proceedings of the Second Annual Symposium on Uranium Mill Tailings Management, Fort Collins, Colorado.
- Parry, W. T., 1974, "Earthquake Hazards in Sensitive Clays Along the Central Wasatch Front, Utah," Geology, Volume 2, No. 11, pp. 559-560.
- Reilinger, R., 1977, "Vertical Crustal Movements from Repeated Leveling in the Great Basin of Nevada and Western Utah," (abstract); EOS, Vol. 58, n. 12, p. 1238.
- Richens, W. D., 1984, personal communication, University of Utah, Dept. of Geology and Geophysics, January 25, 1984, Salt Lake City, Utah
- Richens, W. D., W. J. Arabasz, G. M. Hathaway, P. J. Oehmich, L. L. Sells, and G. Zandt, 1981, "Earthquake Data for the Utah Region - July, 1, 1978 to December 31, 1980"; Special Publication of the University of Utah Seismograph Stations, Dept. of Geology and Geophysics, University of Utah, Salt Lake City, Utah.
- Sarma, S. K., 1979, "Response and Stability of Earth Dams During Strong Earthquakes," Miscellaneous Paper GL-79-13, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.
- Schnabel, P. and H. B. Seed, 1973, "Acceleration in Rocks for Earthquakes in the Western United States"; Bulletin of the Seismological Society of America, Vol. 63, pp. 501-516.
- Seed, H. B. and I. M. Idriss, 1971, "Simplified Procedure for Evaluating Soil Liquefaction Potential," Journal of the Soil Mechanics and Foundations Division, ASCE, Volume 97, No. SM9, Proc. Paper 8371, pp. 1249-1273.
- Seed, H. B. and J. R. Brooker, 1976, "Stabilization of Potentially Liquefiable Sand Deposits Using Gravel Drain Systems," EERC 76-10, University of California, Berkeley.

REFERENCES

- Seed, H. B. and I. M. Idriss, 1981, "Evaluation of Liquefaction Potential of Sand Deposits Based on Observations of Performance in Previous Earthquakes," Session No. 24, ASCE National Convention, St. Louis, Missouri,
- Sergent, Hauskins & Beckwith, 1981, "Assay Borings, Made at Vitro Site, Salt Lake City, Utah," for Mountain States Engineers, (unpublished), Phoenix, Arizona.
- Sergent, Hauskins & Beckwith, 1983, "Evaluation of Potential Earthquake Effects Vitro Site, Salt Lake City, Utah," for U. S. Department of Energy (unpublished), UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico.
- Slemmons, D. B., 1977, "State-of-the-Art for Assessing Earthquake Hazards in the United States: Report 6--Faults and Earthquake Magnitude"; U.S. Army Engineer Waterways Experimental Station Miscellaneous Paper S-73-1, Vicksburg, Mississippi.
- Slemmons, D. B., 1984, personal communication, Mackay School of Mines, University of Nevada-Reno, Reno, Nevada, January 27, 1984.
- Slemmons, D. B., P. O'Malley, R. A. Whitney, D. H. Chung, and D. L. Bernreuter, 1982, Assessment of Active Faults for Maximum Credible Earthquakes of the Southern California--Northern Baja Region, Lawrence Livermore National Laboratory, publication UCID-19125, Livermore, CA, 48 p. with 2 plates.
- Smith, R. B., 1971, "Contemporary Seismicity, Seismic Gaps, and Earthquake Recurrences of the Wasatch Front," Environmental Geology of the Wasatch Front, 1971, Utah Geological Association, Pub. No. 1, Salt Lake City, Utah.
- Smith, R. B., 1974, "Seismicity and Earthquake Hazards of the Wasatch Front, Utah," Earthquake Information Bulletin, Volume 6, No. 4, U. S. Department of Interior, USGS, Washington, D.C.
- Smith, R. B., and M. L. Sbar, 1974, "Contemporary Tectonics and Seismicity of the Western United States with Emphasis on the Intermountain Seismic Belt;" Geological Society of America Bulletin, Vol. 85. pp. 1205-1218.
- Smith, R. B., 1978, "Seismicity, Crustal Structure, and Intraplate Tectonics of the Interior of the Western Cordillera," Cenozoic Tectonics and Regional Geophysics of the Western Cordillera, Geological Society of America Memoir 152, pp. 111-144.
- Stewart, J. W., 1971, "Basin and Range Structure: A System of Horsts and Grabens Produced by Deep-Seated Extension;" Geological Society of America Bulletin, Vol. 82, pp. 1019-1044.
- Swan, F. H., D. P. Schwartz, and L. S. Cluff, 1980, "Recurrence of Moderate to Large Magnitude Earthquakes Produced by Surface Faulting on the Wasatch Fault Zone, Utah," Bulletin of the Seismological Society of America, Volume 70, No. 5, pp. 1431-1462.

REFERENCES

- U. S. Geological Survey, 1976, "A Study of Earthquake Losses in the Salt Lake City, Utah Area," U. S. Geological Survey Open File Report 76-89, Washington, D.C.
- University of Utah, Dept. of Geology and Geophysics, Computer Readout of Earthquakes Within 50 km of Clive, UT: Oct. 1974-Sept. 1983. Readout obtained in February 1984, Salt Lake City, Utah.
- VanHorn, R., 1971, "Faults - Criteria for Their Recognition in the Salt Lake City Area, Utah," Environmental Geology of the Wasatch Front, 171, Utah Geological Association, Publication No. 1, Salt Lake City, Utah.
- Wallace, R. E., 1978, Patterns of Faulting and Seismic Gaps in the Great Basin Province; U.S.G.S. Open-File Report 78-943, pp. 857-868.
- Wallace, R. E., 1982, "Patterns and Timing of Late Quaternary Faulting in the Great Basin Province in Relation to Some Regional Tectonic Features," in Proceedings Volume Chapman Conference, Snowbird, Utah.
- Williams, J. S., 1953, Fault Map of the State of Utah, Bulletin of the Seismological Society of America, Vol. 43, n. 3., plate following p. 282.
- Yegian, M. K. and R. V. Whitman, 1978, "Risk Analysis for Ground Failure by Liquefaction," Journal of the Geotechnical Engineering Division, ASCE, Volume 104, No. GT7, Proc. paper 13900, pp. 921-938.
- Youd, T. L. and D. M. Perkins, 1978, "Mapping Liquefaction-Induced Ground Failure Potential," Journal of the Geotechnical Engineering Division, ASCE, Volume 104, No. GT4, Proc. Paper 13659, pp. 433-446.
- Zoback, M. L. and M. Zoback, 1980, State of Stress in the Western United States; U.S.G.S. Open-File Report 80-801, pp. 359-408.



Appendix I

ECONOMIC IMPACT OF REMEDIAL ACTION,
ALTERNATIVE 2

Table of Contents

	<u>Page</u>
I.1 INTRODUCTION.....	I-1
I.2 ZONING.....	I-5
I.2.1 Business (A) district.....	I-5
I.2.2 Light industrial district.....	I-5
I.2.3 Development potential.....	I-7
I.3 MASTER PLAN.....	I-9
I.3.1 Policy plan.....	I-9
I.3.2 Master plan: phase II.....	I-10
I.3.3 Comprehensive master plan.....	I-18
I.3.4 Master policy declaration for annexation.....	I-18
I.3.5 Conclusions.....	I-19
I.4 LAND USE.....	I-21
I.4.1 Historic and current land use.....	I-21
I.4.2 Projected land uses: 1995.....	I-25
I.4.3 Land Use: changes.....	I-25
I.4.4 Conclusions.....	I-26
I.5 ASSESSED VALUATION.....	I-27
I.5.1 Assessed valuation changes: 1940-1982.....	I-27
I.5.2 Permit valuation changes: 1970-1982.....	I-31
I.5.3 Conclusions.....	I-32
I.6 DEMOGRAPHIC DATA.....	I-33
I.6.1 Historic and current data.....	I-33
I.6.2 Projected: 1995.....	I-33
I.6.3 Changes.....	I-37
I.7 LOCAL LAND VALUES.....	I-39
I.8 EMPLOYMENT.....	I-45
I.8.1 Direct employment.....	I-45
I.8.2 Indirect employment.....	I-45
I.9 PUBLIC REVENUES.....	I-47
I.9.1 Property taxes.....	I-47
I.9.2 Other public revenues.....	I-49

Table of Contents - continued

	<u>Page</u>
I.10 CONCLUSIONS.....	I-53
I.10.1 Development potential.....	I-53
I.10.1.1 Zoning.....	I-53
I.10.1.2 Master plan.....	I-53
I.10.1.3 Land use.....	I-53
I.10.1.4 Construction permit activity.....	I-54
I.10.1.5 Demographics.....	I-54
I.10.2 Economic Benefits.....	I-54
I.10.2.1 Property value.....	I-54
I.10.2.2 Employment impacts.....	I-55
I.10.2.3 Public fiscal revenues.....	I-56
Bibliography for Appendix I.....	I-59

List of Figures

	<u>Page</u>
I-1 Vitro tailings site, City of South Salt Lake, Utah regional map.....	I-2
I-2 City of South Salt Lake, zoning district map.....	I-6
I-3 Salt Lake County, census tract/traffic zone map (with insert).....	I-11

List of Tables

		<u>Page</u>
I-1	City of South Salt Lake, estimated absorption of industrial land, 1980-1990.....	I-14
I-2	City of South Salt Lake, estimated industrial construction, 1980-1990.....	I-15
I-3	City of South Salt Lake, estimated building-to-land coverage ratios, 1980-1990.....	I-16
I-4	Salt Lake County, land use conversion data, selected traffic zones, 1970, 1979, 1980 & 1995.....	I-22
I-5	Salt Lake County, land use data -- a percentage distribution, selected traffic zones, 1970, 1979, 1980, & 1995.....	I-24
I-6	City of South Salt Lake, assessed valuation, selected years, 1940-1982.....	I-28
I-7	City of South Salt Lake, building permit activity, commercial/industrial, selected years, 1970-1982.....	I-29
I-8	City of South Salt Lake, building permits and valuations, 1981-1982.....	I-30
I-9	Salt Lake County, demographic data, selected traffic zones, 1970, 1979, 1980 & 1995.....	I-34
I-10	Vitro tailings site, proposed industrial park, estimated property tax revenues, 1983 dollars.....	I-48
I-11	Vitro tailings site, proposed industrial park, estimated income tax revenue, 1983 dollars.....	I-50
I-12	Vitro tailings site, proposed industrial park, summary of annual benefits, 1983 dollars.....	I-58

I.1 INTRODUCTION

This report analyzes the regional economic impact of two remedial action options for stabilizing the uranium mill tailings located on the Vitro site. The alternatives include stabilization of all material at the site or removal of the material to a new disposal site. The Vitro site is a 128-acre inactive uranium processing site in South Salt Lake, Utah. The Vitro Corporation of America operated a uranium ore processing mill and related storage and transportation facilities on an eight-acre portion of the site between May 1951 and January 1964. The site is currently owned by the Central Valley Water Reclamation Facility Board (CVWRF). Figure I-1 is a map of the region. The property is bounded on the south by 3300 South Street; on the west by 900 West Street (and six vicinity properties); on the north by CVWRF's waste-water treatment plant and Mill creek; and on the east by Western Dry Mix and property owned by T. R. Woodrow and R. J. Herring. The waste-water treatment plant occupies approximately 40 acres directly north of the site.

CVWRF's approved Master Plan identifies intended land uses on the Vitro site as follows:

- Mechanical treatment plant: 100 acres.
- Sludge lagoons: 23-32 acres.
- Temporary industrial park: 20-25 acres.
- County resource recovery facility: 16 acres.
- City culinary waterwell site: 1 acre.

CVWRF has stated that it will develop a temporary industrial park (22.5 acres) on the Vitro site's 3300 South Street frontage property if tailings removal is the adopted remedial action. Based on this assertion, this report estimates the gross economic benefits that might result from the development of an industrial park on the site. CVWRF has not stated the time period during which it expects the temporary industrial park to operate. However, the following discussion of long-term expansion requirements at CVWRF's waste-water treatment facility appears on pages 1-2 of Final Report, 201 Facilities Plan, Central Valley Water Reclamation Facility Board, February 1982, Coon, King and Knowlton; and Brown and Caldwell; "First-stage construction of the Central Valley WRF will expand the existing capacity of the District 1 plant, which has an average annual daily flow of 17 million gallons per day (mgd), to its projected year 2005 flow of 50 mgd." This suggests that the temporary industrial park could operate until construction for the post-2005 expansion began. Based on the following assumptions a 13 year life is estimated for CVWRF's temporary industrial park.

Removal of the tailings to South Clive is assumed to be the adopted remedial action.

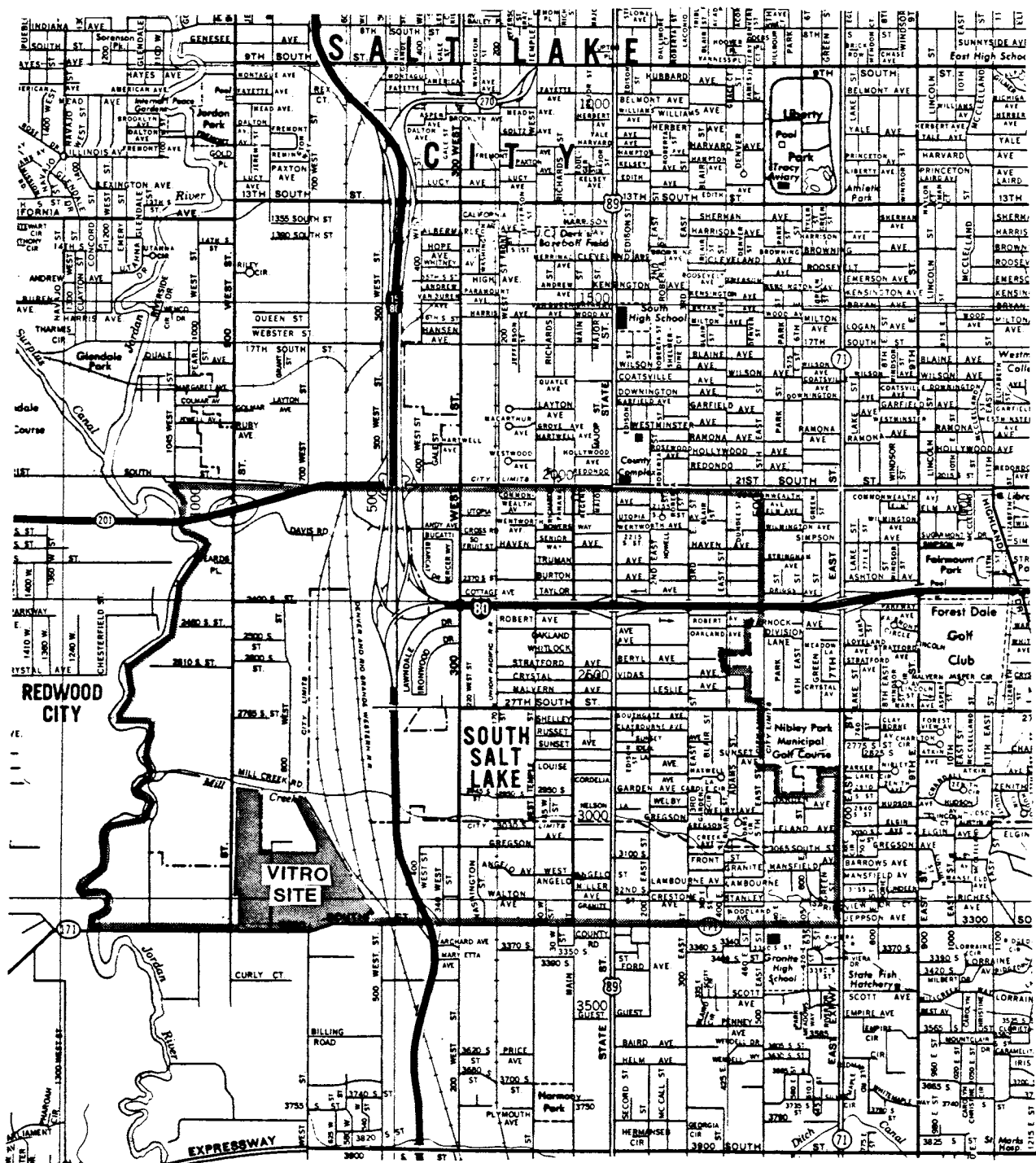


FIGURE I-1
VITRO TAILINGS SITE, CITY OF SOUTH SALT LAKE, UTAH,
REGIONAL MAP

- A three-year clean-up period ending December 1986.
- Occupancy of the temporary industrial park beginning January 1988.
- A five-year construction period for the expansion of CVWRF's waste-water treatment facility to 100 mgd.
- Operational start-up of the 100 mgd facility beginning January 2006.

The economic impacts will be delineated in terms of the regional economy.

The balance of this report will address the following areas: (1) zoning; (2) master plan; (3) land use; (4) assessed valuation; (5) demographics; (6) employment; (7) local land values; (8) public revenues; and (9) conclusions. The relationship among these parameters and their uses in deriving an estimate of regional economic benefits are summarized below.

- Zoning

The zoning designations of the Vitro site will be identified in order to determine if CVWRF's proposed land uses are consistent with the site's current zoning.

- Master plan

The City of South Salt Lake's Master Plan will be analyzed in terms of the City's prospective commercial and industrial development. The analysis will focus on the salient determinants of South Salt Lake's future growth as set forth in the City's Master Plan.

- Land use

Data on land use conversion and projections of future land use will be evaluated in order to identify likely geographic areas for commercial and industrial development.

- Assessed valuation

Data on assessed valuation for South Salt Lake will be analyzed in order to identify trends in the annual rate of change in assessed valuation. In addition, the analysis will focus on commercial and industrial construction permits as indicators of commercial and industrial growth.

- Demographic data

Data on population, employment, dwelling units, cars, and commercial floor space will be analyzed in order to characterize the demography of the 3.6 square mile area surrounding the Vitro site. Historic information, as well as projections, will be considered.

- Local land values

The current market value of the 3300 South Street frontage property will be estimated based on: (1) appraisal reports; (2) the highest and best use of the land; (3) the asking price for comparable adjacent property; and (4) a recent transaction involving the property.

- Employment

The direct and indirect employment impacts of the proposed industrial park will be estimated. The after-tax wages of these employees will constitute the bulk of the region's estimated economic benefits.

- Public revenues

The estimates of public revenues will be based on an estimate of the industrial park's assessed valuation and the number of direct and indirect jobs created by its development.

I.2 ZONING

This section considers the zoning of the Vitro site in terms of its effects on the development of the property. These effects will be delineated in terms of limitations on the types of possible development, as well as uses permitted under the code. Figure I-2 is a copy of the City of South Salt Lake's Zoning District Map.

I.2.1 Business (A) district

The portion of the site which abuts 3300 South Street is zoned Business (A) District to a depth of approximately 750 feet. The purpose of a Business (A) District is to "...promote high quality, well-designed business, office, and retail establishments." (City of South Salt Lake, Title Fifteen, Zoning and Land Use, Chapter 20, page 20-1.) In a Business (A) District, those uses consistent with any of the City's residential zoning designations (R-1, R-1A, R-1B and R-M) or the professional office designation (P-O) are permitted. The following is a summary of other permitted uses. (For a complete listing of permitted land uses, see City of South Salt Lake, Title Fifteen, Zoning and Land Use.)

- Office buildings.
- Food stores.
- Retail.
- Restaurants.
- Gasoline service station.
- Hotels and motels.
- Vehicle sales.
- Commercial amusement places.

In addition, there is a minimum lot size of 6,000 square feet and a maximum building height of 40 feet.

I.2.2 Light industrial district

The balance of the site is zoned Light Industrial District. With the exception of two parcels in the southwest corner of the City, which are zoned Agricultural A-1 and Professional Office (see Figure I-2), and the 3300 South Street frontage portion of the Vitro site, all of South Salt Lake west of I-15 is zoned Light Industrial.

The purpose of a Light Industrial District is to "... provide areas in appropriate locations where warehousing and industrial processes not producing objectionable effects may be established, maintained, and protected." (City of South Salt Lake, Title Fifteen, Zoning and Land Use, Chapter 24, page 24-1.) With the exception of residential uses (zoning designations R-1, R-1A, R-1B, R-S and R-M) and mixed use (zoning designation Mixed), any use permitted in the City's zoning ordinances is permitted in a Light Industrial District. It should be noted that any heavy industrial use is prohibited within the City of South Salt Lake. The following is a brief summary of permitted uses. (For a complete listing of permitted uses, see City of South Salt Lake, Title Fifteen, Zoning and Land Use.)

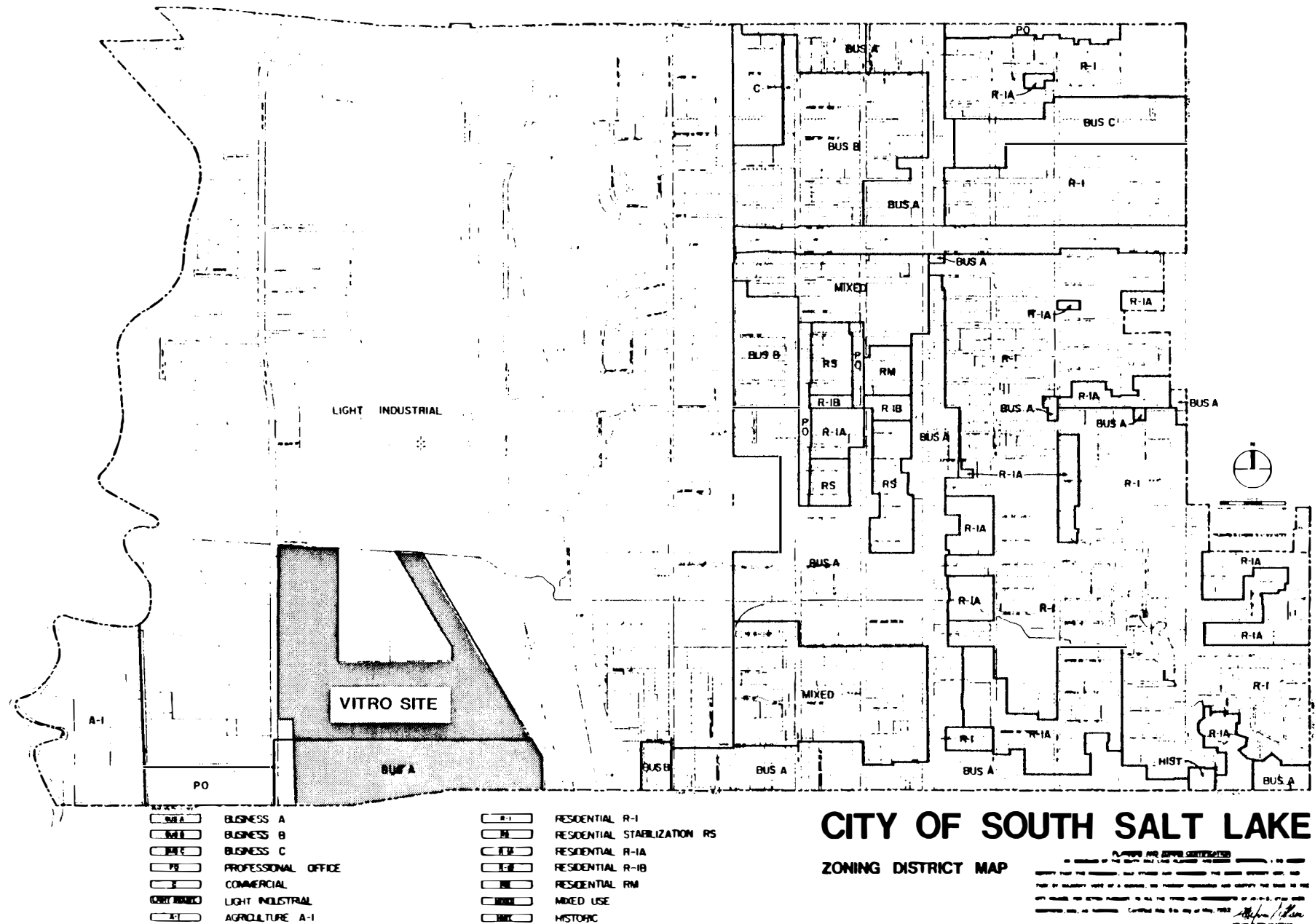


FIGURE I-2. CITY OF SOUTH SALT LAKE, ZONING DISTRICT MAP

- Automobile sales.
- Boiler works.
- Breweries.
- Incinerator.
- Manufacturing.
- Office.
- Service station.
- Warehouse and storage.

There is a setback requirement of 40 to 50 feet in the front. There also is a 20-foot setback requirement for adjacent lots used for parking.

I.2.3 Development potential

Title Fifteen, Zoning and Land Use (City of South Salt Lake) characterizes the uses permitted in a Business (A) District as "limited business and neighborhood shopping" (City of South Salt Lake, Title Fifteen, Zoning and Land Use, Chapter 10, page 10-1). As previously noted, permitted land uses in this District include office buildings, restaurants, hotels, and a variety of retail operations. It should be noted that the 3300 South frontage parcel is the only Business A zoned land west of I-15 in the City of South Salt Lake. Therefore, based on its current zoning, this parcel could be developed for a variety of business, office, and retail uses. However, the permitted uses do not include industrial parks. While this use would be permitted in a Light Industrial District, it is inconsistent with the property's current Business A zoning.

The balance of the Vitro site, which is zoned Light Industrial, can be developed for almost any non-residential or non-heavy industrial use possible.

As previously noted, the development of an industrial park is inconsistent with the 3300 South frontage property's current zoning. In addition, it would appear that, based on existing land uses on adjacent properties and the presence of the waste-water treatment facility, development consistent with a Business A zoning (e.g., office buildings, restaurants, motels) is unlikely. Therefore, a rezoning of the property to Light Industrial to accommodate CVWRF's proposed industrial park seems likely.

I.3 MASTER PLAN

This section is a review of the City of South Salt Lake's Master Plan. The purpose of this review is to analyze the City's goals and expectations with regard to economic growth and industrial and commercial development.

The City of South Salt Lake conducted its master planning process in three phases. The resulting documents and the relationship among the various phases are set forth below.

Phase 1: City of South Salt Lake Policy Plan (no date)

The purpose of Phase I was "to develop an adequate and reliable data base from which problem areas could be defined and quantified for use in subsequent phases in developing the comprehensive plan."

Phase 2: South Salt Lake City Master Plan Phase II, June 1980

The purpose of Phase II was "to analyze the inventory of data that was gathered during Phase I, and identify in quantifiable terms existing trends, problem areas, and strengths of the city.... to recommend goals and objectives for the various alternative futures that exist in the areas of economic development, housing, zoning and land management, code enforcement, transportation facilities, civic pride, and recreational development."

Phase 3: City of South Salt Lake Comprehensive Master Plan, June 1981

Phase III reports on the policies, strategies and procedures that were established in order to achieve the goals and objectives derived in Phase II.

The balance of this section will be devoted to an analysis of those elements of the master planning process which affect economic development in general and development alternatives for the Vitro site in particular.

I.3.1 Policy plan

In the report, it is suggested that a market study be completed in order to determine the City's "potential for attracting or not attracting certain types of businesses." In that regard, the Report notes that the lifting of the Utah Department of Health's ban on development near the Vitro site has resulted in development of a 25-acre industrial park on the old KCPX radio station property by HOMCO Development Co. The property is across 900 West Street from the Vitro site. However, the property was recently sold to the Utah State Retirement Fund (USRF) and is again being offered for sale. A spokesperson for the USRF stated that its proximity to the Vitro site had not affected its value (Blackburn, 1983).

The report states "...there still remains large undeveloped areas for commercial and industrial development particularly in the recently annexed area south of Mill Creek and West of I-15." Although the information is somewhat out-of-date, Table IX, Privately Owned Vacant Land, April 1979 is reproduced below from the Policy Plan.

Zoning	Area	
	(square feet)	(acres)
Residential A	199,260	4.6
Residential B	66,991	1.5
Business A	122,670	2.8
Business B	220,240	5.1
Commercial	21,512	0.5
Industrial	12,244,338	281.1
Agricultural	<u>1,029,000</u>	<u>23.6</u>
Total	13,904,011	319.2

These figures appear to include the portion of the Vitro site, which is currently zoned Business A, in the industrial category.

The report characterizes South Salt Lake as becoming an increasingly significant center of "heavy commerce," which includes sales of automobiles, recreational vehicles and large appliances. This is in addition to its traditional manufacturing and wholesaling roles. However, it warns of "impacts on the City cost pattern, demanding participatory expenditures for the cleaning up of heavy commerce areas, more rigorous and effective buffering between potentially conflicting uses, and increased attention to traffic control and flow."

I.3.2 Master plan: phase II

This report focuses on the section titled Forecast of Economic Conditions in South Salt Lake City. This section includes discussions of industrial and wholesaling growth potential in South Salt Lake, demand for office space in South Salt Lake and the City's future retailing role.

The first area to be addressed is a study of the absorption potential of vacant land zoned for industrial use in South Salt Lake. It should be noted that based on discussions between the authors of the report and the principals of the engineering firm of Coon, King and Knowlton, 70 acres associated with the old Vitro operation were excluded from the study. It is assumed that this is separate from the frontage property along 3300 South, since CVWRF did not purchase the property until 1981.

The report presents annual estimates of the absorption of vacant land zoned for industrial use, industrial construction activity and building-to-land coverage ratios for 1980-1990. With the exception of estimated building-to-land coverage ratios, data are shown individually for traffic zones 328, 329, and 351 and as an aggregate for the rest of South Salt Lake. The estimated building-to-land coverage ratios are shown individually for traffic zones 328 and 329 and as an aggregate for the rest of South Salt Lake. Traffic zones 328, 329, and 351 are part of census tract 116. Traffic zone 328 is north of CVWRF's waste-water treatment facility, traffic zone 329 includes the Vitro site, and traffic zone 351 is east of I-15 and north of 3300 South Street. Figure I-3 is a map of the area and indicates the locations of the above traffic zones.

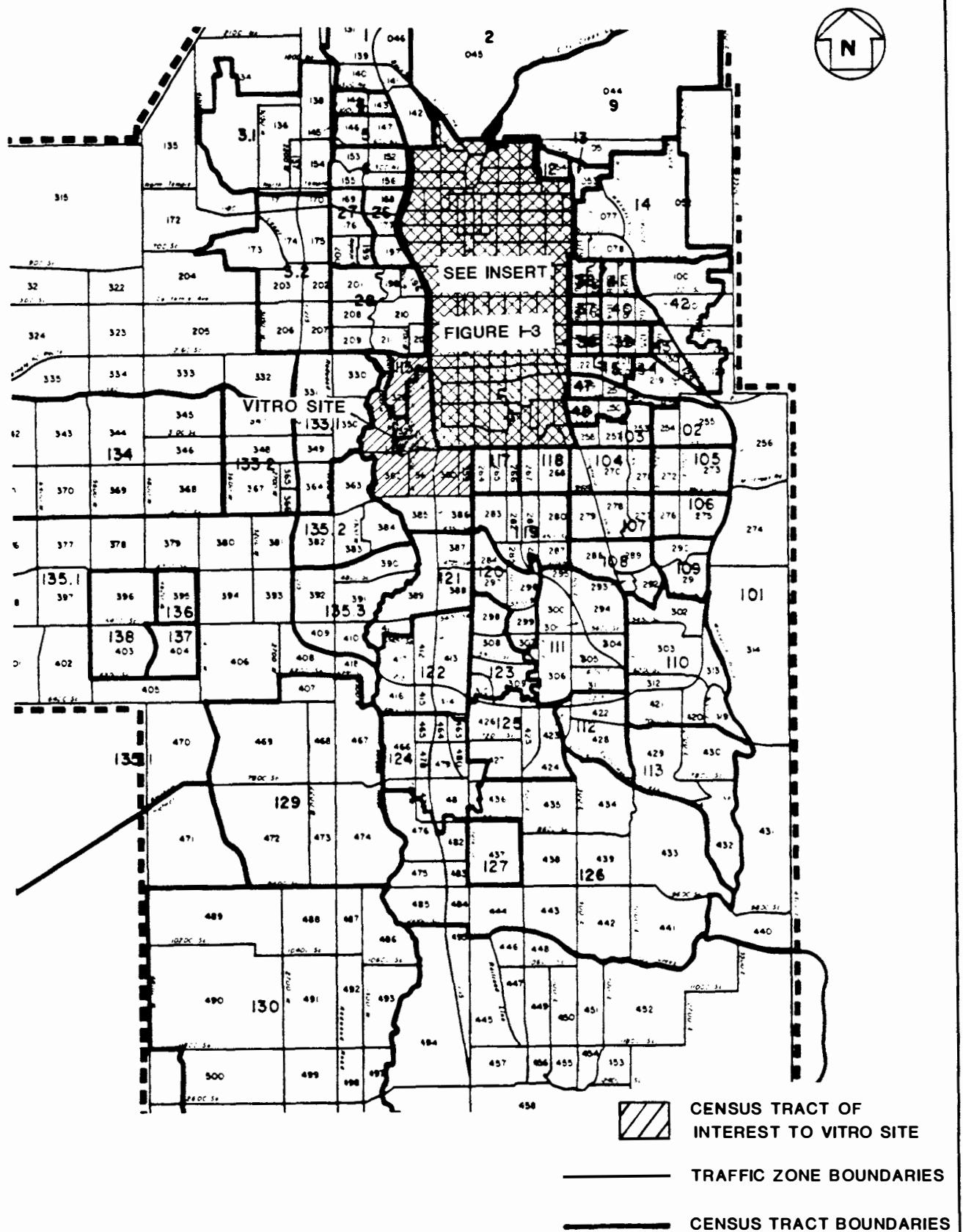


FIGURE I-3
SALT LAKE COUNTY, CENSUS TRACT/TRAFFIC ZONE MAP

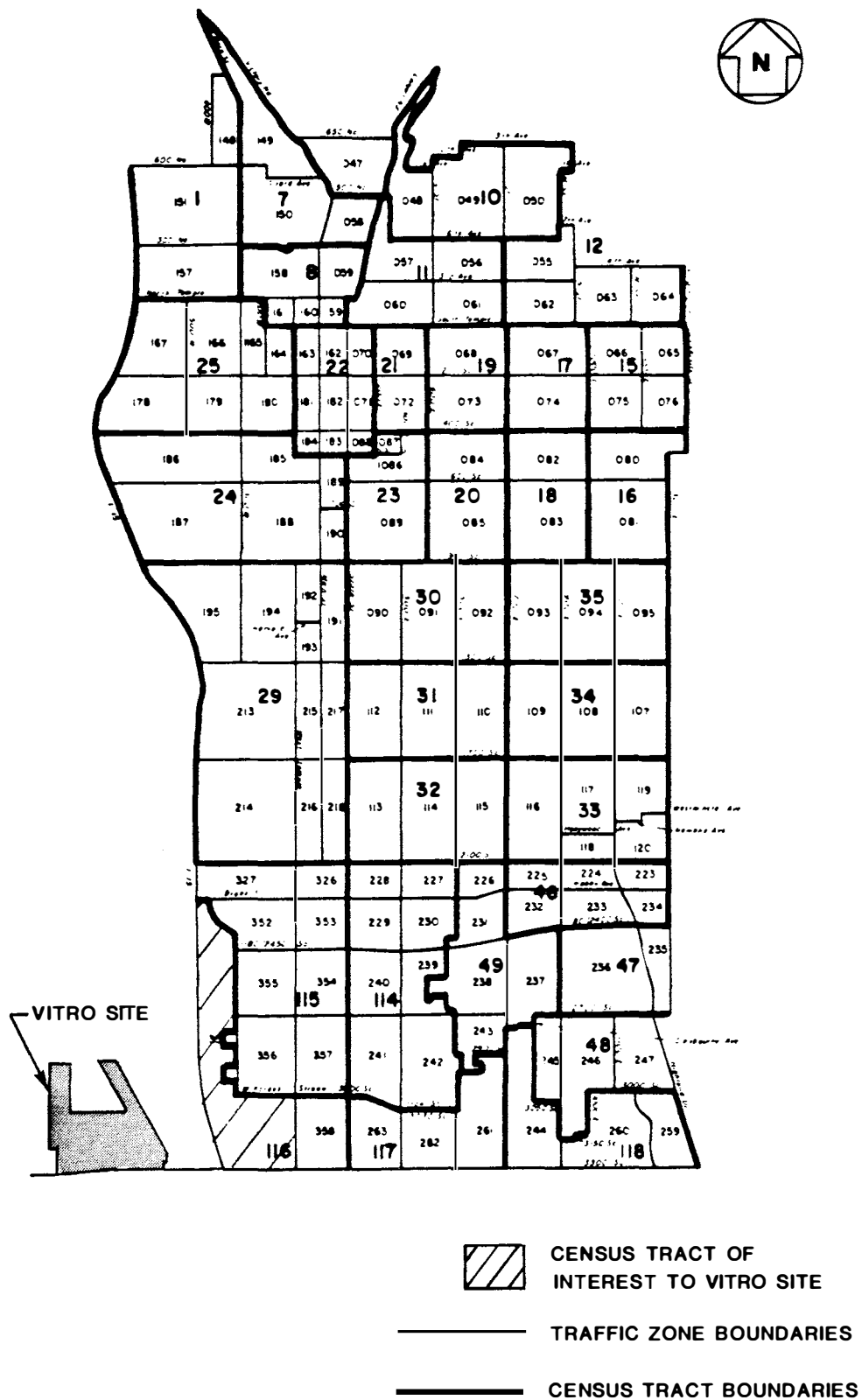


FIGURE I-3
SALT LAKE COUNTY, CENSUS TRACT/TRAFFIC ZONE MAP
(INSERT)

It is estimated that given a healthy regional economy, approximately 84.0 percent of the available industrial acreage will be absorbed by 1990. This scenario assumes that the following "major economic stimuli" occur:

- Deployment of the MX missile system in western Utah.
- Increased extraction of coal reserves in Utah's Overthrust Belt.
- Continued development of statewide water and power projects.

This set of assumptions leads to the "high estimate" for the absorption of industrial land in the City. Table I-1 sets forth projected data on the absorption of industrial land, for selected traffic zones, and the rest of South Salt Lake for the period 1980-1990. Table I-1 also includes a "low estimate" for the absorption of industrial land. These data assume a moderate national and/or regional recession with "cyclical upturns and downturns," during the study period. Under this scenario, 58.0 percent of the available land will be absorbed by 1990.

With regard to future development, the report states "the bulk of new construction (about 70 percent) is expected to be in built-to-suit, rather than integrated speculative developments. This construction will also be comparatively disparate and fragmented, rather than being integrally designed industrial parks...." The HOMCO Development Co. project on 3300 South and the Marketplace Square project west of 900 West are mentioned as possible exceptions. However, neither project is currently being developed. In addition, HOMCO's property on 3300 South was recently sold to the Utah State Retirement Fund, which placed it on the market early this year. The report estimates that future development will result in the following types of land uses.

- Wholesaling, distribution and storage functions: 70.0 percent.
- Industrial use: 16.0 percent.
- Retailing, office and service purposes: 14.0 percent.

The report justifies the above land use scenario, in part, on the basis of the image of the City's west side. It is characterized as having "transportation and other advantages" which render the area prime. However, the report concludes that firms which require prestigious locations would not choose a site in the area. In addition, the report states that "the building of the regional sewage treatment plant will negatively impact the quality of development that will occur in the lands adjacent to it."

The report provides low and high estimates of commercial construction, as shown in Table I-2. These data are based on the projected absorption of industrial acreage in Table I-2 and projected building-to-land coverage ratios, which are shown in Table I-3. The increasing average ratios for traffic zones 328 and 329 reflect "the decreasing availability of larger contiguous tracts of land which are attractive to land extensive facilities with a need for large amounts of exterior storage area." (Land extensive facilities are facilities with low building-to-land coverage ratios.) The assumption is that large parcels will be absorbed early in the period and that the remaining land will be "more suitable for building extensive operations with higher coverage ratios." (Building extensive operations are facilities with high building-to-land coverage ratios.)

Table I-1. City of South Salt Lake estimated absorption of industrial land (acres)

1980-1990

Year	Traffic zone						All others		Total	
	328		329		351					
	High	Low	High	Low	High	Low	High	Low	High	Low
1980	9.28	9.28	21.52	21.52	2.5	1.67	1.23	.55	34.53	33.02
1981	5.27	1.76	24.27	11.77	3.7	1.55	1.07	.52	34.31	15.60
1982	4.48	1.67	20.40	10.80	3.06	1.44	.93	.48	28.86	14.39
1983	3.81	1.59	17.30	10.00	2.53	1.34	.80	.46	24.44	13.39
1984	3.24	1.50	14.60	9.30	2.09	1.25	.69	.43	20.62	12.48
1985	2.75	1.43	12.40	8.60	1.73	1.16	.60	.41	17.48	11.60
1986	2.34	1.36	10.40	7.90	1.42	1.08	.52	.38	14.68	10.72
1987	1.99	1.29	8.80	7.40	1.18	1.00	.45	.36	12.42	10.05
1988	1.69	1.23	7.50	6.70	.97	.93	.39	.33	10.55	9.19
1989	1.44	1.17	6.30	6.30	.80	.87	.33	.31	8.54	8.65
1990	<u>1.22</u>	<u>1.11</u>	<u>5.30</u>	<u>5.80</u>	<u>.66</u>	<u>.81</u>	<u>.29</u>	<u>.29</u>	<u>7.47</u>	<u>8.01</u>
Total	38.19	24.07	148.79	106.09	20.65	13.10	7.29	4.52	214.92	147.78
Percent absorbed										
1990	84.7%	53.4%	83.7%	59.7%	86.8%	55.0%	79.7%	49.4%	84.2%	57.9%

Source: South Salt Lake City Master Plan, Phase II, June 1980

Note: Detail may not add to total due to rounding.

Table I-2. City of South Salt Lake estimated industrial construction
(thousands of square feet)

1980-1990

Year	Traffic zone						All others		Total	
	328		329		351					
	High	Low	High	Low	High	Low	High	Low	High	Low
1980	69.9	69.9	162.2	162.2	43.3	28.9	21.3	9.5	296.7	270.5
1981	48.3	16.1	222.5	107.9	64.1	26.9	18.6	9.0	353.5	159.9
1982	48.4	17.0	220.4	109.6	53.1	25.0	16.0	8.3	337.9	159.9
1983	51.1	17.2	232.1	108.0	43.9	23.2	13.9	8.0	341.0	156.4
1984	47.7	16.2	215.0	100.5	36.2	21.7	12.0	7.5	310.7	145.9
1985	43.2	15.4	194.7	92.9	30.0	20.1	10.4	7.1	278.3	135.5
1986	40.6	14.7	180.3	85.3	24.6	18.7	9.0	6.6	254.5	125.3
1987	34.5	13.9	152.6	79.9	20.4	17.3	7.8	6.2	215.3	117.3
1988	29.3	13.3	130.0	72.4	16.8	16.1	6.8	5.8	182.9	107.6
1989	25.0	12.6	109.2	68.1	13.8	15.1	5.7	5.3	153.8	101.1
1990	21.1	12.0	91.9	62.7	11.4	14.0	5.0	5.0	129.5	93.7
Total	459.1	218.3	1,910.9	1,049.5	357.6	227.0	126.5	78.3	2,854.1	1,573.1

Source: South Salt Lake City Master Plan, Phase II, June 1980.

Table I-3. City of South Salt Lake estimated building-to-land coverage ratios
1980-1990

Healthy economic conditions											
Traffic Zone	Year										
	1980	81	82	83	84	85	86	87	88	89	90
328 & 329	.15	.20	.25	.33	.37	.40	.45	.45	.45	.45	.45
All others	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45

Sluggish economic conditions											
Traffic Zone	Year										
	1980	81	82	83	84	85	86	87	88	89	90
328 & 329	.15	.20	.23	.25	.25	.25	.25	.25	.25	.25	.25
All others	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45

Source: South Salt Lake City Master Plan, Phase II, June 1980.

The report includes an estimate of South Salt Lake's share of office space growth in Salt Lake County between 1980 and 1985. The estimate is based on the following assumptions:

1. Salt Lake County population growth of 84,064.
2. 85 office employees per 1,000 of population.
3. 210 square feet of office space per employee.
4. South Salt Lake's annual share of the growth in office space will be between seven and 13.5 percent.

Based on the above, it is estimated that South Salt Lake's share of total growth will be between 115,600 square feet and 173,000 square feet.

The report also addresses the future of retailing activity in South Salt Lake City. It divides the City's retail structure into three areas.

- Convenience goods.
- Shopping goods.
- General purchases.

Convenience goods are the most frequently purchased types of goods. The amount of purchasing power found in the local area is the key to success in this type of retailing. The report concludes that "... it is extremely doubtful whether additional facilities are warranted either now or in the near future." This is attributed to the declining city population and the fact that the area's income is lower than the regional average. However, the development of some retail space along 900 West to serve the local work force was mentioned as a possibility.

With regard to retail shopping, South Salt Lake is characterized as being "at a distinct disadvantage in any attempt to increase its share of the market for these goods." This is due to the "transient nature of State Street traffic" and the lack of existing or planned shopping centers supplying this level of goods. However, the City appears to be in a relatively good position with regard to general purchases or "heavy commerce retailing." Retail businesses which require large, plain buildings and large outside storage areas, but do not need presituous locations, will contribute to growth in the west and southwest portions of the City.

The section of the report that deals with land use trends contains the following observations regarding the potential for commercial and industrial development in South Salt Lake City.

Eighty-two percent of the remaining developable industrial land will be absorbed by 1990. As previously noted, the section on economic conditions projects that 58.0 percent (low estimate) to 84.0 percent (high estimate) of the available industrial acreage will be absorbed by 1990.

The City is in a disadvantageous position with regard to commercial development due to the area's low average income, minimal purchasing power, and lack of population growth.

- It is doubtful that any significant growth in shopper's goods will occur due to the area's proximity to Salt Lake City's central business district and Murray City.
- South Salt Lake does not attract businesses looking for a prestigious location due to the area's image and its environmental character.
- Very little growth in office space is forecast due to the lack of large suitably located parcels, the mix of industrial uses in the area and the proximity to Salt Lake City and Murray City.

I.3.3 Comprehensive master plan

The Land Use Master Plan, which is part of the Comprehensive Master Plan, is intended to "provide an overall guide to aid in the City's land management functions."

The Land Use Master Plan focuses on the need for single-family, attached, owner-occupied housing in the City (e.g., townhomes). However, it does indicate that "the City will continue its long history of encouraging quality industrial, warehousing, and distribution development west of the O.S.L. Railroad." O.S.L. refers to Union Pacific's Oregon Short Line, which is located west of I-15 at about 140 West.

I.3.4 Master policy declaration for annexation for South Salt Lake City, Utah, January 1980

Pursuant to the Utah Boundary Commission Act of 1979 (HB 61), the City of South Salt Lake has prepared a declaration of policy regarding future annexations to the City. The conditions under which an area may qualify for annexation are summarized below. (See City of South Salt Lake, Statement of Annexation Criteria, Standards, for a complete discussion.)

- The area must be contiguous to the boundaries of South Salt Lake City.
- The area must be identified in the policy declaration statement.
- With certain exceptions, the area can not be within the boundaries of another incorporated municipality.
- The net fiscal effect on municipal services entities displaced by the annexation shall be approximately zero.
- The annexation shall not be for the purpose of acquiring municipal revenues without providing municipal services.

One of the areas identified for possible annexation, Area 1A, extends south from 3300 South Street to 3900 South Street and west from 700 East Street to the Jordan River. This area includes traffic zones 359, 360, 361 and 362 in census tract 116 and traffic zones 264, 265 and 266 in census tract

117. The area contains approximately 1,537 acres with an assessed valuation of \$29.7 million (1977).

Salient demographic and land use data are summarized below.

• population acres	6,059
• dwelling units	2,454
• employment	7,174
• residential acres	335
• commercial acres	169
• industrial acres	218
• agricultural acres	228
• vacant acres	214

Source: Wasatch Front Regional Council, Surveillance of Land Use and Socio-Economic Characteristics 1970, 1979, 1980 and 1995, Surveillance Report, Volume 2, Number 7, April 1982.

I.3.5 Conclusions

In general, the Master Plan characterizes the City of South Salt Lake as being unlikely to experience significant growth in commercial development, shopper's goods, or office space. This is attributed to a declining population and low average income (and, consequently, low purchasing power). The City also is characterized as being at a competitive disadvantage compared to Salt Lake City and Murray City. The Master Plan identifies a target type of firm for business growth in South Salt Lake City -- a business which requires a large plain building with extensive outside storage, but does not require a prestigious location. This is consistent with the area's development as a location for warehousing, distribution, and wholesaling activities.

The Master Plan includes estimates of the annual absorption rate of vacant land zoned for industrial uses in traffic zone 329. Annual absorption ranges from 5.3 acres to 24.3 acres, depending on the year and the underlying economic assumptions. For the period 1980-1990, the average annual absorption rates for the high and low estimates are 13.5 acres and 9.6 acres, respectively. In addition, it is projected that approximately 70.0 percent of the vacant industrial land absorbed in the City between 1980 and 1990 will be in traffic zone 329. Therefore, the City has identified traffic zone 329 and, therefore, the 3300 South Street frontage property as a prime area for industrial growth during this decade.

I.4 LAND USE

Land use in the vicinity of the Vitro site will be characterized by reference to data developed by the Wasatch Front Regional Council (WFRC). These data are published in Surveillance of Land Use and Socio-Economic Characteristics, 1970, 1979, 1980 and 1995, Surveillance Report Vol. 2 No. 7, April 1982. Data are available by traffic zone, as well as census tract, for the following types of land use:

- Agricultural.
- Commercial.
- Industrial.
- Institutional.
- Parks and recreation.
- Residential.
- Transportation.
- Utilities.
- Vacant.

Portions of two census tracts have been selected in order to evaluate changes in land use in the vicinity of the Vitro site. These include traffic zone 328, which is part of census tract 115, and traffic zones 329, 351, 360, 361 and 362, which are part of census tract 116. The area encompassed by these traffic zones is approximately 3.6 square miles. (See Figure I-3.)

Traffic zone 328 is north of the waste-water treatment facility; traffic zone 329 includes the Vitro site, as well as Central Valley's facility, traffic zone 351 is east of I-15 and north of 3300 South Street; and traffic zones 360, 361 and 362 are south of the Vitro site and abut 3300 South. Traffic zones 360-362 also are in the unincorporated portion of Salt Lake County. Table I-4 sets forth data on land use for the traffic zones noted above. Table I-5 summarizes these data in a percentage distribution.

I.4.1 Historic and current land use

"Agricultural," "Vacant," and "Other" land uses accounted for almost 80.0 percent of area land use in 1970. This included approximately 460 acres of vacant land in traffic zones 328 and 329, as well as 237 acres of transportation right-of-ways in zone 329. In addition, it includes over 200 acres of agricultural land in traffic zone 362.

Current land use, which is based on 1980 data, is about 70.0 percent "Agricultural," "Vacant," and "Other". Vacant land in traffic zones 328 and 329 stands at 455 acres. This corresponds to approximately 40.0 percent of the land in these two traffic zones. There also are about 180 acres of transportation right-of-ways in zone 329 and slightly less than 200 agricultural acres in zone 362.

Table I-4. Salt Lake County land use conversion data
selected traffic zones
(acres)

1970, 1979, 1980, 1995

Census tract/traffic zone	Land use	1970	1979	1980	1995
116/329	Agricultural	101.4	92.8	89.5	52.8
	Commercial	5.0	7.9	7.9	15.0
	Industrial	87.9	101.5	101.5	265.0
	Residential	17.0	7.3	7.3	5.0
	Vacant	311.7	388.7	355.9	132.5
	Other	<u>290.6</u>	<u>215.4</u>	<u>218.7</u>	<u>343.3</u>
	Total	<u>813.6</u>	<u>813.6</u>	<u>780.8</u>	<u>813.6</u>
116/361	Agricultural	81.2	7.6	7.6	---
	Commercial	38.9	11.2	13.2	20.0
	Industrial	23.9	115.8	114.2	130.0
	Residential	23.5	23.1	23.1	50.0
	Vacant	45.3	46.6	47.7	0.0
	Other	<u>45.0</u>	<u>53.5</u>	<u>53.5</u>	<u>57.8</u>
	Total	<u>257.8</u>	<u>257.8</u>	<u>259.3</u>	<u>257.8</u>
116/362	Agricultural	214.7	229.4	196.8	80.1
	Commercial	2.7	1.3	1.3	25.0
	Industrial	0.0	6.8	6.8	67.0
	Residential	20.2	12.4	12.2	52.4
	Vacant	76.7	52.3	69.7	12.0
	Other	<u>18.0</u>	<u>30.1</u>	<u>62.9</u>	<u>95.8</u>
	Total	<u>332.3</u>	<u>332.3</u>	<u>349.7</u>	<u>332.3</u>
116/351	Agricultural	24.3	5.6	4.7	8.0
	Commercial	32.8	55.0	56.0	60.3
	Industrial	14.2	33.9	35.5	55.0
	Residential	48.8	38.0	37.0	24.7
	Vacant	61.7	27.5	24.5	10.0
	Other	<u>78.4</u>	<u>100.2</u>	<u>100.2</u>	<u>102.2</u>
	Total	<u>260.2</u>	<u>260.2</u>	<u>257.9</u>	<u>260.2</u>
116/360	Agricultural	59.7	13.1	13.1	0.0
	Commercial	37.4	35.6	36.6	60.0
	Industrial	12.6	77.9	78.0	95.0
	Residential	46.5	33.1	32.3	30.0
	Vacant	44.7	32.3	34.2	6.6
	Other	<u>50.3</u>	<u>59.2</u>	<u>59.2</u>	<u>59.6</u>
	Total	<u>251.2</u>	<u>251.2</u>	<u>253.4</u>	<u>251.2</u>

TABLE I-4 Continued

Census tract/traffic zone	Land use	1970	1979	1980	1995
116/328	Agricultural	0.0	0.0	0.0	0.0
	Commercial	10.5	8.3	8.5	15.0
	Industrial	55.6	119.7	126.7	156.8
	Residential	0.0	0.0	0.3	0.0
	Vacant	148.1	94.2	99.4	45.8
	Other	<u>148.1</u>	<u>140.1</u>	<u>140.1</u>	<u>144.7</u>
	Total	<u>362.3</u>	<u>362.3</u>	<u>375.0</u>	<u>362.3</u>
Total	Agricultural	481.3	348.5	311.7	140.9
	Commercial	127.3	119.3	123.5	195.3
	Industrial	194.2	455.6	462.7	768.8
	Residential	156.0	113.9	112.2	162.1
	Vacant	688.2	641.6	631.4	206.9
	Other	<u>630.4</u>	<u>598.5</u>	<u>634.6</u>	<u>803.4</u>
	Total	<u>2,277.4</u>	<u>2,277.4</u>	<u>2,276.1</u>	<u>2,277.4</u>

Note: Data are updated using building permits. Forecast data for 1995 are based on 1970 to 1976 land use data and are no longer accurate for traffic zones which have experienced rapid growth since 1976.

Agricultural: Agricultural production.

Commercial: Retail trade or services.

Industrial: Manufacturing, processing, or wholesale trade.

Residential: Residential uses.

Other:

Transportation: Land within the boundaries or right-of-way of railroads, pipelines, or streets and highways.

Institutional: Public buildings, educational institutions, prisons, military bases, and other special public uses.

Utilities: Gas, electric, water, or sewer utility purposes.

Parks and Recreation: Parks and recreational uses such as golf courses (cemeteries are attached to this category).

Source: Wasatch Front Regional Council, Surveillance of Land Use and Socio-Economic Characteristics 1970, 1979, 1980 & 1995, Surveillance Report, Volume 2, April 1982.

Table I-5. Salt Lake County land use data -- a percentage distribution
selected traffic zones

1970, 1979, 1980 & 1995

	Land use	1970	1979	1980	1995
Traffic Zones					
328, 329, 351, 360,					
361, & 362					
	Agricultural	21.1%	15.3%	13.7%	6.2%
	Commercial	5.6	5.2	5.4	8.6
	Industrial	8.5	20.0	20.3	33.8
	Residential	6.8	5.0	4.9	7.1
	Vacant	30.2	28.2	27.7	9.1
	Other	<u>27.7</u>	<u>26.3</u>	<u>27.9</u>	<u>35.3</u>
	Total	100.0	100.0	100.0	100.0

Note: Detail may not add to total due to rounding.

1980 data are calculated based on 2,276.1 acres; all other year's data are based on 2,277.4 acres.

I.4.2 Projected land uses: 1995

The projections of area land use shown on Table I-5 were developed by the WFRRC. These data suggest that about one-half of the area's total acreage will still be vacant or devoted to "Agricultural" and "Other" uses in 1995. However, "Agricultural" land use is projected to decrease to approximately 6.2 percent of total land use, as compared to 15.3 percent in 1979. In addition, more than one-third of area land use is projected to be "Industrial" by 1995. Industrial land use in the area stood at 20.0 percent in 1979.

I.4.3 Land use: changes

The net effect of land use conversion between 1970 and 1979 in the vicinity of the Vitro site was a shift from "Agricultural" to "Industrial" land use. There also was a minor shift from "Residential," "Other," and "Vacant" land uses to "Industrial" land use. With regard to individual traffic zones, the following observations can be made:

- Traffic zone 329

Vacant land and land devoted to other uses remained constant at approximately 600 acres. Commercial and industrial land uses increased approximately 18.0 percent, while agricultural and residential land uses decreased by about 15.0 percent.

- Traffic zone 361

Residential, vacant, and other land uses increased by less than 10.0 percent. However, industrial land use increased by 91.9 acres or 385.0 percent. Agricultural and commercial land use decreased by approximately 90.0 percent and 70.0 percent, respectively.

- Traffic zone 362

Land use changes in this traffic zone were relatively minor. They included the development of 6.8 acres of industrial land, a small increase in agricultural land use and relatively small decreases in commercial and residential acreage, as well as vacant land. Industrial land use in 1970 was zero.

- Traffic Zone 351

Agricultural land use was down from 24.3 acres to 5.6 acres, while combined commercial and industrial land use increased from 47.0 acres to 88.9 acres. In addition, residential and vacant land use decreased.

- Traffic zone 360

Residential and agricultural land use decreased 60.0 acres, while industrial land use increased 65.3 acres. Other land uses remained relatively constant (unchanged).

Traffic zone 328

Agricultural land use remained zero. Industrial land use increased 64.1 acres and vacant land decreased 53.9 acres. All other land uses remained, for the most part unchanged.

Land use changes projected to occur through 1995 will result in reductions in agricultural land use and vacant land of 207.6 acres and 434.7 acres, respectively. The majority of these changes are projected to be 313.2 acres of industrial development. In addition, an increase in other land uses of 204.9 acres is projected; this includes an 85.0-acre increase in park and recreational land use in traffic zones 329 and 362, a 53.5-acre increase in utility land use in zone 329 and a 29.4-acre increase in transportation-related land use also in traffic zone 329.

During the period 1970-1979, industrial land use in the six-traffic-zone analysis area increased at an average rate of 29.0 acres per year. Data developed by the WFRC projected 313.2 acres of additional industrial development by the year 1995. This corresponds to an increase of 19.6 acres per year in industrial land use. Commercial land use in the six traffic zones decreased by eight acres between 1970 and 1979. However, data developed by the WFRC project a modest growth in commercial land use of four and one-half to five acres per year through 1995.

I.4.4 Conclusions

The land use data projected for traffic zone 329, which includes the 3300 South frontage property, indicate an annual rate of growth in industrial land use of 10.9 acres for the period 1980-1995. The projected annual rate of growth in industrial land use for the six-traffic-zone analysis area is about 20.4 acres. Therefore, over half of the growth in industrial land use in the 3.6 square mile analysis area is projected to occur in traffic zone 329.

As previously noted, the City's Master Plan projects that between 10.6 (low estimate) and 14.9 (high estimate) acres of vacant industrial land will be absorbed in traffic zone 329 between 1980 and 1990. This corresponds to approximately 70.0 percent of the City's total absorption of vacant industrial land. The projections of land use conversions developed by the Wasatch Front Regional Council are consistent with the City's low estimate of annual absorption. However, the time period for the City's projections is 1980-1990 and the time period for the projections developed by the Wasatch Front Regional Council is 1980-1995. In addition, the data developed by the Wasatch Front Regional Council are estimates of land use conversion, while the City's Master Plan projects the absorption of existing vacant industrial land. Therefore, comparisons of the share of total growth projected for traffic zone 329 are not made. Finally, the projections of land use conversion set forth above are consistent with industrial growth in the vicinity of, if not on, the Vitro site's 3300 South frontage property.

I.5 ASSESSED VALUATION

This section sets forth an analysis of data provided by the City of South Salt Lake and the Salt Lake County Assessor's Office on changes in the assessed valuation of South Salt Lake. As of January 1, 1983, commercial and industrial property was assessed at 20.0 percent of its 1978 fair market value. Residential property was assessed at 15.0 percent of its 1978 fair market value. A statewide reappraisal program, which is partially responsible for the 55.0 percent increase in the City's 1978 assessed valuation was repealed in 1981. It was replaced with a "Factor Law." This approach involves adjusting the 1978 fair market value based on a sales ratio. The sales ratio is the ratio of the sales price to the assessed value, where the sales price is adjusted to 1978 dollars using the composite construction cost index. The sales ratio studies are prepared by the State Tax Commission using data on recent local real estate transactions and assessed values. The effect of the January 1983 change in assessments was an increase in commercial and industrial assessments and, therefore, an increase in property values in general.

Table I-6 summarizes data on changes in assessed valuation in South Salt Lake. Table I-7 summarizes building permit activity for selected years between 1970 and 1982. Table I-8 sets forth detailed data on building permits issued, by type of construction, and the corresponding valuations which the City uses to determine its permit fees. The valuations shown in Table I-8 generally correspond to the contractor's building cost and exclude land, interior improvements, outside improvements, and equipment. The City's commercial category includes all non-residential structural construction activity. The other category includes, among other things, signs and underground tanks. The City has estimated that a project's fair market value is equal to 130 percent of its building permit valuation plus land value.

I.5.1 Assessed valuation changes: 1940-1982

Assessed valuation in South Salt Lake increased at an average annual rate of 7.6 percent between 1940 and 1977. In 1978, assessed valuation increased 55.0 percent. This was due, in part, to a statewide reappraisal program, which has since been abandoned. Subsequent to 1978, the assessed valuation of South Salt Lake moved in an erratic fashion. It increased by 13.9 percent in 1979 and 29.0 percent in 1980. However, in 1981 the City's assessed valuation decreased 1.1 percent.

The 1980 change in assessed valuation was largely due to an annexation completed by South Salt Lake during 1980. The annexation involved land from Mill Creek to 3300 South Street and the Jordan River to 700 East Street. The area had a population of approximately 3,500 at the time of its annexation.

Table I-6. City of South Salt Lake assessed valuation
selected years

1940-1982

<u>Year</u>	<u>Assessed valuation</u> (thousands of Dollars)	<u>Average annual rate of growth</u> (percent)
1940	\$ 2,265	---
1945	2,592	2.7
1955	7,189	10.7
1960	10,778	8.4
1965	15,952	8.2
1970	20,842	5.5
1975	28,287	6.3
1976	31,680	12.0
1977	34,070	7.5
1978	52,797	55.0
1979	60,155	13.9
1980	77,582	29.0
1981	76,754	(1.1)
1982	79,345	3.4

Note: Parentheses indicate a decline.

Source: City of South Salt Lake.

Table I-7. City of South Salt Lake building permit activity
commercial/industrial
selected years

1970-1982

Year	Number of permits	Total value
1970	46	\$2,123,560
1972	70	4,095,331
1974	49	6,291,426
1976	56	6,286,800
1978	56	4,927,511
1981	63	3,016,271
1982	82 ^a	3,848,270 ^a

^aExcludes CVWRF expansion and residential and other permits.

Source: City of South Salt Lake, Policy Plan and Table 8.

TABLE I-8
CITY OF SOUTH SALT LAKE
BUILDING PERMITS AND VALUATIONS
1981-1982

Year/Month	New Commercial		Remodel Commercial		New Residential		Remodel Residential		Other		Total	
	Number (1)	Valuation (2)	Number (3)	Valuation (4)	Number (5)	Valuation (6)	Number (7)	Valuation (8)	Number (9)	Valuation (10)	Number (11)	Valuation (12)
<u>1981</u>												
January	2	\$ 21,000	3	\$ 58,100	1	\$ 210,000	1	\$ 31,000	3	\$ 1,700		
February	2	103,800	0	---	0	---	2	8,200	1	495		
March	2	24,500	1	500	0	---	3	13,572	4	2,280		
April	5	385,000	2	40,874	0	---	3	8,500	4	3,500		
May	5	51,800	4	220,000	0	---	2	1,000	3	8,400		
June	1	325,000	4	156,000	0	---	4	12,000	11	62,500		
July	3	33,500	2	4,200	0	---	2	7,500	5	6,400		
August	1	30,000	2	465,000	0	---	3	6,651	8	1,250		
September	2	213,000	5	54,697	0	---	4	24,000	16	9,750		
October	0	---	3	14,400	1	30,000	0	---	8	37,595		
November	4	501,000	4	92,000	0	---	1	3,000	12	27,500		
December	1	176,000	5	45,900	0	---	2	16,200	9	27,784		
	<u>28</u>	<u>\$ 1,864,600</u>	<u>35</u>	<u>\$1,151,671</u>	<u>2</u>	<u>\$ 240,000</u>	<u>27</u>	<u>\$131,623</u>	<u>84</u>	<u>\$189,154</u>	<u>176</u>	<u>\$ 3,577,048</u>
<u>1982</u>												
January	3	\$ 17,000	3	\$ 22,280	0	\$ ---	0	\$ ---	4	\$ 2,395		
February	0	---	3	48,300	0	---	2	9,000	3	6,500		
March	0	---	6	64,500	0	---	7	34,300	6	16,450		
April	2	638,000	7	102,750	0	---	4	1,000	4	57,500		
May	3	90,391,000 ¹	9	360,750	0	---	5	67,480	2	2,500		
June	4	285,590	6	99,500	1	1,250,000	2	21,000	9	58,562		
July	1	260,000	6	39,100	0	---	3	11,200	3	9,500		
August	2	205,000	8	37,400	0	---	1	500	6	7,450		
September	4	838,000	5	80,600	0	---	2	9,500	6	9,200		
October	0	---	5	40,500	0	---	6	36,049	8	15,200		
November	0	---	2	50,000	0	---	4	15,690	4	5,100		
December	2	250,000	2	18,000	0	---	2	6,800	5	8,356		
	<u>21</u>	<u>\$92,884,590</u>	<u>62</u>	<u>\$ 963,680</u>	<u>1</u>	<u>\$1,250,000</u>	<u>38</u>	<u>\$212,519</u>	<u>60</u>	<u>\$198,713</u>	<u>182</u>	<u>\$95,509,502</u>

Note: Data excludes plumbing, electrical and mechanical.

1. Includes expansion of Central Valley Water Reclamation Facility wastewater treatment plant (+ \$90,000,000).

Source: City of South Salt Lake.

The decrease in assessed valuation recorded during 1981 was due, in part, to the sale of 26.18 acres along the north side of 3300 South Street by Richards-Moench (Richards Realty & Investments and Moench Realty and Investment Co.) to CVWRF. The sale removed 26.18 acres from the City's tax base. However, records provided by the County Assessor's office show that the property had an assessed value of \$70,030 in 1980 and \$58,265 in 1981. This decrease may be due to the aforementioned "Factor Law." In recent years, residential property values in South Salt Lake have been declining due to two factors. First, the stock of housing in the city is relatively homogeneous. In general, it includes smaller homes of an older design, which occupy relatively small lots. Second, development in Murray and West Valley City has resulted in the construction of newer, more spacious homes. This has apparently placed the South Salt Lake housing market at a competitive disadvantage. Concurrent with the recent decline in residential property values, growth in commercial/industrial development has both offset the residential decline and resulted in an overall increase in the City's assessed valuation. However, commercial/industrial construction activity was relatively slow during 1981 and 1982. Therefore, the net effect was a decrease of 1.1 percent in the City's 1981 assessed valuation and a 3.4 percent growth in the City's assessed valuation during 1982. The City of South Salt Lake expects permit-related valuations to reach \$7.0 million during 1983.

I.5.2 Permit valuation changes: 1970-1982

Details with regard to building permits issued for commercial, residential and other construction are set forth in Table I-8. Also included are data on the valuations associated with these permits. As previously noted, these valuations correspond to the contractor's building cost and are used by the City to calculate permit fees.

During 1981, the year in which total valuation decreased 1.1 percent, the City of South Salt Lake issued 176 building permits with a total valuation of \$3.6 million. New commercial and commercial remodeling accounted for 52.1 percent and 32.2 percent, respectively, of total valuation. These two categories also accounted for 35.8 percent of the building permits issued. This is consistent with commercial construction and remodeling having a higher per unit valuation than residential and other construction and remodeling activities.

Permit activity during 1982 was highlighted by the \$90.0 million plus expansion of CVWRF's waste-water treatment facility. Assuming that the CVWRF expansion had a valuation of \$90.0 million, the city issued 181 other building permits with a total valuation of approximately \$5.5 million during 1982. This corresponds to an increase in permit-related valuation of about 54.0 percent.

Based on the data set forth in Table I-7, commercial/industrial permit activity declined in South Salt Lake from 1974 to 1981. From a high of \$6.3 million in 1974, permit-related valuations for commercial/industrial construction and remodeling fell to \$3.0 million in 1981. Commercial/industrial permit valuations rose to \$3.8 million in 1982. As previously noted, the City has estimated that total 1983 permit-related valuations will reach \$7.0 million. To the extent the 1983 figure reflects commercial/industrial construction activity, it may indicate a recovery in the local market.

I.5.3 Conclusions

The City of South Salt Lake's Building Official estimates that the market value of a project is equal to 130.0 percent of the permit valuation (contractor's cost) plus the land value (Stone, 1983). The proposed industrial park would have a permit valuation, in 1983 dollars, of approximately \$8.4 million (22.5 acres; a coverage ratio of 0.35; a total cost of \$32.00 per square foot; and a ratio of total cost to contractor's cost of 1.3). Based on the data set forth in Tables I-7 and I-8, the proposed industrial park (a single project) would have a higher permit valuation than the commercial/industrial construction activity in any year since 1970.

I.6 DEMOGRAPHIC DATA

The demography of the area around the Vitro site will be analyzed by reference to the data and projections published in the WFRC's Surveillance Report Vol. 2, No. 7. These data are set forth in Table I-9. As previously noted, this report also is the source of the data on land use set forth in Tables I-4 and I-5. The analysis will include the six-traffic-zone, 3.6-square-mile area, described in Section I.5, Land Use.

Population data are based on an estimate of population per dwelling unit for each traffic zone and the number of dwelling units in each traffic zone. Data for 1980 were taken from the 1980 census. The number of dwelling units includes single family homes, apartments, mobile homes, and dormitories. Data on dwelling units are updated annually by local planning agencies using building permits. Data for 1980 are based on preliminary census data and data from previous WFRC Surveillance Reports.

Employment is non-agricultural employment and includes wage and salary workers, self-employed workers, and government employees. Data are assembled by the Utah Department of Employment Security and exclude construction employment. Auto registration includes pick-up trucks and is estimated based on a dwelling unit factor developed from 1970 census data and subsequent surveys. Commercial floor area is the area (in hundreds of square feet) in buildings used for retail trade or service industries. These data were originally developed using various survey techniques and, therefore, should be considered estimates. They are updated using building permits.

I.6.1 Historic and current data

The population of the six-traffic-zone analysis area was 1,926 in 1970 and 1,277 in 1980. The total number of dwelling units in the area was 541 in 1970 and 441 in 1980. In addition, the number of cars registered in the area declined from 921 in 1970 to 745 in 1980. Employment in the area increased from 3,529 jobs in 1970 to 9,427 jobs in 1980. Data on the number of square feet of commercial floor area are incomplete. However, commercial floor area in traffic zones 329, 351 and 360-362 increased from 201,300 square feet in 1970 to 285,700 square feet in 1980.

I.6.2 Projected: 1995

Population in the six-traffic-zone analysis area is projected to reach 2,440 by 1995. In addition, the number of dwelling units is projected to reach 1,014 in 1995. Total employment in 1995 is projected to be 12,667. It is estimated that the number of cars in the area will reach 1 666 by 1995. As previously noted, data on the number of square feet of commercial floor area is incomplete. However, commercial floor space, excluding traffic zone 328, is projected at 901,000 square feet by 1995.

Table I-9. Salt Lake County demographic data selected traffic zones

1970, 1979, 1980 & 1995

Census tract/traffic zone	Variable	Average annual rate of growth					
		1970	1979	1980	1995	1970-1980	1980-1995
		--(percent)--					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
116/329	Population	87	59	70	40	(2.2)%	(3.7)%
	Dwelling Units	23	21	21	15	(0.9)	(2.2)
	Employment	63	449	472	4,500	22.3	16.2
	Cars	37	34	34	25	(0.8)	(2.0)
	Commercial Floor Area (00 sq. ft.)	39	NA	215	550	18.6	6.5
116/361	Population	484	267	327	833	(3.8)	6.4
	Dwelling Units	107	93	93	333	(1.4)	8.9
	Employment	380	1,178	1,343	1,600	13.5	1.2
	Cars	226	196	196	706	(1.4)	8.9
	Commercial Floor Area (00 sq. ft.)	272	NA	306	1800	1.2	12.5
116/362	Population	148	120	177	1,019	1.8	12.4
	Dwelling Units	47	43	42	443	(1.1)	17.0
	Employment	195	285	275	250	3.5	(0.6)
	Cars	59	54	53	555	(1.1)	17.0
	Commercial Floor Area (00 sq. ft.)	175	NA	175	800	0.0	10.7
116/351	Population	605	464	381	223	(4.5)	(3.5)
	Dwelling Units	185	166	156	93	(1.7)	(3.4)
	Employment	697	1,960	2,009	1,217	11.2	(3.3)
	Cars	254	227	214	129	(1.7)	(3.3)
	Commercial Floor Area (00 sq. ft.)	805	NA	1,408	2,940	5.8	5.0

Table I-9 Continued

Census tract/traffic zone	Variable	Average annual rate of growth					
		1970	1979	1980	1995	1970-1980	1980-1995
		--(percent)--					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
116/360	Population	602	390	316	325	(6.2)	0.2
	Dwelling Units	179	137	127	130	(3.4)	0.2
	Employment	585	1,554	1,752	1,500	11.6	(1.0)
	Cars	345	264	245	2,920	0.4	9.5
	Commercial Floor Area (00 sq. ft.)	722	NA	753	2,920	0.4	9.5
115/328	Population	0	0	6	0	--	--
	Dwelling Units	0	0	2	0	--	--
	Employment	1,609	3,160	3,576	3,600	8.3	0.0
	Cars	0	0	3	0	--	--
	Commercial Floor Area (00 sq. ft.)	862	NA	NA	2,500	--	--
Total	Population	1,926	1,300	1,277	2,440	(4.1%) ¹	4.4% ¹
	Dwelling Units	541	460	441	1,014	(2.1) ¹	5.7 ¹
	Employment	3,529	8,586	9,427	12,667	10.3	2.0
	Cars	921	775	745	1,666	(2.1) ¹	5.5 ¹
	Commercial Floor Area (00 sq. ft.)	2,875	NA	2,857	11,510	3.6 ¹	8.0 ¹

1. Excludes data for traffic zone 328.

Note: Population: The total number of persons residing in the zone or tract. The zonal population is derived by multiplying an estimated population per dwelling unit factor for each zone by the updated number of dwelling units. The 1980 population was taken from 1980 census data. Only population located within tracted areas was included.

Table I-9 Continued

Dwelling unit: The number of residences within a zone including single family homes, apartments, mobile homes, and dormitories. The dwelling unit total is updated annually by the local planning agencies using building permits. 1980 housing units were compiled from 1980 census preliminary data on housing and previous surveillance data.

Employment: The total number of non-agricultural workers employed in a zone including wage and salary workers, self-employed workers, and government workers. The Utah Department of Employment Security assembles these data using the Unemployment Compensation Coverage file as the primary basis and doing considerable supplemental work. (Construction employment has been removed from the totals.)

Auto registration: The number of passenger vehicles including pickups, registered to persons living in a zone. The auto registration data are also estimated based on a dwelling unit factor which was developed from 1970 census data and surveys.

Commercial floor area: The square feet of area within a building used for retail trade or for service type industries. The value shown in the summary is 100's of square feet per zone or tract. Due to variation in the original survey techniques, these figures should be considered as estimates only. These data are updated using building permits.

NA Indicates data not available.

Source: Wasatch Front Regional Council, Surveillance of Land Use and Socio-Economic Characteristics 1970, 1979, 1980 & 1995, Surveillance Report Volume 2, Number 7, April 1982.

I.6.3 Changes

Population in the analysis area decreased by 649, or 33.7 percent, between 1970 and 1980. The number of dwelling units in the area decreased 18.5 percent during the same time period. However, employment in the area increased substantially during the last decade. Between 1970 and 1980 employment increased by more than 167.0 percent. This corresponds to an average annual rate of growth in excess of 10.0 percent. During the same time period, the area's commercial floor space increased approximately 42.0 percent.

These data illustrate a shift in the demography of the area and are consistent with data on local land use conversion. Both types of information indicate increased industrial development and a movement away from residential land use.

Forecasts of key demographic variables published by the WFRC project consider considerable growth in the six-traffic-zone analysis area between 1980 and 1995. Population is projected to increase by more than 90.0 percent. The number of dwelling units is expected to reach 1,014, an increase of almost 130.0 percent. In addition, commercial floor space in the area, excluding traffic zone 328, is projected to increase more than 200.0 percent. Growth in employment also is projected to increase, but at a less dramatic rate. The growth which has been projected for the 1980-1995 period will reverse a recent trend in the area. As previously noted, the growth in employment and commercial floor space which occurred during the 1970s was accompanied by a decrease in population, dwelling units and registered motor vehicles. By contrast, growth has been projected for all key demographic variables between 1980 and 1995. The projections of land use changes for the area indicate considerable growth in industrial land use and a relatively minor increase in residential land use. In light of the substantial growth in population forecasted for the area, higher density residential land uses are anticipated.

I.7 LOCAL LAND VALUES

In this section the market value of a portion of the Vitro site is estimated. The analysis will focus on the approximately 26.8 acres that CVWRF purchased from Richards-Moench in 1981. This parcel includes tract "B" south, 12.5 acres and 650 feet of frontage on 3300 South, and tract "C" south, 14.3 acres and 1280 feet of frontage on 3300 South. Per the CVWRF Board's approved Master Plan and Rodney Dahl, CVWRF's General Manager, this acreage corresponds to the site of the proposed County Resource Recovery Facility (16 acres) and a portion of the site of the proposed Temporary Industrial Park (20-25 acres). The balance of the acreage for the proposed Industrial Park is located to the west between 700 West, the entrance to CVWRF's Facility, and the six vicinity properties on 900 West.

The purpose of the analysis in this section is to determine the market value of the portion of the Vitro site proposed for development as a temporary industrial park. For the reasons set forth in the body of the EIS, the municipal solid waste-to-energy facility is not evaluated in this report. Based on the assumption that the development of a temporary industrial park requires the removal of the mill tailings, the value of the land if removal is the remedial action selected can be approximated by this use.

One of the methods for establishing the market value of a property is by appraisal. CVWRF's predecessor, Salt Lake City Suburban Sanitary District No. 1, commissioned such an appraisal by Edward P. Westra, MAI-SRA-CPM. The appraisal was performed in connection with CVWRF's predecessor organization's negotiations to acquire the two-tract 26.8-acre parcel described above. The resulting Appraisal Report dated March 19, 1973, defines market value as follows: "...the highest price, expressed in terms of money, that the property will bring after reasonable exposure in the open market, with both the buyer and the seller being fully informed as to the highest and best use of the property, and neither party acting under compulsion or duress." The Appraisal Report covers five tracts including tract "A" (8.8 acres), tract "B" south, (12.5 acres), tract "B" north (16.0 acres), tract "C" south (14.3 acres) and tract "C" north (25.5 acres). This analysis will concentrate on tracts "B" and "C" south for the reasons previously noted.

The following is a summary of the observations and conclusions of the Appraisal Report with regard to the two southern tracts.

Tract "B" South

- Evidence of high water table in area.
- Parcel has been filled above the water level and appears to be stable.
- 650 feet of frontage and 600 feet of depth.
- A railroad spur comes into the property from the north.
- Immediate potential for industrial development.
- The market value of the tract is \$25,000 per acre.

Tract "C" South

Land is built up with tailings from the former Vitro Chemical operation.

- In its present condition, it is unsuitable for development requiring the presence of persons over a sustained period of time.
- No immediate development potential due to the presence of large amounts of radioactive tailings.
- If the tract did not have any fill (tailings) on it, its value would be similar to or slightly lower than tract "B" South.
- Value of frontage along 3300 South drops moving west from the interchange of I-15.
- Therefore, without tailings the average value of this land would be \$22,500.
- The market value of the tract is \$13,500 an acre.
- The market value of the tract assumes that the land with radioactive fill material on it can be utilized subject to reasonable limitations.

Based on the information set forth above, the market value of the property proposed for development as an industrial park and a municipal solid waste-to-energy facility was appraised at \$22,500 to \$25,000 per acre in 1973. It should be noted that this estimate of the market value of the frontage property along 3300 South appears in the contemporaneous business document produced in the normal course of business and not in a document prepared in connection with the current proceedings. In addition, the estimate assumes that the land has "immediate potential for industrial development in accordance with the existing zoning" (i.e., no tailings). At the time of the report (1973), the property was zoned M-2 which permits heavy industrial development.

The Chairman of the Board of CVWRF stated that vacant industrial land in the South Salt Lake area historically increases in value at the rate of 12.0 percent per year (Petersen, 1982). Based on a 1973 market value of \$22,500 to \$25,000 per acre, this indicates a 1983 market value of approximately \$69,900 to \$77,600 per acre.

Another method for estimating the current market value of CVWRF's 3300 South Street frontage property is to rely on a recent (1982) appraisal report. A recent appraisal report was prepared by the Land Department of the Salt Lake County Assessor's office. It was prepared pursuant to a request by the Administrator of the Appraisal Department for "a more detailed appraisal report on the land owned by Salt Lake Sanitary Suburban District and Central Valley Water Reclamation Facility, and referred to as the Vitro Chemical Property..."

The report notes that the frontage property along 3300 South currently is zoned Business (A) to a depth of approximately 800 feet. The balance of the

parcel, including the frontage along 900 West, is zoned light industrial. The report observes that distribution type industrial parks and high technology oriented operations are the predominant land use and existing parks have prime tenants and low vacancy rates. Based on the preceding, it was determined that the highest and best use of the property was as an industrial park. A 21-acre L-shaped parcel in the vicinity of the intersection of 3300 South and 900 West was chosen as the best location for the industrial park.

In order to determine the market value of the property, a number of newly developed industrial parks similar in location and desirability were considered.

The selected developments and their corresponding land values are set forth below:

- Decker Lake Industrial Park: \$35,000 to \$75,000 per acre.
- Yates Industrial Park: \$40,000 to \$87,120 per acre (high end of range based on a value of \$2.00 per square foot).
- Pioneer Industrial Park: \$40,000 to \$80,000 per acre.
- Centennial Park: \$43,560 to \$130,680 per acre (based on a value of \$1.00 to \$3.00 per square foot).

Based on the information set forth above, the recent appraisal report concludes that the 21-acre L-shaped parcel (the prime area for development of the Vitro site) has a value of \$40,000 to \$70,000 per acre. The author of the report indicated that this was the market value, not the assessed value, of the property. As previously noted, vacant industrial property is assumed to appreciate at an annual rate of 12.0 percent. When applied to the range of values noted above, this results in a current market value of \$42,400 to \$74,200 per acre.

An additional method for estimating the market value of the property on 3300 South is based on an analysis of its value per square foot. The value per square foot is a function of land use. After consulting with a local real estate developer, the following range of values was derived depending upon land use, parcel size and externalities (e.g., adjacent land uses, the presence of the waste-water treatment facility) (Simons, 1983).

A recent transaction involving a two-acre site adjacent to I-15 to be developed as a location for a commercial office building indicates a value of \$5.00 per square foot (\$217,800 per acre) for this land use. Based on the size differential between this site and the 3300 South frontage portion of the Vitro site, a discount of 25.0 percent was suggested. This corresponds to a value of \$3.75 per square foot (\$163,350 per acre) for property used as a site for an office building. The prevailing land use in the vicinity of the Vitro site is warehousing and distribution. If the Vitro site's 3300 South frontage property is developed as a location for warehousing activities it is estimated to be worth \$1.25 per square foot (\$54,450 per acre) (Simons, 1983).

The presence of CVWRF's waste-water treatment facility was thought to eliminate the property's use as a location for an office building. In

addition, if the proposed municipal solid waste-to-energy facility is constructed, it was suggested that the value of the property might fall to \$1.00 per square foot (\$43,560 per acre). This is based on the fact that after the construction of the solid waste-to-energy facility, any structure on the subject property would be located between a waste-water treatment facility and a solid waste-to-energy facility.

The final approach to be considered for estimating the market value of the 3300 South frontage portion of the Vitro property involves the asking price for comparable adjacent property currently being offered for sale. The 22.71-acre parcel at the northwest corner of 3300 South and 900 West is currently being offered for sale by the Utah State Retirement Fund. The asking price is \$1,978,495 or \$87,120 an acre. The property was purchased from HOMCO Development Company in the fourth quarter of 1982 and offered for sale early in 1983. A spokesperson for the Utah State Retirement Fund stated that an appraisal report on the property did not mention the Vitro site or the mill tailings (Blackburn, 1983).

In addition to the information set forth above, the following considerations must be evaluated in determining the market value of the Vitro site's frontage property.

- Proximity to the 3300 South interchange with I-15.
- Frontage on 3300 South.
- Availability of a rail spur.
- Construction of the proposed West Valley highway (Goodwin, 1983).
- The availability of utilities.
- Central location.

Another fact is worth noting. In 1981, CVWRF purchased the 3300 South frontage property for \$62,500 an acre. Based on the testimony of CVWRF's General Manager at the March 23, 1983 public hearing in this matter, CVWRF purchased the Vitro site (including the 3300 South frontage property) "with the promise from the federal government that it would be immediately cleaned up and that all of this land would be available for Central Valley purposes." This indicates that CVWRF paid \$62,500 per acre for the 3300 South frontage property in 1981 with the understanding that it would be cleaned up immediately and made available for use as a location for a temporary industrial park and a municipal solid waste-to-energy facility. On the basis of this transaction and the opinion of CVWRF's Chairman of the Board regarding the market appreciation of vacant industrial land in South Salt Lake the 1983 market value of the 3300 South frontage property is approximately \$78,400 per acre.

Based on the data and information set forth above, the 1983 market value of the 3300 South frontage property was estimated to be \$78,400 per acre. This assumes the property is available for immediate development as an industrial park. As the presence of the mill tailings precludes immediate

development, this corresponds to the market value of the property in today's dollars if removal is the adopted remedial action.

This figure is less than the asking price for the property to the west of the Vitro site being offered for sale by the Utah State Retirement Fund. However, that property is not adjacent to Central Valley's waste-water treatment facility. In addition, this price is more than that of any of the other estimates detailed in this report. However, it is based on a recent (1981) transaction in which the buyer (CVWRF) was aware of the presence of the mill tailings but purchased the property contingent on a promise by the Federal government to clean up the property and make it available to CVWRF for development consistent with its adopted Master Plan. As previously noted, CVWRF's adopted Master Plan calls for the construction of a temporary industrial park and a municipal solid waste-to-energy facility on the 3300 South frontage property (see Section I, Introduction). This being the case, it is difficult to imagine a better estimate of the market value of the land than the price that CVWRF paid under the assumption that it would be available for development.

I.8 EMPLOYMENT

This section will analyze the effects of developing CVWRF's 3300 South frontage property in terms of direct and indirect employment. The analysis will focus on the regional employment impacts of developing a temporary industrial park. As previously noted, the estimated life of the temporary industrial park is 13 years (see Section I.1, Introduction).

I.8.1 Direct employment

The estimate of direct employment generated by the development of an industrial park along 3300 South will be based on two assumptions. The first is the building-to-land coverage ratios which appear in Salt Lake County Master Plan, Phase II, June 1980. The second is the estimate of the number of square feet per employee required for warehousing and distribution activities which also appears in Phase II of the City's Master Plan. Assuming that the proposed industrial park is 22.5 acres, this corresponds to 980,100 square feet (22.5 acres x 43,560 square feet per acre). The estimates in the City's Master Plan of building-to-land coverage ratios for traffic zones 328 and 329 in 1986 are 0.45 for "healthy economic conditions" and 0.25 for "sluggish economic conditions." By applying the average of the coverage ratios (0.35) to the square feet of land to be developed as an industrial park (980,100), 343,035 square feet of building area will be constructed.

The City's Master Plan reports that 1,265 square feet are required per employee for warehousing and distribution activities. Based on a figure of 343,035 square feet of building area, this corresponds to approximately 271 employees. Therefore, the development of a 22.5 acre industrial park catering to warehousing and distribution activities will provide direct employment for 271 persons.

I.8.2 Indirect employment

The estimate of indirect employment (used herein) attributable to the proposed industrial park will be based on a statistic used in Economic Impacts of Alternative Remedial Actions for the Vitro Tailings, Nile Eatmon, Utah State Division of Community Development, March 21, 1983. The report states that direct employment in the area will generate an additional 1.6 jobs per direct employee in the local economy. This statistic is attributed to the State Planning Coordinator's Office, State of Utah, 1983. Applying the factor of 1.6 to direct employment of 271 results in a figure for indirect employment of approximately 434 jobs. That is, development of the proposed industrial park will result in the indirect employment of 434 persons within the region. Direct and indirect employment impacts will total 705 jobs.

I.9 PUBLIC REVENUES.

This section will delineate the public fiscal consequences of the proposed industrial park in terms of property taxes, sales taxes, income taxes, business licenses, water sales, and sewer service charges. It should be noted that the estimates set forth in this section are estimates of revenue and, therefore, do not reflect incremental capital or operating costs occasioned by the development of the proposed industrial park. The analysis in this section is in 1983 dollars.

I.9.1 Property taxes

The estimate of property taxes attributable to the proposed industrial park is based on the following assumptions.

- The industrial park will be 22.5 acres. This is based on a range of 20-to-25 acres provided by the General Manager of the CVWRF.
- The building-to-land coverage ratio will be 0.35. This is based on data in the City's Master Plan Phase II as described in Section IX, Employment.
- Construction costs will be \$32.00 a square foot. This is based on an estimated construction cost of \$32.00 per square foot, which appears in Economic Impacts of Alternative Remedial Actions for the Vitro Tailings, Nile Eatmon, Utah State Department of Community Development, March 21, 1983.
- The mill levy in tax district 14B is 81.21. This was the 1982 mill levy for tax district 14B. The components of the 1982 mill levy for tax district 14B are set forth below, in mills.

Salt Lake County General Fund	17.42
South Salt Lake City	6.25
Granite School District	45.25
County Library Fund	3.35
Salt Lake County Water Conservancy District	2.00
Salt Lake County Mosquito District	0.18
Salt Lake City Water and Sewer District	4.16
Central Utah Water Conservancy District	2.00
Hansen Planetarium	0.20
Hogle Zoo	0.40
Total	81.21

- The roll-back figure, which is used to convert current market value to 1978 market values, is 0.69. This figure was used by the Salt Lake County Assessor's Office to convert 1982 market values to 1978 market values. This is done because assessments in Utah are currently based on 1978 market values.

The commercial/industrial assessment will be 20.0 percent of the 1978 fair market value. The current (as of January 1, 1983) commercial/industrial assessment is 20.0 percent of the 1978 fair market value.

Table I-10 details the calculation of the estimated property taxes attributable to the proposed industrial park.

Table I-10. Vitro tailings site proposed industrial park
estimated property tax revenues

1983 dollars

(1)	<u>Land</u>	
	22.5 acres @ \$78,400 per acre	\$ 1,764,000
(2)	<u>Improvement</u>	
	22.5 acres assuming a building-to-land coverage ratio of 0.35 and a construction cost of \$32.00 per square foot	\$10,977,120
(3)	<u>Total Market Value</u>	
	(1) + (2)	\$12,741,120
(4)	<u>Assessed Valuation</u>	
	Assumes a roll-back figure of 0.69 and an assessment of 20.0 percent of the 1978 fair market value	\$ 1,758,275
(5)	<u>Mill Levy</u>	81.21
(6)	<u>Estimated Property Tax Revenues</u>	
	(4) x (5×10^{-3})	\$ 142,790

I.9.2 Other public revenues

Sales tax revenues are assumed to be zero. This is because an industrial park, which caters to warehousing and distribution activities, would not generate sales subject to sales taxes.

State and federal income tax revenues, as well as corporate income tax revenues, were estimated based on assumptions set forth in Economic Impacts of Alternative Remedial Actions for the Vitro Tailings, Nile Eatmon, Utah State Division of Community Development, March 21, 1983. These assumptions are set forth below.

- The average annual salary of each direct and indirect employee is \$14,313.
- State individual income tax revenue is three percent of total salary. This figure is sourced to Statistical Abstract State of Utah, Bureau of Economic and Business Research, 1983.
- Federal individual income tax revenue is 11.0 percent of total salary. The source is the same as above.
- Corporate earnings are six percent of total gross salaries. The source is the same as above.
- Corporate income tax revenues are 48.0 percent of earnings.

Table I-11 below, sets forth details with regard to the calculation of estimated income tax revenues arising from the development of the proposed industrial park.

Table I-11. Vitro tailings site proposed industrial park
estimated income tax revenue

1983 dollars

Individual Income Tax Revenues

(1) Employment:	a. Direct	271
	b. Indirect	434
	c. Total	705
(2) Average Annual Income		\$ 14,313
(3) Total Wages		
	(1.c.) x (2)	\$10,090,665
(4) State Individual Income Tax Revenue		
	(3) x 0.03	\$ 302,720
(5) Federal Individual Income Tax Revenue		
	(3) x 0.11	\$ 1,109,973

Corporate Income Tax Revenues

(6) Corporate Earnings		
	(3) x 0.06	\$ 605,440
(7) Corporate Income Tax		
	(6) x 0.48	\$ 290,611
(8) Total Income Tax Revenues		
	(4) + (5) + (7)	\$ 1,703,304

Revenues from business licenses are estimated assuming an average license fee of \$275 and 29 businesses operating in the proposed industrial park. These estimates were contained in a October 8, 1982, letter from Richard D. Chong of Richard D. Chong and Associates to Jonnalyne Walker, Community Services Coordinator, City of South Salt Lake. On the basis of this information, revenues from business licenses are estimated at \$7,975 per year.

The estimates of revenues from water sales and sewer service charges also are based on data set forth in Richard D. Chong's October 8, 1982, letter to Jonnalyne Walker. Water sales revenues are estimated assuming an average annual water bill of \$240 and 29 businesses. Sewer service revenues are estimated assuming an average annual bill of \$150 and 29 businesses. This corresponds to water sales revenues of \$6,960 per year and sewer service revenues of \$4,350 per year.

I.10 CONCLUSIONS

In this section conclusions regarding the development potential of CVWRF's 3300 South frontage property, as well as an estimate of the gross economic benefits that might result from the proposed project are presented. The development potential will be delineated in terms of zoning, Master Plan, land use and demographic considerations. The conclusions also will address historic data on construction permit activity. The potential economic benefits to the region will be developed based on estimated property values, direct and indirect employment impacts, and projected public fiscal revenues.

I.10.1 Development potential

I.10.1.1 Zoning

The 3300 South frontage portion of the Vitro site is currently zoned Business (A). This zoning designation is inconsistent with an industrial park, as well as a municipal solid waste-to-energy facility. However, most of the permitted uses (e.g., offices, restaurants, retail) appear to be inconsistent with adjacent land uses (e.g., CVWRF's waste-water treatment facility, automobile junk yard). Therefore, it is anticipated that the property could be rezoned to accommodate CVWRF's proposed industrial park.

I.10.1.2 Master Plan

The City's Master Plan emphasizes South Salt Lake's deficiencies in terms of attracting commercial, retail, and office development. This is attributed to the City's declining population and its modest purchasing power. The Master Plan also notes that the area's mixed land use is inconsistent with other, more highly valued, land uses. The Master Plan identifies South Salt Lake as a location for firms seeking large, plain buildings in a non-prestige area. It also characterizes the City as being in a good position with regard to "heavy commerce" (e.g., automobiles, large appliances) and warehouse and distribution activities. Finally, the Master Plan notes that additional operating costs will be incurred by the City as the result of any commercial and industrial growth.

I.10.1.3 Land use

Current and projected land use data identify traffic zone 329, which includes Central Valley's 3300 South frontage property, as a likely area for industrial development. Projections of land use conversion developed by the Wasatch Front Regional Council estimate that industrial land use in traffic zone 329 will increase 10.9 acres per year between 1980 and 1995. This corresponds to more than half of the annual average increase in industrial land use projected for the six-traffic-zone analysis area during this period.

The City's Master Plan contains estimates of the annual absorption of vacant industrial land. These data project an annual average absorption of between 10.6 (low estimate) and 14.9 (high estimate) acres per year between 1980 and 1990 for traffic zone 329. This corresponds to approximately 70.0 percent of the annual average absorption projected for the entire City during this time period.

I.10.1.4 Construction permit activity

Construction of the proposed industrial park will result in construction permits with a combined valuation of approximately \$8.4 million (1983 dollars). For selected years between 1970 and 1982, the total valuation of commercial construction permits issued ranged between \$2.1 million and \$6.3 million per year, excluding the CVWRF expansion. This means that the temporary industrial park proposed by CVWRF would have a permit valuation greater than the total commercial and industrial construction activity during any year for which data were provided since 1970.

I.10.1.5 Demographics

Recent growth (1970-1980) in the six-traffic-zone analysis area has favored employment (167.1 percent) and commercial floor space (41.9 percent). However, for the period 1980-1995, growth is projected for population (91.1 percent) and the number of dwelling units (129.9 percent), as well as employment (34.4 percent) and commercial floor space (215.4 percent, excluding traffic zone 328).

Projections for the period 1980-1995 indicate a decline in the average annual rate of growth in employment from 10.3 percent (the historic average for the period 1970-1980) to 2.0 percent. In addition, approximately 70.0 percent of the projected growth in commercial floor space is expected to take place in the unincorporated portion of the six-traffic-zone analysis area.

I.10.2 Economic benefits

I.10.2.1 Property value

The estimated 1983 market value of CVWRF's 3300 South frontage property is \$78,400 per acre. This is based on the assumption that the property could be immediately developed as a temporary industrial park. This estimate was developed based on the following considerations.

- A 1973 Appraisal Report prepared by Edward P. Westra for Salt Lake City Suburban Sanitation District No. 1. This report concluded that the 3300 South frontage property had a 1973 market value of \$22,500 to \$25,000 per acre, based on the assumption that the property was available for immediate industrial development. This corresponds to a 1983 market value of \$69,900 to \$77,600 per acre based on an annual market appreciation rate for vacant industrial property in the area of 12.0 percent. This market appreciation rate was supplied by the Chairman of the Board of CVWRF.
- In 1983 an Appraisal Report was prepared by the Salt Lake County Assessor's Land Department. This report concluded that, based on development as an industrial park, the property in the vicinity of 3300 South and 900 West had a 1982 market value of \$40,000 to \$70,000 per acre. Based on the assumption that vacant industrial property appreciates at 12.0 percent per year, this corresponds to a 1983 market value of \$42,400 to \$74,200 per acre.

- Based on discussions with a local real estate developer, the 3300 South frontage property has a 1983 market value of \$3.75 per square foot (\$163,350 per acre) if developed as a location for an office building and \$1.25 per square foot (\$54,450 per acre) if developed for warehousing and distribution activities. The presence of CVWRF's waste-water treatment facility, as well as other adjacent properties (e.g., junkyard), was thought to preclude the development of office space on the land.
- A 22.71-acre parcel at the northwest corner of 3300 South and 900 West is being offered for sale by the Utah State Retirement Fund for \$1,978,495 or \$87,120 per acre. This property is comparable to the 3300 South frontage property. However, it is not adjacent to CVWRF's waste-water treatment facility.
- In 1981, CVWRF purchased most of the 3300 South frontage property from Richards-Moench for \$62,500 per acre. Based on statements made by CVWRF's General Manager, this property was purchased with the understanding that it would be immediately cleaned up by the Federal government, which would allow CVWRF to use the property. Per CVWRF's approved Master Plan, the intended use of the property is, in part, the development of a temporary industrial park. Adjusted for the local market appreciation rate for vacant industrial property provided by the Chairman of the Board of CVWRF, this corresponds to a 1983 market value of \$78,400 per acre. This is the price (adjusted to 1983 dollars) which CVWRF paid for the 3300 South frontage property under the assumption that it would be cleaned up by the Federal government and available for development as a temporary industrial park (i.e., the 1983 market value).

I.10.2.2 Employment impacts

The estimate of direct employment attributable to the development of the proposed temporary industrial park is based on the following assumptions.

- A 22.5-acre (980,100 square feet) industrial park.
- A building-to-land coverage ratio of 0.35.
- 1,265 square feet of building per employee for warehousing and distribution activities.

This results in an estimate for direct employment of 271 jobs.

The estimate of indirect employment assumes that each direct job created by the proposed industrial park will result in 1.6 indirect jobs in the local economy. This corresponds to an indirect employment impact of approximately 434 jobs. It should be noted that the local economy refers to a geographic area considerably larger than South Salt Lake. This is because the communities in which the indirect employment impacts will be felt depend on the geographic distribution of the residences of the 271 direct employees. To the extent that the geographic distribution includes all of Salt Lake County,

the economic benefits in terms of employment and, therefore, private sector income will be widely dispersed.

I.10.2.3 Public fiscal revenues

Based on the following assumptions, property tax revenues are estimated at \$142,800 a year.

- Land value of \$78,400 per acre.
- A 22.5 acre industrial park with a building-to-land coverage ratio of 0.35.
- Construction costs of \$32.00 per square foot (1983).
- A roll-back figure of 0.69 (1983 market value to 1978 market value).
- A mill levy of 81.21.

Based on the following assumption, sales tax revenues will be zero.

- An industrial park catering to warehousing and distribution activities will not have any taxable sales.

Based on the following assumptions, income tax revenues will be \$1,703,000 per year.

- Average annual wages of \$14,313 for direct and indirect jobs.
- State income tax is 3.0 percent of total wages.
- Federal income tax is 11.0 percent of total wages.
- Corporate earnings are 6 percent of total wages.
- Corporate income tax is 48.0 percent.

Based on the following assumptions, annual revenues from business licenses, water fees and sewer charges will be \$8,000, \$7,000 and \$4,400, respectively.

- 29 businesses in the industrial park.
- Average business license fee of \$275/year.
- Average water bill of \$246/year.
- Average sewer charge of \$150/year.

Based on the following assumptions, after-tax wages will be \$8,678,000 per year.

- Average annual wages of \$14,313 for direct and indirect jobs.

- 271 direct jobs.
- 434 indirect jobs.
- State and Federal income taxes are 3.0 percent and 11.0 percent of total wages, respectively.

After-tax corporate profits of the companies providing the 705 jobs will be \$290,600 per year based on the following assumption.

- Annual corporate earnings are six percent of total wages.
- The corporate tax rate is 48.0 percent.

Based on the following assumptions, rental income from the industrial park will be \$176,400 per year.

- A 22.5 acre industrial park.
- A market value of \$78,400 per acre.
- An annual rental rate per acre equal to 10.0 percent of the market value per acre.

Table I-12 summarizes the estimated annual economic benefits. Total public revenues are estimated to be \$1,865,000 per year, total after-tax private sector benefits are estimated to be \$8,993,000 and annual rental payments to CVWRF are estimated to be \$176,000.

Table I-12 clearly illustrates that the majority of the economic benefits are a function of after-tax private sector income. The geographic distribution of this benefit is dependent upon the geographic distribution of the direct employees. Therefore, it was not distributed between the City of South Salt Lake and the rest of Salt Lake County. In addition, the estimate of economic benefits associated with the proposed industrial park is not dependent upon estimated land values. This is because only two components of estimated economic benefits are directly related to property values. They are property taxes estimated at \$143,000 per year and rental payments to CVWRF estimated at \$176,000 per year.

Finally, construction expenditures for the proposed industrial park are estimated at approximately \$11.0 million (see Table I-10, Line 2). It is estimated that each dollar invested in the proposed industrial park will result in \$1.40 of additional economic activity due to the multiplier effect. (See Economic Impacts of Alternative Remedial Actions for the Vitro Tailings, Utah State Division of Community Development, Nile Eatmon, March 21, 1983.) This corresponds to an estimated \$15.4 million in additional economic activity due to the construction of CVWRF's temporary industrial park. The geographic distribution of this activity will depend on the geographic distribution of the construction employee's residences, as well as the geographic distribution of construction material purchases.

Finally, construction of an industrial park on an alternate portion of the Vitro site or on a comparable vicinity property could mitigate the potential loss of all of the economic benefits estimated above.

Table I-12. Vitro tailings site proposed industrial park
summary of annual benefits

1983 dollars
(000)

Benefit	South Salt Lake <u>Lake</u>	Salt Lake County <u>County</u>	<u>Total</u>
• Public Revenues	(1)	(2)	(3)
Property Taxes	11	132	143
Sales Taxes	0	0	--
Income Taxes	1)	1)	1,703
Business Licenses	8	0	8
Water Fees	7	0	7
Sewer Service Charges	<u>4</u>	<u>0</u>	<u>4</u>
Subtotal	<u>\$ 30</u>	<u>\$132</u>	<u>\$ 1,865</u>
• After-Tax Wages	1)	1)	\$ 8,678
• After-Tax Corporate Profits	\$315	0	315
• Rental Income	176	0	176
Total	<u>\$521</u>	<u>\$132</u>	<u>\$11,034</u>

1) Depends on geographic distribution of direct employees.

BIBLIOGRAPHY

- Jerold H. Barnes, Principal Planner, Salt Lake County Planning Commission, personal communication, April 1983.
- D. Blackburn, Utah State Retirement Fund, personal communication, April 1983.
- Eleanor L. Brennan, Chief Deputy, Salt Lake County Assessor's Office, personal communication, March 1983.
- Scott Brown, Administrative Assistant, Commissioner Barker's Office, Salt Lake County, Utah, personal communication, March 1983.
- Correspondence from Richard D. Chong of Richard D. Chong and Associates to Jonnalyne Walker, Community Services Coordinator, City of South Salt Lake, Utah, October 8, 1982.
- Richard D. Chong, Richard D. Chong and Associates, personal communication, April 1983.
- City of South Salt Lake, Policy Plan, (no date).
- City of South Salt Lake, Master Plan Phase II, June 1980.
- City of South Salt Lake, Comprehensive Master Plan, June 1981.
- City of South Salt Lake, Title Fifteen, Zoning and Land Use.
- City of South Salt Lake, Zoning District Map, May 6, 1982.
- City of South Salt Lake, Transportation Phase, South Salt Lake City Master Plan, Phase III, March 1981.
- City of South Salt Lake, South Salt Lake, Utah, Financial Statements for the Year Ended June 30, 1981.
- Coon, King and Knowlton; and Brown and Caldwell, Final Report 201 Facilities Plan, Central Valley Water Reclamation Facility Board, February 1982.
- Mick Crandall, Program Director, Wasatch Front Regional Council, personal communication, March 1983.
- Statement of Rodney L. Dahl, General Manager, Central Valley Water Reclamation Facility Board on behalf of himself and the Central Valley Water Reclamation Facility Board supplemented by Statement of James Weaver, Consulting Economist, Washington, D.C., March 23, 1983.
- Rodney L. Dahl, General Manager, Central Valley Water Reclamation Facility, personal communication, March 1983.

Bibliography (cont.)

Draft Environmental Impact Statement, Vitro Tailings Site, City of South Salt Lake Utah.

James W. Davis, Mayor, City of South Salt Lake, Utah, personal communication, March 1983.

Nile Eatmon, Utah State Division of Community Development, Economic Impacts of Alternative Remedial Actions for the Vitro Tailings, March 21, 1983.

Nile Eatmon, Utah State Division of Community Development, personal communication, March 1983.

Mike Embly, Controller, Central Valley Water Reclamation Facility, personal communication, March 1983.

Franklin Associates, Ltd., Salt Lake County Final Report, Future Waste Management, Procurement Planning, February 1983; and Wasatch Front Regional Council, Final Report.

Gregg Goodwin, Director Intergovernmental Relations Division, Salt Lake County Administrative Services Department, personal communication, March 1983.

Colleen Jacobsen, Staff Appraiser, Land Department Salt Lake County Assessor's Office, personal communication, March 1983.

Colleen M. Jacobsen, Salt Lake County Assessor, Land Department, Proposed Value Estimate, Vitro Chemical Property, October 4, 1982.

Ken Jensen, Utah State Job Service, personal communication, May 1983.

Johns, R.E., Jr., Archer, V.E., Warren, D., The Vitro Uranium Mill Tailings: An Assessment of Health Risk and Remedial Action, September 21, 1982.

Jan Klein, Employment Counselor, Utah State Government Job Service, personal communication, April 1983.

Mason, James O., Maxell, Marvin H., Anderson, Larry F., Utah Department of Health, Vitro Uranium Mill Tailings Remedial Action, Position Paper, January 17, 1983.

Master Policy Declaration for Annexation for South Salt Lake City, Utah, January 1980.

Neff Petersen, Chairman of the Board, Central Valley Water Reclamation Facility, personal communication, March 1983.

Salt Lake County Planning Division, Vitro Analysis, March 23, 1983.

Bibliography (cont.)

Dan Simons, Simons & Co., personal communication, March 1983.

Ronald Stone, Building Official, City of South Salt Lake Utah, personal communication, March 1983.

Izzy Wagner, Wagner Industries, personal communication, March 1983.

Jonnalyn Walker, Community Services Coordinator, City of South Salt Lake, Utah, personal communication, March 1983.

Wasatch Front Regional Council, Surveillance of Land Use and Socioeconomic Characteristics 1970, 1979, 1980 and 1995, Surveillance Report Vol. 2, No. 7, April 1982.

Edward P. Westra, Appraisal Report, Property of Richards-Moench, located at Northside of 3300 South between 500 and 700 West, Salt Lake County, Utah, March 19, 1973.

Appendix J

LIST OF AGENCIES, ORGANIZATIONS, AND PERSONS RECEIVING COPIES OF THIS FEIS

Federal Agencies

Corps of Engineers
Tom Skordal

Department of the Interior
Bureau of Land Management
Frank Snell
Gary Wicks
Joe Sovick
Fish and Wildlife Service
Larry England

Environmental Protection Agency
Headquarters, Washington, D.C. (5)
Stanley Lichtman

Region VIII (5)
John Welles
John Geidt
Phillip Nyberg

Department of Energy
Donald H. Groelsema
Steven Miller
Steve Woodbury
E. L. Keller
John Baublitz

UMTRA Project, Albuquerque Operations
J. A. Morley
M. L. Matthews

Housing and Urban Development
Headquarters, Washington, D.C.

Nuclear Regulatory Commission
Leo B. Higginbotham (10)

Office of Management and Budget
Richard Brozen

Sandia National Laboratories
F. W. Bingham
M. L. Merritt
M. S. Tierney

Office of Technology Assessment, U.S. Congress
Fran Rudoff

Elected Officials

U.S. House of Representatives
James Hansen
Dan Marriott
Howard C. Nielson

U.S. Senate
E. Jake Garn
Orrin G. Hatch

Utah Governor
Scott M. Matheson

Utah House of Representatives
George L. Gygi
Vivian N. Jensen
Ervin M. Skousen
Samuel S. Taylor
Beverly White

Utah Senate
K.S. Cornaby
Fred W. Finlinson
Karl G. Swan

Salt Lake County Commission
Bart Barker
C. Scott Brown
D.M. Stewart, Chairman

Tooele County Commission
Reed Russell
Charles Stromberg, Chairman

City of South Salt Lake
James W. Davis, Mayor

City of Tooele
John Cluff, Mayor

City of Grantsville
Keith Brown, Mayor

State Agencies

Utah Governor's Office
Kent Briggs
Jim Butler
Lisa Fagerlund

Utah Department of Health

Mike Stapley, Acting Director

Division of Community Health Services

Richard E. Johns, Jr., M.D.

Division of Environmental Health

Ken Alkema

Bureau of Air Quality, Brent C. Bradford

Bureau of Public Water Supplies, Gayle J. Smith

Bureau of Radiation Control, Darrell Warren

Bureau of Sanitation, Mervin R. Reid

Bureau of Solid and Hazardous Waste Management

Dale D. Parker

Bureau of Uranium Mill Tailings Management

Larry F. Anderson

Bureau of Water Pollution Control

Calvin K. Sudweeks

Utah Department of Natural Resources

Temple Reynolds

Division of State Lands and Forestry

Donald G. Prince

Water Research Laboratory

Chris Daffy

Utah Department of Public Safety

Larry E. Lunnen

Utah Department of Transportation

LeGrand Jones

Robert A. Chaney

William Hurley

Utah Geological and Mineral Survey

Genevieve Atwood

Utah Science Advisory Council

James Brophy

Bartell Jensen

Randy Moon

Gareth Welch

Utah State Clearing House

Breck Cook

Arizona Radiation Regulatory Agency

Richard Blanton

Colorado Department of Health

A.J. Hazle

Commonwealth of Pennsylvania
Bureau of Radiation Protection, Thomas M. Gerusky

Idaho Department of Health and Welfare
Robert Funderburg

Navajo Environmental Protection Administration
Louise Linkin

New Mexico Department of Health and Environment
Thomas E. Buhl

North Dakota Department of Health
Dana K. Mount

Oregon Department of Energy
Lynn Frank

Texas Department of Health
Edgar D. Bailey

Wyoming Department of Environmental Quality
Lyle Randen

Local Agencies

Central Valley Water Reclamation Facility Board
Rodney Dahl (2)

Salt Lake City-County Health Department
Harry L. Gibbons, M.D., M.P.H.
Jeff V. Throckmorton

Salt Lake County Administrative Services
Gregg Goodwin

Tooele County Building and Zoning
Joe Urbanik

Tooele County Human Services
Gary Dalton

Uranium Mill Tailings Task Force
Robert Immitt
Richard Wells

Wasatch Front Range Council
Ed Blaney

Organizations

Environmental Action, Inc.
Environmental Defense Fund
Friends of the Earth
League of Women Voters
National Audubon Society
National Wildlife Federation
Natural Resources Defense Council, Inc.
New Mexico Mining Association
Sierra Club
Southwest Research and Information Center
Paul Robinson
Two Rivers Citizens Association

Libraries

Freedom of Information Reading Room
U.S. Department of Energy
Washington, D.C.

Salt Lake County Library
209 East 400 South, Salt Lake City, UT

Salt Lake County Library
2480 South State, Salt Lake City, UT

Tooele Public Library
Tooele, UT

Brigham Young University
Harold B. Lee Library

University of Utah Library Office
Salt Lake City, UT

Utah State University Library Office
Logan, UT

Weber State College Library Office
Ogden, UT

Albuquerque Operations Office
U.S. Department of Energy
Albuquerque, NM

Chicago Operations Office
U.S. Department of Energy
Argonne, IL

Idaho Operations Office
U.S. Department of Energy
Idaho Falls, ID

Nevada Operations Office
U.S. Department of Energy
Las Vegas, NM

Oak Ridge Operations Office
U.S. Department of Energy
Oak Ridge, TN

Richland Operations Office
U.S. Department of Energy
Richland, WA

Savannah River Operations Office
U.S. Department of Energy
Aiken, SC

Energy Resource Center
U.S. Department of Energy
Oakland, CA

Regional Energy/Environment Center
Denver Public Library
Denver, CO

Individuals

Vivian Abele
Sherry Adderly
Carl S. Anderson
Eldon R. Anderson
Jerron Atkin
Jim Baker
Howard Berkes
Devan Berrett
Nancy Bloyer
Jack Bratcher
Alvin Britton
J. Keith Brown
George Bourne

Margaret Casper
Brenda Chamberlain
Dennis Christensen
Golda Christensen
Laurie Christensen
Mary Christensen
Joyce Christiansen
Robert W. Church
J. H. Coffman
T. Truman Cope
Monroe Cotten
Karl C. Dean
P. M. DeDycker
John C. Dempsey
John F. Doherty
Dr. German Dominguez
David K. Dougherty
D. L. Durler
Michael R. Embley
Vira Claire Emerick
Frances Farley
Joe Ferrill
Dane Finerfrock
Ed Firmage
Anthony Fischio
H. Paul Friesema
Al Gedicks
Kevin Griffin
Amira Hamdy
Mabel E. Hancock
Floyd Garn Hatch
Milo Higley
Udell Hill
Blaine N. Howard
Janice Huffman
Ed Jackson
Ann E. Jochens
Tosh Kano
W. F. Kirk
Walter Kisieleski
Margaret P. Lee
B. Litzlower
Custer L. Lynn
Ron Mace
Dr. Sidney Mark
J. M. McElfish, Jr.
Elsie A. Lynn
Claudia Miller
Don Montgomery
Dustin J. Moody
Emmett Moore

George Morrison
Pamela Nerry-Libby
Thelda Nix
Robert F. Overmeyer
Sandy Peck
Stanley Perkes
M. John Pilney
Oren Probert
A. Richards
Rich Richards
Jack Ritter
Charlie Roberts
Bernice Russell
Henry W. Rust
Doug Sayers
Carl A. Seibert
Vee J. Sharp
John Spear
Allan R. Staker
Zelpha Sweat
Beverly Towne
Susie Vader
Norman Van Wagoner
Volney Wallace
Leslie Wattier
Stanley R. Weyland
June Wickham
Jim Woolf
Harvey Wright
Ruth H. Yates
Fred E. Yost