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Nevada Nuclear Waste Storage Investigations Project

Technical Correspondence in Support of the Final Environmental Assessment

Arthur R. Morales

Prepared by
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Albuquerque, New Mexico 87185 and Livermore, California 94550
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Nevada Nuclear Waste Storage Investigations Project

TECHNICAL CORRESPONDENCE IN SUPPORT OF THE FINAL ENVIRONMENTAL ASSESSMENT

Compiled by

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ABSTRACT

This document is a collection of five technical memoranda and letters written to support statements in the Final Environmental Assessment for the Nevada Nuclear Waste Storage Investigations Project. The information pertains to various aspects of a high-level nuclear waste repository that may be constructed at Yucca Mountain on the Nevada Test Site.

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FOREWORD

This document contains five separate technical memoranda and letters supporting information in the Final Environmental Assessment (EA) for the Nevada Nuclear Waste Storage Investigations Project, which is studying the feasibility of constructing a high-level nuclear waste repository at Yucca Mountain in Nevada. The memoranda and letters are collected in this report as a convenient means of providing referenceable, previously unpublished information cited in the Final EA document. The Final EA document (to be published by the Department of Energy) was not completed at the time this collection of technical correspondence was assembled. For that reason, the reader is cautioned that some of the references herein to specific parts of the EA, such as table numbers, may not be correct when the final EA is published.

Arthur R. Morales
Nuclear Waste Engineering
Projects Division
Sandia National Laboratories

December 1985

POTENTIAL FOR CONCENTRATING HALIDE SALTS IN THE GROUNDWATER NEAR THE WASTE PACKAGE

Jeffrey W. Braithwaite

Sandia National Laboratories

Albuquerque, New Mexico 87185

January 8, 1986

Uel S. Clanton
Waste Management Project Office
U.S. Department of Energy
Nevada Operations Office
P.O. Box 14100
Las Vegas, Nevada 89114

Subject: Potential for Concentrating Halide Salts in the Groundwater Near the Waste Package

I have performed a relatively simple analysis of the potential for concentrating halide ions in the groundwater that could eventually contact the waste package. I sent a copy of the first draft of this letter to Dave Jorgenson (SAIC) and W. Glassley (LLNL) earlier in the week. I have since had the letter reviewed by Elmer Klavetter, Bob Prindle, and Steve lambert. I have made several minor text modifications. This version supersedes the previous memo dated September 27, 1985.

As we discussed last week on the telephone, I considered the two heat-driven mechanisms that have been proposed for producing such an effect:

1. Water drips from a seeping fracture directly onto a waste package that has a container temperature above the boiling point of the water. As the water evaporates, a salt residue is deposited on the container. When the package cools and water returns to the immediate package environment, the salt residue dissolves into the water producing elevated salt concentrations.

2. The halide salts contained in the groundwater are precipitated in the rock matrix as the thermal output of the waste package vaporizes the water producing a dryed-out zone. Then, when the rock cools and the groundwater re-enters the region, the precipitated salt will dissolve into the leading edge of the resaturation front producing higher dissolved concentrations of salt than in the typical groundwater percolating through the region.

I have summarized my thoughts, the analysis, and the conclusions I reached concerning each of these mechanisms in the remainder of this letter. Also, I have given my limited perspective on the consequence of such concentration processes. However, before either of the two mechanisms are discussed, I think we need to remember that in order to have a consequence of higher concentrations of halide in the groundwater, a process must exist that allows this groundwater, in liquid phase, to contact the waste package. In the unsaturated zone with air gaps present (as all emplacement designs currently have), such a mechanism has not been identified. The assumption behind the analyses that follows is that the groundwater will flow across the borehole wall, through the air gap, and contact the waste package.

Mechanism 1: Salt deposition on the container

Wang and Narasimhan (1985) have studied isothermal flow in the partially saturated, fractured, porous tuffs of Yucca Mountain. Their results can be used to show that water should flow in fractures under steady-state or even quasi-steady-state conditions applicable to this mechanism only if the matrix is near full saturation. Also, the two-phase flow studies conducted by Pruess et al. (1984) show, under the strongly heat-driven conditions expected for the Yucca Mountain situation, that flow in the fractures will be dominated by the vapor phase.

This concentration mechanism depends on the existence of a water-producing fracture at the emplacement borehole wall that allows water to drip directly on a hot waste package. Certainly, waste will not be placed in any fractured locations through which water is actively flowing (if indeed such fractures are found). Low seepages or even transient events would have to be the source for the dripping water. If the waste package is hot enough to vaporize the groundwater, then it is also hot enough to dry the surrounding rock matrix. The work of both investigators referenced above strongly suggests that seepages (either matrix or fracture) or transient events that could lead to a small quantity of fracture flow through the dry or even partially saturated tuff present during the thermal period are not probable. Therefore, mechanism 1 is not considered to be a viable process for concentrating salt in the groundwaters at Yucca Mountain.

Mechanism 2: Salt concentration due to precipitation within the rock matrix

Evidence does not exist that suggests that this particular mechanism is not viable for the conditions expected within Yucca Mountain. However, the question that needs to be addressed is "what level of salt concentration will be reached in the groundwater?" The answer to this questions is dependent on a number of factors, including:

- the concentration of salt in the vadose water
- the mineralogy of the host rock
- the extent of the dry-out zone
- the rate and characteristics of resaturation of the dry-out zone
- the diffusivity of the dissolved salt in the resaturated host rock
- the kinetics of dissolution of the precipitated salt

The current state of knowledge about each of these factors is insufficient to allow a detailed determination of this concentration mechanism to be completed. For this reason a bounding calculation was made. The assumptions associated with each of these factors and a summary of the bounding calculations are discussed separately below.

Concentration of salt in the vadose water: The concern with the concentration of salt in the groundwater is related to waste package performance. As will be discussed, the time following emplacement before the borehole area resaturates will probably be between 300 and 800 years. Because the containment time is required to be a minimum of 300 to 1000 years, we only need to address the effects of increased concentration on container performance. That is, dilution with percolating groundwater and diffusion should substantially reduce the salt concentrations by the time the waste form becomes exposed to the groundwater. Concentration of the chloride ion will be considered in this analysis because this particular ion is known to have a detrimental effect on the corrosion characteristics of stainless steels, if its concentration is sufficiently high. Other ions expected to be present in the groundwater should not have negative consequences with limited increased concentration (e.g., calcium, sulfate, magnesium) or could even promote beneficial results (e.g., nitrate).

Because there are not any analyses of vadose zone water, the analysis from J-13 well water was used in this study. A chloride concentration of 6.8 ppm was assumed (Kerrisk, 1984).

Mineralogy of the host rock: LANL, in their mineralogical studies, have not identified any chloride containing minerals, even in trace concentrations, within the Topopah Spring formation (Bish, 1985; Carlos, 1985). This result might be due to the circulation-drilling method used to obtain the core samples, or more probably simply to their very low occurrence. One of the objectives of exploratory shaft testing will be to characterize the extent of any soluble minerals within the various units. For this study, it was assumed that minerals containing even trace concentrations of chloride are not present within the Topopah Spring unit. This is an important factor because it limits the total quantity of chloride available for concentration. As the dry-out front proceeds outwards, the only salt that will be precipitated is that which is contained within the water being evaporated. Local "heat-pipe" effects cannot dissolve and precipitate additional chloride, which could occur if chloride-containing minerals were present.

Extent of the dry-out zone: Detailed thermal analyses of potential emplacement designs have not been completed. However, the results given in Blanford (1985) were used to bound the size of the dry-out zone. Blanford determined the maximum temperature as a function of location for a spent fuel repository using information and material properties from the unit-evaluation study. From these results, a dry-out zone with a maximum radius of 30 meters was estimated. The time to reach this maximum extent was calculated to be approximately 200 years. These values will be used in the analysis described below. However, unpublished results using a conduction model with the best site characteristics and design information currently available, show that the extent is probably limited to 16-20 meters. A rigorous, two-phase flow determination of the temperature profile has not been completed to date. The extent of the dry-out zone is important because it, together with the groundwater concentration, limits the quantity of chloride that is available for concentration.

Resaturation rate of the host rock: The study conducted by Blanford does not provide the information needed to estimate resaturation rates and times. The results from a LLNL study (Stein, 1984) were used to estimate and overall time to resaturation of 800 years. This LLNL study assumed conditions similar to the Blanford analysis. The unpublished study discussed in the previous paragraph determined a resaturation time of approximately 300 years. Resaturation times could be important if diffusion rates for the dissolved chloride are important. With such long resaturation times and the high suction head in the matrix, the assumption was made that the matrix outside the dry-out zone will remain saturated. The resaturation velocity was assumed to be linear at 30 meters per 600 years or 50 mm/year. This velocity is important when determining the relative importance of diffusion versus convection.

Chloride diffusivity: The diffusivity (D_e) of sodium chloride though the porous tuff matrix was calculated based on the equation given in Reid (1977) to be

$$D_e = 1 \times 10^{-6} \text{ cm}^2/\text{sec}$$

at 100°C. This effective diffusivity incorporates porosity of 10% and a tortuosity factor of 5.

Precipitated salt dissolution kinetics: During the evaporation process, several salts and compounds will be co-precipitated. This list includes silica, which is probably the major component in the water at the time of vaporization. The presence of silica in the precipitate could substantially reduce the actual dissolution kinetics compared to a pure halide salt. However, it was assumed that the salt dissolves instantaneously upon contact with the first water contacting it during the resaturation process. This assumption could lead to higher concentrations of salt than is actually the case.

Estimate of concentration effect: Given the factors and conditions outlined above, the first issue to be resolved is whether or not diffusive transport is important relative to convective transport. A relatively crude way to determine this is to calculate the Peclet number (N_{pe}):

$$N_{pe} = \frac{\text{water velocity} * \text{distance}}{\text{effective diffusivity}}$$

This number represents the ratio of material transferred by bulk flow to material transport by diffusion (Szekely, 1971). With the information given above, the Peclet number for this situation equals approximately 500. This

result tells us that diffusion is not very important and, with the instantaneous dissolution kinetics, that the chloride ion concentration may build up in the first packet of water following the saturation front back to the waste package. The prediction of the actual concentration in this package cannot be made with a simple calculation, but can be bounded by considering the root-mean-square distance the chloride ions will travel in the 600-year resaturation time to be the characteristic thickness of the packet. This distance (x) is given by the following equation

$$X = (D_e * t)^{0.5}$$

and for these conditions equals approximately 150 cm. The quantity of chloride precipitated in the 30-meter high dry-out zone is approximately 1.8×10^{-3} gr/cm^2 of horizontal surface area.

Assuming all this salt is concentrated at the end of the resaturation period in the 150 cm column of water next to the borehole wall, the chloride concentration would be approximately equal to 1.2×10^{-4} gr/cm^3. This concentration represents a maximum increase of about 20X over that originally present in the groundwater. The resaturation times and dry-out distances from the more recent unpublished thermal calculations result in a slightly lower concentration factor (17). If the original groundwater composition is similar to J-13, then the maximum concentration is 120 to 150 ppm.

Conclusion

Of the two possible mechanisms for concentrating salt in the groundwater, only the one that involves precipitation of the salt in the dry-out zone and immediate dissolution of that salt in the resaturating water is viable for the conditions expected at Yucca Mountain. This mechanism could possibly increase normal groundwater chloride compositions by a factor of 20. The process for transporting this concentrated groundwater to the container surface has not been identified. However, if it is assumed that the groundwater can flow across the borehole wall and contact the container, then the issue of the significance of this increase must be addressed. LLNL has been and is continuing to study container corrosion in solutions concentrated by a factor of 10. Their results have not shown any detrimental effects of this increased concentration to date, if gamma radiation is not present. At the time the resaturation front reaches the package (300-800 years), gamma radiation would have decreased to insignificant levels. LLNL certainly must confirm this conclusion, but the information currently available shows that any thermally-driven process that leads to an increase in salt concentration in the groundwater should not adversely affect waste containment or isolation.

References

Bish, D., and D. Vaniman, "Mineralogical Summary of Yucca Mountain, Nevada," LA-10543-MS, 1985 (in preparation).

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Wang, J. S. Y., and T. N. Narasimhan, "Hydrologic Mechanisms Governing Fluid Flow in Partially Saturated, Fractured, Porous Tuff at Yucca Mountain," SAND84-7202, April 1985, pp. 28-44.

Sincerely,

Jeffrey Braithwaite

Jeffrey W. Braithwaite
NNWSI Repository Performance
Assessments
Division 6312

JWB:6312:mjh:1377r

Copy to:
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72-12142-1.6/QNQ

POPULATION DISTRIBUTION AT YUCCA MOUNTAIN SITE

R. I. Brasier

Sandia National Laboratories

Albuquerque, New Mexico 87185

date: May 8, 1985

to: Jean Younker, SAIC

from: R. I. Brasier, SNL/LATA

subject: Population Distribution at Yucca Mountain Site

The original population distribution given in the EA, reference Jackson and Gram, Preliminary Safety Assessment Study for the Conceptual Design of a Repository in Tuff at Yucca Mountain, SAND83-1504, December 1984, lists the population within an 80 Km (50 mile) radius as 19,908 persons. This distribution is described in Figure 1, attached. The number was derived from 1980 census data, U.S. Department of Commerce, Bureau of the Census General Population Characteristics, Nevada, 1980 Census of the Population, Part 30, Series PC80-1-B30, May 1982, in which the population for a given county was divided by the county area to give an average population density. In some cases, this resulted in the inclusion of people who actually live in more densely populated areas but are outside the 80 Km radius. The effect is a conservative estimate of population.

A second approach has been taken for more recent (unpublished) calculations. The known population of towns is subtracted from the county population to give an average rural population density. The towns actually within the 80 Km radius (Beatty, Indian Springs, etc.) are included. This results in a population of 11,674 persons as described in Figure 2. This compares favorably with the EPA estimate of .5 persons per square kilometer given in EPA 600/4-83-032, Offsite Radionuclide Monitoring Report, Radiation Monitoring Around US Nuclear Test Areas, Calendar Year 1982, July 1983. (The area of a circle of 80 Km radius is 20,106 Km^2.)

None of this addresses the issue of the population in the year 2000. The only population growth figures available are for metropolitan Las Vegas.

I hope this is of some help.

RIB:6311:sj
Attachment

Copy to:
6311 R. I. Brasier

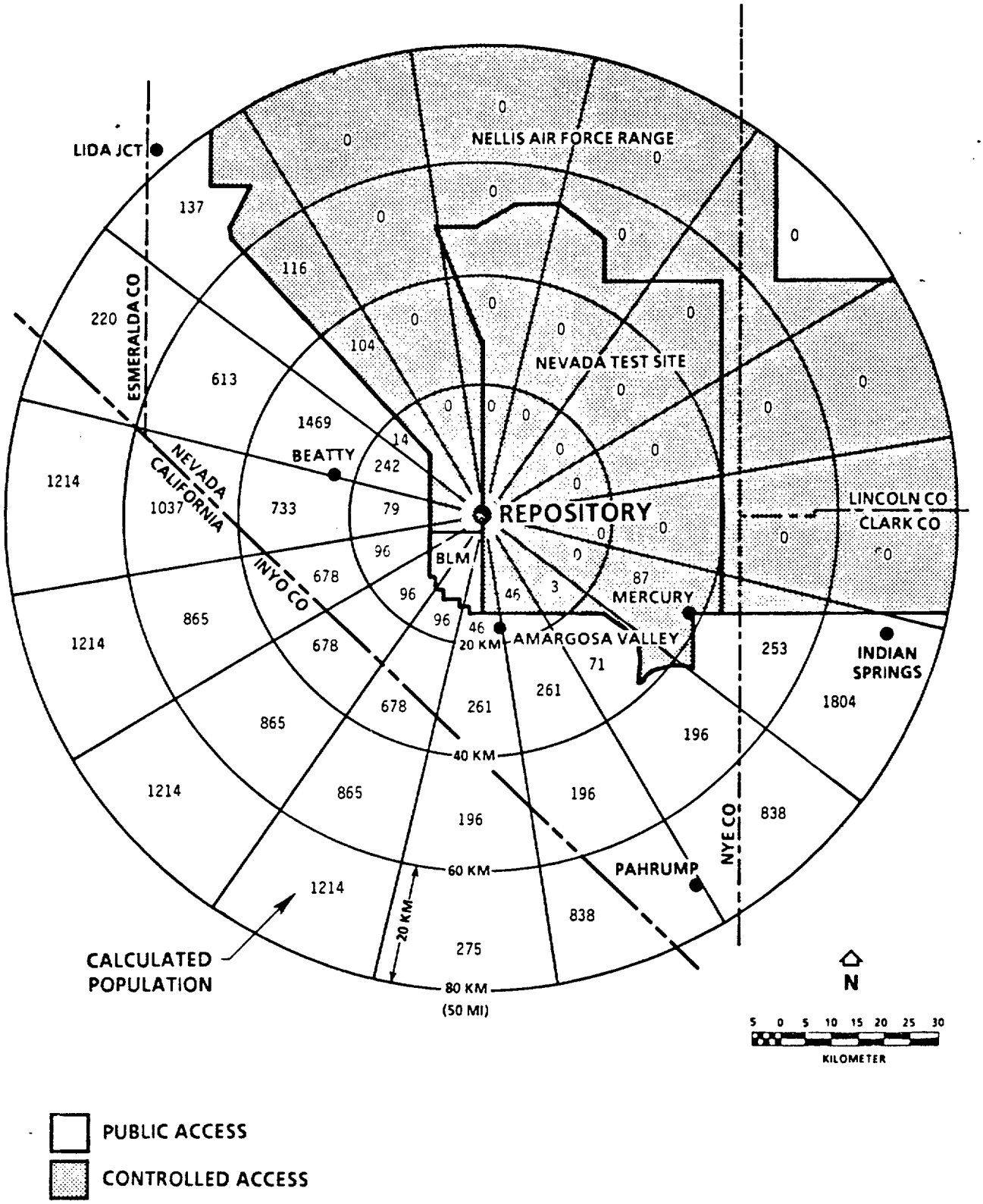

Figure 1. Calculated Population Distribution in an 80-km- (50-mi-) Radius Area Around the Prospective Repository Site

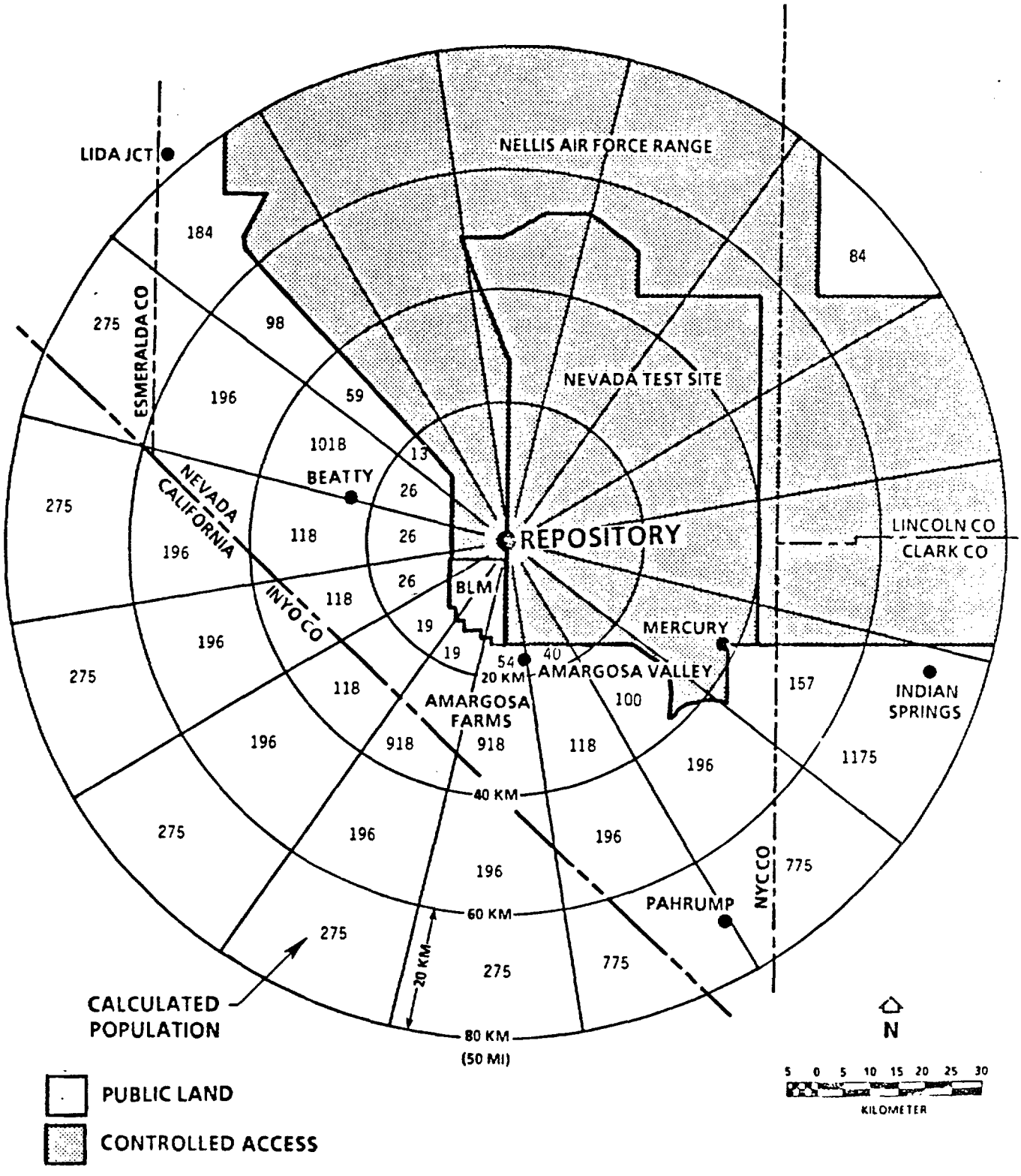

Figure 2. Calculated Population Distribution in an 80-km- (50-mi-) Radius Area Around the Prospective Repository Site

NNWSI REPOSITORY--PROPOSED SANITARY WASTE AND WATER SYSTEMS

T. W. Eglinton

Sandia National Laboratories

Albuquerque, New Mexico 87185
November 11, 1985

Larry P. Skousen
U.S. Department of Energy
Nevada Operations Office-WMPO
P.O. Box 14100
Las Vegas, NV 89114

Dear Larry:

Subject: NNWSI Repository - Proposed Sanitary Waste and Water Systems

This letter supersedes the Sandia memo from T. W. Eglinton to L. P. Skousen dated September 5, 1985.

A. Sanitary Waste Systems

1. Based upon an estimated 45-90,000 gallons per day sanitary waste water flow rate range, a packaged trickling filter plant with effluent disposal evaporative ponds is being considered at the central surface facilities. The effluent limitations will conform to the requirements established by the Nevada State Board of Health for secondary treatment.

2. Current plans for off-site sanitary sewage disposal measures will include septic tanks with seepage pits, absorption trenches or seepage beds. Hypalon-lined evaporative pond(s) will be used for mine waste water effluents. These structures will be located beyond the repository geologic block.

B. Water Systems

1. The following is the estimated water usage at the repository during the life of the project (excluding retrieval option). It will rise to a peak of over 120 million gallons at the end of the sixth year and decrease to about 115 million gallons per year and remain at this level for the next 26 years. The average water demands for the following 23 years of operation will be approximately 2,500,000 gallons per year - this latter 23 year estimate, represents the minimum water requirement for any given period. The water usage then increases to approximately 25 million gallons per year for 8 years until closure.

2. The maximum estimated yearly water consumptions have been based upon the following:

   a. Assumptions
      (1) Vertical waste emplacement scenario
      (2) Recycling of waste water neglected
      (3)* Maximum personnel = 1900 and average personnel (years 0-32) = 1600
      (4) Future plant contingencies = 25%
      (5) Final calculated numbers have been rounded for simplification
      (6) 250 working days/year

   b. Personnel Consumption (Surface Facilities). Using 50 gallons per capita per day usage,

1900 x 50	= 95,000 gpd peak
	= 66.0 gpm peak
average gallon per day 1600 x 50	= 80,000 gpd average
	= 55 gpm average

   c. Process Consumption
      (1) Cooling towers and evaporative coolers. Using mechanical draft (wet type) the evaporative losses, drift and 1-percent blowdown = 200 gpm peak
      = 100 gpm average
      = 144,000 gpd

      (2) Cooling towers for down-hole waste emplacement drift chilled water systems = 20 gpm peak
      = 20 gpm average
      = 29,000 gpd

      (3) Miscellaneous (vehicle washdown, decontamination, demineralizers, laundry, etc.) = 40 gpm peak
      = 20 average
      = 29,000 gpd

---

* The manpower numbers were developed and used in the Two-Stage Repository Report, SAND84-1351, Rev. 1, and published in the Yucca Mountain Final Environmental Assessment, Table 5.3.

d. Surface-Underground Construction (sealing, bratticing, structures, etc.)

(1) Assume a 56 cubic yard per day capacity concrete batching plant. With 35 gallons of water required per cubic yard of concrete, 35 x 56 = 2,000 gpd
= 1.5 gpm avg.
= 5 gpm peak

(2) Muck (dust control). With 2,500 tons per day tuff removed (90 pounds per cubic foot density), approximately 20 gallons of water will be required per ton of material = 50,000 gpd
= 35 gpm avg.
= 70 gpm peak

e. Underground Water Consumption (Dust control at working headings, equipment and personnel needs) = 36,000
= 25 gpm avg.
= 50 gpm peak

f. Fire (sprinkler systems, hydrants). Assume 2,500 gpm, utilizing a total of 750,000 gallons of dedicated storage. This demand has been neglected for concurrent peak flow conditions.

g. Recap - Note: The following estimate is for years of construction through emplacement years 0 through 32

Function	Peak Gallons per Minute (gpm)	Average Gallons per Minute (gpm)	Peak Gallons per Day (gpd)	Average Gallons per day (gpd)
1. Personnel Consumption	66	55.5	95,000	80,000
2. Process Consumption				
Towers (surface facilities)	200	100	144,000	144,000
Tower (u.g. facilities)	20	20	29,000	29,000
Miscellaneous	40	20	29,000	29,000
3. Surface-Underground Construction				
Concrete	5	1.5	2,000	2,000
Muck	70	35	50,000	50,000
4. Underground Consumption	50	25	36,000	36,000
Sub-totals	451	257	385,000	370,000
25-percent safety factor			96,250	92,500
			481,250	462,500

3. Present plans call for the construction of new water wells and storage provisions to be located at the proposed central surface facilities. Water for domestic, process, and fire needs will be treated and distributed from the new systems throughout the repository complex.

4. Since existing well J-13 is located approximately 5 miles southeast of the central surface facilities, this water source will be substituted by the new wells. It will be used in the interim for the Exploratory Shaft Facility, and the initial repository construction forces.

Sincerely,

T. W. Eglinton

T. W. Eglinton
Nuclear Waste Engineering Projects
Division 6311

TWE:6311:sj

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ENVIRONMENTAL ASSESSMENT REPORT CHAPTER 5.1, TABLE 5-3 REVISION

Earl Gruer

Sandia National Laboratories

Albuquerque, New Mexico 87185

date: December 18, 1985

to: Memorandum of Record

Art Morales for

from: Earl Gruer, 6311

subject: Environmental Assessment Report Chapter 5.1, Table 5-3 Revision

This memorandum concerns the adjusted allocation of the estimated average number of construction related workers during the years 1998 through 2000 (3 years) as scheduled in table 5-3.

The rationale for the adjusted allocations from the surface support personnel category to the direct construction related categories of: direct construction, construction support, construction managers and inspectors for the years 1998, 1999 and 2000 is based upon several assumptions. It is assumed that: 1) the operating contractor's surface support personnel (comprised of both contracted and directly employed trade workers) and involvement in site activities (including occupancy modifications and special equipment installation) will increase as the prime construction contractors' forces and activities decrease, 2) the relative percentage of workers in each of the direct construction related activities remains the same and 3) the total worker years does not change. (Total worker years was derived from the 2-stage report cost estimate).

The specific number of reallocated workers from surface support personnel to the direct construction categories was determined based upon the assumptions above. See attached graphs 1 and 2.

Attached are the work sheets used to balance table 5-3.

ERG:6311:sj
Attachments: Worksheets 1, 2 and 3, dated 9/13/85
Graphs 1 and 2: dated 9/13/85

Copy to:
6310 T. O. Hunter
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Revised 9/13/85

TABLE 5-3

REPOSITORY WORKERS

WORKSHEET 1 OF 3

Average Annual Number of Workers - Vertical Emplacement

	Years																
	1993	1994	1995 and 1996	1997	1998	1999	2000	2001	2002 thru 2018	2019	2020 thru 2024	2025	2026 thru 2046	2047	2048 thru 2054	2055	Total Worker-Years
Construction Contractor(s)																	
Direct Construction	87	346	519	433	344	173	82							39	77	39	3,120
Construction Support	10	39	58	48	42	21	10							5	9	5	359
Mining Contractor																	
Direct Mining	35	140	210	175	149	149	149	149	149	75				57	113	57	4,879
Mining Support	70	280	420	350	253	253	253	253	253	127				57	113	57	7,885
Operating Contractor																	
Construction Managers	20	81	121	101	82	41	20										587
Inspectors	12	48	72	60	46	23	10										343
Quality Assurance Personnel	12	47	70	87	91	78	79	79	84	75	67	37	8	14	20	10	2,820
Surface Emplacement Personnel					44	44	54	54	107	107	107	57	7	4			2,865
Surface Support Personnel				529	800	800	936	1,058	1,058	1,058	1,058	574	89	59	29	15	31,177
U/G Emplacement Personnel					20	20	40	40	80	80	80	44	7	4			2,155
U/G Support Personnel				34	34	34	34	34	34	60	86	69	51	51	51	26	2,812
Subtotal - Vertical Emplacement	246	981	1,470	1,817	1,905	1,636	1,667	1,667	1,765	1,582	1,398	781	162	290	412	209	59,002
Indirect Employment	379	1,511	2,264	2,798	2,934	2,519	2,567	2,567	2,718	2,436	2,153	1,203	249	447	634	322	90,849
Total - Vertical Emplacement	625	2,492	3,734	4,615	4,839	4,155	4,234	4,234	4,483	4,018	3,551	1,984	411	737	1,046	531	149,851

(MOVE WORKERS FROM OPERATIONS TO CONSTRUCTION)

Average Annual Number of Workers - Horizontal Emplacement

	Years																
	1993	1994	1995 and 1996	1997	1998	1999	2000	2001	2002 thru 2010	2011	2012 thru 2024	2025	2026 thru 2046	2047	2048 and 2049	2050	Total Worker-Years
Construction Contractor(s)																	
Direct Construction	85	338	507	423	340	173	86							58	116	58	2,807
Construction Support	9	37	56	47	40	20	11							7	13	7	316
Mining Contractor																	
Direct Mining	29	115	172	143	57	37	37	37	37	19				57	113	57	1,491
Mining Support	57	229	344	287	115	64	64	64	64	32				57	113	57	2,516
Operating Contractor																	
Construction Managers	18	72	108	90	75	38	19										528
Inspectors	11	43	65	54	45	23	11										317
Quality Assurance Personnel	10	42	63	79	76	60	62	62	67	65	64	35	7	14	21	11	2,266
Surface Emplacement Personnel					44	44	54	54	107	107	107	57	7	4			2,865
Surface Support Personnel				511	768	768	895	1,022	1,022	1,022	1,022	556	89	59	29	15	30,027
U/G Emplacement Personnel					23	23	45	45	90	90	90	49	7	4			2,406
U/G Support Personnel				17	17	17	17	17	17	35	53	45	36	36	36	18	1,889
Subtotal - Horizontal Emplacement	219	876	1,315	1,651	1,600	1,267	1,301	1,301	1,404	1,370	1,336	742	146	296	441	223	47,428
Indirect Employment	337	1,349	2,025	2,543	2,464	1,951	2,004	2,004	2,162	2,110	2,057	1,143	225	456	679	343	73,036
Total - Horizontal Emplacement	556	2,225	3,340	4,194	4,064	3,218	3,305	3,305	3,566	3,480	3,393	1,885	371	752	1,120	566	120,464

Source: SAND84-1351 (MacDougall et al., 1984)

Notes: (1) The average annual number of workers includes a 10% allowance for vacation, sick leave, and other absenteeism plus a 30% contingency allowance.

(2) The distribution of construction workers assumes that 10% of the total number of workers are support personnel.

(3) Indirect employment assumes 1.54 indirect workers for each direct worker as used by McBrien and Jones (1984).

WORKSHEET 2 OF 3

Labor Account	a	b Percent of Total Const.	c 1993 1994 1995	d 1996	e 1997	f 1998	g 1999	h 2000	i 2001	j 2001 thru 2055	k Total Change	l Worker Original	m Years New
						YEAR							
VERTICAL EMPLACEMENT													
Direct Construction	Orig	67	See Table 5-3	519	433	173	0	0	0	See Table 5-3	--	2,694	--
	Revised	NC		NC	NC	344	173	82	NC		+426	2,694	3,120
Construction Support	Orig	8		58	48	19	0	0	0		--	305	--
	Revised	NC		NC	NC	42	21	10	NC		+54	305	359
Const. Managers	Orig	16		121	101	40	0	0	0		--	484	-
	Revised	NC		NC	NC	82	41	20	NC		+103	484	587
Inspectors	Orig	9		72	60	24	0	0	0		--	288	-
	Revised	NC		NC	NC	46	23	10	NC		+55	288	343
TOTAL CONSTRUCTION	Orig	100		770	642	256	0	0	0		--	3,771	--
	Revised	100		NC	NC	514	258	122	NC		+638	3,771	4,409
HORIZONTAL EMPLACEMENT													
Direct Construction	Orig	68		507	423	169	0	0	0		--	2,377	--
	Revised	NC		NC	NC	340	173	86	NC		+430	2,377	2,807
Const. Support	Orig	8		56	47	19	0	0	0		--	264	--
	Revised	NC		NC	NC	40	20	11	NC		+52	264	316
Const. Managers	Orig	15		108	90	36	0	0	0		--	432	--
	Revised	NC		NC	NC	75	38	19	NC		+96	432	528
Inspectors	Orig	9		65	54	22	0	0	0		--	260	--
	Revised	NC		NC	NC	45	23	11	NC		+57	260	317
TOTAL CONSTRUCTION	Orig	100		736	614	246	0	0	0		--	3,333	--
	Revised			N	NC	500	254	127	NC		+635	3,333	3,968
Surface Support	Orig	Vert.		0	529	1,058	1,058	1,058	1,058		--	31,815	--
		Horiz.		0	511	1,022	1,022	1,022	1,022		--	30,662	--
	Revised	Vert.		NC	NC	800	800	936	NC				31,177
		Horiz.		NC	NC	768	768	895	NC				30,027
	Change	Vert.		NC	NC	-258	-258	-122	NC		-638		
		Horiz.		NC	NC	-254	-254	-127	NC		-635		

NC = No Change

TABLE 5-3

REPOSITORY WORKERS

Worksheet 3 of 3

Average Annual Number of Workers - Vertical Emplacement Years

	1993	1994	1995 and 1996	1997	1998	1999	2000	2001	2002 thru 2018	2019	2020 thru 2024	2025	2026 thru 2046	2047	2048 thru 2054	2055	Total Worker-Years
Construction Contractor(s)																	
Direct Construction	87	346	519	433	344	173	82							39	77	39	3,120
Construction Support	10	39	58	48	42	21	10							5	9	5	359
Mining Contractor																	
Direct Mining	35	140	210	175	149	149	149	149	149	75				57	113	57	4,879
Mining Support	70	280	420	350	253	253	253	253	253	127				57	113	57	7,885
Operating Contractor																	
Construction Managers	20	81	121	101	82	41	20										587
Inspectors	12	48	72	60	46	23	10										343
Quality Assurance Personnel	12	47	70	87	91	78	79	79	84	75	67	37	8	14	20	10	2,820
Surface Emplacement Personnel					44	44	54	54	107	107	107	57	7	4			2,865
Surface Support Personnel				529	800	800	936	1,058	1,058	1,058	1,058	574	89	59	29	15	31,177
U/G Emplacement Personnel					20	20	40	40	80	80	80	44	7	4			2,155
U/G Support Personnel				34	34	34	34	34	34	60	86	69	51	51	51	26	2,812
Subtotal - Vertical Emplacement	246	981	1,470	1,817	1,905	1,636	1,667	1,667	1,765	1,582	1,398	781	162	290	412	209	59,002
Indirect Employment	379	1,511	2,264	2,798	2,934	2,519	2,567	2,567	2,718	2,436	2,153	1,203	249	447	634	322	90,849
Total - Vertical Emplacement	625	2,492	3,734	4,615	4,839	4,155	4,234	4,234	4,483	4,018	3,551	1,984	411	737	1,046	531	149,851

Source: SAND84-1351 (MacDougall et al., 1984)

Notes: (1) The average annual number of workers includes a 10% allowance for vacation, sick leave, and other absenteeism plus a 30% contingency allowance.

(2) The distribution of construction workers assumes that 10% of the total number of workers are support personnel.

(3) Indirect employment assumes 1.54 indirect workers for each direct worker as used by McBrien and Jones (1984).

TABLE 5-3 (concluded)

REPOSITORY WORKERS

Worksheet 3 of 3 (concluded)

Average Annual Number of Workers - Horizontal Emplacement

	Years																
	1993	1994	1995 and 1996	1997	1998	1999	2000	2001	2002 thru 2010	2011	2012 thru 2024	2025	2026 thru 2046	2047	2048 and 2049	2050	Total Worker-Years
Construction Contractor(s)																	
Direct Construction	85	338	507	423	340	173	86							58	116	58	2,807
Construction Support	9	37	56	47	40	20	11							7	13	7	316
Mining Contractor																	
Direct Mining	29	115	172	143	57	37	37	37	37	19				57	113	57	1,491
Mining Support	57	229	344	287	115	64	64	64	64	32				57	113	57	2,516
Operating Contractor																	
Construction Managers	18	72	108	90	75	38	19										528
Inspectors	11	43	65	54	45	23	11										317
Quality Assurance Personnel	10	42	63	79	76	60	62	62	67	65	64	35	7	14	21	11	2,266
Surface Emplacement Personnel					44	44	54	54	107	107	107	57	7	4			2,865
Surface Support Personnel				511	768	768	895	1,022	1,022	1,022	1,022	556	89	59	29	15	30,027
U/G Emplacement Personnel					23	23	45	45	90	90	90	49	7	4			2,406
U/G Support Personnel				17	17	17	17	17	17	35	53	45	36	36	36	18	1,889
Subtotal - Horizontal Emplacement	219	876	1,315	1,651	1,600	1,267	1,301	1,301	1,404	1,370	1,336	742	146	296	441	223	47,428
Indirect Employment	337	1,349	2,025	2,543	2,464	1,951	2,004	2,004	2,162	2,110	2,057	1,143	225	456	679	343	73,036
Total - Horizontal Emplacement	556	2,225	3,340	4,194	4,064	3,218	3,305	3,305	3,566	3,480	3,393	1,885	371	752	1,120	566	120,464

Source: SAND84-1351 (MacDougall et al., 1984)

Notes: (1) The average annual number of workers includes a 10% allowance for vacation, sick leave, and other absenteeism plus a 30% contingency allowance.

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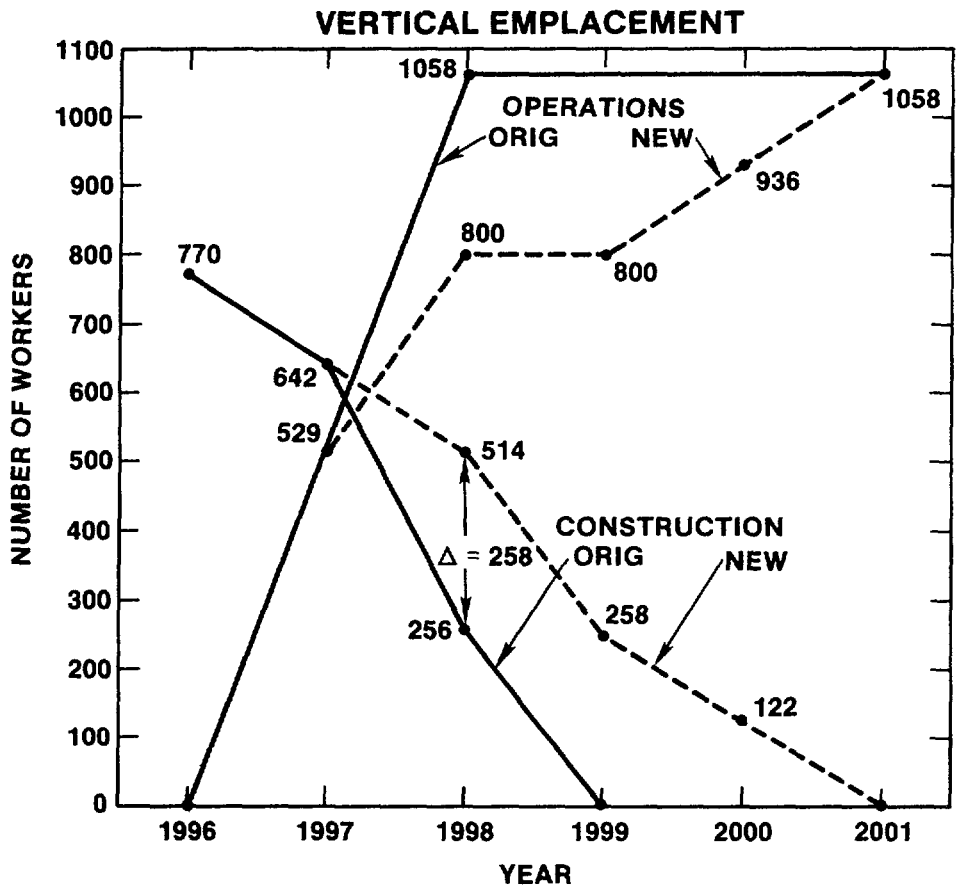
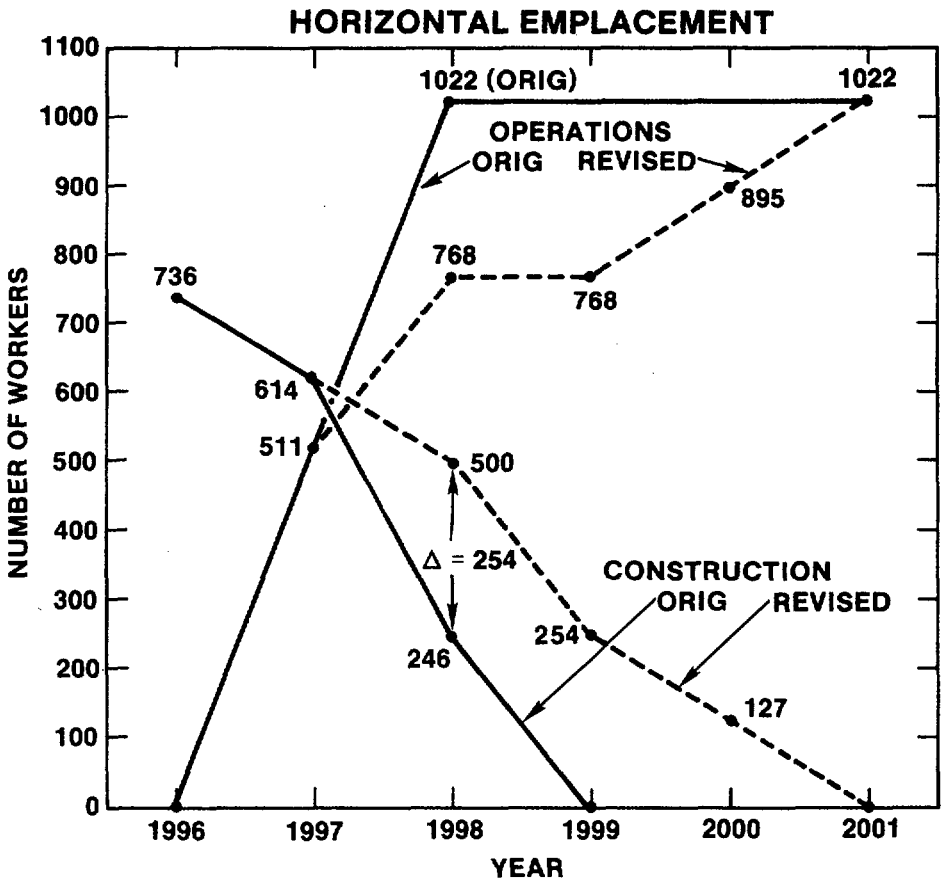

VERTICAL EMPLACEMENT
NUMBER OF WORKERS
YEAR
1100
1000
900
800
700
600
500
400
300
200
100
0
1996
1997
1998
1999
2000
2001
1058
1058
OPERATIONS
ORIG
NEW
936
800
800
770
642
529
514
CONSTRUCTION
ORIG
NEW
Δ = 258
258
256
122


HORIZONTAL EMPLACEMENT
NUMBER OF WORKERS
YEAR
1100
1000
900
800
700
600
500
400
300
200
100
0
1996
1997
1998
1999
2000
2001
1022 (ORIG)
1022
OPERATIONS
ORIG
REVISED
895
768
768
736
614
511
500
Δ = 254
CONSTRUCTION
ORIG
REVISED
254
246
127

DETERMINATION OF MAXIMUM TEMPERATURE AS A FUNCTION OF DISTANCE FROM A SPENT FUEL AND A COMMERCIAL HIGH-LEVEL WASTE REPOSITORY

M. L. Blanford

KEYSTONE MEMO 6310-84-1

Sandia National Laboratories

Albuquerque, New Mexico 87185

Date: 2/14/1985

To: T. O. Hunter

From: J. R. Tillerson, 6314

Subject: Determination of Maximum Temperature as a Function of Distance from a Spent Fuel and a Commercial High-Level Waste Repository

The attached document has received peer review by 6310 staff and has been prepared for distribution to NNWSI TPO's and participants. Referenced documents by Svalstad are all drafts and have not received peer review.

Attachment - RE/SPEC Inc. Technical Letter Memorandum RSI-0002

Copy to:
6314 J. R. Tillerson
6314 A. J. Mansure
6314 File 1112d

Reviewer - J. W. Braithwaite
Div. 6312
2/14/85
Date

Referee - A. J. Mansure
Div. 6314
2/14/85
Date

Joe R. Tillerson - 6314
2/14/85
Date

Albuquerque, New Mexico
Calgary, Alberta, Canada

RE/SPEC INC.

Technical Letter Memorandum RSI-0002

To: Chip Mansure
Nuclear Waste Engineering Projects Division 6311
Sandia National Laboratories
Albuquerque, NM 87185

cc: Terje Brandshaug
Sam W. Key
David K. Parrish
Darrell K. Svalstad

From: Mark L. Blanford Mark Blanford

Date: January 30, 1985

Subject: Determination of Maximum Temperature as a Function of Distance from a Spent Fuel and a Commercial High-Level Waste Repository—SNLA Contract 37-8656, Task IV.

1 Introduction

Although the primary function of a commercial high-level nuclear waste repository is to isolate from the accessible environment spent fuel rods or reprocessed commercial high-level waste, the disposal of low-level waste may also be required. Low-level wastes, possibly including organics, such as floor sweepings, contaminated clothing, processing liquids, and the like are inevitably generated in the handling and processing of nuclear waste. While, unlike high-level waste, these wastes do not produce significant amounts of heat in themselves, they do emit radiation and must be isolated from the accessible environment.

One particular problem becomes evident when disposing wastes including organics in the vicinity of a heat-generating repository—they have the potential for organic decomposition if the temperature rises too far. In designing a repository for both types of waste, then, one must balance hazard against cost—the hazard of high temperature versus the cost of mining additional excavations some distance away from the primary repository. In this context, a snapshot of the temperature

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distribution throughout the repository at any given point in time is not particularly useful. Rather, one would like to have a map of the maximum temperature ever reached as a function of distance from the repository.

This study has produced just such maximum temperature profiles, based on the simplified analytic three-dimensional thermal model (SPECTROM-349) of an underground waste repository described by Svalstad [1984a]. More significantly, it has yielded a tool for producing that map, given any particular arrangement and emplacement sequence of various heat-producing waste forms in a model repository.

A description of the procedure and some initial results are given in the remainder of this report. Thermal properties, depth below the surface, and thermal loading are representative of a repository in the Topopah Spring Member at the proposed nuclear waste repository site at Yucca Mountain, on and adjacent to the Nevada Test Site.

2 Computational Procedure

In the present study, two generic repository configurations were considered: 1260 acres (5.10×10^6 m^2) of spent fuel (SF) at 57 kW/a (14.1 W/m^2), and 645 acres (2.61×10^6 m^2) of commercial high-level waste (CHLW) at 100 kW/a (24.7 W/m^2). For simplicity, these were represented as single rectangular panels as shown in Figure 1. The SF panel is 6,000 ft by 9,148 ft (1,829 m by 2,788 m), while the CHLW panel is 5,000 ft by 5,619 ft (1,524 m by 1,713 m). These panels are buried at a depth of 390 m, with a nominal thickness of 4 m. The entire half-space modeled was considered to be homogeneous with a constant average thermal conductivity (k) of 1.46 W/m-K, and volumetric heat capacity (ρC_p) of 0.07636 W-yr/m^3-K. These properties were chosen [Svalstad, 1983a and 1984b] to simulate the detailed thermal stratigraphy used in the unit evaluation [Johnstone, *et. al.*, 1984]. A linear geothermal temperature gradient was superimposed on the temperatures produced by the waste, from 13.1°C at the earth's surface through 25.2°C at the repository.

The coordinate system, the repository boundary, the location of the heat-producing panels, and the thermal properties as described here were taken directly from a previous study by Svalstad [1983b].

The waste itself was assumed to be commercial high-level waste or a combination of PWR and BWR spent fuel, having a heat generation rate of the form

$$q(t) = F \sum_{i=1}^{n} A_i e^{-\beta_i t}$$

with the constants A_i and β_i given in Table 1.

Table 1

Exponential Decay Constants for SF and CHLW [Shirley, 1983].

	SF		CHLW	
Term	A_i	β_i	A_i	β_i
1	0.77	0.027	0.088	0.26
2	0.20	0.0021	0.85	0.024
3	0.025	0.000053	0.068	0.0015
4			0.000068	0.000037

To determine maximum temperatures, SPECTROM-349 [Svalstad, 1984a] was modified to search in time for the maximum temperature rather than give a snapshot of temperature at a particular time. SPECTROM-349 evaluates temperature by numerically integrating an analytic expression for heat conduction in a half-space. In the present study, SPECTROM-349 was modified by the inclusion of a MAXTEMP input directive that yields an additional pair of plots for each profile or contour request. These plots show the maximum temperature as a function of position, and the time of maximum temperature, respectively.

3 Description of Results

Temperature profiles were calculated at three locations:

1. Horizontally along C–C′ from the block boundary extending 500 m,
2. Vertically through point A, the center of the block, and
3. Vertically through point B, the edge of the block.

Temperature profiles for these three locations are shown in Figures 2, 3, and 4, respectively. Part (a) of each figure is for a spent fuel repository, and part (b) is for a commercial high-level waste repository. Each of the profile plots on the left of the figure contains two curves. One is a standard temperature profile at 500 years after emplacement. The other is a "maximum temperature" profile, representing an envelope of the maximum of all standard temperature profiles over time. As such, each location on the "Profile of Maximums" represents temperature at a different point in time.

In addition to these profiles, temperature contours were mapped in a vertical plane through C–C′, showing the maximum extent of 37.78°C (100°F), 50°C, 75°C, and 100°C temperatures (Figure 5).

In addition to the temperature plots, each of Figures 2–5 contain an additional

Table 2

Stand-Off Distances (in meters).

	Horizontally from Edge		Vertically above Center		Vertically above Edge	
	SF	CHLW	SF	CHLW	SF	CHLW
100°F	170	123	263	245	173	150
50°C	45	37	202	176	81	69
75°C	0	8	88	74	0	20
100°C	0	0	23	37	0	0

plot (on the right) showing the time at which the maximums were attained, as a function of position. Note that at locations close to the repository, the maximums occur at relatively early times (on the order of 50 years), while farther away the maximums are not reached for many thousands of years.

Let us briefly review the behavior of these two idealized repository configurations. The center of the spent fuel repository reaches a maximum temperature of 117°C 60 years after emplacement. The commercial high-level waste configuration causes a corresponding temperature peak of 164°C after 43 years, but the peak temperatures drop off much more rapidly as you move away from the repository. The picture is similar at the repository edge. There SF causes a temperature peak of 71°C 60 years after emplacement, while CHLW peaks at 43 years with a temperature of 95°C.

Fifty meters beyond the repository edge the picture has changed, in that the SF yields a higher maximum than the CHLW. The SF has caused a 49°C peak at 111 years. The peak temperature due to CHLW, however, is only 47°C here, attained 62 years after emplacement.

Table 2 summarizes the stand-off distances required to stay below particular temperature levels. These distances are presented more generally by the temperature contours in Figure 5. But in particular, for example, to ensure that the temperature will never rise above 50°C in the vicinity of the spent fuel repository, you would have to stay more than 45 m away from its edge horizontally, or more than 202 m above its center, or more than 81 m above its edge vertically.

4 References

Johnstone, J. K., R. R. Peters, and P. F. Gnirk, 1984. *Unit Evaluation at Yucca Mountain Nevada Test Site: Summary Report and Recommendation*, SAND83-0372, Sandia National Laboratories, Albuquerque, NM.

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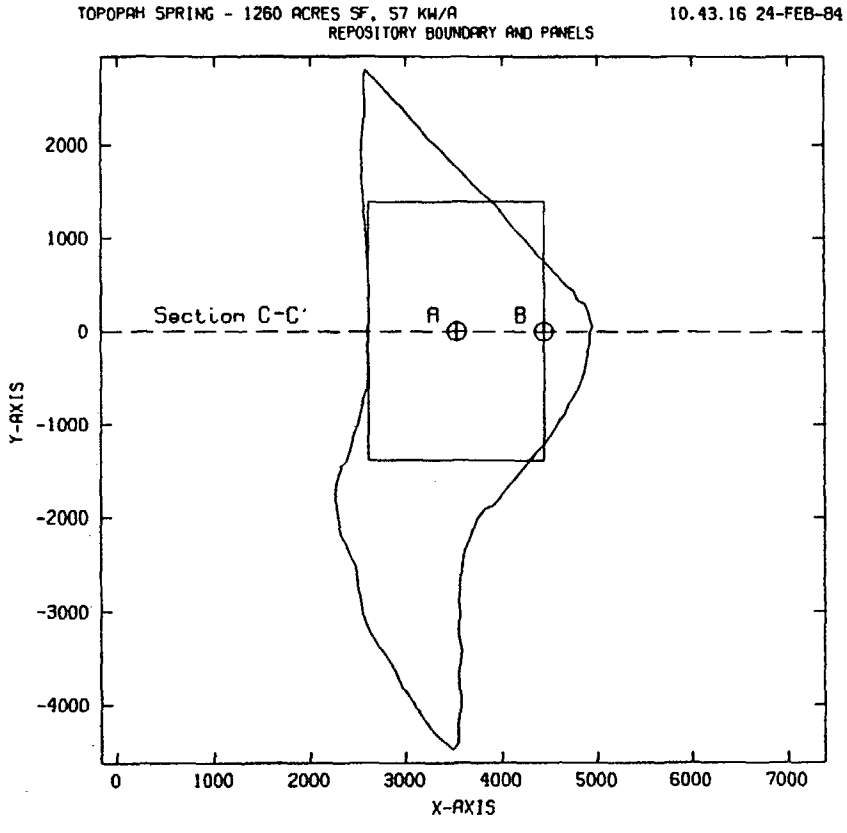


Figure 1a.
Repository Block Boundary and Relative Location of the 57 kW/a Spent Fuel Repository (Total Area of 1260 Acres)

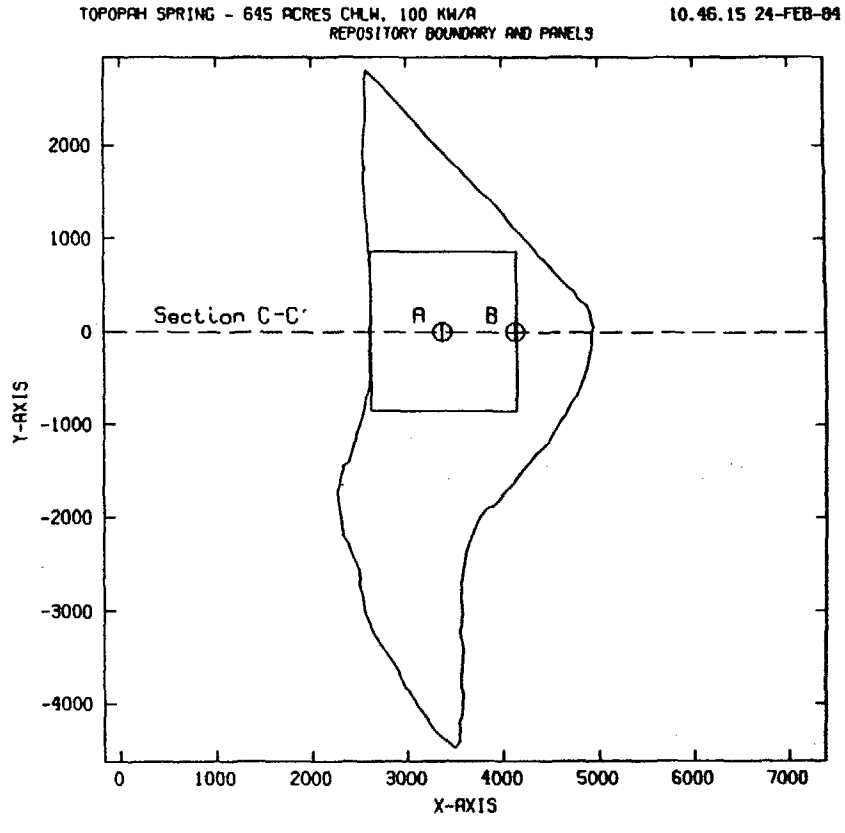
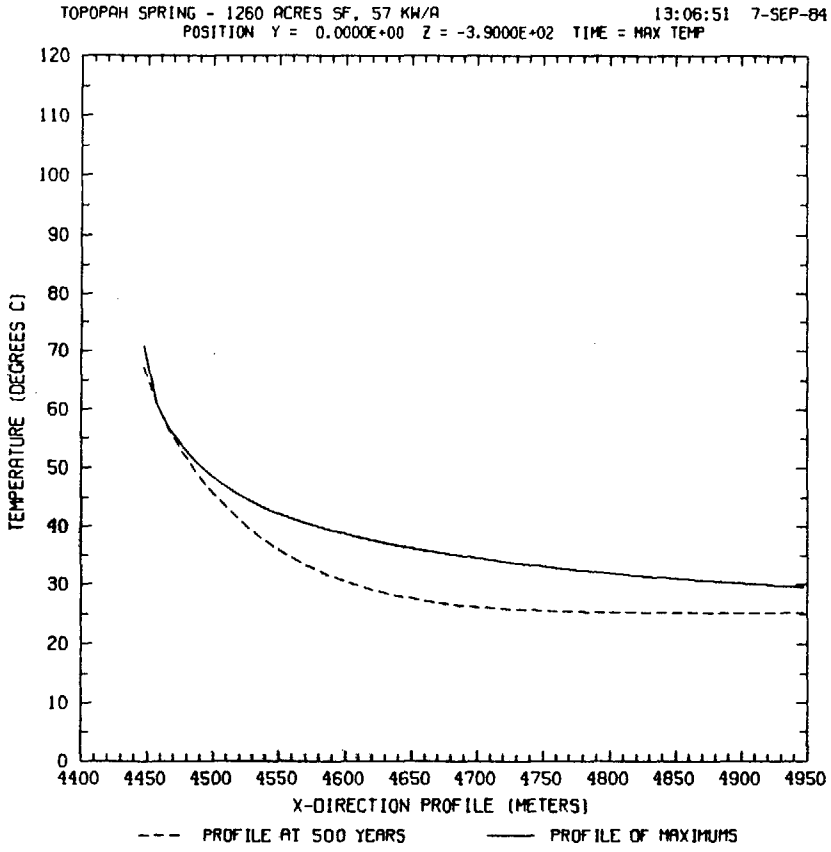
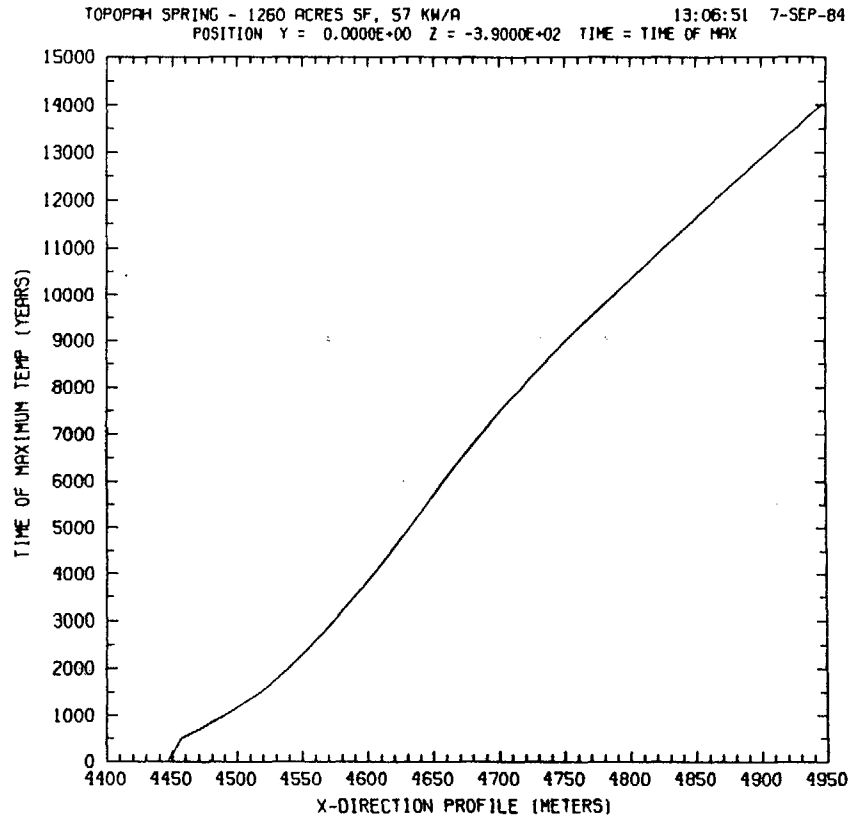


Figure 1b.
Repository Block Boundary and Relative Location of the 100 kW/a Commercial High-Level Waste Repository (Total Area of 645 Acres)





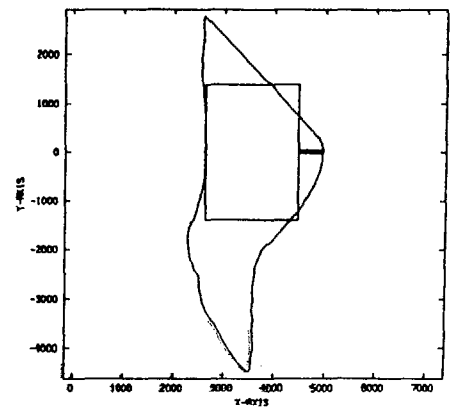
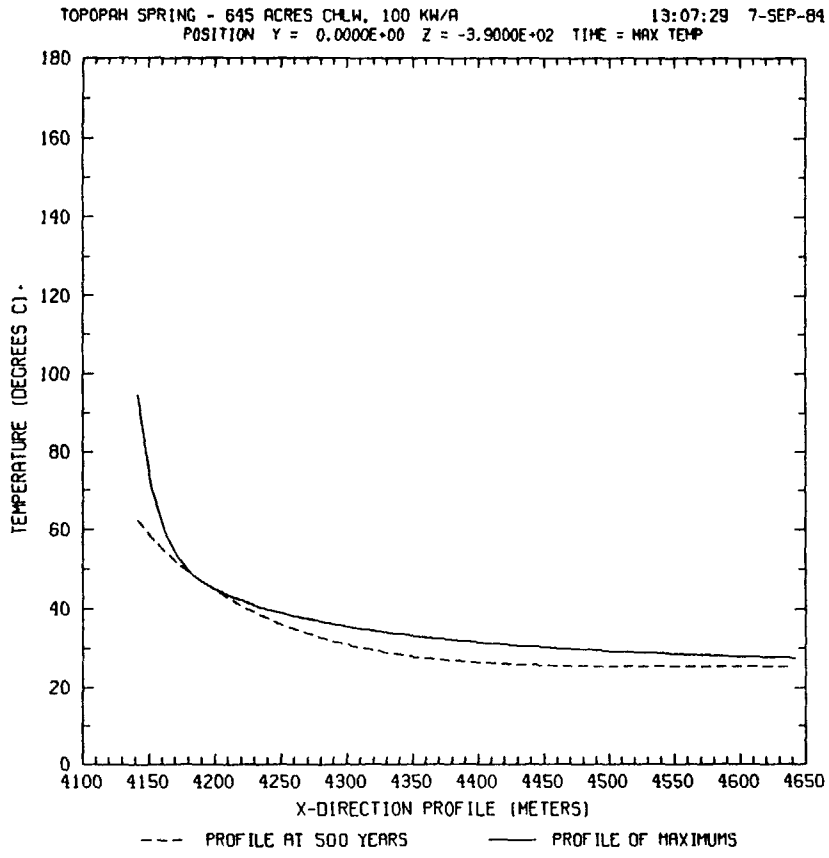
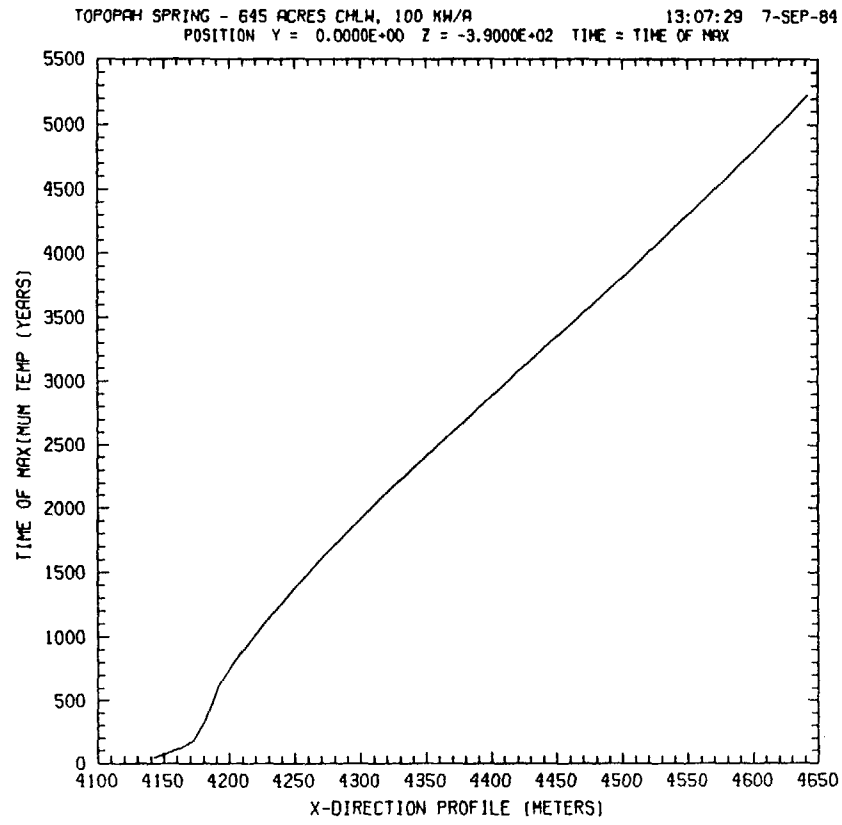


Figure 2a.
Horizontal Profiles of Temperature (left) and Time of Maximum Temperature (right) along C–C′, for Spent Fuel.





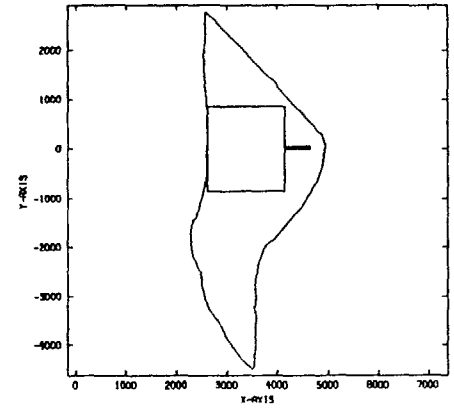
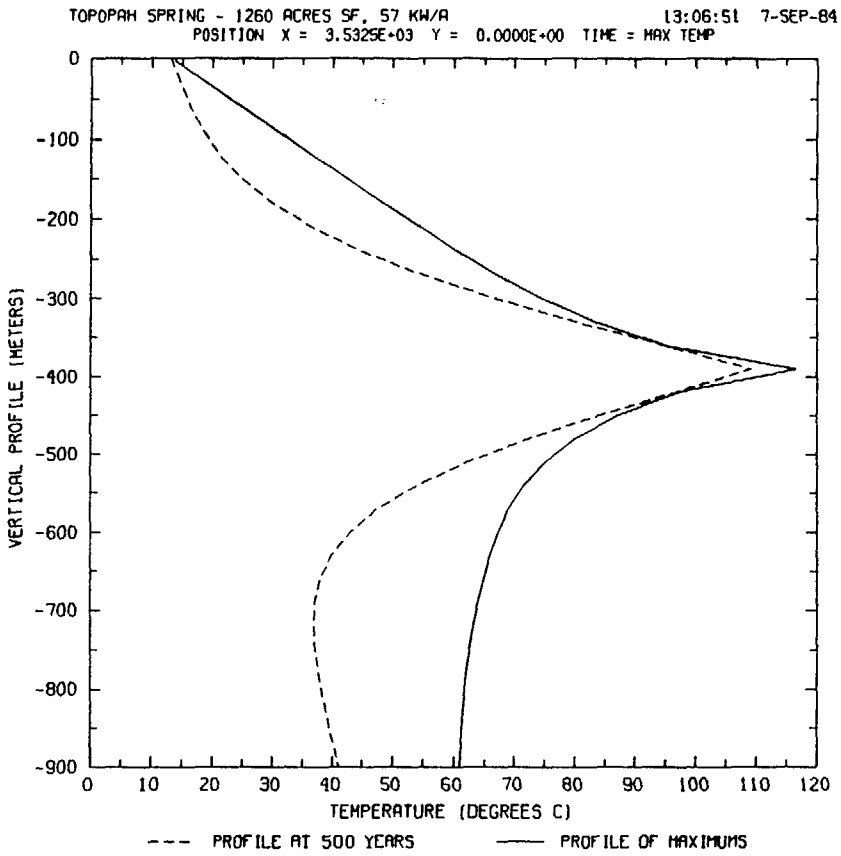
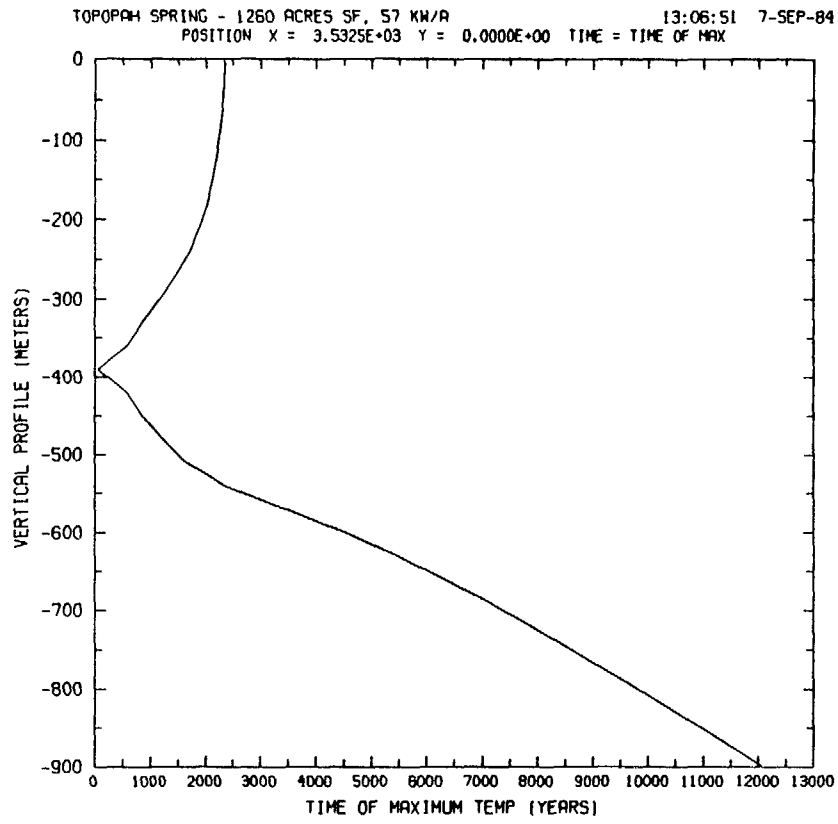


Figure 2b.
Horizontal Profiles of Temperature (left) and Time of Maximum Temperature (right) along C–C′, for Commercial High-Level Waste.





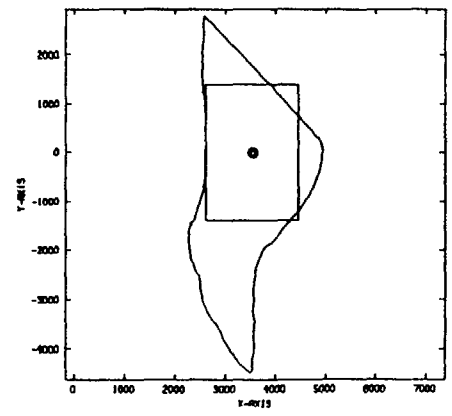
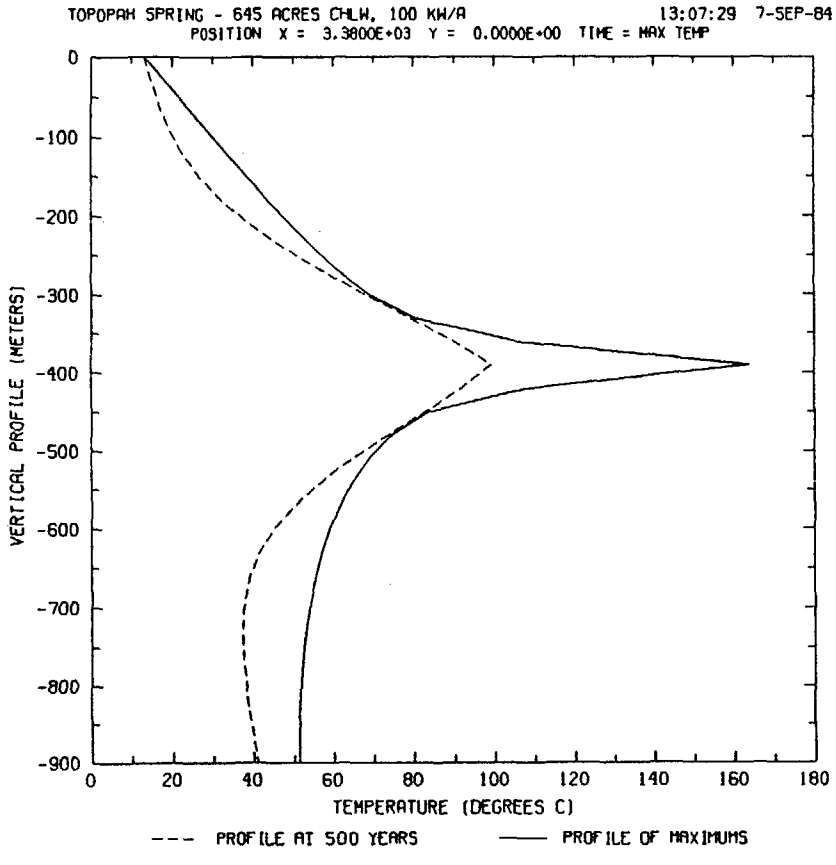
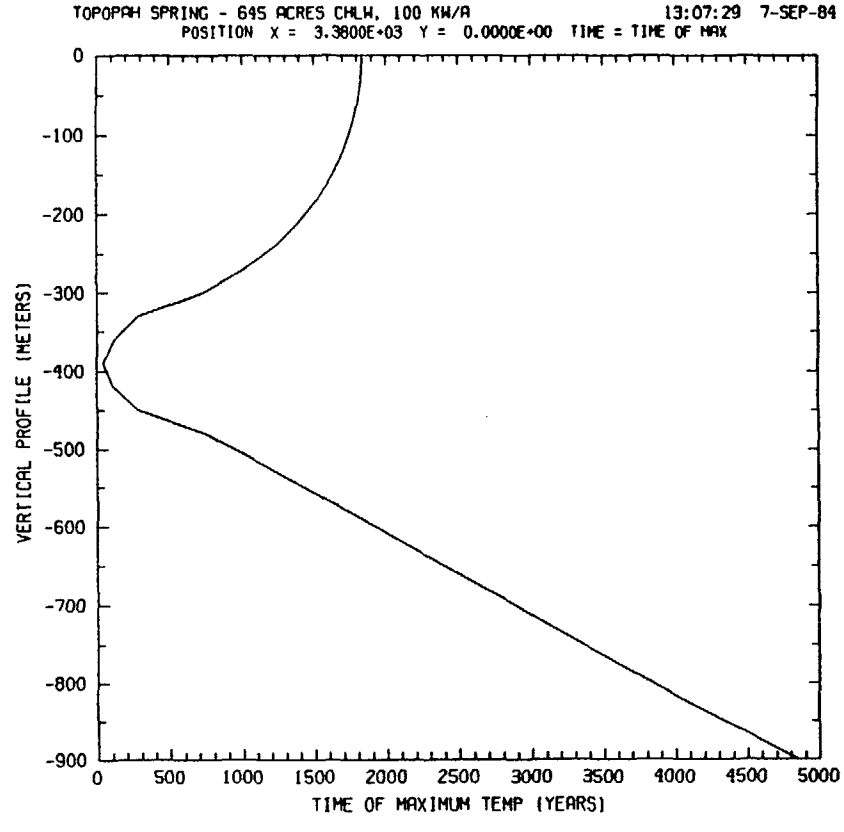


Figure 3a.
Vertical Profiles of Temperature (left) and Time of Maximum Temperature (right) through Center of Repository, for Spent Fuel.





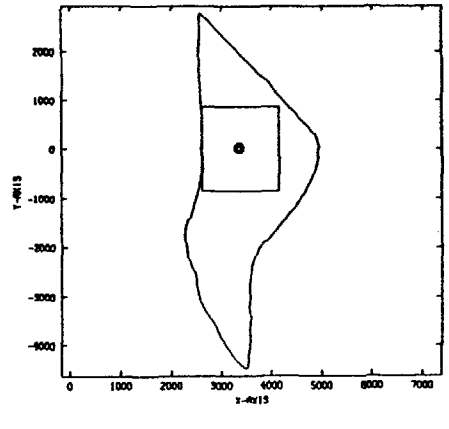


Figure 3b.
Vertical Profiles of Temperature (left) and Time of Maximum Temperature (right) through Center of Repository, for Commercial High-Level Waste.

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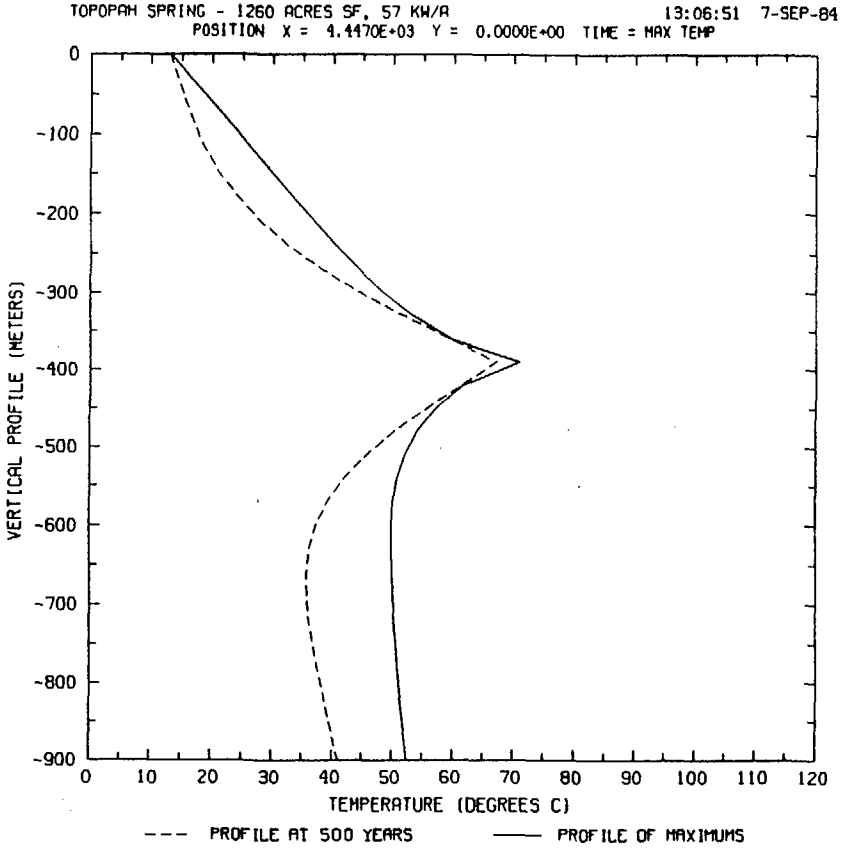
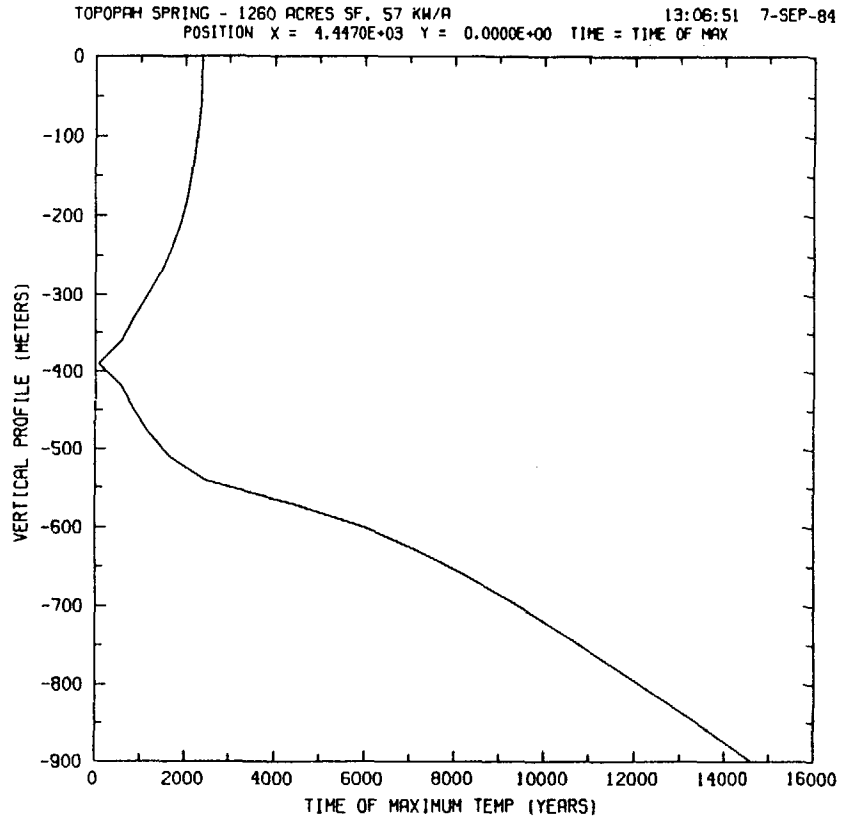




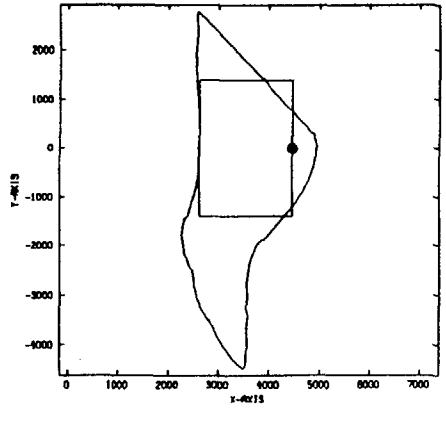
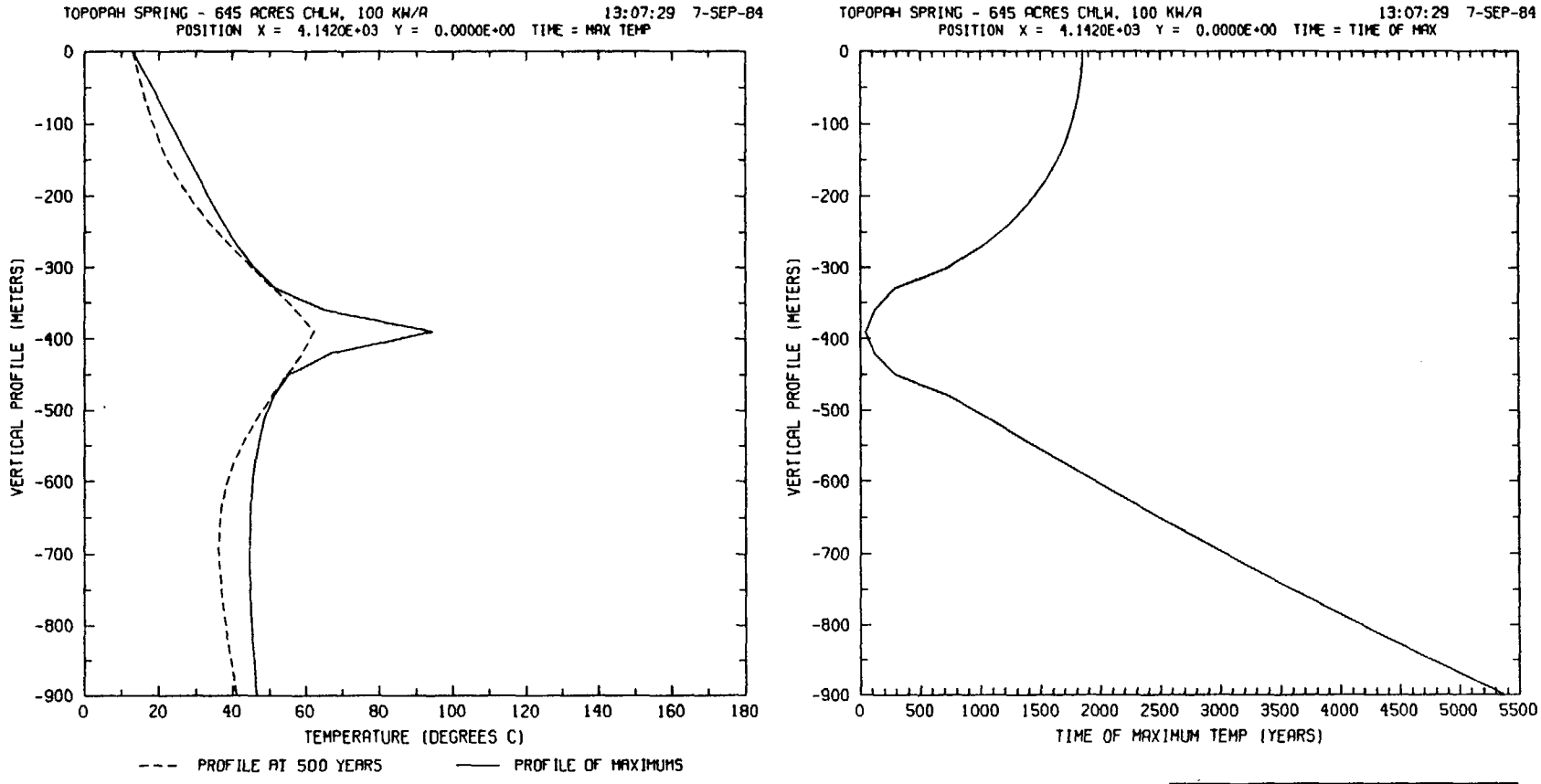


Figure 4a.
Vertical Profiles of Temperature (left) and Time of Maximum Temperature (right) through Edge of Repository, for Spent Fuel.



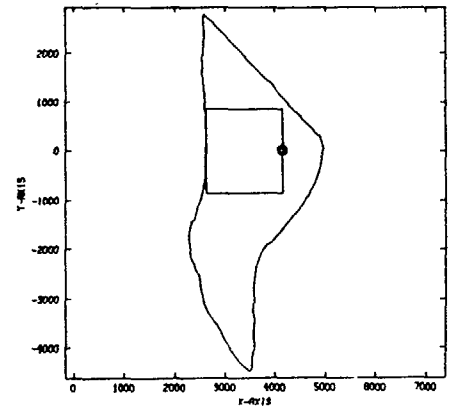
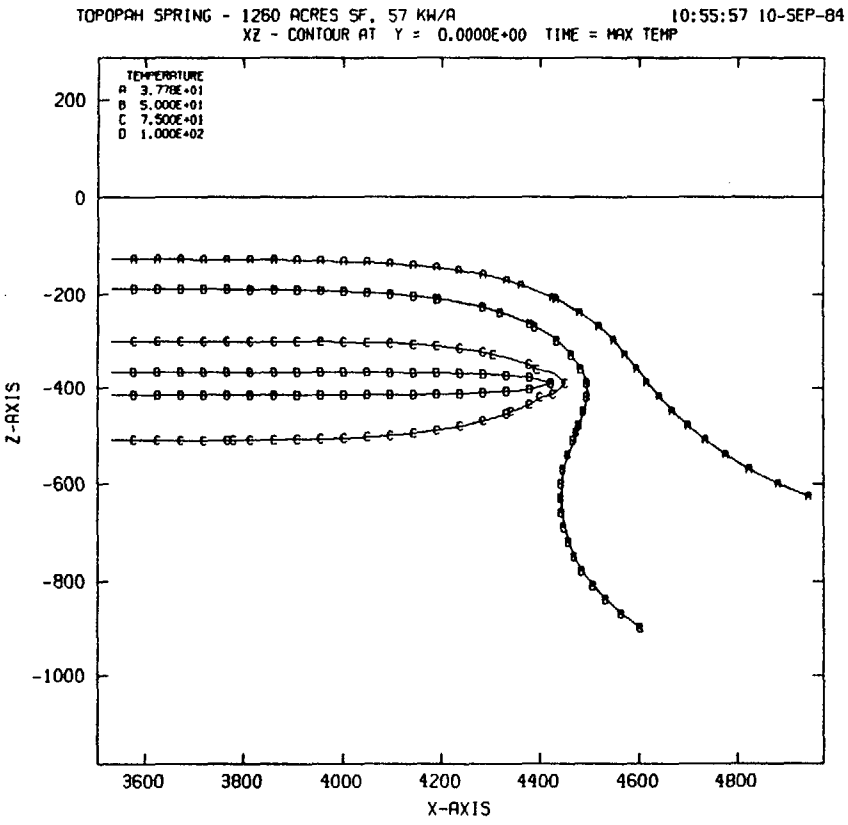
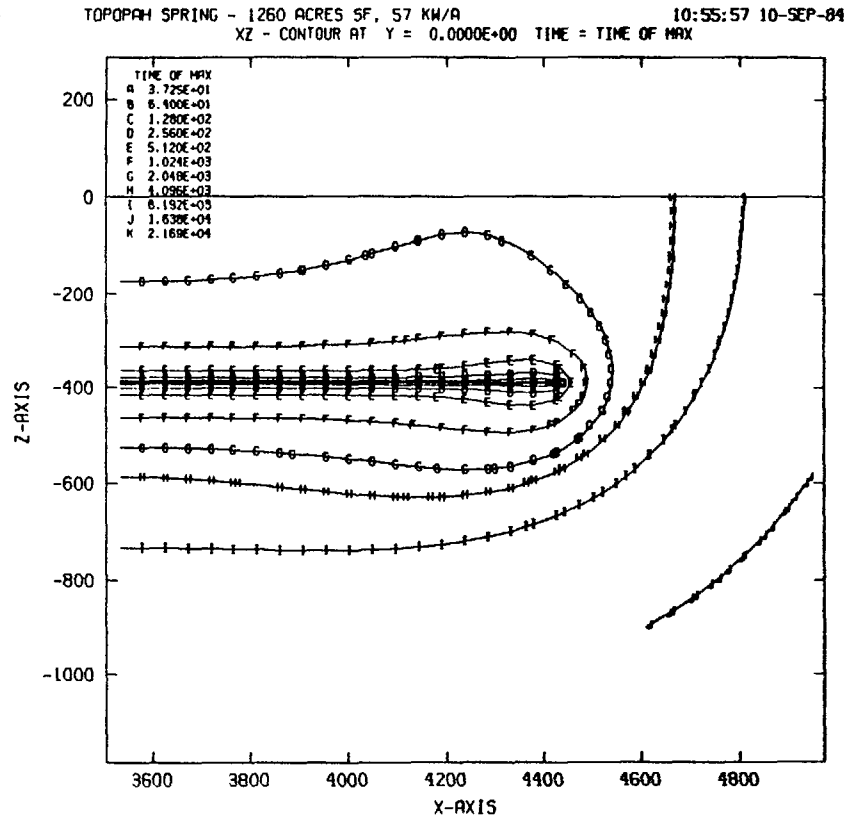


Figure 4b.
Vertical Profiles of Temperature (left) and Time of Maximum Temperature (right) through Edge of Repository, for Commercial High-Level Waste.





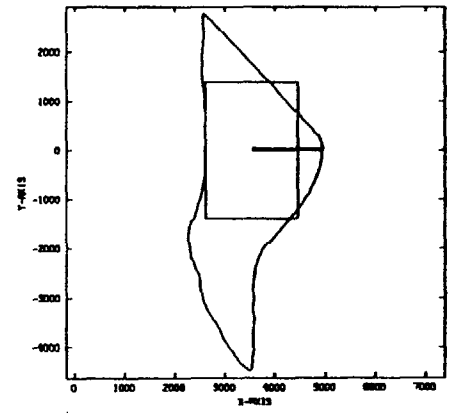
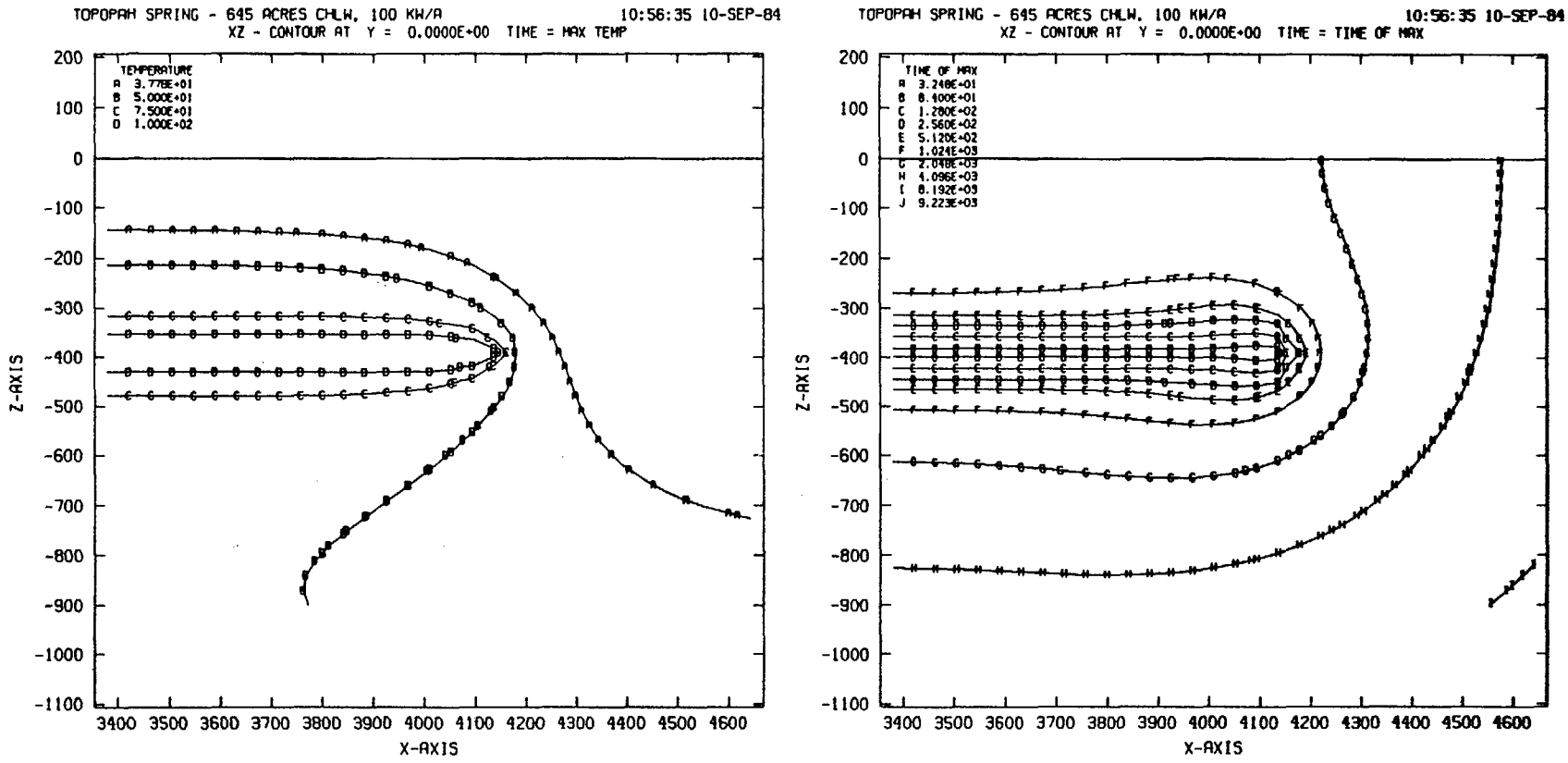


Figure 5a.
Contours of Temperature (left) and Time of Maximum Temperature (right) on a Vertical Plane through C–C′, for Spent Fuel.



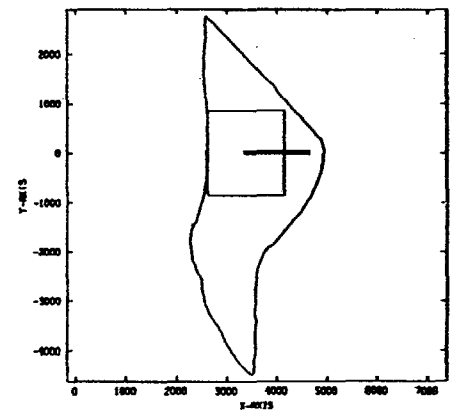


Figure 5b.
Contours of Temperature (left) and Time of Maximum Temperature (right) on a Vertical Plane through C–C′, for Commercial High-Level Waste.

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