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WELDON SPRING SITE REMEDIAL ACTION PROJECT, WASTE FORM PLACEMENT SUPPORTING STUDY NO. 9A, REVISION 1, FINAL - (USED AS A REFERENCE IN OU3 RI/FS/PP REPORT)

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Weldon Spring Site Remedial Action Project

Waste Form Placement
Supporting Study No. 9A

MKES Report No. 3840R-7004-01

Revision 1

April 1992

Final

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WASTE FORM PLACEMENT AND COMPACTION SUPPORTING STUDY 9A

1 INTRODUCTION

1.1 Purpose

The purpose of the study was to determine recommended placement and compaction requirements for various waste forms and operational scenarios for the proposed Weldon Spring Site disposal facility.

1.2 Scope

The scope of this study includes the following items:

- Recommend placement methods and compaction requirements for specified waste forms.
- Identify special placement and compaction requirements for bulk wastes such as large thick-walled pipes, vehicles, building debris, and rubble.
- Assess waste form layer sequencing, placement strategy, and configuration alternatives for treated sludge, soil, debris, and rubble. Of particular concern is the placement of metal waste (e.g., vehicles, forklift, locomotive, large thick-walled pipes) to be placed intact, and the potential for differential settlement around these metal wastes.
- Discuss placement criteria that will help provide adequate slope stability, and recommend methods for assessing stability (e.g., types of failure modes, material properties).

- Perform preliminary settlement analysis for various alternative layering and placement options and potential mitigation measures.

1.3 Background

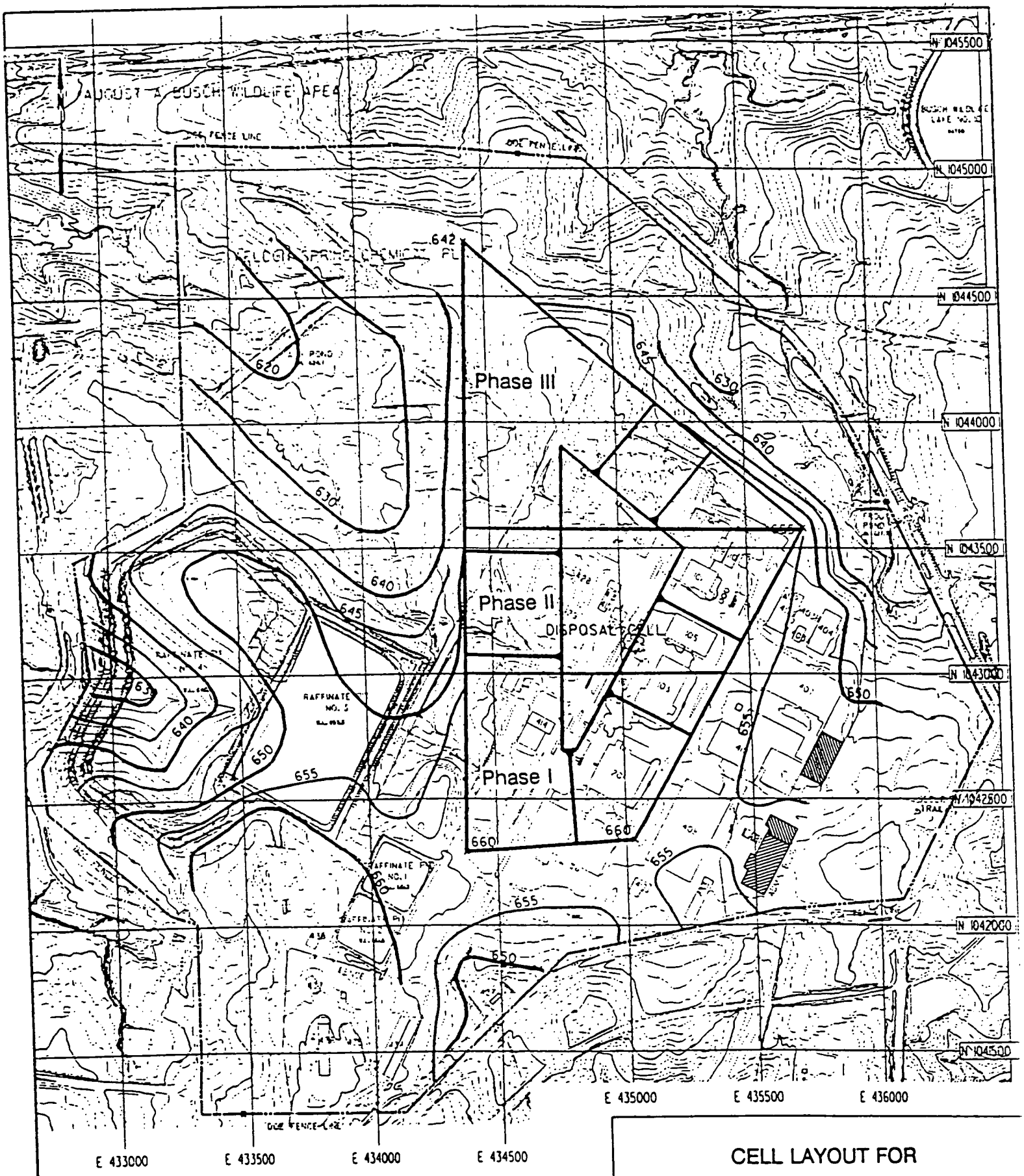
Two primary alternatives for on-site waste disposal are currently being considered. Waste material will be disposed of either in a single large cell (Figure 1-1), or in two cells (Figure 1-2). For the single cell alternative, the raffinate sludges and other radioactively or chemically contaminated non-soil wastes will be mixed with contaminated soil, cement and fly ash, to form either a grout-like material that sets up as a stable product or a soil-like material that can be compacted to a stable condition. It now appears that stabilization can be achieved over a broad range of waste/cement ratios. Satisfactory results occur with mixtures ranging from the grout-like material that sets up to form a weak solid to soil-like material that can be compacted. The other wastes will be either mixed with or entombed in the cement-stabilized waste, or placed and compacted as in a typical landfill operation. This alternative is known as cement stabilization/solidification (CSS). For the two-cell scenario, one cell would contain vitrified waste, and one cell would contain primarily untreated, less radioactively and chemically contaminated waste. This combination is known as the vitrified alternative (VIT).

A Project Management Contractor (PMC) team provided a preliminary evaluation of waste forms, volume reduction methods, sludge treatment alternatives, and potential scenarios for waste placement and configuration. Input was provided in the form of tables, IOCs, telephone conversations, meetings, and previous study reports.

Raw waste quantities were taken from the Fall 1991 Waste Quantities Quarterly Report (MKF 1991). Volumes for treated waste were taken from IOCs from the PMC (MK&F & JEG 1991a). Detailed assessments of these data were performed in order to determine recommended waste form placement and compaction requirements.

Reports and other documents developed as part of the following Supporting Studies provided additional information which was used in various aspects of the current study:

- Waste Removal, Transportation, and Reclamation (Task 814, MKF and JEG 1991f)



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LEGEND:

- PROPOSED 10' CONTOUR
- PROPOSED 5' CONTOUR
- EXISTING BUILDING TO REMAIN
- PERMANENT BUILDING TO BE ADDED

500 0 500
SCALE FEET

CELL LAYOUT FOR SINGLE CELL SCENARIO

FIGURE 1-1

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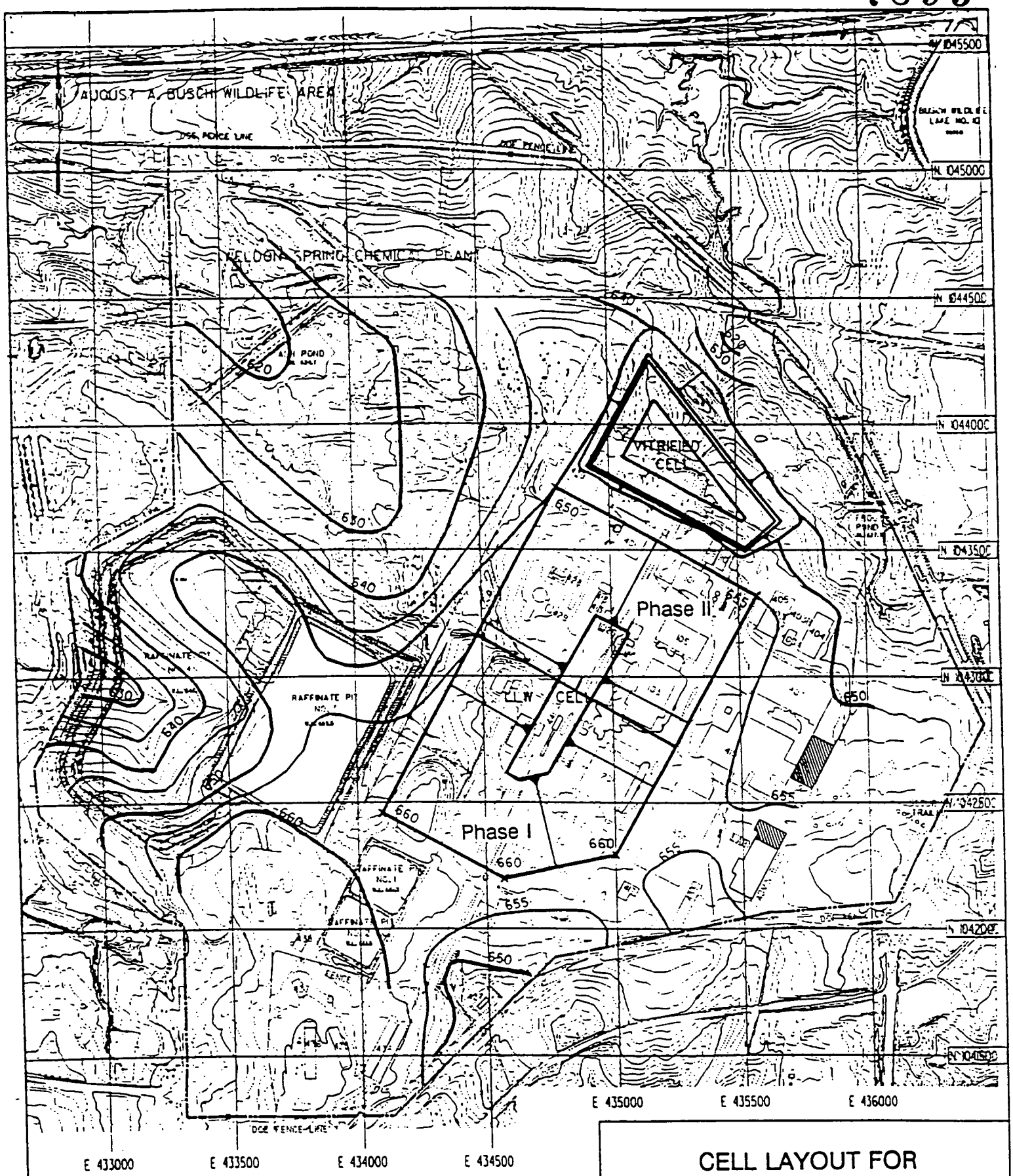

LEGEND:

PROPOSED 10' CONTOUR

PROPOSED 5' CONTOUR

EXISTING BUILDING TO REMAIN

PERMANENT BUILDING TO BE ADDED

500 0 500

SCALE FEET

CELL LAYOUT FOR DOUBLE CELL SCENARIO

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FIGURE 1-2

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- Chemical Solidification/Stabilization (Task 815, MKF and JEG 1991c)
- Vitrification Treatment (Task 816, MKF and JEG 1991d)
- Volume Reduction Facility (Task 817, MKF and JEG 1991e)
- Disposal Cell Construction Operation Scenarios (Task 824, MKF and JEG 1991b)
- Disposal Facility Siting Study (Task 902C, MKES 1991b)
- Alternative Cover Assessment (Task 914, JEG 1991)
- Radon Barrier Evaluation (Task 919, MKES 1991c) (Information from this study affects desirability to place radon-generating wastes away from the face of the cell.).
- Liner & Foundation Evaluation Study (Task 938, MKES 1991e)

The current study will be used as background information for the following activities:

- Supporting Study 20, Equipment Selection (Task 920)
- Supporting Study 24, Leachate Characterization (Task 924)
- Supporting Study 34, Subsidence Study (Task 934) (That study will include a preliminary evaluation of whether waste settlement will cause unacceptable deformation of the radon barrier and cell cover.)
- Supporting Study 44 (Task 944) (That study will address the infiltration and water migration through the cover, waste, leachate system, and liner.)
- Preparation of design documents related to waste placement.
- Refinement of differential settlement calculations.

1.4 Technical and Regulatory Concerns

Applicable or Relevant and Appropriate Regulations (ARARs) for WSSRAP have been discussed at length by Dames & Moore (1989) and in the Feasibility Study (FS) (ANL 1990). Only the following few ARARs are expected to have any affect on this study:

- ARARs concerning radon emissions to the atmosphere are discussed in the FS on pages G-11 to G-16, and are addressed by Task 919, Radon Barrier Evaluation (MKES 1991c).

- Pages G-21 and G-44 of the FS discuss criteria for the handling of asbestos. This may affect the allowable methods for handling asbestos.

- The Solid Waste Disposal Act as amended (42 USC 6901, et seq.) and Solid Wastes (40 CFR 264), Subpart N, Landfills, state that liquids may not be placed in a landfill unless all free-standing liquid has been removed (FS, p. G-51). It is not clear how this may affect the placement of CSS, which may still have free liquid at the time of placement (ORNL, 1989), even though the free liquids would be used up in the hydration of the cement/fly ash during the first few weeks following placement. This question will be addressed by the PMC and regulatory representatives in upcoming meetings.

In addition to the above ARARs, the FS specifies that the following regulation will be followed:

- Occupational Safety and Health Administration Standards (29 CFR 1910; 1910.1000) regarding personnel exposure limits (FS, p. G-17).

2 DESIGN CRITERIA BASIC DATA AND ASSUMPTIONS

2.1 Design Criteria

The following design criteria are recommended as a result of this and other studies:

- In general, waste should be placed in a manner that is readily constructable and minimizes the need for detailed field control and specialized handling techniques or construction equipment.

- To the extent practical, the waste placement method selected should fill voids in debris and rubble and densify the waste materials in order to make maximum use of waste storage space and produce cell stability and integrity.

- Material strength and placement criteria must provide adequate slope stability.

- To the extent practical, total and differential settlement should be minimized.

- No waste form should be placed adjacent to another waste form with which it might be reactive.

- It may be useful to design the placement of waste layers to minimize the required thickness of radon barrier. This may mean placing lower-level radioactive soil-like wastes near the top of the waste pile to function as a radon flux inhibiter, or placing more highly contaminated radioactive waste farther from the cell cover.

2.2 Available Data and Information

Data used for this study are available in the previously listed documents (see Section 1.3 above), and particularly the IOC from the PMC titled Background Information Associated with Supporting Study 9a, Waste Form Placement and Compaction, June 26, 1991 (MKF and JEG, 1991a).

2.3 Assumed Waste Quantities

Waste quantities were provided in the Waste Quantities Quarterly Report (MKF 1991). These quantities were separated into waste type categories in an IOC from the PMC (MKF & JEG 1991a). The in situ and disposal quantities reported in the IOC are listed in summary form in Table 2-1. (Items in this table are cross referenced with items in Table 2-4, mentioned in the following section.) Table 2-2 presents the volume percentage of each waste form in the non-CSS waste, and in the total waste, including CSS. Table 2-3 presents the percentage of each waste form in the vitrified and non-vitrified disposal cells. These disposal volumes are also shown graphically in a bar chart (Figure 2-1) and three pie charts (Figures 2-2 through 2-4).

2.4 Assumed Schedule of Waste Availability

A schedule of remedial actions, including when it is anticipated that wastes will be available from specific sources, was provided in an IOC from the PMC (MKF & JEG 1991a). This schedule is listed in summary form in Table 2-4. (Items in this table are cross referenced with items in Table 2-1.) Figure 2-5 shows this information graphically, with the list re-sorted by start-date. Figure 2-6 again presents this information graphically, but with the waste forms grouped according to Table 2-1.

2.5 Assumed Analysis of Infiltration

A separate analysis of infiltration into and through each cell will be performed by others, and design of a leachate collection system or systems was not a part of the waste form placement and compaction study. However, for the purpose of this study, it was assumed that some infiltration would occur over the 1000-year design life of the cell, and that this infiltration could result in hydro-compression of the soil-like wastes leading to additional settlement (Brandon & Duncan 1990) and corrosion of the metal wastes. This assumption and the issue of hydro-compression should be re-evaluated when the cover evaluation study provides an average rate of infiltration over the design life of the disposal cell.

TABLE 2-1 : WASTE GROUPINGS & POTENTIAL TREATMENTS							
			CSS Alternative Disposal Vol., cy		VIT Alternative Disposal Vol., cy		Cross Ref to Table 2-4
No.	Item	In situ vol. cy	CSS Waste form	Other waste forms	Vitrified Cell	Non-Vit. Cell	
1.	SLUDGE	227,700	300,600		34,844		1,37,38
a.	Raffinate Pits	220,000					1
b.	Quarry	4,100					23
c.	Site WTP	2,200					23
d.	Quarry WTP	1,400					
2.	SOILS/SEDIMENTS	423,130	140,210	316,910	84,976	316,910	
a.	Raffinate Pits	153,500					2-5,21
b.	Quarry	52,000					21
c.	Ash Pond	8,200					14
d.	Frog Pond	7,000					15
e.	North Dump	7,600					13,23
f.	South Dump	16,900					16
g.	TSA Area	4,100					21,23
h.	Site WTP Area	7,100					21,23
i.	Around Chem. Plant Buildings	26,400					44,49
j.	Beneath Chem Plant Buildings	59,000					47,48, 50-52
k.	Lakes 34, 35, 36	20,000					17
l.	Vicinity Properties	3,600					53-58
m.	Slough VP	30,000					21,59
n.	Retention Pond Removals (@ Raff. Pits)	1,830					7
o.	Other Retention Pond Removals	25,900					30
3.	METALS	62,385					
	Shred			13,101		13,101	
	Reduce			8,734		8,734	
	Intact			40,550		40,550	
a.	Chem. Plant Metals	51,385					
	1. Conduit						24,26
	2. Piping						24,26
	3. HVAC Ducts						24,26
	4. Tanks						24,26
	5. Misc. equipment						24,26
	6. Furniture						24,26
	7. Siding/Roofing (Al)						24,26
	8. Siding/Roofing (Steel)						24,26
	9. Structural						24,26
	10.RR Rails						24,26
b.	Quarry Metal @ TSA	10,500					22
	Raff. Pit Debris @ TSA	500					25
4.	MASONRY BLOCK DEBRIS	7,300		7,300		7,300	
a.	Masonry Block	7,300					24,26

TABLE 2-1 : WASTE GROUPINGS & POTENTIAL TREATMENTS

No.	Item	In situ vol. cy	CSS Alternative Disposal Vol., cy: CSS Waste form	CSS Alternative Disposal Vol., cy: Other waste forms	VIT Alternative Disposal Vol., cy: Vitrified Cell	VIT Alternative Disposal Vol., cy: Non-Vit. Cell	Cross Ref to Table 2-4
5.	ROCK/CONCRETE DEBRIS	104,961		104,961		104,961	
a.	Quarry WTP	300					25
b.	Site WTP	400					35
c.	Chem.Plant Slab/Foundation	51,514					10-12
d.	Sludge/Soil Treatment Facility	900					33
e.	Vol. Reduction Facility	500					36
f.	Quarry Rock Concrete	50,300					24,26
g.	U/G Piping	1,047					24,26
6.	ASBESTOS	10,089		10,089		10,089	
a.	Friable	4,716					25
b.	Non-friable	5,373					25
7.	PPE	7,813		781		781	
a.	Discarded (disposable) PPE	7,813					28
8.	MISCELLANEOUS DEBRIS	281		281		281	
a.	"Sanitary Landfill" type	281					25
9.	CONTAINERIZED MATERIALS	309		170		170	
a.	Cont. Chemicals (RCRA)	139					27
b.	Other "434 materials"	170					
10.	SOIL/GRAVEL MIXTURES	90,800		90,800		90,800	
a.	TSA Foundation	22,000					31
b.	MSA Foundation	14,500					32
c.	Raff. Pit Haul Road	10,800					7
d.	Army 5 & 6 Haul Road	1,800					58
e.	Site Haul Roads	16,400					23,29
f.	Quarry Haul Road	3,500					21,23
g.	Raff. Pit Bottom	15,400					2-5
h.	FO Slough	1,600					60
i.	Ash Pond Bottom	4,000					14,23
j.	Frog Pond Bottom	800					15
11.	WOOD	32,210		6,442		6,442	
a.	Treated Wood	2,510					
	1. Cooling Tower & Misc.						26
	2. Furniture						
	3. Quarry RR Ties						
	4. Site RR Ties						
	5. Paper/Books						
b.	Untreated Wood	29,700					
	1. Quarry						
	2. Site						
	3. Slough VP						
	Totals	966,978	440,810	600,119	119,820	600,119	

TABLE 2-2 : CSS ALTERNATIVE, WASTE FRACTIONS

		In situ vol. cy	Disposal Vol., cy		Fraction of Non-CSS waste	Fraction of total waste
			CSS	Non-CSS		
1.	SLUDGE	227,700	300,600			28.9%
a.	Raffinate Pits	220,000				
b.	Quarry	4,100				
c.	Site WTP	2,200				
d.	Quarry WTP	1,400				
2.	SOILS/SEDIMENTS	423,130				
	To be treated		140,210			13.5%
	Not to be treated			316,910	52.8%	30.4%
a.	Raffinate Pits	153,500				
b.	Quarry	52,000				
c.	Ash Pond	8,200				
d.	Frog Pond	7,000				
e.	North Dump	7,600				
f.	South Dump	16,900				
g.	TSA Area	4,100				
h.	Site WTP Area	7,100				
i.	Around Chem. Plant Buildings	26,400				
j.	Beneath Chem Plant Buildings	59,000				
k.	Lakes 34, 35, 36	20,000				
l.	Vicinity Properties	3,600				
m.	Slough VP	30,000				
n.	Retention Pond Removals (@ Raff. Pits)	1,830				
o.	Other Retention Pond Removals	25,900				
3.	METALS	62,385				
	Shred			13,101	2.2%	1.3%
	Reduce			8,734	1.5%	0.8%
	Intact			40,550	6.8%	3.9%
a.	Chem. Plant Metals	51,385				
	1. Conduit					
	2. Piping					
	3. HVAC Ducts					
	4. Tanks					
	5. Misc. equipment					
	6. Furniture					
	7. Siding/Roofing (Al)					
	8. Siding/Roofing (Steel)					
	9. Structural					
	10.RR Rails					
b.	Quarry Metal @ TSA	10,500				
	Raff. Pit Debris @ TSA	500				
4.	MASONRY BLOCK DEBRIS	7,300		7,300	1.2%	0.7%
a.	Masonry Block	7,300				

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TABLE 2-2 : CSS ALTERNATIVE, WASTE FRACTIONS

		In situ vol. cy	Disposal Vol., cy CSS	Disposal Vol., cy Non-CSS	Fraction of Non-CSS waste	Fraction of total waste
5.	ROCK/CONCRETE DEBRIS	104,961		104,961	17.5%	10.1%
a.	Quarry WTP	300				
b.	Site WTP	400				
c.	Chem.Plant					
	Slab/Foundation	51,514				
d.	Sludge/Soil					
	Treatment Facility	900				
e.	Vol. Reduction					
	Facility	500				
f.	Quarry Rock					
	Concrete	50,300				
g.	U/G Piping	1,047				
6.	ASBESTOS	10,089		10,089	1.7%	1.0%
a.	Friable	4,716				
b.	Non-friable	5,373				
7.	PPE	7,813		781	0.1%	0.1%
a.	Discarded (disposable) PPE	7,813				
8.	MISCELLANEOUS DEBRIS	281		281	0.0%	0.0%
a.	"Sanitary Landfill" type	281				
9.	CONTAINERIZED MATERIALS	309		170	0.0%	0.0%
a.	Cont. Chemicals (RCRA)	139				
b.	Other "434 materials"	170				
10.	SOIL/GRAVEL MIXTURES	90,800		90,800	15.1%	8.7%
a.	TSA Foundation	22,000				
b.	MSA Foundation	14,500				
c.	Raff. Pit Haul Road	10,800				
d.	Army 5 & 6 Haul Road	1,800				
e.	Site Haul Roads	16,400				
f.	Quarry Haul Road	3,500				
g.	Raff. Pit Bottom	15,400				
h.	FO Slough	1,600				
i.	Ash Pond Bottom	4,000				
j.	Frog Pond Bottom	800				
11.	WOOD	32,210				
a.	Treated Wood	2,510		6,442	1.1%	0.6%
	1. Cooling Tower & Misc.					
	2. Furniture					
	3. Quarry RR Ties					
	4. Site RR Ties					
	5. Paper/Books					
b.	Untreated Wood	29,700				
	1. Quarry					
	2. Site					
	3. Slough VP					
	Totals	966,978	440,810	600,119	100.0%	100.0%
	Total Waste			1,040,929		

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TABLE 2-3 : VITRIFIED ALTERNATIVE, WASTE FRACTIONS

No.	Item	In situ vol. cy	VIT Alternative Disposal Vol., cy		Vitrified Fraction	Fraction Non-Vit Waste
			Vitrified Cell	Non-Vit. Cell		
1.	SLUDGE	227700	34,844		29.1%	
a.	Raffinate Pits	220,000				
b.	Quarry	4,100				
c.	Site WTP	2,200				
d.	Quarry WTP	1,400				
2.	SOILS/SEDIMENTS	423,130	84,976	316,910	70.9%	52.8%
	To be treated					
	Not to be treated					
a.	Raffinate Pits	153,500				
b.	Quarry	52,000				
c.	Ash Pond	8,200				
d.	Frog Pond	7,000				
e.	North Dump	7,600				
f.	South Dump	16,900				
g.	TSA Area	4,100				
h.	Site WTP Area	7,100				
i.	Around Chem. Plant Buildings	26,400				
j.	Beneath Chem Plant Buildings	59,000				
k.	Lakes 34, 35, 36	20,000				
l.	Vicinity Properties	3,600				
m.	Slough VP	30,000				
n.	Retention Pond Removals (@ Raff. Pits)	1,830				
o.	Other Retention Pond Removals	25,900				
3.	METALS	62,385				
	Shred			13,101		2.2%
	Reduce			8,734		1.5%
	Intact			40,550		6.8%
a.	Chem. Plant Metals	51,385				
	1. Conduit					
	2. Piping					
	3. HVAC Ducts					
	4. Tanks					
	5. Misc. equipment					
	6. Furniture					
	7. Siding/Roofing (Al)					
	8. Siding/Roofing (Steel)					
	9. Structural					
	10.RR Rails					
b.	Quarry Metal @ TSA	10,500				
	Raff. Pit Debris @ TSA	500				
4.	MASONRY BLOCK DEBRIS	7,300		7,300		1.2%
a.	Masonry Block	7,300				

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TABLE 2-3 : VITRIFIED ALTERNATIVE, WASTE FRACTIONS

No.	Item	In situ vol. cy	VIT Alternative Disposal Vol., cy		Vitrified Fraction	Fraction Non-Vit Waste
			Vitrified Cell	Non-Vit. Cell		
5.	ROCK/CONCRETE DEBRIS	104,961		104,961		17.5%
a.	Quarry WTP	300				
b.	Site WTP	400				
c.	Chem.Plant Slab/Foundation	51,514				
d.	Sludge/Soil Treatment Facility	900				
e.	Vol. Reduction Facility	500				
f.	Quarry Rock Concrete	50,300				
g.	U/G Piping	1,047				
6.	ASBESTOS	10,089		10,089		1.7%
a.	Friable	4,716				
b.	Non-friable	5,373				
7.	PPE	7,813		781		0.1%
a.	Discarded (disposable) PPE	7,813				
8.	MISCELLANEOUS DEBRIS	281		281		0.0%
a.	"Sanitary Landfill" type	281				
9.	CONTAINERIZED MATERIALS	309		170		0.0%
a.	Cont. Chemicals (RCRA)	139				
b.	Other "434 materials"	170				
10.	SOIL/GRAVEL MIXTURES	90,800		90,800		15.1%
a.	TSA Foundation	22,000				
b.	MSA Foundation	14,500				
c.	Raff. Pit Haul Road	10,800				
d.	Army 5 & 6 Haul Road	1,800				
e.	Site Haul Roads	16,400				
f.	Quarry Haul Road	3,500				
g.	Raff. Pit Bottom	15,400				
h.	FO Slough	1,600				
i.	Ash Pond Bottom	4,000				
j.	Frog Pond Bottom	800				
11.	WOOD	32,210				
a.	Treated Wood	2,510		6,442		1.1%
	1. Cooling Tower & Misc.					
	2. Furniture					
	3. Quarry RR Ties					
	4. Site RR Ties					
	5. Paper/Books					
b.	Untreated Wood	29,700				
	1. Quarry					
	2. Site					
	3. Slough VP					
	Totals	966,978	119,820	600,119	100.0%	100.0%
	Total Waste			719,939		

000019

TABLE 2-4 : SCHEDULING & MATERIAL AVAILABILITY INFORMATION

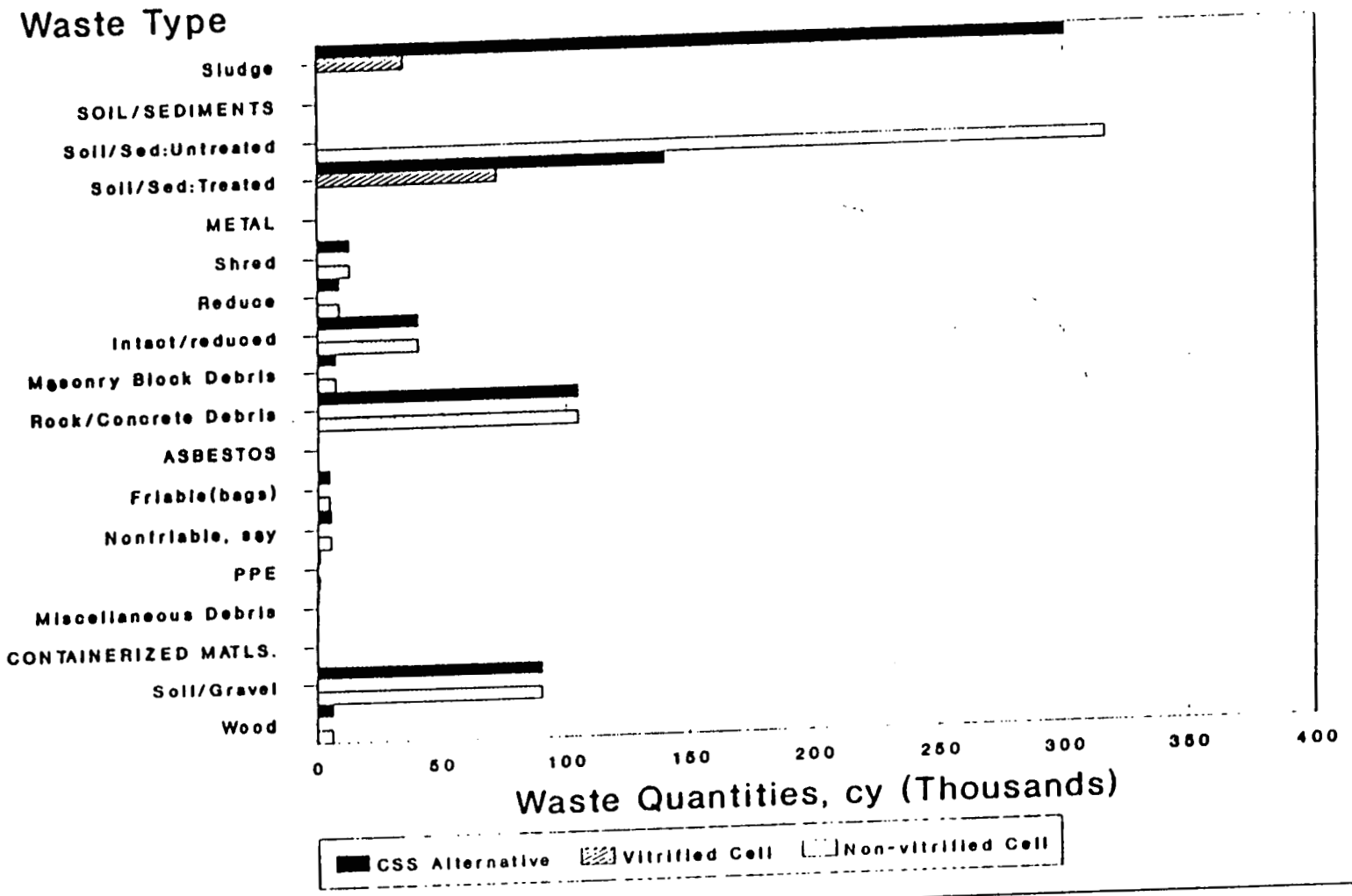
No.	Item	Quantity	Units	Start	End	Duration	Cross Ref
1	Dredge Sludge	220,000	cy	03/01/95	12/01/97	1006	1a
	EXCAVATE SOILS						
2	Pit 1	8,446	cy	05/02/95	06/11/95	40	2a,10g
3	Pit 2	8,446	cy	07/01/95	08/11/95	41	2a&10g
4	Pit 3	54,057	cy	04/15/97	09/15/97	153	2a&10g
5	Pit 4	97,951	cy	03/01/98	12/01/98	275	2a&10g
6	Excavate Rubble, Pit 4	500	cy	12/01/98	12/21/98	20	3b
7	Remove Haul Road	12,630	cy	03/01/99	04/20/99	50	2a,10c
8	Clear/Grub for waste etc	37	ac	03/01/93	06/20/93	111	11b
9	Clear/Grub for Rot Basin	14	ac	03/01/94	04/01/94	31	11b
	FOUNDATION REMOVAL (CONCRETE)						
10	Fdn Removal, Ph 1	19,000	cy	06/23/93	10/06/93	105	5c
11	Fdn Removal, Ph 2	26,399	cy	11/23/93	04/23/94	151	5c
12	Fdn Removal, Ph 3	7,392	cy	10/10/95	11/18/95	39	5c
	EXCAVATE						
13	N Dump	7,600	cy	07/01/93	08/01/93	31	2e
14	Ash Pond	12,200	cy	06/02/99	07/06/99	34	2c,10i
15	Frog Pond	7,800	cy	04/11/96	05/05/96	24	2d,10j
16	S Dump	16,900	cy	10/15/97	12/01/97	47	2f
17	Bunch Lakes	20,000	cy	04/01/98	05/15/98	44	2k
18	Op Soil/Sludge Treat Fac			03/08/95	06/01/99	1546	-
19	Op TSA, Filling			08/16/92	02/15/95	913	-
20	Op MSA, Filling			06/18/91	01/19/96	1676	-
	TRANSPORT FROM TSA, ASH POND, MULCH PILE, ETC.						
21	Clay/soil (highly contam.)	100,000	cy	03/01/95	06/01/99	1553	2a,2b
22	Rubble	40,700	cy	03/01/95	06/01/99	1553	3b2,5f
23	TSA soils	71,400	cy	04/01/95	08/01/99	1583	2g,2h
	Transport from MSA						Untreated-2b,2e & clear & grub soils
24	To size red fac	86,300	cy	03/01/95	06/01/99	1553	
25	Haul to cell	166,546	cy	03/01/95	08/01/99	1614	In all rubble categories, 3,4,5 (not 5b,5e), 6, 8
26	Operate vol. red. facility	128,400	cy	03/01/95	07/01/99	1583	
27	434 mail disposal			03/01/95	01/01/2000	1767	
28	PPE compaction, loading	7,813	cy	06/18/91	06/20/2000	3290	7a
29	Rem Soil/Agg Roads	16,400	cy	10/02/99	12/02/99	61	10a
30	Rem Rot Dikes	25,900	cy	09/21/99	12/20/99	90	2o
31	Close TSA	22,000	cy	08/02/99	09/15/99	44	10a
32	Close MSA	14,500	cy	08/02/99	09/20/99	49	10b
33	Close sludge proc fac	900	cy	06/02/99	07/02/99	30	5d
34	Op Site WTP			08/16/92	11/11/99	2643	
35	Close Site WTP	400	cy	11/11/99	12/02/99	21	5b
36	Close vol red fac	500	cy	09/21/99	10/22/99	31	5a
37	Haul CSS to Cell	440,810	cy	03/01/95	06/01/99	1553	From 1 & 2
38	Vit Alt	123,600	cy	03/01/95	06/01/99	1553	From 1 & 2

000020

TABLE 2-4 : SCHEDULING & MATERIAL AVAILABILITY INFORMATION

No.	Item	Quantity	Units	Start	End	Duration	Cross Ref
	CELL CONSTN. OPERATIONS (CSS)						
39	Phase 1			03/03/94	10/10/96	952	
40	Phase 2			06/04/95	05/18/98	1079	
41	Phase 3			03/01/97	06/19/2000	1206	
	CELL CONST. OP. (NON CSS)						
42	Phase 1			06/05/94	12/17/97	1291	
43	Phase 2			05/11/96	06/15/2000	1496	
	VITRIFICATION ALTERNATIVE:						
	VIT CELL CONSTRUCTION			07/05/94	11/02/94	120	
44	Exc. U/G Piping & ass. soils	20,000	cy	06/23/93	10/01/94		
45	Phase I	7,800	cy	06/23/93	12/23/93	183	2i
46	Phase II	12,200	cy	03/01/94	10/01/94	214	2i
	EXC. SURFACE SOILS						
47	Phase I	40,700	cy	02/27/94	04/23/94	55	2j
48	Phase II	25,200	cy	03/01/96	04/02/96	32	2j
	CSS ALTERNATIVE						
49	Exc U/G Piping & assoc. soils	20,000	cy	06/23/93	11/18/95	878	2i
	EXC. SURFACE SOILS						
50	Phase I	15,000	cy	10/07/93	11/01/93	25	2j
51	Phase II	25,200	cy	03/01/95	04/02/95	32	2j
52	Phase III	25,200	cy	03/01/96	04/02/96	32	2j
	VICINITY PROPERTIES						
53	Exc Army #1 Soil	1,160	cy	09/01/95	09/08/95	7	2l
54	Exc Army #1 & Bunch #4	680	cy	10/15/95	10/20/95	5	2l
55	Exc Army #3	60	cy	09/25/95	09/28/95	3	2l
	ARMY 5 & 6						
56	Clear/Grub	2.5	ac	06/15/99	06/23/99	8	2l
57	Exc Soil	1,700	cy	07/07/99	07/15/99	8	2l
58	Remove Access Road	1,800	cy	07/21/99	07/27/99	6	2l
	FEMME OSAGE SLOUGH						
59	Excavation	30,000	cy	06/01/99	09/01/99	92	2m
60	Remove Access Roads	5,100	cy	09/01/99	10/01/99	30	10f,10h
	QUARRY RESIDUAL						
61	Excavation	20,100	cy	03/01/99	06/01/99	92	5f

000021



WASTE FORM DISPOSAL QUANTITIES

FIGURE 2-1

REPORT NO. MKES-3840R-7004-0

ORIGINATOR: JBF	DRAWN : ND	DATE : DEC. 1991

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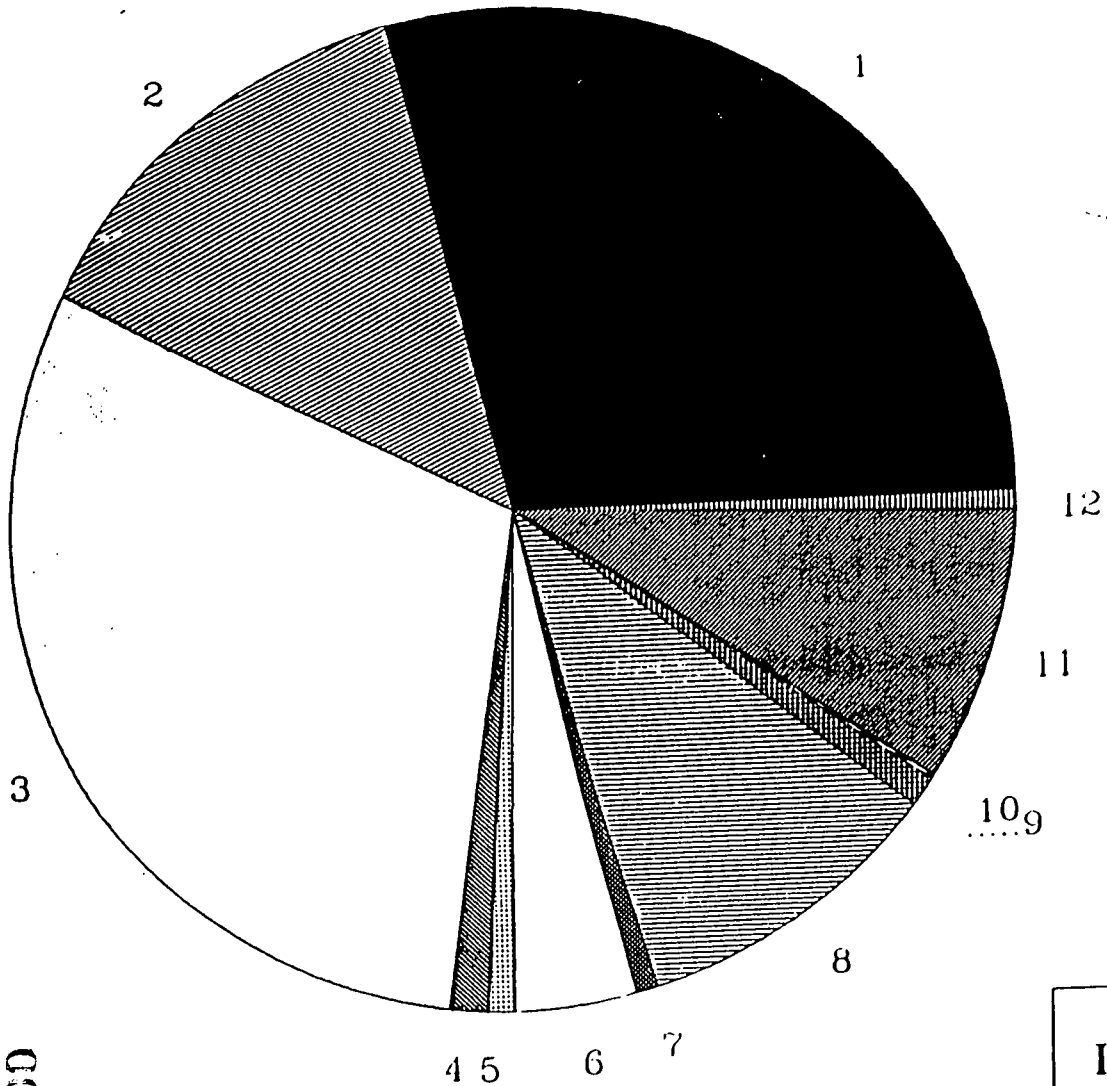

Volume Breakdown for CSS Alternative		
		Vol, cy
1	CSS from SLUDGE	300,600
2	CSS from SOILS/SEDIMENTS	140,210
3	SOILS/SEDIMENTS- Not to be treate	316,190
4	SHRED METALS	13,101
5	REDUCE METALS	8,734
6	INTACT METALS	40,550
7	MASONRY BLOCK DEBRIS	7,300
8	ROCK/CONCRETE DEBRIS	104,961
9	ASBESTOS	10,089
10	PPE	1,232
	MISCELLANEOUS DEBRIS	
	CONTAINERIZED MATERIALS	
11	SOIL/GRAVEL MIXTURES	90,800
12	WOOD	6,442

CSS VOLUME BREAKDOWN
Including Untreated Soil

FIGURE 2-2

REPORT NO. MKES-3840R-7004-0

ORIGINATOR: JBF | DRAWN : ND | DATE : DEC. 1991

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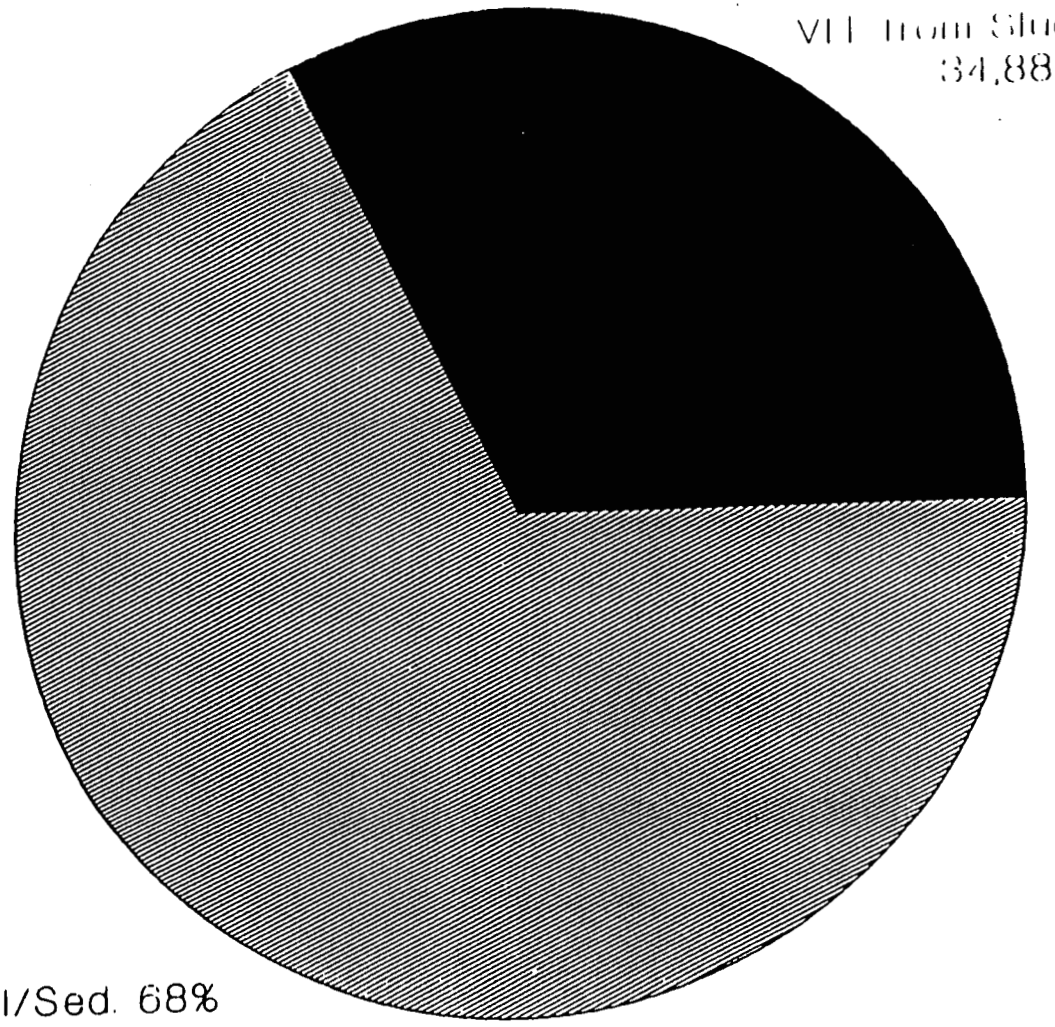

VITRIFIED VOLUME BREAKDOWN

FIGURE 2-3

REPORT NO. MKES-3840R-7004-0

ORIGINATOR: JBF	DRAWN : ND	DATE : DEC, 1991

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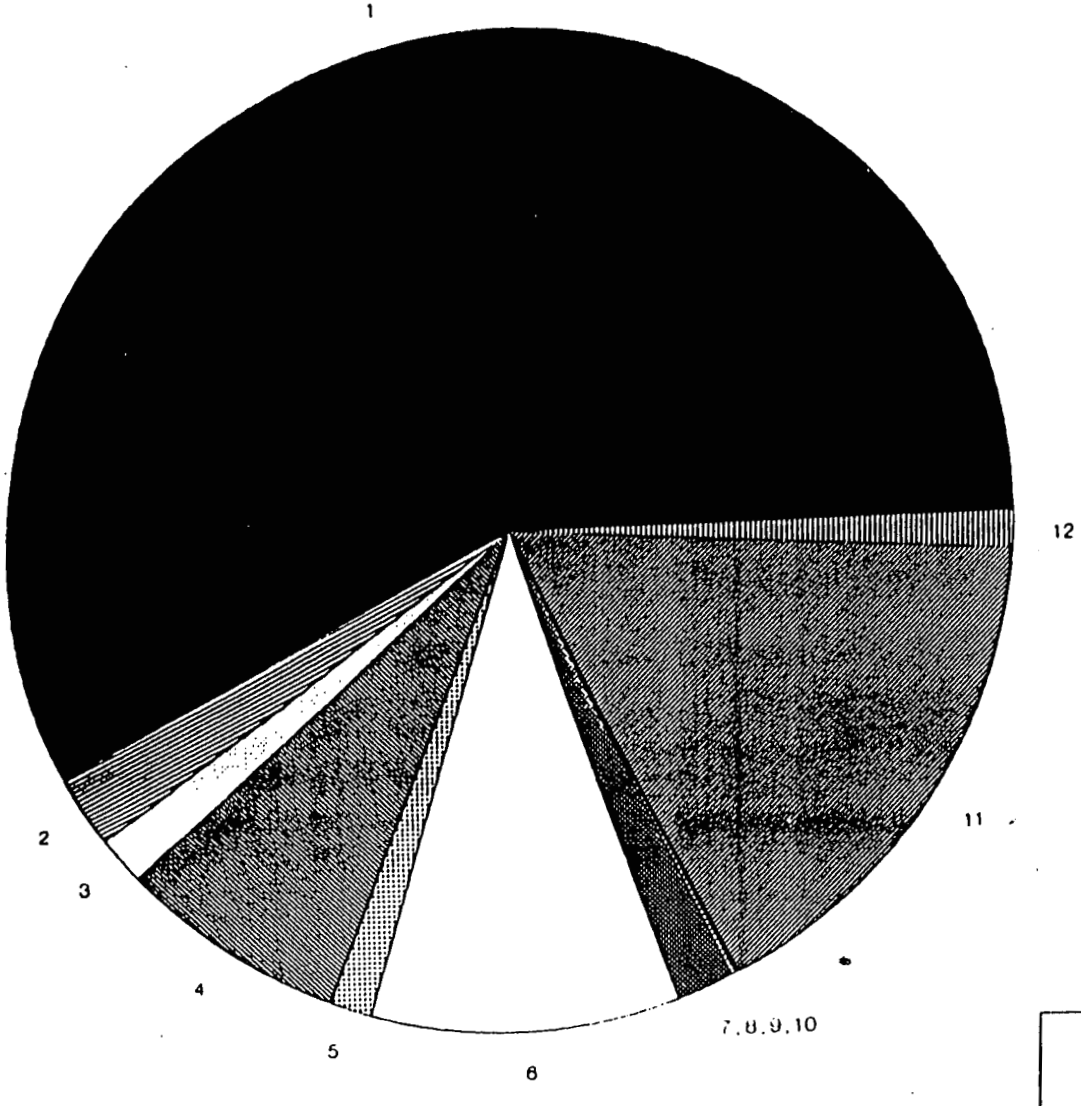

Non - Vitrified Volume Breakdown		
		Vol, cy
1	SOILS/SEDIMENTS	316,910
2	SHRED METALS	13,101
3	REDUCE METALS	8,734
4	INTACT METALS	40,550
5	MASONRY BLOCK DEBRIS	7,300
6	ROCK/CONCRETE DEBRIS	54,661
7	ASBESTOS	10,089
8	PPE	781
9	MISCELLANEOUS DEBRIS	281
10	CONTAINERIZED MATERIALS	170
11	SOIL/GRAVEL MIXTURES	90,800
12	WOOD	6,442

NON-VITRIFIED
VOLUME BREAKDOWN

FIGURE 2-4

REPORT NO. MKES-3840R-7004-A

ORIGINATOR: JBF	DRAWN : ND	DATE : DEC. 1991

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Waste Availability Schedule

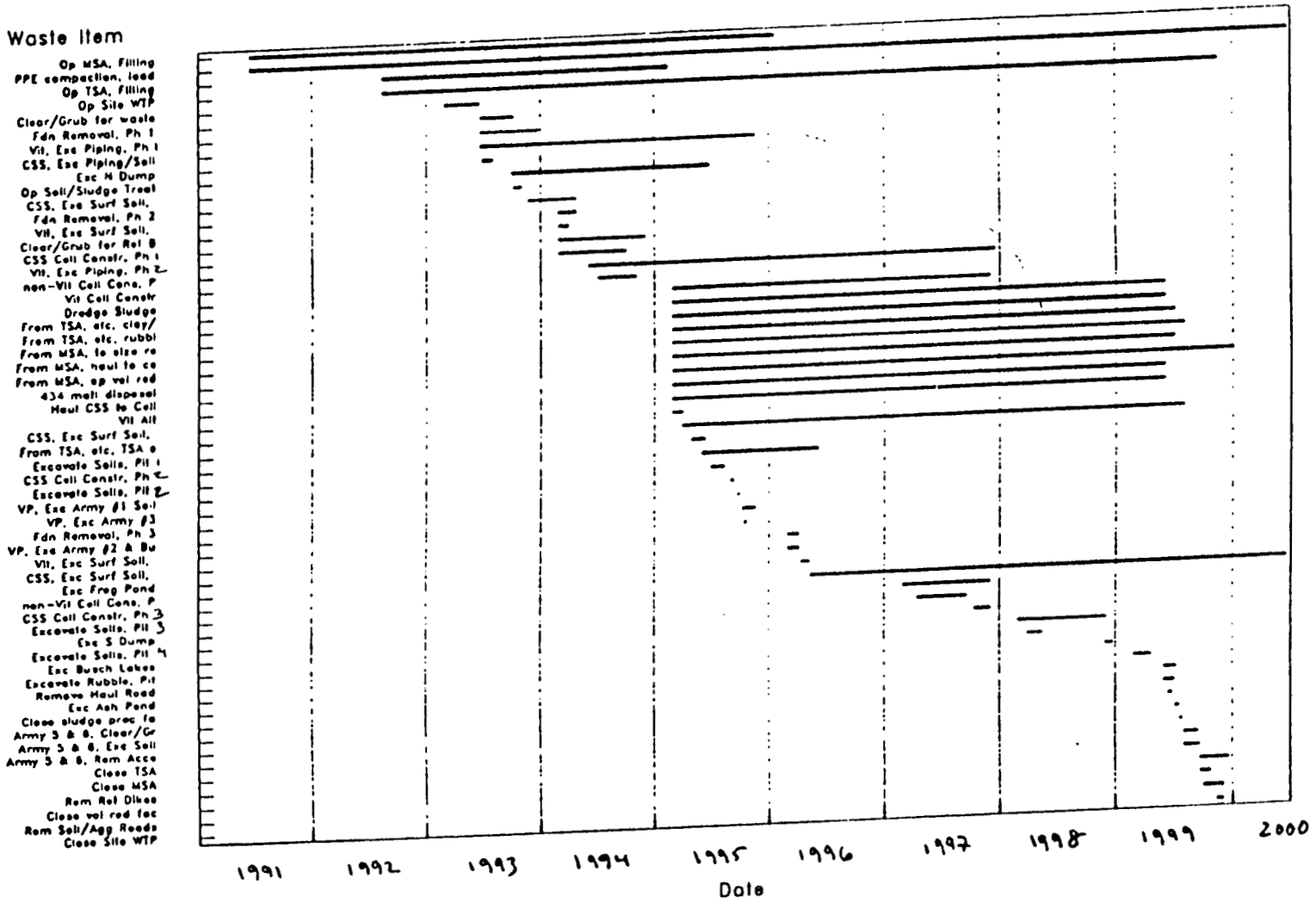

Figure 2-5

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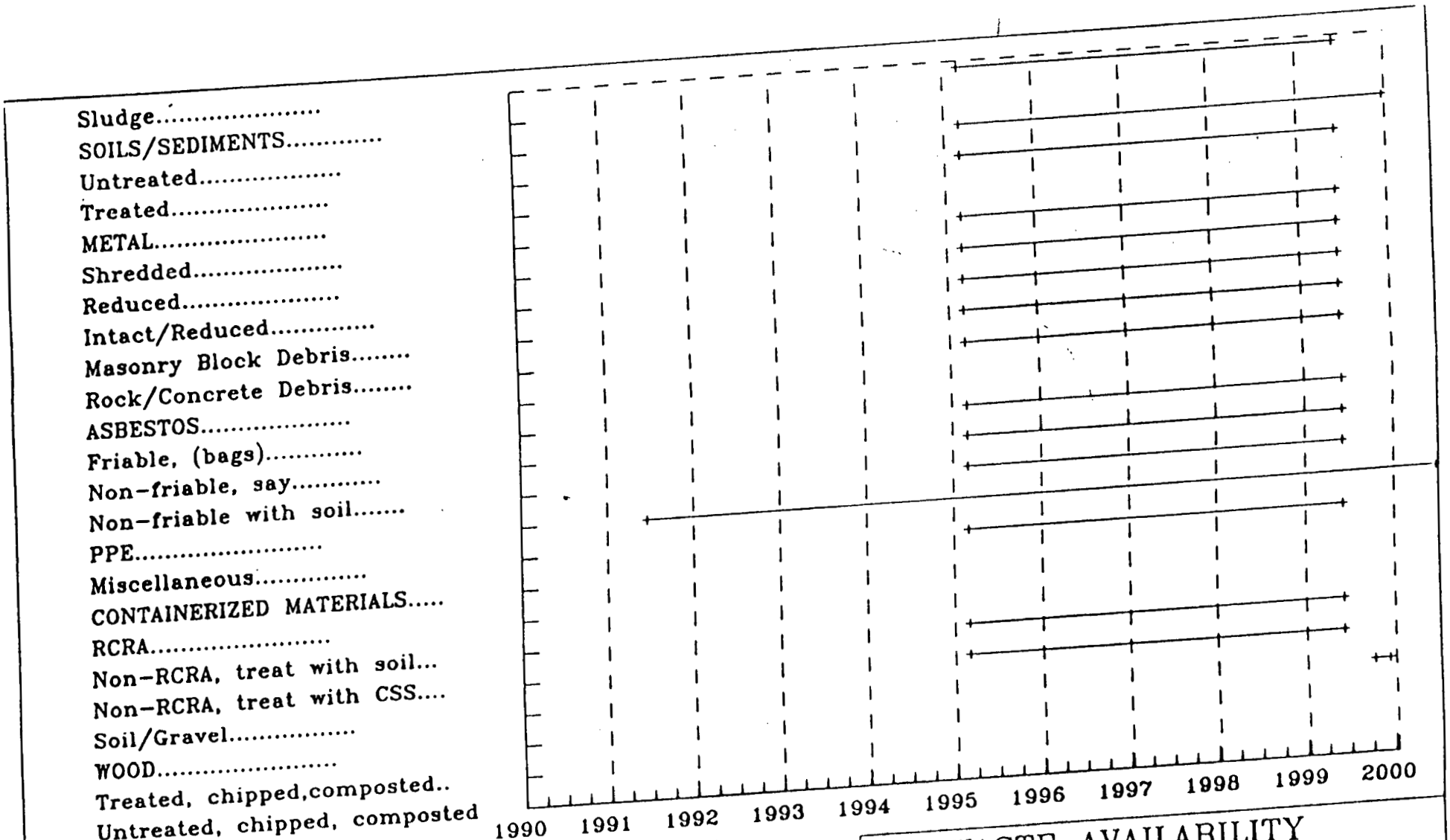

WASTE AVAILABILITY SCHEDULE

FIGURE 2-6

REPORT NO. MKES-3840R-7004-A

ORIGINATOR: JBF	DRAWN : ND	DATE : OCT. 1991

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3 DESCRIPTION AND EVALUATION OF WASTE FORM PLACEMENT OPTIONS

3.1 Potential Primary Waste Forms

3.1.1 Treated Raffinate Sludge and Radioactive Soils

The raffinate sludges are very high water content (just under 30 percent solids by weight) chemical plant waste products. They contain radioactive metals (primarily uranium, thorium, and radium), other metals, and chemical wastes. Lime (CaO) was added as the raffinate was placed to precipitate the wastes out of solution and to neutralize the acidity of the waste stream (nitric acid). Treatment options currently being considered for raffinate sludge at the site include vitrification and cement/fly ash stabilization and solidification. Raffinate pond water, and any water that may be removed during dewatering, will be treated by the Site Water Treatment Plant prior to off-site release.

There are approximately 106,220 cubic yards of either highly radioactively contaminated soils, defined as having more than 300 pCi/g of total uranium, or soils with high concentrations of 2-4 DNT (more than 1300 ppm). These soils will be treated along with the sludge by one of the methods described below.

Under one disposal option, vitrified material would be produced by heating dewatered raffinate sludges to a molten state to form glass. Because of the chemical composition of the waste, a stable vitrified glass requires more silica than is present in the sludge. This increase in silica can be obtained by mixing the sludge with local clayey soils prior to vitrification. Studies are still in progress, but it appears that a sludge:clay ratio of about 70:30 by dry weight will provide a stable glass (Pegg et al. 1991). The operating scenario for vitrification has assumed a dry solids weight ratio of 50:50, which was used for determining the amount of soil to be vitrified with the sludge. For the vitrified alternative, it has been proposed to vitrify radioactively and chemically contaminated soils as well as the raffinate sludge. The amount of contaminated soil requiring treatment is approximately two times the amount of soil needed to raise the silica content for vitrification. This soil would come from the raffinate pit bottom material and other radioactively contaminated soils to raise the silica content during vitrification. Soils would be added to the sludge in equal proportion by dry weight, and any surplus highly contaminated soils could be vitrified separately.

Under the second option, raffinate sludge would be mixed with cement and fly ash to form a grout-like or soil-like CSS product. The highly radioactive and nitroaromatically contaminated soils would also be stabilized with cement/fly ash. Both the ratio of soil to sludge and the ratio of waste to cement, will affect the product consistency and long-term characteristics. Gilliam and Francis (ORNL 1989) have performed a preliminary study of the CSS alternative with sludges, and have developed preliminary mix recommendations. They suggest the mix ratio may be varied during construction to fit the actual sludge composition and desired waste characteristics. In one preliminary design mix, free water would remain after 21 days, and the 21-day unconfined compressive strengths would be greater than 200 psi (ASTM C109-80). The slump of the fresh test CSS was high (pourable). By varying the mix ratio, viscosity or slump of the fresh CSS could be controlled as required.

3.1.2 Contaminated Soils

Contaminated soils typically contain less than one percent metals or nitroaromatics, with the exception of aluminum and iron (Tables 5.2-1 to 5.2-5 in MKF and JEG 1990). Assuming the contaminants present do not have much mechanical effect at these concentrations, the soils are expected to have mechanical properties essentially identical to those of uncontaminated site soils. Soils that are highly chemically and/or radioactively contaminated will be vitrified or stabilized with cement/fly ash. Less contaminated soils may be placed directly in the cell and compacted by normal earthwork methods.

Three general placement alternatives are being considered for soils. To reduce radon flux, they could be placed as a separate layer over the other wastes (e.g., just under the radon barrier), they could be placed as soil zones at other locations, or they could be mixed with other wastes, such as metals, rubble, etc., prior to or during waste placement. These alternatives are discussed in more detail in following sections.

Soils in a given layer should be placed in uniform lifts with an uncompacted lift thickness of 12 inches or less. The moisture content should be at or slightly above optimum, and the soil should be compacted to a minimum of 95 percent of maximum dry density per ASTM D698 using conventional sheepsfoot compaction equipment. Other compaction equipment, such as hoe-rams or vibratory shaker heads, may be needed if there are tight

spaces that are inaccessible to sheepsfoot compactors. This compaction requirement may be modified as a result of settlement studies performed during design.

3.1.3 Gravel and Concrete, Rock, or Masonry Rubble

When no longer needed, contaminated gravel and paving from temporary road beds and other working surfaces will be placed in the cell. Concrete, rock, and masonry rubble will be crushed to a nominal 2.5-inch maximum size. If more than 5 percent of the material is larger than 3 inches in maximum dimension, special spreading and compaction methods should be used, as described below in the sections on CSS or VIT waste placement. Crushers can produce relatively well graded material so long as the source does not contain excessive quantities of rebar or other metal (telecon MKES, 1991d). Well graded gravel or crushed rubble may be placed and compacted as a gravely soil, using vibratory compaction, in accordance with the criteria given above for soil placement and compaction. A required density of 70% relative density may be used if the material is predominantly large gravel.

If the gravel or rubble is not well graded, i.e., if it is gap graded or uniformly graded, voids may be left in the compacted waste if special measures are not taken. If voids develop, particle rearrangement within the gravel or rubble may result in settlement of that waste layer, or particles from the overlying wastes may migrate down into the voids, potentially resulting in settlement of the overlying layer. Poorly graded gravel or rubble may still be placed in a manner similar to well graded material, with the following potential modifications: It may be appropriate to mix the material with a binder or filler materials, such as clayey waste soils or sand-sized granular wastes. If the gravel or rubble appears to have a self-filtering gradation (Sherard 1979), it may be placed without binder or filler material, but it should be covered with a waste form that will not migrate into the gravel or rubble. Evaluation of gradation characteristics and potential for particle migration may be evaluated visually by an experienced field engineer or technician, and by application of conventional filter criteria (Sherard 1984a and 1984b) based on the results of standard gradation tests (ASTM D422).

3.1.4 Miscellaneous Wastes

Other waste categories at the site include shredded and intact metal, asbestos containing material (ACM), personnel protective equipment (PPE), miscellaneous sanitary

landfill materials, containerized radioactive and chemical wastes, and wood. Each of these categories is discussed in the following sections describing the CSS and VIT alternatives.

3.2 Potential Waste Form Placement Methods and Equipment Selection

Grout-like CSS material will be carried to the cell and placed by pouring from dumpcrete trucks or by using a concrete pump and boom. It should generally be spread in horizontal lifts to enhance stability of the disposal cell and to minimize differential settlements.

For both the CSS and VIT alternatives, large intact metal wastes should be entombed in a pourable CSS product. For the CSS alternative, there will be plenty of CSS to accomplish the entombment; for the VIT alternative, a minimum amount of pourable CSS should be produced from slightly contaminated soils in order to accomplish the entombment; alternatively, clean grout could be purchased from off-site and used in lieu of CSS. This has the advantage of not requiring the construction of a grout plant for the VIT alternative.) Placement of individual pieces of equipment or other intact metal waste should be performed with patience and care in order to optimize the use of space and to assure the CSS will be able to fill as many voids as possible. A gradall or large excavator with a thumb will probably be indispensable for this operation. The bucket will enable the operator to place and move CSS product. The thumb will enable grabbing and placing of metal waste in optimal positions. Vibration of the CSS with concrete vibrators will probably be required to help the CSS flow into all the voids. Placement of the CSS over and around the intact metal may be facilitated by the use of front-end loaders, excavators, back-hoes, or gradalls. Dozers may be used in some situations. Additional details of CSS placement are discussed below in the section on settlement.

It is presumed that metal wastes will be delivered to the cell by truck. Most of the wastes will be suitable to handling by a loader or an excavator/gradall. A Caterpillar 225, 235, or 245 Excavator will be able to lift equipment weighing in the range of 10,000 to 25,000 pounds, depending on the reach required (Caterpillar 1989, pp. 204-206). It is anticipated that this will handle all but a few of the largest waste items. The largest, heaviest pieces may require a crane for unloading and placing. Prudent placement of large metal wastes will be critical, as discussed in Section 5.3. In particular, care should be taken to prevent pipe or large hollow metal equipment from becoming buoyant and floating in

freshly poured CSS. This may be accomplished by filling the hollow waste forms, weighting them down, placing the CSS slowly enough over a period of days so that the CSS beneath is set before CSS is bought up around the hollow waste. Large heavy equipment (e.g., the locomotive) should be placed above a zone of poured CSS or gravel or rubble to provide support for large bearing pressures that may occur. The heavier metal wastes should generally be located toward the edges of the cell in order to distribute the load away from the center of the cell and thus reduce differential settlement. Other metal wastes may be size-reduced (cut into pieces with maximum dimensions of about 8 feet) or shredded. Size-reduced materials may be placed in a manner similar to intact wastes, or similar to rubble discussed below.

Soil-like wastes, gravels, and crushed rock, concrete, and masonry, will be hauled to the cell in conventional dump trucks and scrapers. Spreading and compaction may be accomplished by conventional earthwork equipment. Clayey materials should be compacted with a sheepsfoot compactor, while granular material with low fine content (i.e., less than 12 percent passing a No. 200 sieve) should be compacted with a vibratory smooth drum roller or track-walked with track-mounted dozer or loader.

Containerized materials will be treated in different ways depending on the material that is containerized. Listed RCRA and TSCA liquid wastes will be disposed of in off-site facilities (e.g., at Oak Ridge). The remaining containerized materials are not listed RCRA waste; they include salt, sand, sulfur bricks, soils, and containers. They will be removed from their containers prior to final placement in the cell. Any strong acids, bases, or potentially reactive materials will be neutralized prior to stabilization treatment and placement in the cell. All materials that fail to meet land ban criteria will be stabilized, possibly by being processed as CSS.

Methods of placement for other waste forms are discussed below in the sections on CSS and vitrified alternatives.

3.3 Potential Waste For Layer Sequencing and Zonation

It is not anticipated that there will be significant hazard due to reactive or shock-sensitive wastes being placed or mixed in the cell. The large majority of the wastes contain very small fractions of contaminants (< 1% by weight) contained in soil or other bulk wastes.

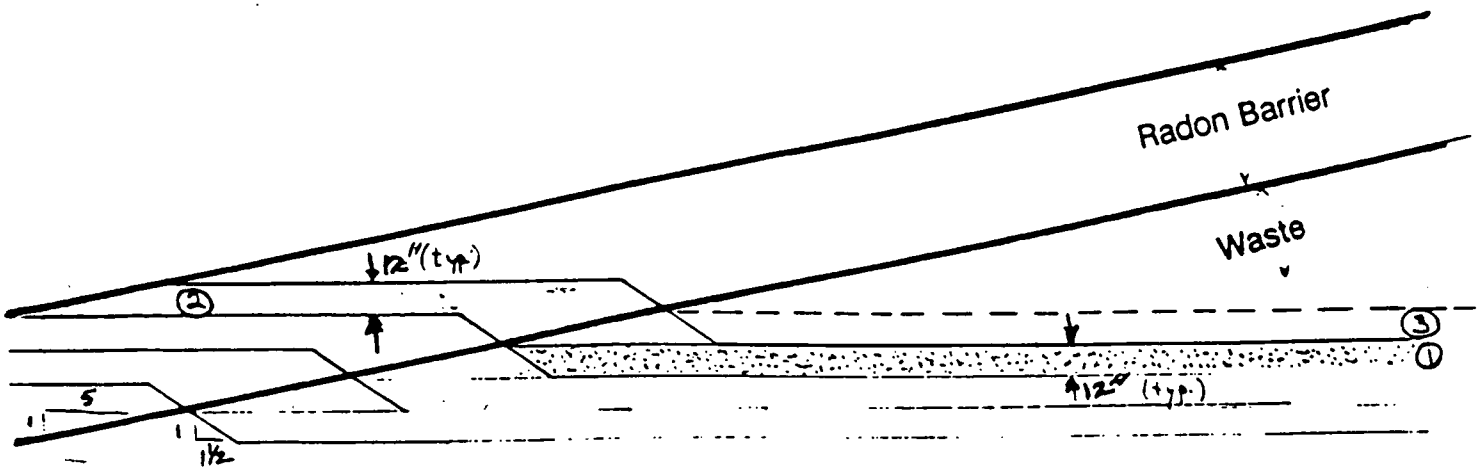
Contaminants are not expected to be found in concentrations that will cause any reactive or hazardous conditions even if the wastes are placed with and mixed with each other. The only exceptions to this are the several hundred drums of containerized chemical and radioactive waste products currently being stored in Building 434. Any RCRA solid will require stabilization to meet RCRA requirements, which is the subject of Study 41 (Task 941) now in progress. RCRA liquids will removed from the site for incineration at the DOE's Oak Ridge facility.

In order to minimize the effects of differential settlement, it is desirable to place the heavier or denser wastes toward the perimeter or outside of the disposal cell. The CSS is expected to be the least-dense major waste form. Some of the large equipment will be the most dense waste form, but the associated volume is relatively small. The gravels and concrete rubble will be the densest major waste form. Thus, to the extent practical the gravel and concrete rubble should be placed near the edge of the waste pile, with the CSS placed toward the middle. The volume of heavy metal equipment is not considered large enough to warrant special placement toward the edge of the cell, but should not be concentrated in one location.

Raffinate sludges were pH-neutralized by the addition of lime during placement in the raffinate pits. This has resulted in an average of 40 to 50 dry weight percent lime in the raffinate sludge, which in turn has led to the need to add silica to the raffinate sludge to achieve a stable vitrified product (Pegg et al. 1991). Thus, it will be necessary to process soil-like wastes at a rate that supplies adequate silica to the vitrification process.

3.4 Drainage During Cell Construction

During heavy rains, runoff will flow over the surface of wastes in the cell and become contaminated. If this water were to flow onto the cover material, the cover could become contaminated and need to be removed and replaced with clean cover material. Therefore, during the construction of the disposal cells for any of the alternatives, the inner portion of the cover material (i.e., the radon barrier) must be kept higher than the adjacent waste. In general the surface of the waste should slope away from the cover for at least 10 feet. Runoff should be directed to a central collection location, where it will be pumped to water retention ponds, the raffinate pits, or the Site Water Treatment Plant equalization basin. The water will be tested and, if necessary, treated to meet National Pollution Discharge



1. Most Recent Lift of Waste
2. Most Recent Lift of Radon Barrier
3. Next Lift of Waste

Note : For 4' thick radon barrier, the volume of required radon barrier material will increase by 32 % to account for material below the theoretical bottom of radon barrier.

"SAW TOOTH" SHAPE OF
BOTTOM OF RADON BARRIER

FIGURE 3-1

000034

In addition to the 227,700 cubic yards of sludge being processed as CSS, about 106,220 cubic yards of soil-like waste will be processed as CSS. Studies are currently underway under the direction of the PMC to further test various mixes of sludge, soil, cement, and fly ash for the purposes of selecting an appropriate mix. It now appears to be possible to vary the mix in ways that will yield either or both of the following consistencies:

1. A high-slump grout-like material which can be poured and placed in a manner similar to concrete.
2. A soil-cement type of product which can be placed and compacted with conventional earthwork equipment.

For this study, it was assumed that enough of the CSS to entomb the metal wastes would be produced as a pourable grout, while the remaining CSS could be handled in either of the two forms.

The soil-like waste will be delivered to the cell at various rates, depending upon the material source. The following summary provides the volume by major source area of soil-like waste and the estimated delivery rate, as described in the operational scenario for waste removal, transportation, and reclamation (see MKF and JEG 1991b, p 15).

Table 3-1: Soil-like Waste Estimated Delivery Rates

Source Area	Total Volume (cu yd)	Delivery Rate (cu yd/hr)
TSA, Ash Pond & Mulch Pile	71,400	56.3
Site Ponds and Dumps	36,900	70.8
Site Surface Areas	50,400	150
Underground Pipe	13,000	56.3
Raffinate Pit Bottom	118,900	68.8
Road Surface Reclamation	30,830	56.3
Water Control Removal	25,900	100
Busch Lakes	20,000	84.9
Total	367,330	(weighted avg) 79.3

There will be a need to assure that there is enough low-level radioactive soil-like waste to construct the working surface over the leachate collection system and the cover over the waste to slow radon flux (see Section 6). The Radon Barrier Evaluation (MKES 1991c) indicates that low-level radioactive, soil-like wastes will come from the sources shown in the following table:

Table 3-2: Source Availability and Quantities of low-level Radioactive, Soil-like Wastes

No. on Table 2-4	Location	Start Date	Quantity (cy)	
1-5	Raffinate Pit Soil	5/2/95		118,900
7, 29, 58, 60	Road Base	3/1/99		35,930
14	Ash Pond	6/2/99		11,910
15	Frog Pond	4/11/96		7,800
13	North Dump	7/1/93		5,930
16	South Dump	10/15/97		14,780
N/A	TSA area	2/1/92		4,000
N/A	Site Water Treatment Plant area	12/1/91		7,100
17	Lakes 34, 35, and 36	4/1/98		20,000
23	TSA and Mulch Pile	4/1/95		8,442
30	Retention Dikes	9/21/99		25,900
50-52	Around and beneath the chemical plant buildings	10/7/93	15,000*	65,400
		3/1/95	25,200*	
		3/1/96	25,200*	
49	Underground Piping	6/23/93		17,960
N/A	Femme Osage Slough	3/1/99		30,000
53-55, 57	Vicinity Properties	9/1/95		3,600
	Total:			377,652

* Quantities are from Table 2-4; not consistent with Table 1 of MKES 1991c.

Note: Any items with start dates before early 1995 imply that material will be stockpiled either at the TSA or Site Soil Spoil Area (Site SSA).

Section 6 will discuss the amount of low-level radioactive soil-like waste that may be needed to create a 1- to 2-foot-thick layer of radon-flux-inhibiting waste. The total quantity needed to form this layer under the radon barrier and a 1-foot thick layer over the leachate system may be on the order of 126,000 to 189,000 cy. Approximately a third of this material would be needed for each of the three phases of the CSS alternative, and approximately a half for each of the two phases of the non-vitrified cell in the VIT alternative. From an

examination of the above table and Table 2–4, it can be seen that there may be enough material available at each stage without any special effort. The schedule of availability should be studied in more detail in the next phase of work, and coordinated with the final radon barrier study report (MKES 1991c). If future studies indicate timely availability of this material may be a problem, some of the excavation sequence may need to be modified to make additional low-level radioactive soil-like wastes available earlier. This will be coordinated with the radon barrier evaluation study (Task 919).

Under current projections, rubble will be delivered to the cell at a rate of 40 cubic yards/hour (MKE and JEG 1991b). The rubble and soil-like material (222,000 cubic yards and 378,000 cubic yards, respectively) could be spread or spread and compacted using dozer, motor-grader, disc harrow, water truck and compactor over the projected 45 months of active waste placement in the cell. At that rate, this crew will handle an average of 103 cubic yards per hour based on 6.5 productive hours per day. However, Phase 3 of the disposal cell is located over the MSA. Therefore, all materials stockpiled in the MSA will need to be placed during Phases 1 and 2 in order to empty the MSA prior to the construction of the Phase 3 cell foundation. This is not expected to have any adverse affect on the placement operation or performance of the waste pile.

3.5.2 VIT Alternative

For the VIT alternative, the critical path for cell construction will be production of vitrified material. Vitrification will proceed at a basically steady rate for the duration of the cell construction, which will dictate the time of the vitrified cell construction. Construction of the non-vitrified cell will be scheduled to match the schedule for construction of the vitrified cell.

Approximately 107,000 cy of vitrified material will be placed in the cell over a 4-year period. It will be delivered to the cell at a rate of approximately 18 cy/hr on an 8-hour/day basis, mixed with an appropriate amount of clay binder to provide cohesion to the waste and to improve cell stability, and compacted.

The rates of delivery for the remaining material are assumed to be similar to those described in the preceding section regarding the CSS schedule.

4 WASTE SETTLEMENT AND SLOPE STABILITY

4.1 General

Throughout the design life of the facility, the disposal cell will need to be secure, with regard to the possible effects of settlement and the consideration of slope stability. These two topics are discussed in the immediately following sections. In addition, the potential for shallow sliding to occur along a slide plane just below the cover, in the proposed zone of soil-like waste, is discussed in a later section regarding placement of the soil-like waste for the CSS alternative (Section 5.1 below).

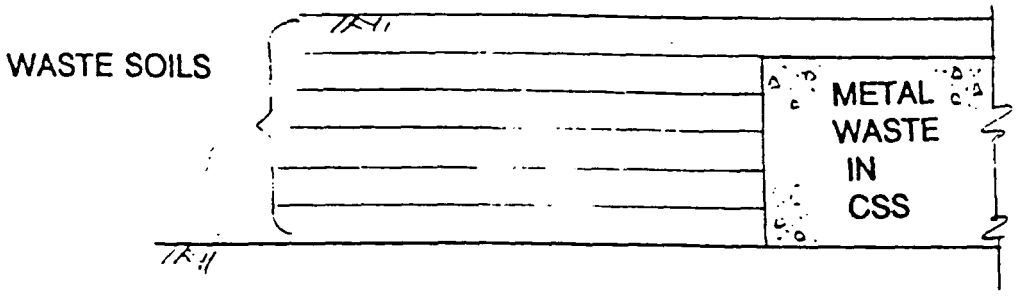
4.2 Settlement

Two aspects of settlement are potential concerns for the disposal cell. First, variations in thickness and compression characteristics of the waste can result in differential settlement of the top of the waste with two possible effects on the overlying cell cover:

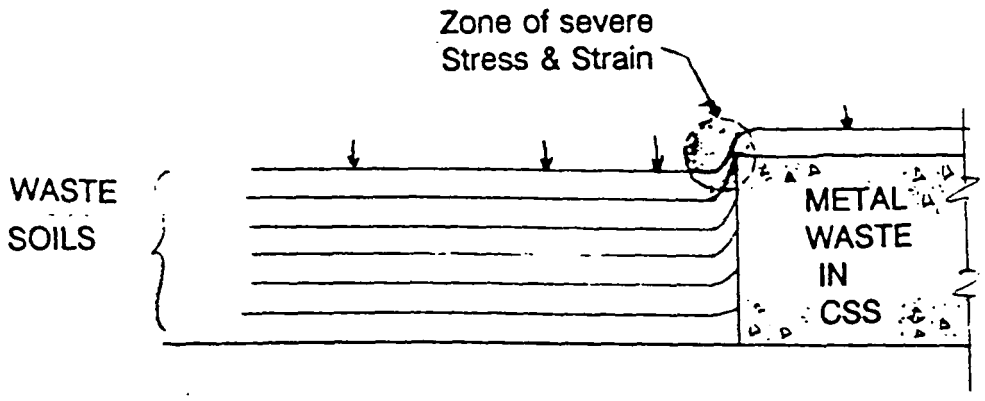
1. Excessive differential in the cell cover could cause the relatively flat top of the cell to develop areas of potential ponding.
2. Local differential settlement could result in excessive strains and cracking in the cover material.

The amount of anticipated differential settlement should be accounted for in the cell and cover design.

Second, differential settlement between different waste forms in the cell interior could lead to local strains or voids developing as one waste form settles more than the other. This could be particularly true at near-vertical or overhanging surfaces of large metal wastes such as the locomotive, large stainless steel tanks, and calciners. (Stainless steels wastes may be recycled off-site if it is determined they can reasonably be decontaminated.) Such a situation is depicted schematically in Figure 4-1. If soil-like waste were to be placed against a vertical or overhanging surface, the soil would compress more than the adjacent metal waste, and stresses would develop in the soil above the contact. A local void could develop if the differential consolidation becomes large enough. This void could work upward, eventually threatening the cell cover. Methods to prevent this from occurring are discussed later in this section.



WASTE JUST AFTER BEING COVERED



WASTE BENEATH 70' OF OVERBURDEN

POOR CSS PLACEMENT - VERTICAL FACE

FIGURE 4-1

Compression of the metal and CSS waste forms will be negligible and nearly instantaneous as overburden is placed above them. The amount of compression will be a function of Young's modulus of elasticity and the overburden stress. Young's modulus for steel is on the order of 30,000,000 psi. There are no data available for the modulus of CSS for WSS. Mr. Mike Gilliam of ORNL, who directed the laboratory investigation of the CSS, expects the properties of the CSS to be similar to Portland cement concrete or grout. According to the ACI manual (1983), a concrete with the strength and density properties reported by ORNL (1989) would have a modulus of 400,000 to 600,000 psi. Based on a comparison of moduli for concrete, soil cement (modulus of 100,000 to 1,000,000 psi, per Catton, 1952), and roller-compacted concrete (modulus of 144,000 to 243,000 psi, per Krauch, 1981), an estimate of the modulus of CSS on the order of 100,000 psi is considered conservative.

Compression of soil-like wastes will result from a combination of relatively instantaneous compression due to soil elasticity and time-dependent settlement due to other factors. A minor amount of compression will also result from further decomposition of composted wood waste. A preliminary estimate of anticipated settlement was performed (MKES 1991h). It was conservatively assumed that infiltration through the cover would cause the waste to become saturated or nearly saturated during the 1000-year design life of the cell. If the soil-like wastes become saturated, they will experience hydrocompression. The magnitude of calculated hydrocompression should account for the effects of primary consolidation and secondary compression. The results of the preliminary calculation are summarized in the following table:

Table 4–1: Estimated Waste Settlement

	Soil-Like Waste	CSS	Vitrified Waste
Maximum Layer Compression During Construction	5%	0.3%	Not a concern
Maximum Layer Compression Following Construction	3.3%	0	Not a concern
Settlement Following Construction	1.5 ft	0	Small

It may be noted that the settlement and compression values for the soil-like waste are over an order of magnitude more than the corresponding values for CSS, which are

negligible as far as design is concerned. Thus, in the CSS alternative, the only concern will be the settlement that will occur in the soil-like wastes, as well as the wood waste. Minor amounts of settlement may occur in other waste forms, but are not expected to be a major concern due to the small volumes of these waste forms. An evaluation of the consequences of settlement in the CSS alternative will need to consider the location and thickness of the soil-like and wood waste forms. The total thickness of soil-like wastes will probably be less than 15 feet, and the resulting settlement due to compression of these waste will be less than 4 inches; i.e. less than 1%. This should not be a significant design problem. Settlement of the foundation may still be a concern.

In the VIT alternative, the non-vitrified cell will be composed largely of soil-like wastes, and the values for soil-like waste in the above table will apply. It will be particularly important to configure the CSS portion of waste in the non-vitrified cell to minimize any detrimental effects of differential settlement. It is considered that a conventional cover can be designed to accommodate the anticipated settlement without cracking. Recommendations regarding placement of CSS for this alternative are given in the following sections.

To consider the possibility of ponding on the top of the cell, a worst-case scenario may conservatively be assumed. (Ponding will not be a threat on the side slopes under any settlement scenario.) In this worst-case scenario, a waste pile constructed entirely of soil-like waste would result in settlement on the order of 1.5 feet at the high point of the cell and potentially a much smaller amount at the edge of the top of the cell. The maximum possible change in slope would be 1.5 feet in about 100 feet, or about 1.5 percent. As long as this settlement is not localized, its potential effects on drainage (i.e., potential ponding on the top of the cell) can be compensated for by overbuilding the top of the cell by a slope of 1.5 percent superimposed on the slope of 2 percent required for drainage design. Task 914 is addressing this concern in more detail (see JEG 1991).

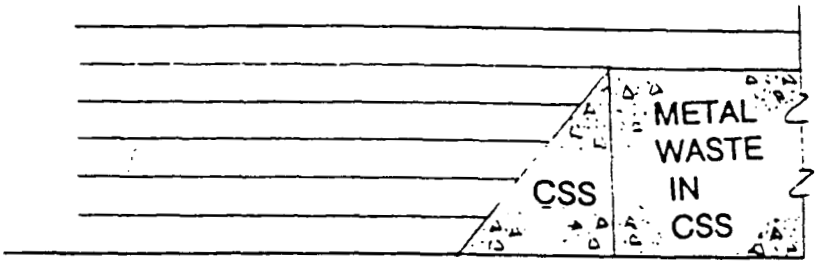
Local differential settlement of soil could also cause ponding or cracking of the clay cover. To determine the settlement which could cause cracking, procedures developed by Lee and Chen (1969) can be used to predict lateral soils strain as a function of settlement, and available data on cracking strain, can be used to relate settlement and cracking. This information can be used with the dimensions of rigid wastes to be placed in the cell and entombed in CSS to determine the slope at which CSS grout should be placed adjacent to

the rigid waste to reduce the potential effects of settlement on cover cracking. It is assumed that this procedure will be used in the final design of the cell. For illustrative purposes a non-rigorous rough approximation will be used here to give some idea of how local differential settlement could be accounted for in design.

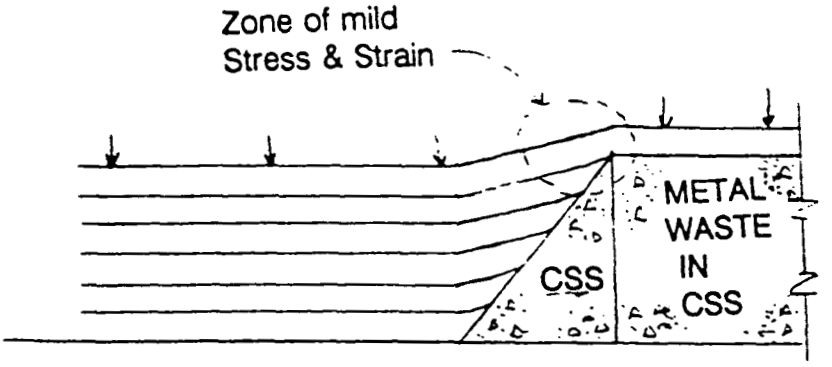
It is anticipated that CSS will be placed without formwork, and will come to rest against previously placed waste or at its natural angle of repose. For illustrative purposes, the following discussion assumes a hypothetical situation where CSS may have been placed quite steeply. For example, if a block of CSS were formed with a 5-foot vertical side, the soil adjacent to this block could compress on the order of 1 to 2 inches, while the metal would compress a negligible amount (Figure 4-1). If a wedge of grout were poured against the block at a slope of about 0.8H:1V, the differential settlement would be spread out over a span of 4 feet (see Figure 4-2). A rough index of the resulting shear strain would be the ratio 1" to 2" per 48", or 2 to 5 percent. Experience with earthdams constructed on hard-rock foundations suggests that these values may be acceptable. Some dams with abutments steeper than about 0.5H:1V have experienced cracking within the embankment. Therefore flattening of dam foundation excavations has been recommended to reduce the steepness of the abutment to about 0.5H:1V or flatter.

With these considerations in mind, it is recommended that any metal wastes that would be placed with a vertical dimension greater than about 18 inches be entombed with pourable CSS to prevent excessive strains and potential cracking or void formation in the adjacent soil. The slope of the outside face of the pourable CSS should be no steeper than that determined to be acceptable by analysis. In addition, poured CSS should be placed over previous layers of poured CSS rather than over soil, to minimize differential strains on the upper zones of CSS, as shown on Figure 4-3. The exception to this is that thin lifts of soil-like wastes, gravel, or rubble may be placed between zones of poured CSS.

Settlement of the foundation beneath the cell has been evaluated by Task 938 (MKES 1991e). Foundation settlement could lead to spreading of the base of the wastes. The potential for cracking of wastes and stretching of the synthetic and clay liner elements should be considered under Task 934 (proposed subsidence study) and/or the CDR task on liner and foundation design.



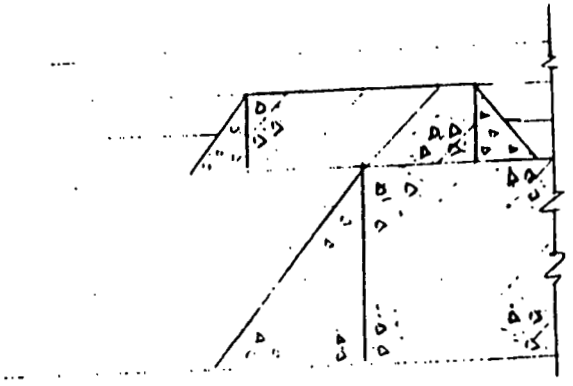
WASTE JUST AFTER BEING COVERED



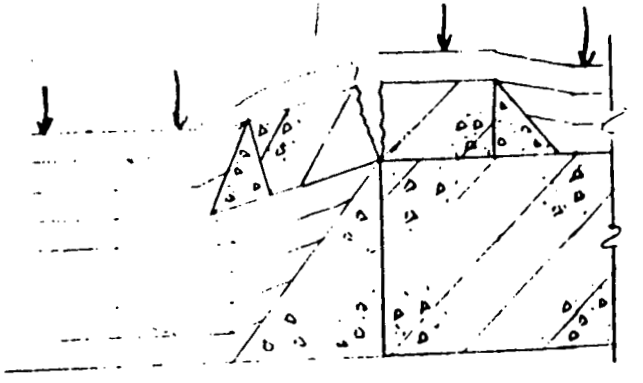
WASTE BENEATH 70' OF OVERBURDEN

GOOD CSS PLACEMENT - SLOPING FACE

FIGURE 4-2

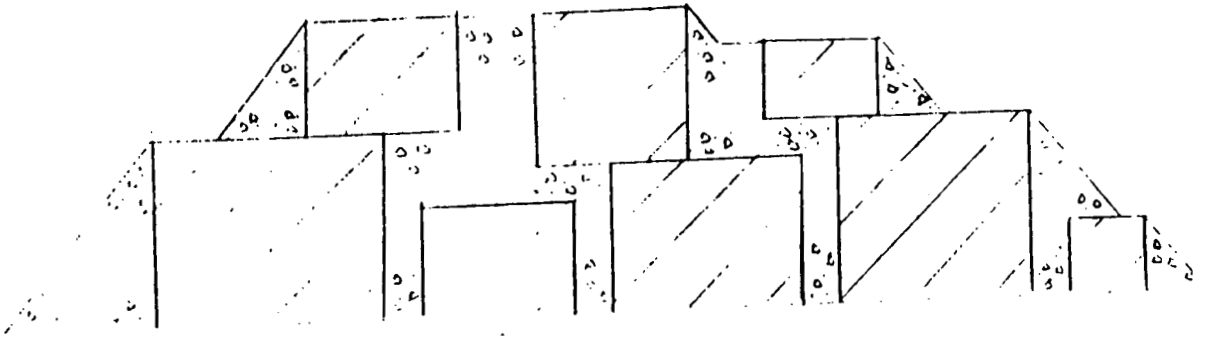


WASTE JUST AFTER BEING COVERED



WASTE BENEATH 70' OF OVERBURDEN

WRONG : CSS Around Upper Metal
Cracks under Final Waste Load



RIGHT : All CSS Entombed metal supported on
CSS, except lowest lift.

STACKING OF INTACT WASTES
FIGURE 4-3

000044

4.3 Slope Stability

The stability of the disposal cell has been evaluated in Task 938 (MKES 1991e). The results of that study indicate that the cell will be stable against sliding for both short and long term under static and seismic conditions. That study assumed soil-like strengths for the stability analysis. The major waste forms will have strengths at least as high as the values used by that study for soil-like waste. The friable asbestos and wood waste products will have lower strengths, but these waste forms comprise a minor amount of the total waste volume. Therefore the wood and friable asbestos should be placed in thin layers that are horizontal or slope slightly toward the center of the disposal cell. They should not be placed within about 50 feet horizontally from the inner edge of the cell cover, to preclude the possibility of shallow, local instability developing. Future studies should confirm the results of the Task 938 stability studies, with refinement as necessary, based on conceptual or final design parameters.

5 CSS CELL

5.1 Contaminated Soil Placement

The upper portion of the cell bottom liner will consist of 6 inches of fine granular material over 12 inches of granular drain material over a flexible membrane liner. In order to avoid disturbing or plugging this leachate collection system and to provide a stable working surface for equipment, a minimum of 1-foot of soil-like waste should be placed over the leachate collection system before placing CSS or metal wastes. This may be accomplished by a compactor or dozer spreading out piles of soil-like waste to produce a 1-foot lift working surface. In this way it will be possible to prevent the waste placement equipment from ever coming in contact with the leachate system.

Radon emissions are a concern that needs to be considered in the zonation of the waste placement. The highest radon emissions will come from the CSS-treated raffinate sludge. In addition, some contaminated soils will have moderately high radon emissions. Preliminary calculations indicate that radon emissions from the most radioactive CSS can be adequately controlled by placing about 2 feet of soil over the CSS. This number may be reduced based on better estimates of the emanating fraction of radon from the CSS waste form. If less-radioactive, contaminated soils are to be used for this soil cover, the quantity required will use up most of the available soil of this type.

The rate of radon emission will vary inversely with the thickness of the soil layer covering the CSS. Based on the ALARA process, it therefore makes sense to place as much soil over the CSS as is reasonably possible, as long as it significantly reduces the radon flux.

Preliminary calculations of slope stability against sliding through a thin soil-like layer were performed. An infinite slope method was used, with the cover configured as shown in Figure 5-5 of the draft Land Disposal Facility Alternative Cover Assessment (JEG 1991). Strength parameters were taken from the draft Liner and Foundation Assessment report (MKES 1991e). It was conservatively assumed that the radon barrier and low-level radioactive soil could become saturated, with a piezometric surface at the bottom of the filter sand (i.e., just above the radon barrier) and seepage occurring parallel to the slope. These preliminary calculations indicate that the safety factors will be acceptable, as shown below for potential thicknesses of 0 to 4 feet:

Table 5-1: Infinite Slope Stability

Thickness of Low-Rad Layer (ft)	Safety Factor		
	Short-Term Static min = 1.3	Long-Term Static min = 1.5	Long-Term Seismic min = 1.1
0	8.5	2.9	1.9
2	6.5	2.5	1.5
4	5.3	2.2	1.3

5.2 CSS and Non-Soil-Like Wastes

The preceding section suggests that contaminated soil with low radioactivity should be placed directly over the leachate system, over the top of the CSS (and just under the cell cover), or both. Some amount of the contaminated soil is relatively high in radioactive contamination and will be treated as CSS. Of the non-soil-like wastes, about 63 percent will be CSS from raffinate sludge or highly contaminated soil (compare Figure 2-2).

Nine percent of the waste will be masonry, rock, and concrete rubble that has been size-reduced to about 2.5 inches or less. Depending on the actual gradation curve of this material, it may be spread in lifts and compacted (if the material is relatively well graded) or spread in lifts and covered with CSS grout to fill most of the voids. Some amount of mixing of CSS and rubble may be required to assist in filling voids in the rubble.

Nine percent of the waste will be soil and gravel that results from closure of haul roads and other remedial facilities. This material will generally become available toward the end of the remedial work. It may be spread in lifts and compacted as normal engineered fill.

There is a small amount of asbestos to be placed in the cell. About 1 percent of the non-soil-like waste will be friable asbestos (currently stored in bags), and about 1 percent non-friable, largely in the form of roofing, siding, flooring, and 8- to 12-inch O.D. transite pipe. The non-friable portion may be placed in a manner similar to that described for intact metal wastes below. It has previously been proposed to place the friable material in trenches excavated into soil-like wastes, preferably near the top of the cell in order to

minimize overburden loading and subsequent deformation of the friable asbestos component. It now appears that most of the soil-like waste will be located either at the very top or the very bottom surface of the waste pile, and it may be difficult to excavate trenches in poured CSS material. It is therefore now proposed that the friable asbestos be placed in troughs in the CSS and then covered with CSS. Other burial methods may be possible as well. The key in evaluating acceptability of a burial method is that the asbestos bags and non-friable asbestos not be broken during the placement operation, so that the asbestos is not exposed to the air, and that it not be placed in a manner which results in excessive settlement. Isolated lengths of 8- to 12-inch O.D. transite pipe or sheets of roofing, siding, or flooring encased in CSS should not affect cell performance.

A small amount of composted wood is also to be placed in the cell. The estimated volume of wood after it has been composted is 6442 cy. The compressibility and decomposition potential of the wood are expected to be substantially reduced by composting. However, some compressibility and further decomposition potential will still exist. Three alternative placement methods were considered. First, the wood may be mixed in small percentages (< 5% by volume) with pourable CSS. Once set, the CSS will have enough strength to support the overburden even though it has weak materials within it. In order to minimize the effects of the wood in the CSS, this process should be used only in the upper 15 feet of the CSS, and not within 30 feet horizontally of the interior edge of the cell cover. The second alternative is to mix the wood relatively uniformly (at < 5% by volume) with the gravel materials from the remedial facilities closure. There may be some resulting volume reduction following completion of the cell, but only a fractional loss in strength would occur. The Third alternative is to place the wood near the top of the cell to reduce the overburden pressures acting on it. The wood should be spread out as a relatively uniform lift over a wide area to minimize the thickness of the wood in the cell. For the proposed CSS cell configuration, the top area is about 305,000 sf. For this area, the 6442 cy of composted wood, spread over the top of the whole cell would be about 7 inches thick. Even if the composted wood were to lose an additional 20 percent in volume, this would result in only about 1.2 inches of settlement, which would be relatively uniform across the top of the whole cell. However, this would result in a large weak plane in the waste. This is the least preferred alternative.

A very small amount (about 781 cy, which is less than 1 percent of the waste volume) of compressed PPE is also to be placed in the cell. This material will be compressed into

drums, and the drums placed in the cell. Because the quantity is so small, these drums may be placed one by one, in isolated locations, and entombed in CSS.

As stated above in Section 3.2, containerized materials will be treated in different ways depending on the material that is containerized. There are about 170 cy of RCRA-regulated materials which will be disposed of off site. These include salt, sand, sulfur bricks, soils, and containers (drums). Any strong acids, bases, or potentially reactive materials will be neutralized prior to stabilization. Radioactively contaminated RCRA liquids are expected to be transported to Oak Ridge for incineration.

There is a small volume (281 cy) of material that has been classified as "Miscellaneous Debris." These are composed of sanitary landfill type wastes that include ceramics, porcelain, glass, and graphite. Oversized portions of this material should be handled with concrete rubble during and after volume reduction.

The remaining waste forms to be discussed include various forms of metal debris. Of the metal to be placed in the cell, about 13,101 cy will be shredded, 8734 cy will be size-reduced, and 40,550 will be placed in the cell intact. There are about 440,810 cy of CSS that will be placed along with the metal debris. A key part of this study is to evaluate the most appropriate method of placing these wastes together.

The shredded metal waste will come from the crusher/nuggetizer as fragments no larger than about 6 or 8 inches. These materials should be spread in loose, open lifts about 6 to 8 inches thick, and covered with pourable CSS. The CSS should be vibrated with a concrete vibrator or worked slightly with a backhoe or other piece of equipment to move the CSS down into the voids in the metal.

The size-reduced metal waste will be in the form of beams, plates, or parts of large processing equipment (maximum dimension of 8 feet). The material may be placed in the cell and covered with grout. It should generally be placed lying flat, or with the largest dimension horizontal. However, the orientation of each piece should be selected to minimize the number or volume of any voids that might not be filled by CSS poured on top of and around it. In some situations it may be most appropriate to set the piece into a pile of wet CSS, and work it down into the CSS to fill voids on the bottom side. The piece may then be covered with CSS.

The larger, intact pieces of metal waste may be placed in a manner similar to that described above for size-reduced material. Any hollow tanks, pipes, etc., should be filled with CSS after being placed in the disposal cell. This may be accomplished by pouring CSS through access holes, through the end of pipes, etc. In particular, care should be taken to avoid creating a buoyant condition where the piece might float upward in an excessively deep lift of CSS. Because the CSS may be nearly twice as dense as water, this may occur sooner than might appear likely. To prevent this from occurring, the piece may need to be at least partially filled with CSS before CSS is placed around it.

5.3 Sequencing

The sequence of placement of materials of various types in the cell has a moderate amount of flexibility, but there are certain restrictions that should be observed. The purpose of these restrictions will be to protect the final cell integrity and to reduce radon emissions.

The current plan is to construct the CSS cell in three phases. Although the final layout of the cell and of the phases has not been determined, it appears from preliminary siting work (MKES 1991b, Study 2C) that each phase will contain roughly a third of the total waste volume. Using some simplifying assumptions for this stage of the evaluation of waste placement, the approximate volume of waste that will be required to raise the waste surface one foot is as shown below for various elevations of the waste pile working surface.

Table 5–2: Disposal Cell Waste Volume vs Cell Height

Height Above Foundation	CY/Vertical Foot of Waste Per Phase
0	21,000
20	14,000
40	9,000
60	4,700

The MKF and JEG Construction Operation Scenario report (1991b) indicates that the waste placement will occur over a period of about 800 working days (p. 15). With a total waste volume of 963,363 cy (Table 2-1), this would average out to about 1200 cy per day, which is about 1 to 3 inches of rise per day over a given phase of the waste pile.

Some of the larger waste forms, including intact and size reduced metals, may be placed in a heap rather than in a thin lift (MKES 1991g). The entire heap would then be entombed with poured CSS. Heaping of wastes will only be acceptable if it is determined

that an adequate filling of voids can be assured for a specific heap. The acceptability of a specific waste composition for a heap would need to be determined during construction for any proposed mix of wastes.

If large, intact metal pieces or other debris elements were placed directly over the leachate collection gravel, there would be a risk of the metal dragging through or penetrating the gravel, potentially damaging the FML. Therefore, the leachate collection system should be protected by covering it with soil-like waste, as described above in Section 5.1.

The CSS, whether in the form of grout or a soil-like mix, may be placed nearly monolithically, or it may be interspersed with soil-like wastes (as distinct from soil-like CSS). If soil-like waste is interspersed within the CSS, it should be placed in either small isolated quantities or in relatively uniform layers that extend across the entire working surface of CSS. When CSS placement resumes after being interrupted by soil-like waste placement, it should only be placed where it is underlain at depth by previously placed CSS. Concrete rubble, shredded metal, and other wastes, should be incorporated into the CSS as described above. The soil-like wastes and gravelly materials from the closure of remedial facilities may be placed near the top of the cell, or along one side of the cell. One construction sequence would be to raise the Phase I portion of the cell to a predetermined elevation with CSS, and then move the CSS placement operation to Phase II while the soil-like waste is placed on the top of Phase I. The sequence could be repeated for Phases II and III as well.

The large, intact wastes should be placed relatively low in the cell. This will allow for experimentation with the methods of entombment while there is still plenty of space in the cell to adjust the operations. However, the heavy, dense pieces of equipment (such as the locomotive) should be placed over a zone of CSS that is at least 5 feet thick, or over a zone of gravel or rubble material that is at least 7 feet thick, in order to spread the load and reduce potential differential settlement beneath the waste.

For purposes of radon migration through the cell cover, the wastes having the highest level of radioactivity would ideally be placed at the lowest, most central position in the cell. However, this may potentially produce elevated radon flux downward through the leachate collection system. (This will be addressed by JEG in Study 35.) In addition, the sequence

of sludge excavation for CSS production may not allow enough flexibility to control where and when the more highly radioactive wastes will be placed.

6 VITRIFIED ALTERNATIVE

6.1 Vitrified Cell

The vitrified material will be in the form of small glass beads or pellets about 1/4 to 3/8-inch diameter. The disposal volume of vitrified soil and sludge is shown in the pie chart in Figure 2-3. The current plan calls for the material to be placed in an unlined disposal cell with a composite cover. The material will be mixed with about 15 percent uncontaminated clay to serve as a binder to produce a mechanically stable waste product. The clay and vitrified material should be mixed together on the disposal cell. (Mixing the clay and vitrified material prior to placement on the cell is not desirable because it would create an opportunity for spills to occur outside of the disposal area.) Mixing on the cell may be accomplished by placing the materials beside each other in approximately proper proportions. Adjacent piles of materials would then be mixed together with a grader, dozer, loader, or disk. After mixing has produced a relatively homogeneous blend of the two materials, the material should be spread in lifts not exceeding 12 inches in uncompacted thickness. It may then be compacted, by track-walking with a dozer or by using a vibratory compactor, to at least 90 percent of maximum dry density as determined by ASTM D698.

6.2 Non-vitrified Cell

6.2.1 Contaminated soil placement

Approximate quantities of waste forms and the percent of the total waste volume that each represents are shown on the pie charts in Figure 2-4.

In order to protect the leachate collection system and to provide a stable working surface for equipment, a minimum of one foot of soil-like waste should be placed over the leachate collection system before placing other wastes, as described above in Sections 5.1 and 5.3.

Radon emissions are a concern that must be considered in the zonation of the non-vitrified waste in placement for the VIT alternative. The highest radium concentrations will be in the vitrified material that will be placed in the vitrified cell. However, some remaining wastes with lower levels of radioactive contamination will be placed in the non-vitrified cell.

Some of the soil-like wastes will be treated to form CSS grout in order to entomb the metal wastes. Where practical, this CSS should be produced from the low-level radioactively contaminated soils. (Alternatively, clean grout could be purchased from off-site for the purpose of waste entombment.) There are also other forms of radioactive wastes. Preliminary calculations indicate that radon emissions from the most radioactive non-vitrified waste can be adequately controlled by placing a 1- or 2-foot thick layer of soil over the waste. This would potentially preclude the need for a radon barrier; however, the cell cover design will require an infiltration barrier. If less-radioactive contaminated soils are to be used for this soil cover, it will require use of about 63,000 to 125,000 cy of the soil-like waste for 1 or 2 feet of cover, respectively.

While the CSS alternative requires placement of a cover using as much low-level or non-radioactive soil-like waste as is easily available to reduce radon escape, the non-vitrified cell may require a large amount of soil for mixing with other wastes as binder, filler, or cover. This could use up a large portion of the soil-like wastes so that there might not be a large quantity of soil-like waste available for placement over the top of the waste for radon control. In this case, radon flux would need to be controlled by a traditional radon barrier without the aid of the low-level or non-radioactive soil-like wastes.

6.2.2 Placement of Other Waste

There are currently estimated to be about 423,130 cy of soil-like wastes, based on quantities reported above in Section 2. The Radon Barrier Evaluation draft Report (MKES 1991c) indicates this material can be roughly broken down into the following groups: (Note: This table varies slightly from Table 1 of that report, because 30,000 cy are being moved from the highly radioactive to the low-radioactive category by the team working on Draft B of that report. Also note that the following quantities do not add up to 423,130. An attempt will be made to reconcile these numbers in preparation of the final draft of this report.)

Table 6-1: Radioactivity of Wastes

Waste Description	Volume (cy)	Projected Radium-226 (pCi/g)
Raf Pit Liner and other soils with high projected radium-226.	219,100	1146
Low-Radioactive Soil	186,300	3.74
Total	405,400	n/a

About 106,220 cy of the more radioactive wastes are expected to be vitrified, based on levels of radioactivity. In any case, about 51,000 cy of the more radioactive of these soil-like wastes may be needed to mix with the raffinate sludge before vitrification in order to provide enough silica to produce a stable vitrified glass. Depending on the results of the radon barrier evaluation study (Supporting Study 19), on the order of 63,000 to 126,000 cy of soil-like waste with lower levels of radioactivity may be placed over the bulk of the wastes to reduce radon flux, and 63,000 cy may be used to form a working layer over the leachate collection system. This would be taken from the "low-radioactive" soil-like wastes. This would leave about 127,910 to 190,910 cy of soil-like wastes. Some of this remaining soil-like waste (perhaps 60,000 cy) would be mixed with cement/fly ash to form a grout for the purpose of entombing the large metal wastes. The remainder would be placed with and around the smaller rubble and other waste forms.

The waste form includes various forms of metal debris. Of the metal to be placed in the cell, about 13,101 cy will be shredded, 8734 cy will be size-reduced, and 40,550 cy will be placed in the cell intact.

The larger, intact pieces of metal waste include a small locomotive, numerous engines, forklifts, and other miscellaneous equipment. This material is bulky with large voids not only around the outside of the equipment but also within the equipment, in areas such as engine compartments and so on. It would be quite difficult and expensive to thoroughly fill the interior of the equipment with untreated waste soil. Even if the larger voids could be filled effectively, there would still be small voids within the waste pieces. Over the 1000-year design life of the cell, there is a possibility that the metal could rust out and leave unbridged voids within the disposal cell, an undesirable condition. To reduce the rate of corrosion, and to minimize the effects of such corrosion, the VIT alternative should utilize

enough pourable CSS to entomb the intact metal wastes. This CSS could be delivered to the cell by concrete or dumpcrete trucks, and it could be worked into the metal waste by an excavator or gradall. Although this may not fill every void, it should fill all the larger voids and a significant number of the smaller voids as well. It is anticipated that the hydraulic conductivity of the CSS will be low enough to significantly reduce the rate of corrosion. In addition, the strength of the CSS product after it has set will be similar to that of very weak concrete. It will remain stable, to bridge any voids of the type described above. Alternatively, clean grout may be purchased from off-site.

The intact metal may be placed in the cell and covered with grout, as described in Section 5.2. The estimated volume of metal wastes to be placed intact is about 40,550 cy. This quantity was determined by estimating the smallest rectangular box shape that would fit around each piece. The average density of the intact waste was estimated to be about 15 pcf (5 cy per ton), which indicates a porosity of 97 percent. Thus 40,000 to 50,000 cy is a reasonable preliminary estimate of the volume of CSS required to entomb the intact wastes, including filling some of the interior voids.

The estimated volume of metal wastes to be size-reduced is about 7400 cy. As stated in Sec. 5.2, the size-reduced metal waste will be in the form of beams, plates, or parts of large processing equipment, with maximum dimensions of about 8 feet. The material should generally be placed in relatively thin lifts. It should generally be placed lying flat, or with the largest dimension horizontal. Soil-like waste should then be spread over the metal with a dozer, grader, loader, or other piece of equipment. The soil-like waste should be worked slightly to cause as many of the voids as possible in the metal waste layer to be filled with soil. The composite metal and soil-like waste layer should then be compacted by track-walking or with a compactor. The process may then be repeated. The orientation of each piece should be selected to avoid nesting and to minimize the number or volume of any voids that might not be filled by placing and compacting soil on top of and around it. Hand compaction may be required around some pieces of waste.

As an alternative to covering the size-reduced metal with soil, it may be placed and entombed with CSS grout, as described above for intact wastes. Because there are about 7400 cy of size-reduced metal wastes, it may take about 7400 cy of CSS to entomb all of it, if this alternative is selected.

As stated in Section 5.2, the shredded metal waste will come from the crusher/nuggetizer as fragments no larger than about 6 or 8 inches. These materials should be spread in loose, open lifts about 6 to 8 inches thick, and covered with soil-like wastes. If the masonry, rock, and concrete rubble is relatively well graded, it may be used to cover the shredded metal wastes.

Sixteen percent of the waste will be masonry, rock, and concrete rubble that has been size-reduced to about 2.5 inches or less. Depending on the actual gradation curve of this material, it may be spread in lifts with maximum uncompacted thickness of 12 inches and compacted (if the material is relatively well graded). If the material is uniformly graded or gap graded, it should be mixed with soil-like waste and then compacted.

Sixteen percent of the waste will be soil and gravel that results from closure of haul roads and other remedial facilities. This material will generally become available toward the end of the remedial work. It may be spread in lifts with maximum uncompacted thickness of 12 inches and compacted as normal engineered fill.

The following discussion of ACM, wood, PPE, containerized materials, and miscellaneous debris is nearly identical to the CSS discussion of these materials in Section 5.2. There is a small amount of asbestos to be placed in the cell. About 1 percent of the non-soil-like waste will be friable asbestos (currently stored in bags), and about 1 percent non-friable, largely in the form of siding, roofing, flooring, and transite pipe. The non-friable portion may be placed in a manner similar to that described above for size reduced metal wastes. The pipe may be left intact and does not need to be crushed prior to placement or filled with CSS after placement. However, future studies should determine the maximum overburden rating for the pipe in order to determine how far below the top of the disposal cell the pipe may be placed without being susceptible to crushing. The friable (bagged) material should be placed in trenches excavated into soil-like wastes, preferably near the top of the cell in order to minimize overburden loading and subsequent deformation of the friable asbestos component. The bags should be covered with soil and the trench filled and compacted with soil-like waste. Other burial methods may be possible as well. The key in evaluating acceptability of a burial method is that the asbestos bags not be broken and that the asbestos not be exposed to the air or be placed in a manner that results in excessive settlement.

A small amount of composted wood is also to be placed in the cell. The estimated volume of wood after it has been composted is 6442 cy. Most of the potential compressibility of the wood is expected to have occurred during the composting. However, some compressibility and further decomposition potential will still exist. The wood should be mixed relatively uniformly with the gravel materials from the remedial facilities closure. The amount of wood should be limited to about 3 to 5 percent of the mixture. There may be some resulting volume reduction following completion of the cell, but only a fraction of the strength would be lost.

A very small amount («1 percent) of compressed PPE is also to be placed in the cell. It is recommended that this material be placed in trenches or holes excavated in the soil-like fill. The PPE should then be placed, covered with soil-like waste. The soil-like waste should then be compacted in a similar manner to the procedure for friable asbestos described above.

Containerized materials will be treated in the same way as for the CSS alternative, as described above in Sections 3.2 and 5.2.

There is a small volume of material that has been classified as "Miscellaneous Debris." These are composed of sanitary landfill type wastes that include ceramics, porcelain, glass, and graphite. Oversized portions of this material should be handled with concrete rubble during and after volume reduction.

6.2.3 Sequencing

The sequence of material types placed in the non-vitrified cell has a moderate amount of flexibility, but there are certain restrictions that should be observed. The purpose of these restrictions will be to protect the final cell integrity and to reduce radon emissions. This discussion is very similar to the discussion for CSS sequencing in Section 5.3.

The current plan is to construct the non-vitrified cell in two phases. Although the final layout of the cell and of the phases has not been determined, it appears from an examination of preliminary siting work (MKES 1991b, Study 2C) that each phase will contain roughly half of the total waste volume. Using some simplifying assumptions for this stage of the evaluation of waste placement, the approximate volume of waste that will be

required to raise the waste surface one foot is as shown below for various elevations of the waste pile working surface.

Table 6-2: Disposal Cell Waste Volumes vs Cell Height

Height Above Foundation	CY/Vertical Foot of Waste Per Phase
0	19,000
20	12,000
40	6,700
60	2,600

The MKF-JEG 1991b (Construction Operation Scenario) report indicates that the waste placement will occur over a period of about 800 working days (p. 15). With a total non-vitrified waste volume of 600,119 (cy Table 2-1), this would average out to about 750 cy per day, which is about one half to 3 inches of rise per day over the waste pile.

Some of the larger waste forms, including intact and size reduced metals, may be placed in a heap rather than in a thin lift. The entire heap would then be entombed with poured CSS. Heaping of wastes will only be acceptable if it is determined that an adequate filling of voids can be assured for a specific heap. The acceptability of a specific waste composition for a heap would need to be determined during construction for any proposed mix of wastes.

In order to protect the leachate collection system, a minimum of one foot of soil-like waste should be placed over the leachate collection system before placing other wastes, as described above in Sections 5.1 and 5.3.

Within a given phase of disposal cell operation, any CSS should be placed as nearly monolithically as possible. It should not be interspersed with lifts of soil-like waste. Size-reduced metal should be incorporated into the CSS as described above.

The large, intact wastes should be placed relatively low in the cell. This will allow for experimentation with the methods of entombment while there is still plenty of space in the cell to adjust the operations. The bulk density of most of the metal waste entombed in CSS will be similar or slightly higher than the other waste forms. Therefore it is not expected to settle significantly more than any adjacent waste. The possible exceptions to this are the locomotive and any other massive, heavy metal piece. These waste items should be placed above at least 5 feet of CSS-entombed material, or over at least 7 feet of concrete rubble

and gravel if this material is found to be well graded. These measures will function to spread the load through relatively incompressible zones, so that when it encounters a more compressible zone the differential loading will be minimized.

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